Environmental Management in Military Activities of the South African National Defence Force

By

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AUTHOR'S DECLARATION

I, Hezekiel Bheki Magagula, hereby declare that the work presented in this thesis is my own original work and that it has never been previously submitted in part or in its entirety at any other university for a degree.

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I, Hezekiel Bheki Magagula, student number 9330631 hereby declare that I am fully aware of the University of Fort Hare's policy on plagiarism and I have taken every precaution to comply with the regulations.

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DEDICATION

I wish to dedicate this work to my children, Aphiwe and Mandlenkosi, my mother, sisters and brothers. I am delighted that what I started eight years ago, have managed to successfully complete.

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ABBREVIATIONS / ACRONYMS

Abbreviation/Acronym	Definition
ADF	Australian Defence Force
AER	Annual Environmental Report
ATF	Amphibious Task Force
BAA	Battlefield Area Assessment
BEM	Base Environmental Management
Bde	Brigade
BS	British Standard Institute
CEMML	Centre for Environmental Management of Military Lands
CPL	Corporal
CSIR	Council for Scientific and Industrial Research
DEAT	Department of Environmental Affairs and Tourism
DETR	Department of Environment, Transport and the Regions
DMOD	Danish Ministry of Defence
DNAEPC	Danish Nature and Environmental Protection Commission
DND/CF	Department of National Defence and the Canadian Forces
DoA	Department of Agriculture
US DoD	United States Department of Defence
DoDMV	Department of Defence and Military Veterans
DPW	Department of Public Works
DU	Depleted Uranium
DWAF	Department of Water Affairs and Forestry
EBS	Environmental Base Survey
ECA	Environment Conservation Act
EC	Environmental Conservation
ECCO	Environmental Compliance for Commanding Officers
ECOps	Environmental Considerations during Military Operations
ECR	Environmental Closure Report
EEI	Emerging Environmental Issues

Abbreviation/Acronym	Definition
EE & T	Environmental Education and Training
EIA	Environmental Impact Assessment
EIP	Environmental Implementation Plan
EMAS	Eco-Management and Audit Scheme
EMF	Environmental Management Facility
EMI	Environmental Management Inspectorate
EMP	Environmental Management Programmes/Plans
EMS	Environmental Management System
EO	Environmental Officer
EP	Environmental Protection
ERF	Environmental Review Forum
ES	Environmental Services
ESWG	Environmental Security Working Group
6 SAI Bn	6 South African Infantry Battalion
FYAR	Fiscal Year Annual Report
GAO	United States Government Accountability Office
GCI	Green Cross International
GMI-EMF	Grahamstown Military Installation Environmental Management Facility
GMI	Grahamstown Military Installation (6 South African Infantry Battalion)
GMTA	Grahamstown Military Training Area
GOC	General Commanding Officer (General Officer Commanding)
HQ	Head Quarters
IDP	Integrated Development Plan
IEM	Integrated Environmental Management
IEMP	Integrated Environmental Management Procedure
IEMS	Integrated Environmental Management System
ISO	International Organisation for Standardization
ITAM	Integrated Training Area Management
Lt. Col.	Lieutenant Colonel
Maj.	Major
MIEco.M	Military Integrated Ecological Management

Abbreviation/Acronym	Definition
MIEEP	Military Integrated Environmental Education Plan
MIEIA	Military Initiated Environmental Impact Assessment
MIEM	Military Integrated Environmental Management
NATO-CCMS	North Atlantic Treaty Organisation Committee on the Challenges of Modern Society
n.d.	Not Dated
NEMA	National Environmental Management Act
NGO	Non-Governmental Organisation
NWA	National Water Act
NWMS	National Waste Management Strategy
OC	Commanding Officer (Officer Commanding)
OHS	Occupation, Health and Safety
PMoD	Portuguese Ministry of Defence
POL	Petroleum, Oil and Lubricants
RFIM	Regional Facilities Interface Manager
SA	South Africa
SAACTC	South African Army Combat Training Centre
SAAF	South African Air Force
SANDF	South African National Defence Force
SDS	Supplier Disposal Specifications
SGT	Sergeant
SSO Env. Serv.	Senior Staff Officer, Environmental Service
UNEP	United Nations Environmental Programme
UXO	Unexploded Ordinance
WCED	World Commission on Environmental Development
WMD	Weapon of Mass Destruction
WO1	Warrant Officer First Class

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ABSTRACT

This thesis presents research findings on current environmental management practices used by the South African National Defence Force (SANDF). Two case studies are presented; the first is the Grahamstown Military Installation (6 South African Infantry Battalion) and the second the South African Army Combat Training Centre (42 Brigade). A combination of three sampling techniques, namely, the stratified, purposive and link-tracing (snowball) samplings were employed and structured questionnaires and semi-structured interviews with key SANDF officials were used as primary data. In addition, secondary data sources in the form of *inter alia* the first and second editions of the Environmental Management Plan for Defence (2001 & 2008 respectively); the development and implementation of environmental education and training in the military: a joint United States-Republic of South Africa Environmental Working Group Project (2003); Overarching Strategic Statement for 2011; Integrated Environmental Management Information Series: Linking Environmental Impact Assessment and Environmental Management Systems (2004); The Department of Defence Strategic Plan (2010): Republic of South Africa and the South African Defence Review (2012) were studied.

In addition, field observations were also carried out within the two military installations training areas between July, 2011 and November, 2013. Primary data on the conditions of training areas, waste removal after training exercises, pollution prevention measures, and rehabilitation efforts to restore degraded training ranges were collected. Furthermore, composite surface sediment samples and water samples were collected for analysis. A total of fifty-six surface sediments and thirty water samples were analysed for the concentrations of heavy metals using the ICP-MS.

Results revealed that there are variations in attitudes and perceptions towards considerations and incorporation of environmental issues into military activities. These attitudes and perceptions are predominantly positive. Statistical analysis (ANOVA) did not reveal any significant differences in responses, especially, between military ranks. However, sporadic significant differences were found in five of the statements in the questionnaire from respondents with different service periods. Furthermore, the emphasis placed on environmental protection within defence force activities worldwide has compelled the South African Department of Defence and Military Veterans (DoDMV) to regulate the management of the environment within its properties. Yet, these efforts have faced numerous challenges ranging from financial to human resource deficiencies. It was found that environmental management practices and programmes at different military installations vary significantly.

Consequently, six environmental management programmes were identified at South African Army Combat Training Centre, while only one environmental management programme was identified at Grahamstown Military Installation. This programme is a collaborative effort between the SANDF/DoDMV and the Department of Water Affairs and Sanitation to eradicate invasive alien plant species. In the light of the analysis of official documents and interviews with respondents, it was established that the DoDMV does not have a budget for environmental management services and environmental management is yet to be incorporated into formal military training programmes. There is a severe shortage of environmentally qualified and knowledgeable personnel within the SANDF. Subsequently, all these drawbacks lead to the failure of the implementation of the Defence Force’s Environmental Management System (EMS) and inadequate management of the environment at military installations of the SANDF. Consequently, these challenges have severely compromised the commitment of the

SANDF to honour its environmental management obligations. Such deficiencies tend to undermine the sustainable utilisation of the national assets entrusted to the Defence Force. Therefore, this thesis argues that environmental management programmes for the SANDF are based on a very weak foundation. This thesis proposes an ideal model for the successful implementation of the EMS and management of the environment at SANDF military installations.

The analysis of water and soil samples led to the identification and quantification of heavy mental pollutants. The concentrations of heavy metals in water samples were varying between <0.01 to <0.05mg/l, but generally constant. Thus, no significant or meaningful statistical results were obtained. Pearson’s correlation coefficient was used to analyse the concentrations of heavy metals obtained in the sediment samples. This analysis revealed that most of the pairs (heavy metals that correlate in either way) display positive correlations; except for Cd which shows negative correlation with Cr, Cu, and Pb.

Principal component analysis was also used to extract the major components. Four principal components were extracted: principal component 1 had loading values of 0.959, 0.931, 0.900 and 0.692 for Ni, Co, Sr and Cr. Meanwhile, principal components 2 and 3 were loaded with Cu, Pb and Cd, Zn, respectively. Variability of the heavy metal concentrations and other properties were determined using the Hierarchical Cluster Analysis (HCA). The concentrations of heavy metals in GMI and SAACTC were found to be decreasing in the order of Pb>Cu>Zn>Cr>Sr>Ni>Co>Cd. The possible sources of Pb, Cu, Zn and Cd were identified as fuel spillages, oil leakages

from military vehicles, bullet shells and other metallic fragments generated by military weaponry (during training exercises).

A time series of high-resolution satellite imagery was analysed to explore land cover change at the Grahamstown Military Installation and the South African Army Combat Training Centre. At the Grahamstown Military Installation the results indicate that the dense forest appeared to have decreased by 3.24% over the period of observation. Over the same period, bare land surfaces and shrub lands have also increased by 1.85% and 1.91%, respectively. The change in dense forest can be attributed to efforts in trying to eradicate the invasive *Opuntia Indica* plant species within the training area. At the South African Army Combat Training Centre, the dense vegetation cover decreased by 9.33%, whereas grassland vegetation increased by 9.45%. At the same time, the bare-land surface decreased by 0.11%, which could be linked to the increase in the grassland vegetation covered surface. The decrease in dense vegetation can be associated with an increase in the veld fire frequency reported in the environmental reports at this site.

Given the findings of the study, the thesis recommends that it is critical to recruit environmental professionals to lead the environmental management programme of the SANDF. The SANDF, through the DoDMV, must adequately invest in the environmental management facilities to realise its obligation to environmental protection and sustainability. External linkages and collaborations with relevant institutions and experts are highly recommended for the SANDF to achieve significant environmental protection and sustainability. Environmental education awareness and training programmes and activities must be incorporated into the formal training of the SANDF. This approach will improve the environmental management practice and

profile of the SANDF. The environmental research unit of the SANDF environmental programme must be resuscitated, restructured and well-resourced to carry out all the necessary environmental management research required within the defence territories. Furthermore, action learning appears to be appropriate for the SANDF to improve and consolidate the already existing positive attitudes and perceptions on environmental protection and sustainability in military planning and executions of military training exercises. In addition, phyto-remediation or bioremediation is recommended for implementation in all the military training areas of the SANDF, to reduce environmental pollution by heavy metals.

Key Words

Military, training area, environment, defence, integrated, pollution, vegetation, sediments, heavy metals, management, protection, cultural sustainability

CHAPTER I

BACKGROUND TO THE STUDY

Introduction

The primary responsibilities of military forces in all countries are the same. Among others, military forces are expected to safeguard the sovereignty of a country, assist in maintaining law and order thereby ensuring internal peace (D’Souza, n.d), protect its citizens, and all of its resources. Malan (1994) states that it is universally accepted that the primary role of a nation's armed forces is to protect the state against hostile military action. Hostile military action poses a threat to all the components of the state: it may not only lead to the relatively sudden destruction or distortion of a state's physical infrastructure, resources and institutions, but can also threaten the survival or continuation of the state as a social entity.

To meet all these responsibilities, armed forces are regularly divided into specific units. These units are in most cases the Air Force, the Navy (except for land locked countries) and the Army (i.e., the ground forces). Together, all these units are tasked to defend the integrity of the country’s international borders from external aggression (D’Souza, n.d) so as to ensure that no intruders will illegally enter a country.

In order for these responsibilities to be met successfully, armed forces need to be trained and provided with the required resources. The success of military forces in executing their responsibilities depends heavily on proper training. According to the

United States Government Accountability Office (GAO) (2005), a fundamental military readiness principle is that a military force must train for combat situations if they are to succeed in them. It is often during these training exercises that military forces induce serious adverse environmental impacts on their own country, especially during the testing of weapons to ensure readiness (Emerging Environmental Issues [EEI], 2006). Hence serious attention must be given to the environmental condition of the training ranges.

Military training ranges are important national assets and play a critical role in preparing military forces for their wartime mission (GAO, 2005). However the continuous explosions, moving vehicles and live-firing tend to degrade the environmental conditions of the training ranges. Many training ranges worldwide have been degraded to such an extent that training itself has become difficult. For example, the United States Department of Defence (USDoD) has reported that it is facing major difficulties in carrying out realistic training at its ranges due to a number of constraints (GAO, 2005), one of which is the physical degradation of the ranges. Operations or activities that degrade the physical environment require that an armed force control large tracts of land especially when environmental considerations are not incorporated into military activities to avoid degradation of training ranges. In turn, such conditions adversely affect the preparedness of military forces, and thus jeopardize the safety of military personnel. In his 2007 outline of environmental support to military missions, Daniel (2007) appropriately reflected on the dilemma:

> owing to pressure on the utilisation of land and encroachment on military areas, the chances of acquiring alternative land [in South Africa] for

military training are non-existent. Therefore, the impact of military activities on the environment is one of the major challenges to the future of realistic military training[1].

This is a clear indication that Departments of Defence (DoD) across the world are facing major challenges with regards to the degradation of training ranges. This, in a way explains the reason why DoDs control even larger shares of the land resources in their respective countries. In most cases, these land areas are at risk of degradation because the concept of sustainable operations in military training ranges is not considered in all efforts to achieve military mission readiness (EEI, 2006). In the United States, the Department of Defence (DoD) manages more than 30 million acres of land (Fiscal Year Annual Report [FYAR], 2004). Some of these areas are reported to have become inappropriate for proper and realistic military training.

Thus, the USDoD manages approximately 1.25% of land (Johnson *et al*., 2011), while the Australian defence force is also the largest landowner (managing over 1.69% of the land) in Australia (Australian Department of Defence, 2010; Wu & Wang, 2011). The Portuguese military owns more than 23 000 hectares of land (Ramos & de Melo, 2006). Thus, the Portuguese military controls more than 0.25% of the total landmass of Portugal. In South Africa, the DoDMV (SANDF) at this stage it had approximately 492 140 hectares of land under its control (Mckenzie, 1998a). This figure probably excludes the pieces of military lands in the former homeland areas where title deeds

[1] Daniel, Lt Col Elsa (2007): Environmental Support to Military Mission. *SA Soldier*, 14(8), 45

of state land are not readily available. However, the 1996 White Paper on National Defence for the republic of South Africa states that the South African National Defence Force (SANDF) controls 500 000 hectares of state owned land (South African Department of Defence, 1996). Thus, the DoDMV controls approximately 0.4% of the state-owned land (Magagula, 2014). The environmental impact of military activities in most of these land areas has never been studied.

The growing environmental awareness from the 1970s to-date, has led to significant developments and changes in the management of environmental issues. Countries have formulated environmental laws and policies for better management of the environment. There are also numerous international environmental treaties and agreements signed by countries pledging their commitment to environmental protection and sustainability. In the US, the National Environmental Policy Act (of 1969)**,** was promulgated for numerous purposes. These include promoting efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man. The United Kingdom too, has enacted environmental laws to safe guard their environment, for example the Environment Protection Act of 1990 (*http://www.legislation.gov.uk/ukpga/1990/43/introduction,* 27 January 2007).

South Africa also followed suit with the promulgation of the National Environmental Management Act [NEMA] (Act No. 107 of 1998), which requires that every individual, group of persons, companies, firms and even national department that may negatively affect the environment, the DoDMV included, must have environmental management systems (EMS) (Daniel, 2007) to mitigate the negative impact of their activities. All government departments must have an environmental implementation plan (EIP) which is revised every four years to ensure improvement in environmental performance (Jacobs *at al.*, 2002). An EMS is described as an indicator of the environmental performance of an organization in controlling human activities that have a significant impact on the environment (Rowland-Jones *et al.*, 2005). By law the DoDMV/SANDF has to comply with the environmental regulations of the country and other international environmental agreements or treaties.

Conceptual Framework

This study is intended to explore environmental management associated with the military activities of the SANDF. The focus of the study is on the ground forces (ground troops) of the SANDF. The study is located within the broader framework of environmental studies. It seeks to draw on but also expand upon the concept of environmental impact assessment (EIA), environmental auditing, and environmental management systems (EMS) which have emerged within the field of environmental management in the last decade or so. In recent years concepts such as EIA, environmental audit, EMS and so forth have broaden theories on environmental protection, as well as rights or justice. In this research environmental protection and environmental sustainability were adopted to study and analyze the environmental impacts associated with military activities, as well as the impacts of environmental consideration on military planning and military proficiency.

These theories advocate for the protection, preservation, conservation and restoration of the degraded environment. Environmental protection and conservation (EP&C) are fundamental to human security (Singh, 2004). These theories argue for the protection and sustainable utilization of natural resources, such that even future generations will be able to benefit from them (Erdogan & Baris, 2007). In the environmental era, the major challenge facing nations is no longer deciding whether conservation of the environment is appropriate, but rather how it can be achieved in the national interest given the available resources (World Commission on Environment and Development [WCED], 1987; Singh, 2004).

The concepts environmental sustainability (ES) and environmental protection (EP) are used in this study as defined by Whitford (2009) and Lếvệque and Mounlou (2003) respectively to mean: long-term preservation of our environment for the future (i.e., viability of ecosystems, natural resources and best environmental practices that do not culminate in the degradation and depletion of natural resources); operations/practices aimed at safeguarding the environment together with all its components against abuse by human activities. Environmental components refer to the physical, biological, social, economic, cultural, historical, and political issues. ES and EP provide ways of observing and understanding the world and its biotic aspects. These theories critically examine the interaction between humankind and the environment (Padoch & Sears, 2005).

In the current study, the concept of cultural sustainability has been isolated from the social dimension of sustainable development. In other words, it has been used as the fouth pillar of the concept suatainable development (or sustainability) as it was first introduced by Hawkes in 2001 (Soini & Birkeland, 2014). This approach has been adopted to adequately analyse the cultural resource management programme of the

SANDF. Cultural sustainability is defined by Duxbury and Gillette (2007) as the ability to retain cultural identity and to allow change to be guided in ways that are consistent with the cultural values of the people, including the language. This implies that development and any other activities taking place in any geographic locality should protect and preserve the cultural identity of the inhabitants. Thus, culture in sustainability concept is associated with the social capital which encapsulates the traditions, values, heritage, place, the art, diversity and the social history of the area concerned (Duxbury & Gillette, 2007).

Padoch and Sears (2005) argue that the way humans relate to or utilize the environment determines whether or not it is sustainable. It is within this context that conservation argues for humankind to know the problems that affect their health and well-being, and that of other communities, not to mention the environment in which we live (Padoch & Sears, 2005). Furthermore, Padoch and Sears (2005) argue that humankind needs to know what its role is in creating those problems and it must engage collectively in seeking solutions to them. It is on the basis of these notions that the EP and ES theoretical framework has been adopted to analyze the environmental problems associated with military activities, as well as to propose possible effective solutions to these problems.

Therefore, it is through the lenses of environmental protection and environmental sustainability (including cultural sustainability) that the conception of environmental management systems (EMS) and other environmental management tools, environmental management standards, rationale for implementing EMS as well as its benefits in the military, the impacts of military activies on the environment, contamination (i.e., chemical pollution and existence of landmines in areas used for military purposes) were analysed.

BRIEF CONTEXTUAL BACKGROUND OF THE STUDY

This section attempts to contextualize the research questions, aims, objectives, research design and the techniques adopted as well as used in this study. The brief review of the literature here allows one to state the deficiencies noted in the literature. In addition, this has also allowed the researcher to state upfront the gaps that exist in the literature that this study addresses. An in-depth review of the literature is presented in Chapter III.

The Environment as a Military Weapon

Ancient military tactics involved the use of the environment as a weapon to weaken the enemy. Dutch (2006) argues that the most ancient use of the environment as a weapon was the deliberate spread of natural plagues. Some armies would catapult carcasses and corpses over walls, and even contaminate water sources to ensure outbreaks of diseases to weaken the enemy (Dutch, 2006). In some instances the physical environment itself was used as an effective weapon. For example, in situations where environmental disasters are deliberately triggered to cause direct damage to the enemy.

The mountain warfare in the Alps during World War I illustrates how the physical environment was used as a weapon (Dutch, 2006). Dutch (2006) states that the Italian and Austrian armies used artillery to trigger snow avalanches on their opponents. During World War II, the environmental weapon tactic was again used by the Allies in their "dam busting" raids in the Ruhr valley which resulted in downstream flooding with serious military consequence (Dutch, 2006). Conca and Wallace (2012) argue that the Jiyeb power station was deliberately bombed during the 2006 Israeli invasion into Lebanon. Water supplies and sanitation facilities in various countries such as Lebanon in 2006, Gaza in 2009 were destroyed during conflicts (UNEP, 2007). The UNEP and UNCHS (1999) report that the NATO air strikes in Kosovo destroyed numerous industrial facilities, and as such caused significant environmental contamination. Yuzon (1996) mention that the Iraqi ground forces deliberately set ablaze oil installations and dumped thousands of crude oil barrels in the sea causing severe ecological damage. Furthermore, Lacoste (1973) states that the US forces bombed the dikes of the Red River in Vietnam to induce flooding and subsequent destruction of the military installation located nearby. In recent times, the use of the environment as a weapon and its deliberate destruction is no longer acceptable, given the importance attached to the environment and a realization of how human activities have affected it to-date.

Lack of Explicit Environmental Provisions on Overseas Military Base Agreements

The environmental impact of military operations in some cases may not only be confined to an Army's own country. For example, countries that have overseas military bases have impacted significantly on the environment of the host country (or countries). Lindsay-Poland and Morgan (1998) show that the USDoD has approximately 800 military locations in other countries. Consequently, the US military forces have left a legacy of environmental problems throughout the world. Lindsay-Poland and Morgan (1998) further state that this has happened because most of the overseas military base agreements were signed prior the era of environmental awareness. These agreements contain extremely vague (if any) environmental provisions.

Consequently, the US military (USDoD) has exploited this lack of explicit obligation with regard to environmental protection and clean-up at the closure of military installations (base camps). It is not only the US that has affected the environment of other countries through vague or non-existent environmental provisions in overseas military base agreements. Watts (n.d) attests that the British military forces left unexploded ordnance (UXO) on the fringes of pastoral communities in Kenya. These are the sites where the British forces conducted military training activities. Consequently, many children of these villages have been maimed by these bombs.

The 1999 conflict in Kosovo also left behind a severe problem of UXO which will take many years to be addressed (International Committee of the Red Cross, 2001, *www.icrc.org* 5/3/2017). As of 2001, approximately 74.2% of people were killed by UXO and related devices in Kosovo (Landmine Action, 2002). Accordingly, the Geneva International Centre for Humanitarian Demining [GICHD] (2002) reports that on estimates, there were more than 50 000 anti-personnel mines throughout Kosovo's land area. According to the Landmine Action (2002), more than 72% of deaths and injuries in Eritrea were caused by UXO. In Afghanistan, UXO accounted for 64% of deaths and injuries between 1997 and 1998 (Landmine Action, 2002). The GICHD (2002) estimated that approximately 6 000 UXO existed in Afghanistan by the year 2001. Cambodia was also affected by UXO and landmines planted during the 2000 to 2001 conflict.

Another example of this legacy was evident when the US military evacuated the Subic Naval Station and Clark Air Base in the Philippines in 1992. Tons of toxic chemicals dumped on the ground and in water bodies or buried in uncontrolled landfill sites were discovered (Lindsay-Poland & Morgan, 1998). This study also found that in Germany where US troops were still stationed (in 1998), industrial solvents, firefighting foams and many other forms of waste destroyed local ecosystems near the military bases. Areas set aside for public benefit such as national parks and recreational areas can suffer a slow and almost undetectable degradation resulting from nearby military installations (Garten *et al.*, 2003).

The US National Security Strategy (1994) reported that the US was the first nation to search for solutions to environmental problems generated by military installations, especially at local or domestic installations. The USDoD has taken major strides to incorporate environmental protection in military operations at the domestic level. However, when it comes to overseas bases, environmental concerns have not been incorporated into military planning and operations. According to Lindsay-Poland and Morgan (1998), the Pentagon is applying a double standard in its domestic and overseas clean-up programmes. They perceive this to imply that the health of foreigners and their environment is worth less than that of Americans (Lindsay-Poland & Morgan, 1998).

Physical Environmental Impacts of Military Activities

A number of studies have been conducted to ascertain the environmental impact of military activities. The Centre for Environmental Management of Military Lands (CEMML) (n.d.) and Pearce (2003) report that soil erosion; loss of topsoil and sediment deposition can be significant environmental issue in military training lands. In addition to soil erosion, Tikhomirov (2006) further indicates that the soil suffers considerable damage from explosions and manoeuvring military vehicles (including destroying the soil structure, causing decline to soil quality) and oil-based pollution all leading to soil deterioration. Military training exercises also affect the environmental condition of training lands by removing and/or disturbing vegetation cover (Haugen *et al.*, 2003). The lack of vegetation cover increases sediment transfer and sedimentation in nearby water bodies.

Pearce (2003) states that the United Nations Environmental Programme (UNEP) report indicates that the US military vehicles caused widespread degradation of fragile desert ecosystems in Iraq during the 1991 war, and their recovery will take decades. This is a clear indication of how military activities can even affect ecosystems. Goran *at al.* (1983) found that frequent and repeated use of an area tend to show a high level of degradation of flora, fauna and soils compared to infrequently used land. They also noted that young seedlings do not survive in areas frequently used. Damage of ground vegetation leads to a loss of species, especially those with low “wear resistance”, and such ground disturbances result in a decrease in water infiltration into the ground (Goran *et al*., 1983).

Chemical Pollution of Military Activities

Throughout the history military activities during war and peace-time training has negatively affected the environment (Al-Damkhi, 2007). The environmental effects caused by military practices include physical impacts and chemical contaminants. The physical impacts include destruction to the land’s vegetation cover and alteration of soil structure as well as creation of deep ruts on the ground surface (Sample *et al*., 1998; Quist *et al.*, 2003; Nyakatawa *et al.*, 2010). Military training exercises also increase significantly the compaction of soil thereby reducing infiltration rate (Whitecotton *et al.*, 2000). Regarding chemical pollution, studies conducted by Diaz and Massol-Deya (2003), Clausen *et al.* (2004), Schmidt (2004), Riefler and Medina (2006), Greičiūtė *et al*. (2007) and Amaral *et al.* (2009) have reported on various forms chemical contaminations of military controlled land. The contaminant include heavy metals and white phosphorous (Schmidt, 2004), explosive compounds such as RDX (*hexahydro-1,3,5-trinitro-1,3,5-triazine*), TNT (*2,4,6-trinitrotoluene*) as well as HMX (*octahydro-1,3,5,7-tetranitro-1,3,57-tetrazocine*) (Clausen *et al.,* 2004); DNT (*dinitrotoluene*) (Amaral *et al.*, 2009). *Nitroglycerine* (NG) is also mentioned as one of the common pollutants in military training ranges (Riefler & Medina, 2006).

Other chemical pollutants associated with military installations include fuels (petroleum hydrocarbons), solvents, heavy metals, ethylene glycol and asbestos. Notar (1996) argues that the Gulf War of 1991 had significant environmental impacts of varying kinds. The US forces fired rounds containing depleted uranium (DU) and depleted uranium adds traceable radioactive heavy metal residues to an already contaminated environment (Notar, 1996). Lamas *et al.* (2002) report that even though DU is considered less radioactive than natural uranium, it is still a serious hazard due to the alpha-radiation it emits. The DU is a threat to both human health and to the environment because of its toxicity. Hulme (2004) shows that a 120 mm DU penetrator generates between 2 to 7 pounds (i.e., equivalent to 0.907 kg to 3.175 kg) of uranium oxide dust. This metal impacts on the environment every time live shooting military training takes place (Lamas *et al.*, 2002).

Nitroglycerin (NG) and *2,4-dinitrotoluene* (2,4-DNT), used as propellants, are the main chemical pollutants found in the soil and in underground water at military firing ranges (Riefler & Medina, 2006). Riefler and Medina (2006) state that both NG and 2,4-DNT have toxic effects on humans and the environment. Kelly (2003) states that US military operations contaminated ground water and created toxic dumps in many places through nuclear waste, discarded fuel, chemicals and unexploded munitions.

Normal military training and preparation for war cause significant environmental pollution through the release of munitions constituents such as perchlorate (a thyroid toxicant), RDX (an explosive compound and neurotoxicant) and TNT (an explosive compound linked to anemia and alteration of liver function) (Schmidt, 2004).

Weapons of Mass Destruction

Historically the use of chemicals to modify the environment, such as the defoliation of vegetation to deprive the enemy of cover was much more destructive. The defoliation in Vietnam was caused by a chemical compound called Agent Orange which destroyed huge tracks of forest ecosystems. This chemical compound alters the metabolism of plants and causes defoliation (Ana *et al*., 2007). Some of the chemical warfare involves the emission of gases (e.g., phosgene) that cause lung irritation while some cause burns (e.g., mustard gas). Other examples are the nuclear bombing of Hiroshima and Nagasaki in 1945 that led to contamination of huge tracks of land (Al-Damkhi, 2007).

These chemical weapons [weapons of mass destruction (WMD)] were banned. Their banning came from scientific evidence available that chemical weapons have lasting environmental effects (Hulme, 2004). A recent example of the fear of WMD was the invasion of Iraq in 2003 by the United States of America and its allies who assumed that there were WMD in Iraq (Szabo, 2007). However, no WMD were eventually found, but the environment had already suffered significant impact as a result of the war. Contrary, Joffe (2000) argues that the enormous investments in military industries in Iraq that produce WMD have significantly contributed to environmental degradation. In the quest of forcing Iraq to comply with the ban of production of WMD, the US Air Force dropped more than 27 000 bombs and other ordnance on Iraq, and more than 800 missiles during the 1991 war (Pearce, 2003).

Pearce (2003) further demonstrate that the 2006 invasion saw a far worse situation than in the 1991 attack on Iraq. During the Iraq war (of 2006) more than 750 oil wells were deliberately set ablaze, consequently, the scorched-earth tactic released more than 156 million barrels of crude oil which formed about 399 oil lakes contaminating approximately 49 km^2 of the desert landscape (Al-Damkhi, 2007). Al-Damkhi (2007) further states that the smoke and soot from the burning of the oil-fields resulted in severe air pollution that affected approximately 953 km^2. Furthermore, the former Soviet Union case has clearly shown that brutal environmental legacy and disregard can persist for many decades though the political system may have changed (Joffe, 2000). All these cases described in this section show the relevance of incorporating environmental concerns into military training and mission plans.

Environmental Impacts of Military Activities in Africa

The environmental impacts of military activities in Africa are mainly caused by minefields [i.e., landmines and unexploded ordnance (UXO)] that were laid during decades of civil wars that have characterized this continent (Herbst, 2004). About twenty-nine (29) African countries have been affected by minefields (Stott, 2004). These minefields have severely affected economic activity, mainly in the agricultural sector. Vast areas in different countries in Africa are regarded as degraded merely because of anti-personnel mines. Kanyamibwa (1998) states that significant effort is required to effectively address environmental problems caused by civil wars in African countries such as Mozambique, Angola, Somalia, the Democratic Republic of Congo, Sierra Leone and Rwanda. Kanyamibwa (1998) also mentions that during and after a war, environmental concerns/problems are not given top priority.

Studies on environmental problems related to military activities at country level are very scarce. There are many reasons why military environmental problems have been neglected for so long. Some of the reasons could be the sensitive nature of the institutions, lack of transparency in the operations of military institutions and the political nature of military organizations. In South Africa, some of the land controlled by the military during the apartheid era was located within ecologically sensitive areas with high conservation value, thus military activities have had a significantly negative environmental impact (Mckenzie, 1998b). Good examples are the three controversial weapon testing sites which are: the De Hoop and Rooi Els in the Western Cape, and St. Lucia in KwaZulu-Natal. (1998b) states that these weapon testing sites were established in a shroud of secrecy and in an authoritarian manner. According to Mckenzie (1998b), there is evidence of negative environmental impact emanating from the weapon testing in these areas.

Environmental Legislation of South Africa

Every country in this environmental era is expected to formulate a legislative framework to guide the utilization, management, protection and conservation of its natural resources. These legislations have to be applicable to all sectors of the society without bias if they are to achieve the desired outcomes. It is on this understanding that the SANDF is expected to comply with a number of legislations which were promulgated to protect the environment from unsustainable utilization and exploitation by any means of human practices. Some of these legislations include: (1) the Constitution of the Republic of South Africa (Act No. 108 of 1998); (2) Environment Conservation Act (Act No. 73 of 1989) [especially Section 24 (b)(i)]; (3) National

Environmental Management Act (Act No. 107 of 1998) which requires that every national department (the DoD included) that may negatively affect the environment to compile and implement environmental management systems (EMS); (4) National Water Act (Act No. 36 of 1998); (5) Defence Act (Act No. 42 of 2002) [especially Section 63 (3)]; (6) White Papers on environment; (7) Policies including SANDF policy, environmental policy. All these legislations are reviewed and their application to DoDMV operational activities is discussed in Chapter II of this thesis.

Deficiencies in the Literature

To-date, long-term soil pollution problems associated with explosives substances have remained poorly studied (Tikhomirov, 2006). Furthermore, the impact and/or influence of military activities on land degradation and demilitarization of landscapes has received inadequate attention, especially on the African continent. The mapping of military pollution hot-spots as well as physically degraded military lands in countries is still lacking (Vines, 1998; Pearce, 2003). No study has attempted to investigate and assess the capacity of military personnel to effectively incorporate environmental considerations in their planning (NATO/SPS, 2008). Nor has there been a study that has investigated the impact of implementing EMS on military proficiency (Wang & Wu, 2013). Moreover, no study has attempted to investigate the quantity of toxic wastes and explosives used in military training ranges (Interstate Technology & Regulatory Council, 2005).

This study is intended to assess the capacity of the military to incorporate environmental concerns in the operations of the SANDF. It also intended to investigate the impact of EMS on military proficiency of South African soldiers. Furthermore, it intends to investigate the accumulation of toxic wastes and explosive substances within selected military installations of the SANDF. It is also the intention of this study to map military pollution hot-spots and degraded military training lands in South Africa.

Aims

The aims of the study are three-fold: it explores the extent of environmental protection and conservation practices in the SANDF and assesses the challenges and capacity of the SANDF to effectively implement environmental protection and conservation without jeopardizing the preparedness of military forces, and further explores the ecological footprints of the South African military force.

Objectives

The objectives of this study are:

1. To investigate the extent to which the SANDF complies with environmental legislation.
2. To investigate the extent to which the SANDF integrates environmental protection practices and conservation in its training and operational activities.
3. To investigate major challenges in the implementation of effective EMS.
4. To investigate how the implementation of EMS has affected troops training and weapon testing.
5. To assess the level of degradation of the selected South African military training ranges.

6. To investigate best management practices within active firing/ammunition training ranges.

Research Location

The study was conducted in two military training installations of the SANDF (described in Chapter V). These installations are Grahamstown military installation (6 SAI) and SA Army Combat Training Centre (Lohatla). The selection criteria used included evidence of military operations, potential devastation of the environment arising from military operations, geographic dimension (i.e., uniqueness, military aggression, frequency).

Garten *et al.* (2003) used a classification system when studying the effects of military operations on indicators of soil quality. Their study classified the study sites and developed five categories based on the level of disturbance. The categories were: (1) reference areas, (2) light military use, (3) moderate military use, (4) heavy military use, and (5) remediated sites. The current study adopted two of these categories: these are light military use and heavy military use. In addition, the current study considered the aspect of military operational aggression in each category, especially in relation to the physical environmental impacts of military activities and the quantification of the level of degradation of the military installation (training ranges).

Summary

Primary responsibilities of military forces are similar. These include safeguarding the sovereignty of a country, keeping internal peace (D'Souza, n.d), and protecting the country against military hostility (Malan, 1994). These responsibilities require military forces to train and prepare for combat at all times. It is during these training exercises that military forces inflict considerable damage on the environment. It is because military training also entails weapon testing and use of live ammunitions shooting. Throughout history of humankind no attention has been paid to the conditions and state of military training ranges.

It is only in the last three to four decades that ministries of defence have noted the necessity to protect and conserve military training ranges. This has come as a result of a shortage of land for military operations. This has forced a number of countries in some parts of the world to consider incorporating environmental concerns into military training programmes and every day operations. These countries are Denmark, the United Kingdom, Canada, the United States of America, the Czech Republic (NATO/CCMS, 2000) and South Africa has followed suit. The implementation of environmental management systems in all these countries is an effort to prevent the adverse environmental impact of military activities. It is also an attempt to promote the protection and conservation of the national assets of these countries.

This study has adopted environmental protection and conservation conceptual framework to study and analyze the environmental impacts associated with military

operations, impacts of environmental considerations on military planning and military proficiency. This theory aims to promote the protection and conservation (sustainable utilization) of natural resources.

Numerous studies on environmental impacts and military activities have been conducted in many countries. These studies have focused on issues ranging from the use of biological and chemical weapons and effects of military vehicle manoeuvre on physical environment. Others have focused on the implications of the lack of concrete environmental provisions on agreements signed for the establishment of military bases in other countries. In such instances, the host country tends to suffer the environmental consequences of military operations left behind at the closure of the military installation. Impacts associated with such a situation include unexploded ordnance, dumping of toxic chemicals in the ground and in water bodies and others buried in an unauthorized landfill sites (Lindsay-Poland & Morgan, 1998). In some cases industrial solvents, firefighting foam and other waste have been found to have caused adverse effects on ecosystems. The US has been criticized for applying a double standard in the clean-up programme in its local and international military installations (Lindsay-Poland & Morgan, 1998).

The physical effects of military activities include soil erosion, loss of topsoil and sedimentation of water bodies, thereby affecting aquatic biota (CEMML, n.d; Pearce, 2003). Other physical effects include the destruction of soil structure and the decline in soil quality (Tikhomirov, 2006). The obvious effect of military operations involves the alteration of environmental conditions such as the removal and disturbance of vegetation cover (Haugen *et al.*, 2003). Thus, this affects underground water quantity and quality as well as increasing surface runoff.

Chemical pollutants found in both surface and underground water sources near military installation include fuel, solvents, heavy metals, ethylene glycol, depleted uranium, nitroglycerin and 2,4-dinitrotoluene. All these chemicals are harmful to both humans and the environment (Riefler & Medina, 2006). Military induced groundwater contamination and toxic dumps are wide spread in the US (Kelly, 2003).

In Africa, the environmental impact associated with military operations is evident in the vast areas of minefields common in some African countries. These minefields were created over many decades of civil wars on the continent. The minefields have severely affected agricultural productivity in many of these African countries. Countries that have been significantly affected include Mozambique, Angola, Somalia, Democratic Republic of Congo, Sierra Leone, and Rwanda (Kanyamibwa, 1998).

In South Africa, there is evidence that the then South Africa Defence Force (SADF) affected many ecological sensitive areas with conservation values. These areas were used as weapon testing grounds (Mckenzie, 1998a). In the past few years, the DoDMV has collaborated with the USDoD in an effort to introduce and implement the military integrated environmental management (MIEM). The main aim of MIEM is that environmental concerns be incorporated into military training programmes and other military activities.

There are numerous deficiencies identified in the literature. This poses a challenge to both academics and researchers to address these gaps information and knowledge. The major challenge that has been noted in Africa is that information on land controlled by military sectors in all countries and impacts of military activities and operations on environment is unavailable in the public domain.

The next chapter (Chapter II) provides an overview of some of the legislations that affects the practices and activities of the SANDF. Thus, for the SANDF to ensure that its activities are not harmful to the environment, it ought to comply with all the relevant environmental protection legislations.

CHAPTER II

OVERVIEW OF LEGISLATIONS AFFECTING ENVIRONMENTAL MANAGEMENT IN THE SOUTH AFRICAN MILITARY FORCE

Introduction

This chapter focuses on reviewing environmental related policies and legislations that have been mentioned in Chapter I, which the DoDMV must comply with, in their day-to-day operations. These are the environmental laws that must be effectively implemented and enforced across all sectors of the society, to ensure that the environmental resources of the country are sustainably utilized and conserved for future generations. It is important to note that South Africa has done very well in promulgating all these laws. The major questions that arise are: Are these laws implemented and enforced across all the sectors of the society? How is the implementation and enforcement of these laws monitored and evaluated? This chapter reviewed the following legislations: The Constitution of the Republic of South Africa Act 108 of 1996; Environment Conservation Act, No. 73 of 1989; National Environmental Management Act, No. 107 of 1998; the 1996 White Paper on National Defence and the National Defence Act (Act No. 42 of 2002); National Water Act, No. 36 of 1998; Integrated Pollution and Waste Management.

Overview of the Constitution of the Republic of South Africa in Relation to the SANDF Environmental Practices

This is the supreme law of South Africa. All other laws are informed by this law. Consequently, any practice that contravenes the constitution is unlawful. The relevance of the Constitution to this study lays in Section 24 of the Bill of Rights which makes a provision for the environment. It is stated in this section that: “everyone has the right to:

(a) an environment that is not harmful to their health or well-being; and

(b) have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that:

    (i) prevent pollution and ecological degradation;

    (ii) promote conservation; and

    (iii) secure ecologically sustainable development and use of natural resources while promoting justified economic and social development.”[2]

The South African Department of Defence has to ensure that all its operations do not violate this section of the constitution. It has to make significant efforts not to make the environment harmful to the citizen of the country particularly when a base is closed (i.e., it ease to be utilized as a military installation). Thus the clean-up leading to the closure of the base must be carried out efficiently. Though this task can be seen as time consuming, but it is the responsibility of the DoDMV to make such areas habitable to civilians again. The DoDMV also has the responsibility to protect our environment and prevent ecological destruction through prevention of pollution of any kind, implementing effective environmental management systems to minimize the impact on the environment, avoiding disturbance of ecological sensitive areas as well as restoration of already degraded areas.

[2] Constitution of the Republic of South Africa Act 108, of 1996. Constitution Twelfth Amendment Act, 2005

Environmental Management Tools and Legislations: Implications to the Practices of the SANDF

Environmental consciousness around the world started in the early 1970s. This was triggered by the enactment of environmental policy in 1970 by the United States of America (Sowman *et al.*, 1995). In 1969 the United States of America enacted the National Environmental Policy Act (NEPA) aimed at integrating environmental concerns in development planning (Saidi, 2010). This policy made it compulsory for environmental impact assessment (EIA) to be conducted for every major development (Sowman *et al*., 1995). EIA attempts to introduce consideration of environmental issues at all important decision-making stages of the proposed development undertakings (Kaatz *et al.*, 2005). Thus, Cashmore (2004) defined EIA as a decision tool employed to identify and evaluate the probable environmental consequences of certain proposed development actions.

Hence EIA is seen as a procedure for identifying and investigating the environmental consequences of development and as a major tool in decision-making. Sowman *et al*. (1995) believe that this action by the US government, led to the development and implementation of formal as well as informal environmental evaluation procedures right across nations. The first formal EIA system in the US was established on the 1st of January 1970, which was in response to the growing public outcry on adverse environmental consequences of most economic development projects (Cashmore 2004; Betey & Godfred, 2013). Subsequently, many developing countries adopted environmental evaluation procedures in the late 1970s (Robinson, 1992; Sowman *et al.*, 1995; Eggenberger & Partidário, 2000; Bhatt & Khanal, 2010; Phatak & Kanhe, 2013). According to Saidi (2010), South Africa's first experience of EIA was in the 1970s when the less-structured British-style of EIA was used for large scale projects. However, Sowman *et al.* (1995) state that South Africa was a bit sluggish to develop environmental evaluation procedures relevant to its conditions. It was only in 1989 that South Africa enacted the environmental legislation which provided for the determination of environmental policy to guide decision-making processes of development (Sowman *et al.*, 1995; Saidi, 2010).

This legislation is called Environment Conservation Act (Act No. 73 of 1989). This Act provides for regulation of activities that may have detrimental effects on the environment and requires that environmental impact reports be prepared for development activities (Sowman *et al.*, 1995; Saidi, 2010). However, EIA was voluntary and there were no procedures and methods codified in law and furthermore there were no formal administrative systems in place to process EIA at any government level despite enabling clauses in the Act (Duthie, 2001). The voluntary EIAs were only carried out for those projects that were typically controversial (Hill, 2000).

Sowman *et al.* (1995) believe that the key constraints to the development and implementation of environmental evaluation procedures in South Africa then were: the absence of a general environmental policy, lack of political will and awareness of the need to consider environmental issues, authoritarian system of government, lack of accountability by decision-makers, inadequate public participation, inefficient administrative structures, legislative inadequacies, lack of environmental expertise and financial resources. Similarly, Hill (2000) also mention that the major weaknesses of EIA in South Africa then, were related to ill-defined allocation of responsibility for environmental management, and insufficient use of method in exercising this responsibility. In addition, inadequate institutional and organisational arrangements, lack of involvement of environmental specialists in monitoring and enforcement of compliance with environmental legislation as well as vague schedules and uncertain budgets were some of the major constraints for effective execution of EIA system (Hill, 2000). Furthermore, Sowman *et al.* (1995) indicate that another additional factor that constrained the implementation of environmental evaluation procedures in South Africa was the recognition by proponents of EIA that direct transfer of United States and European models to South Africa would not work. Indeed, this was a valid argument, there are many cases where copying of models elsewhere without modification have failed to produce the desired results or outcome.

Subsequent to the lack of implementation of environmental management tools in South Africa led to enormous pressure put onto the South African government by the international community to introduce EIA as a legal mechanism for regulating activities that may have harmful effect on the environment (Sowman *et al.*, 1995). Since EIA has proved to be an effective tool for raising the consciousness of both the developers and administrative authorities of the essence of environmental protection and sustainability (Saidi, 2010). Great strides were taken by the South African government to develop guidelines, procedures and mechanism to introduce EIA. According to Sowman *et al.* (1995), EIA committee was formed in 1983 to drive the process of developing EIA procedures and mechanism for implementation. This committee initiated research, organized workshops and consulted widely on EIA issues. This clearly indicated that South Africa wanted to have environmental procedures and mechanisms of implementation that are compatible with the South African conditions (Duthie, 2001). Government officials, professional, experts and academics contributed significantly to the development of the EIA model of South Africa. These contributions range from identifying elements needed to be incorporated into the EIA procedures and mechanisms of implementation (Sowman *et al.*, 1995). Sowman *et al.* state that a conclusion to introduce EIA as a comprehensive, holistic planning procedure was reached at a National Workshop held at Midmar in KwaZulu Natal in 1985. This meant that a broader philosophy which should be flexible, generally applicable, widely accepted and practical to implement was required (Kidd & Retief, 2009).

Subsequently, a working group was appointed to develop a philosophy on environmental evaluation for South Africa and to establish a systematic procedure for incorporating environmental concerns into planning, development, management actions, processes and decision-making. After another two years of further research, consultation and review of previous work, a document on integrated environmental management (IEM) in South Africa was published (Sowman *et al.,* 1995; Wood, 1999). The concept of IEM was chosen as the overarching and holistic philosophy for environmental management in South Africa (Kidd & Retief, 2009). The justification provided was that, IEM is an approach that integrates environmental considerations into all stages of planning, and the development process; and it requires post-impact assessment monitoring and management. It is also reported that IEM was chosen because the term EIA was inappropriate and perceived to be too limited in scope, reactive, anti-development, separate from the planning process (Kidd & Retief, 2009), and often cause costly unnecessary delays (Sowman *et al.*, 1995).

Consequently, the Council for the Environment recommended that the government adopts the principles and procedures of IEM which would ensure a more holistic and responsible attitude towards the environment by developers and professionals. Due to its holistic view of the environment, the IEM procedure relies on active participation of many different organizations and individuals that interact in a complex manner (Avis, 1994). Thus, all stakeholders were happy to adopt a procedure that would ensure integration of environmental considerations at all stages of development and decision-making. This could be attributed to the fact that the primary objectives of IEM are to promote environmentally sound development and to marry the opposing concept of development and conservation with the emphasis on saving the resource base for future generation (Avis, 1994). The basic principles underpinning IEM procedures are[3]:

- informed decision-making, accountability for information on which decisions are taken,
- accountability for decisions taken,
- broad understanding of the term environment (i.e., to include physical, biological, social, economic, cultural, historical and political components),
- open and participatory approach in planning and decision-making,
- consultation with interested and affected parties,
- consideration of alternative options,
- mitigation of negative impacts and enhancement of positive aspects of development,

[3] Department of Environment Affairs (1992) cited in the Strategic Environmental Assessment in South Africa by Department of Environmental Affairs and Tourism & CSIR (2000); and Sowman *et al*, (1995)

- ensure that social costs are outweighed by social benefits,
- democratic regard for individual rights and obligations,
- compliance with these principles during all stages of the planning, implementation and decommissioning of proposals (i.e., from cradle to grave),
- opportunity for public and specialist input in the decision-making process.

According to Sowman *et al.* (1995), many government departments, most notably the Department of Water Affairs, Mineral and Energy Affairs, Transport supported the IEM approach. Participation and contribution from the Department of Defence and Military Veterans is not mentioned (Sowman *et al.,* 1995). The adoption of IEM procedural document in 1989 coincided with the promulgation of the new environmental legislation (i.e., Environment Conservation Act, No. 73 of 1989) which repealed the Environmental Conservation Act (No. 100 of 1982).

By the year 1997, EIA regulations were promulgated in terms of Sections 21, 22 and 26 of the Environmental Conservation Act (No. 73 of 1989) (Sandham & Pretorius, 2008). Consequently, Wood (1999) argues that EIA belatedly became a statutory requirement for various potentially harmful activities by the year 1997. Seven main components of EIA process were also outlined in the regulations include: pre-application consultation, plan of study for scoping, scoping report which should incorporate public involvement or participation, plan of study for EIA, environmental impact report which should also involve public participation, authority review and the last stage being the issuing of the record of decision with conditions of approval (Sandham & Pretorius, 2008). Since then, EIA has become a legal requirement in South Africa for all activities that may have harmful effect on the environment (du

Pisani & Sandham, 2006). At present, however, EIA is governed by sections 23 and 24 of the National Environmental Management Act (No. 107 of 1998) (Saidi, 2010).

The Environment Conservation Act: Implications for the SANDF Practices

The Environment Conservation Act (ECA), (Act No. 73 of 1989) is divided into five parts. Part I deals with policy for environmental conservation, part III focuses on the protection of natural environment, and part IV mainly focuses on the control of environmental pollution and part V explains the control of activities which may have detrimental effect on the environment. This legislation, among other issues it prohibits environmental pollution of any kind. It further talks against the discarding, and unauthorized dumping of litter or waste on any land or water surface. According to the Act, no one is allowed to establish, provide or operate any disposal site without a permit issued by a relevant authority (may involve officials from Department of Water Affairs and Forestry, and/or department of Environmental Affairs and Tourism) on behalf of the Minister.

This Act also gives the Minister the right to exempt any person or group of persons from obtaining a permit, subject to certain conditions as the Minister may deem fit. The Minister of Water Affairs may, from time to time, by notice in the Gazette issue directions with regard to:

(a) the control and management of disposal sites in general;

(b) the control and management of certain disposal sites or disposal sites made for specific types of waste; and

(c) the procedure to be followed before any disposal site may be withdrawn from use or utilized for another purpose.

The ECA further states that no person shall discard waste or dispose of it in any other manner, except:

(a) at a disposal site for which a permit has been issued in term of this law; or
(b) in a manner or by means of a facility or method and subject to such conditions as the Minister may prescribe.

Section 21 of the ECA indicates activities which may probably have detrimental effect on the environment. Eleven activities and or group of activities are highlighted, but not limited thereto. For this study only six of the eleven activities are considered. This includes the following:

(a) land use and transformation;
(b) water use and disposal;
(c) resource removal;
(d) transportation;
(e) waste and sewage disposal; and
(f) chemical treatment

All these activities are likely to occur in a military installation; therefore, the SANDF/DoDMV is expected to apply for permission or authorization whenever such activities are to be undertaken. This is done in compliance with Section 22of the ECA, which states that no person shall undertake an activity identified in terms of Section 21(1) or cause such an activity to be undertaken except when authorization has been issued by the Minister or by a competent authority or local authority or an officer. Authorization shall only be issued after consideration of reports concerning the impact of the proposed activity and of alternative proposed activities on the environment, which should be compiled and submitted by such persons and in a manner as may be prescribe. This simply means that environmental evaluation [environmental impact assessment (EIA)] must be undertaken to ascertain environmental impacts of the proposed activity. Glazewski (1992) correctly noted that the ECA does not mention that EIA studies must adhere to the IEM procedures, to ensure that the philosophy of environmental evaluation accepted in South Africa informs EIA processes.

Therefore, the SANDF is expected to comply with this legislation. Consequently, the SANDF should not allow or should prevent environmental pollution through proper handling and management of all form of waste in all its installations. Waste generated in military installations has to be transported and disposed of in an approved disposal sites (or landfill sites). It should also take initiatives to protection and ensure sustainability of the environment, but not jeopardizing military proficiency of the soldiers.

Effects of the National Environmental Management Act on the SANDF's Activities

The National Environmental Management Act [NEMA] (Act No. 107 of 1998) of South Africa requires that every national department that may affect the environment, the DoD included, must have environmental management systems (EMS) (Daniel, 2007) to mitigate against negative impacts associated with the day-to-day activities of such departments; and these departments must also develop environmental implementation plan (EIP) (Jacobs *et al.*, 2002). EMS is described as an indicator of the environmental performance of an organization to control its activities that have significant impact on the environment (Rowland-Jones *et al.*, 2005). According to this Act (NEMA), the EMS and EIP must be reviewed every four years thereafter. This is meant to ensure improvement on environmental management practices/performance by the concerned department.

There are five purposes of EIP and EMS. Of the five purposes, only three are relevant to this study. One of the purposes is that EIP and EMS are aimed at striving for the achievement, promotion and protection of a sustainable environment; the other, argue for securing the protection of the environment across the country as a whole; and the last one states that the Minister of the environment will be able to monitor the achievement, promotion and protection of a sustainable environment[4].

In 2005 the Department of Environmental Affairs and Tourism (DEAT) started to form the Environmental Management Inspectorate (EMI). The EMIs (also referred to as "the Green Scorpions") are officials in DEAT, and other organs of state, such as the provincial departments of environment, and municipalities. The EMI units were formed with the aim of monitoring compliance and enforcement of environmental legislations and regulations (including authorization issued under legislation in their mandate) (Fourie, 2005)[5]. The EMI are responsible for enforcing the NEMA (Act No. 107 of

[4] Chapter 3: Procedures for Co-operative Governance: environmental implementation plans and environmental management plans. National Environmental Management Act (Act No. 107), 1998.
[5] Melissa Fourie: The National Environmental Management Act (NEMA) and the Environmental Management

1998), Environment Conservation Act (Act No. of 1989); National Water Act (Act No. 36 of 1998); Biodiversity Act, No. 10 of 2004, Protected Areas Act, No. 57 of 2003 and other national environmental legislations.

The EMIs have powers to conduct *routine inspections* – entering premises, sometimes without warrants for specific purpose and seizing evidence; *investigations* – questioning witnesses, copying documents, inspect and remove articles or substances, taking photographs, taking samples and removing waste; *enforcement* – search, seizure, roadblocks, arrest; and also have *administrative powers* – issue compliance notices. This shows how serious the South African government is on ensuring that the environment is protected and well managed. Therefore, by law, the SANDF has to comply with environmental regulations of the country. Nevertheless, the question that arises is "do the EMI have enough powers to investigate environmental practices in the South African Army? This remains to be seen, given the nature of the Defence Force.

The National Environmental Management: Biodiversity Act (Act No. 4 of 2004) and its Implications on the Activities of the SANDF

This legislation is meant to provide a framework to regulate the management and conservation of biodiversity in South Africa in line with the NEMA (Act No. 107 of 1998). It is all about preventing unauthorized introduction and spread of alien and invasive species. It is also meant to prevent and minimize harm to local ecosystems

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Inspectorate. Presentation to Prosecutor Training Course, 25 July 2005. Fourie is the Director of Enforcement in the Department of Environmental Affairs and Tourism of the South African Government.

and biodiversity likely to arise due to the existence of such species. Eradication of invasive species in ecosystems and habitats where ecological harm is highly likely to occur is emphasized.

The prevention of spread of alien and invasive species in the army is highly impossible. Military vehicles are used in different parts of the country and even beyond the borders of South Africa. Thus, seeds and spores of invasive species can attach themselves to these machineries and imported unintentional to local ecosystems and habitats, especially to military training areas. Indeed, evidence of existence of invasive plant species within military training areas can be observed. As such, attempts to eradicate these species in the whole of South Africa and including military training areas are underway. The Working for Water Programme (WWP) driven by the Department of Water Affairs has expanded to military controlled land areas. The military training area of the 6 South African Infantry Battalion in Grahamstown is heavily infested with the alien *Opuntia Indica* species; it is where the WWP has been implemented.

Part 2 of this Act, emphasize that the control and eradication of invasive species must be carried out through means of mechanisms that are appropriate for the species concerned and the environmental in which it occurs. It other words, it should not be copying of a method elsewhere and implementation of it in another area. The method adopted must also be directed to the off-springs, propagating material and re-growth of the species. It is also emphasized that the action taken to control and eradicate invasive species must not cause significant harm to biodiversity and damage to the environment. The Act also mention that all organs of states in all three spheres of government must have an invasive species monitoring, control and eradication plan or programme for the land under their control (should form part of the environmental management plan). Thus, the integrated development plans (IDPs) of municipalities must incorporate plans or strategies (i.e., monitoring, control and eradication) to deal with invasive. Therefore, cooperation and linkages between the SANDF and other government departments can be forged in the implementation of these programmes. Where the designated environmental officers in the SANDF can cooperate and work together with environmental officers of other departments. This can also be expanded to include academic institutions and research institutes to carry out scientific research on various issues related to control and eradication of invasive species.

The 1996 White Paper on SANDF (Defence) and the Defence Act, of 2002

The White paper on National Defence Force for the Republic of South Africa covers nine (9) topics which are important to the defence force. Each of these topics constitutes a chapter in the White paper. Of all these, this study is only interested in the land and environmental issues covered in Chapter 9 of the White paper. The 1996 White paper symbolizes a fundamental shift from the aggressive and repressive strategies of the apartheid government and seeks to bring defence policy into line with democratic principles, Bill of Rights and international laws on armed conflict (Nathan, 1998).

According to the White Paper (1996), prior to the new dispensation in South Africa, the SANDF controlled approximately 500 000 hectares of state-owned land. All this land are required for effective force development and preparation, including field exercises and weapons testing. The White Paper (1996) does acknowledge that some of the land utilised by the Defence Force was previously occupied by people who suffered from forced removals during the apartheid era. With the land redistribution and restitution programme in force in South Africa, a number of land claims have been filed by affected communities for some of the land under the control of the SANDF. To this end, the SANDF has initiated a land rationalization process in an effort to make land available for restitution and redistribution.

The White Paper (1996) explicitly states that the SANDF has a moral and legal obligation to utilize its properties in a responsible manner. This implies that the SANDF has responsibilities to avoid and minimize land degradation onto the land under its control. Thus, in addition to both its primary and secondary functions, it also has to concentrate on ensuring that environmental and ecological degradation are prevented and that all the natural resources on land under its control are sustainably utilized, for military or civilian use in the future.

The Minister and the Chief of the Defence Force are responsible for ensuring the exercise of proper ecological management and control of military properties (White Paper, 1996). It further states that there must be co-operation between the DoDMV with other government departments and environmental organisations. To ensure that the DoDMV meet its environmental obligation, the White Paper indicates that Environmental Services within the SANDF must be established to engage in environmental planning and research; ecological and environmental management of military properties; cultural resource management; and environmental education. According to the White Paper (1996), the Environmental Services will be tasked to ensure that the environmental suitability of military facilities for present and future military and national use. The White Paper (1996) argues that the SANDF policy on the environment must be consistent with the

- national policy and include the following guidelines:

  the protection of species and habitats and the conservation of bio-diversity and natural resources;
- the protection of the environment against disturbance, deterioration, poisoning or destruction as a result of human activity and structures;
- the maintenance and improvement of environments which contribute to the quality of life of South African citizens; and
- the provision of a healthy working environment for its personnel.

It is further stated in the White Paper (1996) that the planning and execution of military activities will take into account the environmental implications that may result thereof. Incorporation of environmental concerns into planning and execution of military activities and programmes is meant not to jeopardize the long-term potential of land and other natural resources. The White Paper emphasize that the SANDF is committed to the application of the Integrated Environmental Management Procedure[6] (IEMP) in the planning and establishment of physical development on land under its authority.

Furthermore, environmental impact assessments (EIA) should be undertaken and rehabilitation measures be applied to counter, as much as possible, the negative

[6] Environmental evaluation method recommended for environmental management in South Africa by the Council for the Environment in 1989 (Department of Environment Affairs, 1992)

impact of development, operations and other activities on the environment. Accordingly, military properties are regarded and managed as conservation areas, to realize this, the use of these properties require the integration of environmental considerations and concerns into military operations. According to the White Paper (1996), the SANDF will participate in environmental forums and enlist the support of experts in refining and implementing its environmental policy. Furthermore, the SANDF will endeavour to instil a sense of awareness and environmental responsibility in the training of recruits.

Section 63 (3) of the Defence Act (Act No.42 of 2002) states that the Minister must ensure that the training of military personnel promotes the objectives of, and in accordance with the Constitution and the law, including customary international law and international agreements bidding on the Republic of South Africa. In addition, Section 65 of the Act, refer to designation of areas for training and states that the Minister may at the request of the Chief of the Defence Force, as and when the exigencies of the training require to designate any area, whether on a public or private property as an area in which the Defence Force may execute military exercises. However, this is subject to comments/submissions from interested and affected parties, as well as the National Environmental Management Act (Act No. 107 of 1998). It is pleasing to learn that the DoDMV do recognize the environmental law, regulations and management tools of the country. This gives hope that even land under military control will not be degraded due to military operations; but sustainably utilization for future military occupation.

The National Water Act in Relation to SANDF Practices

As is stated above, the Constitution of the Republic of South Africa (Act 108 of 1996) is the broader law framework of the country wherein all other legislations are hinging on. In the Bill of Rights of the constitution a provision is made that 'everyone must have the right of access to sufficient food and water' [s27(1)] and for the state to take reasonable legislative and other measures, within its available resources, to achieve progressive realization of all the rights [s27(2)] enshrined in the constitution. As a result of this mandate from the constitution, the National Water Act (NWA) [Act No. 36 of 1998] was promulgated. The NWA is administered by the Department of Water Affairs and Forestry (DWAF). In this Act water is considered as a public resource; therefore no single individual can claim ownership of it, even when the source is on or run across a privately owned land. The right to use water is granted to users, through a license system which users must pay for the quantity consumed over a specific period. However, there are cases where water users do not require a license but do pay for it; those include households, hospitals, and educational institutions.

The relevance of the NWA to this study relates to water pollution[7] and pollution of water courses. The NWA advocates for the duty of care for effective water resource management and pollution prevention. The duty of care is imposed onto the owner of the land, a person who lease or uses the land on which activities or processes which cause or likely to cause pollution of the water course to take all necessary and

[7] Water pollution as defined in the National Water Act is a direct or indirect alteration of physical, chemical or biological properties of a water resource so as to make it: (a) less fit for any beneficial purpose for which it may reasonably be expected to be used or (b) harmful or potentially harmful – (aa) to the welfare, health or safety of human beings; (bb) to any aquatic or non-aquatic organisms; (cc) to the resource quality; or (dd) to property

reasonable measures to prevent pollution from continuing, occurring, or recurring and to clean the effects of pollution (Craigie & Fourie, 2005)[8]. Chapter 3, part 4 of the NWA deals with pollution prevention and in particular pollution occurring in a situation where pollution of a water source occurs or might occur as a result of any activity carried out on the land. Section 19 subsection (I) mandate the land owner or the person(s) managing the land to take necessary actions to remedy the situation and cease the activity that pollute or has a potential to pollute the water source. Obviously, it might be very difficult to impossible to cease military activities due to potential pollution of water resources. However, adequate actions to control and prevent pollution are expected to be implemented by the SANDF where risk exist (the land user or owner, or person controlling the land, or the occupier of the land as spelt out in section [s19 (ss2)]). Subsection 3 of section 19 of the NWA outlines the responsibilities of the catchment management agencies (CMAs) in cases where pollution of water sources has occurred or there is a potential for water pollution within the catchment. Thus, the SANDF must work hand in hand with CMAs to remedy polluted water sources and also acquire skills and capacity to prevent future water source pollution.

Part 5 Section 20 (ss 1- 6), deals with pollution occurring due to accident or incident of substance spillage. This section clearly explains that a person who has failed to prevent pollution of water from occurring due to incident of substance spillage must be held responsible and be charged accordingly (i.e., applying the ‘polluter pays principle’). It further elaborates that emergency incidents or accidents must be

[8] Frances Craigie & Melissa Fourie. Polluter Pays: An Overview of South Africa’s Pollution, Waste and Environmental Impact Assessment Legislation. Joint Presentation on 28 July 2005. Craigie is a Deputy-Director: Compliance and Enforcement, Gauteng Department of Agriculture, Conservation and Environment (GDACE).

reported to the Department of Water Affairs, South African Police Services, Fire Department and/or the catchment management agency. Moreover, the person who owns the substance must take reasonable measures to contain and minimize the effects of the incident on the environment (water resource); and that the person undertakes clean-up measure and remedy the effects of the incident. In keeping with these regulations, the SANDF is bound by law to prevent and report such incidents accordingly.

The duty of care suggested in the NWA is undoubtedly affects the SANDF too. Incidents of water pollution due to accidental spillage of harmful substances are common in militarized landscapes. Consequently, any form of water pollution occurring on military controlled land, the SANDF/DoDMV must take full responsibility and the necessary action to ensure that such activities causing or likely to cause pollution cease immediately and/or effective measures be implemented to mitigate their effects on water sources. However, the NWA does not specify the types of pollutants referred to therein. The most common source of pollutants in military training sites includes sediments, and chemical pollutants explained in Chapters I and III. Heavy metals and other pollutants find their way into water courses and thus disrupting aquatic ecological processes.

The ecological effects or impacts of sediments are well documented. Some of the studies that have documented impact of heavy metals on the environment include but not limited to Arfsten *et al.* (2001), Pinto and Salgado (2004), Mashi *et al.* (2005), Briner (2006), Andrae *et al.* (2007), Duruibe *et al.* (2007), Robinson *et al.* (2008), Khan *et al.* (2008), Lasheen *et al.* (2008), Peralta-Videa *et al.* (2009), Singh *et al.* (2010), Badr *et al.* (2011), Mochunong *et al.* (2012), Moo *et al.* (2013) and many more. Thus heavy metal pollutants from the SANDF activities such as fuel spillages and residue from bullet fragments must be monitored in line with environmental protection and sustainability.

The Integrated Pollution and Waste Management in Relation to Military Waste Management

All government departments in South Africa are required to introduce the model suggested in the White Paper on Integrated Pollution and Waste Management (of 2000) as well as in the White Paper on Environmental Management Policy for South Africa (1997). This model is known as the “4Rs” of solid waste management. The 4Rs refers to reduce, reuse, recycle and repair. This White Paper also sets out the principles that underpin the National Waste Management Strategy (NWMS). The NWMS is then translates the policy principles into strategic plans and actions. This means that by law, departments and municipalities have the responsibility of waste collection and disposal in approve sites. The National Environmental Management Act (Act No. 107 of 1998) also emphasizes the need for development to be sustainable and requires that ‘waste is avoided, or where it cannot be altogether avoided, then it has to be minimized and reused or recycled where possible, and otherwise disposed of in a responsible manner’.

South African waste management is controlled by laws which are all hinged and centred on the following legislative frameworks: The Constitution of the Republic of South Africa (Act 108 of 1996), The National Environmental Management Act (Act 107 of 1998), Environment Conservation Act (Act No. of 1989), The Local Government:

Municipal Structures Act (Act 117 of 1998) and The Local Government: Municipal Systems Act (Act 32 of 2000).

The Department of Environmental Affairs and Tourism (2004a) suggests that since waste management is mostly controlled through municipal by-laws and, each municipality makes its own by-laws, there are often clashes with the policies and Acts. Very often these clashes lead to discrepancies in enforcement, regulation and administration of waste management functions between the different district municipalities. However, it is believed that waste generated in the territories of the Defence Force is the responsibility of the DoDMV to deal with its waste. This means that the DoDMV must put waste management measures in place to effectively reduce, manage and recycle its waste. This will ensure that military ranges are operated in a sustainable manner and in compliance with environmental laws of the country.

In terms of the National Waste Management Strategy, emphasis is on waste avoidance, minimization, recycling and through to responsible disposal. South Africa is one of the few countries in the world that has embarked on undertaking serious measures against the problem of solid waste (IP & WM, 1996). Clearly, the country is following in the footsteps of first world countries such as Sweden, the USA and Canada. South Africa has also recently adopted the ‘zero waste’ strategy of managing waste. The ‘zero waste’ is a philosophy that aims to guide people in the re-design of their resource-use system with the aim of reducing solid waste to zero. In simply terms - ‘zero waste’ is an idea to extend the current ideas of reducing and recycling waste to form a circular system where as much waste as possible is reused.

The ‘zero waste strategy’ is one of the key inroads adopted by the Municipal Waste Management Strategy and this strategy promotes re-use and recycling (DEAT, 2004b). It also requires individuals to take strategic measures in dealing with the waste they produce whilst manufacturers are urged to develop products that do not necessarily create waste and that can be recycled easily. The question is: has the DoDMV taken initiatives to implement these two strategies to deal with all of its military waste?

Summary

It is a serious challenge for the DoDMV to integrate environmental concerns into their day-to-day operations because of the nature of this institution. However, this is not an excuse because continuous damage to the environment has serious repercussions. All the legislations briefly reviewed in this chapter, were meant to ensure sustainable utilization of South Africa’s natural resources and the protection of the environment. The Constitution advocates for the protection and conservation of the environment through sustainable development and utilization of natural resources, as well as to achieve a fair balance between development and the environment. South Africa adopted environmental impact assessment (EIA) almost three decades later than other countries. It was only in the late 1990s (1997 to be exact) that a legislative framework was promulgated to make environmental evaluation compulsory in South Africa prior to any development undertaken (Wood, 1999; Sandham & Pretorius, 2008). Integrated environmental management (IEM) was adopted in South Africa as a philosophy that underpins environmental evaluation studies/processes (Sowman *et al.*, 1995). IEM was envisaged to have a holistic approach to environmental issues due to its extensive integration and interaction of many stakeholders (i.e., different organizations, individuals, practitioners, professionals etc.) from the planning through to the operational phase of the project (monitoring) (Sowman *et al.*, 1995; du Pisani & Sandham, 2006). The adoption of this philosophy coincided with the promulgation of the Environment Conservation Act (Act 73 of 1989), which was meant to enforce environmental evaluation and promote environmental protection and conservation (du Pisani & Sandham, 2006). However, this Act does not explicitly state that EIA studies have to conform or incorporate IEM procedures (Glazewski, 1992).

The National Environmental Management Act (Act 107 of 1998) makes it compulsory for all government departments and private firms to have environmental management systems (EMS) or environmental management programmes (EMP) as well as environmental implementation plans (EIP), which should be revised every four years to improve on their environmental performance. All these environmental management tools are aimed at achieving, promoting and protecting sustainable environment (du Pisani & Sandham, 2006). Consequently, environmental management inspectorate (EMI) has been established to enforce and monitor compliance with environmental legislations.

The 1996 White Paper on defence is in line with democratic principles, the Bill of Rights and international laws on armed conflict (Nathan, 1998). The White Paper mention that in addition to both the primary and secondary functions of the DoDMV, more attention will be given to prevent environmental and ecological degradation, and that natural resources on military lands are managed and utilized more sustainably. It further states that environmental services will be established within the DoDMV structure to ensure proper environmental planning, research, ecological and environmental management within military operations. According to the White Paper of 1996, integrated environmental management procedures (IEMP) will be applied in all environmental planning and that EIA will be used where necessary. In complying with the NWA, the DoDMV must prevent pollution of water sources; and report any accidental or incidents of spillage of hazardous substances that might harm the environment. Thereafter, measures must be taken to remedy the environmental effect of the substance, within a specified period of time given by the relevant authority (e.g., Catchment Management Agency, or Department of Water Affairs, or Department of Environmental Affairs and tourism). Waste generated from military installations has to be managed in accordance with the relevant laws. Waste must be disposed of in a proper and approved site(s). The DoDMV is also expected to introduce the 4R model or method of environmental management, this is: reduce, re-use, recycle and repair. This is believed to lead to the ambitious 'zero waste' model (DEAT, 2004b).

Chapter III provides a detailed review of literature related to environmental management with particular focus to the defence sector. The literature is reviewed under specific themes ranging from the conception of environmental management systems in general to contamination of the environment through military activities or actions and degradation of military controlled areas.

CHAPTER III

LITERATURE REVIEW

Introduction

A literature review was conducted to recapitulate information already available on environmental impact of military activities as well as on environmental protection, sustainability and management in military training ranges. This is to set the boundaries and create a strong foundation for the study. The literature has been summarized, evaluated and in some instance new information has been synthesized in an effort to generate new interpretation in line with this study. Furthermore, to set a framework within which to analyse and discuss the data collected around many of the variables of interest to environmental management in military. Generally, research related to environmental protection and sustainability as well as management in military installations appears to be limited.

Contextual Background on Military Environmental Management Issues

Studies have been conducted to understand the impact of military activities on the environment. Literature on this subject is dominated by research conducted in developed countries. There is little to no literature available on military environmental impact in developing and less developed countries. The need for the protection of the environment in wartime emerged after the Vietnam War (Hulme, 2004). It has been noted that developed and some developing countries have, in the last few decades, begun seeking solutions to environmental problems associated with military activities during peacetime. This emerged from the observation that military training ranges are becoming degraded over time as a response to the aggressive nature of military practices. In addition, military training areas are degraded because of the lack of environmental considerations/integration into military training programmes and other associated activities. Thus conflicting with the principles of environmental sustainability which advocates for the maintenance of the natural capital to continue meeting the needs of humanity without compromising the abilities and functions of the ecosystems (Morelli, 2011). It is worth mentioning that there are many published books dealing with environmental problems, however, very few of these mention or address environmental problems of military nature (e.g., Cock & McKenzie, 1998; Hulme, 2004).

Given this, the key questions are: Are there no significant environmental problems associated with military activities during peacetime? Are military activities during peacetime conducted within the acceptable or best practices of environmental protection and sustainability? Are military organizations transparent and willing to share their shortfalls or challenges in the management of the environment? Are scholars just ignoring the practices of armed force in relation to the environment? The answer to the first three questions is definitely "No"; and the answer to the last question is "Yes". Harmse (n.d) argues that most of the books (English publications) on environmental issues (such as Environmental Science and Environmental Management) originate in the United State of America. Therefore, book authors ignore and/or refrain to write about it because America has contributed significantly to numerous wars in the past (Harmse, n.d). According to Harmse, only two British published (authored) books refer to environmental effects of war. These are Goudie (1981) and Goudie and Viles (1997) both contain only one paragraph on the impacts of military activities/operations onto the environment (Harmse, n.d).

Long before the 1960s, there were not much attention given to environmental abuse emanating from human activities in general (Rome, 2003). From the 1970s, there was a great interest by scientists to probe environmental issues, but military related environmental impacts did not receive the attention like other issues (NATO-CCMS, 2005). Could the reason be that the political nature of defence forces the world over does not allow access to their territories? Obviously defence forces are sensitive and secretive political entities of states. Lack of environmental awareness to military organization has played a major role in the negligence of environmental problems associated with their activities.

There must be a change in the mind set of military organisations, so that military associated environmental impacts can be prioritized and receive attention (NATO-CCMS, 2000). As such, the continuous damage of the environment by military activities without appropriate management plans put in place, is not compatible with sustainability of the natural resources (Goodland, 1995). In addition, the manner in which laws are enforced, must be applied equally to the military sector (NATO-CCMS, 2000; Ramos & de Melo, 2005). In other words defence forces must be held accountable for their impact on the environment (Dorfman, 2004), if the principle of sustainable utilization and protection of the environment is to be realized.

Conception of Environmental Management System Standards

From the 1970s onwards there has been an increase in environmental awareness. This awareness has intensified in recent decades, during which time governments, industries and citizens across the world have become more sensitized about environmental issues and the need to manage these issues in a systematic manner (NATO-CCMS, 2000). According to NATO-CCMS (2000), the eagerness to manage the environment more appropriately led to the conception and development of environmental management system (EMS). EMS is defined in the ISO 14001 (2004) as part of the overall management system that includes organizational structure, planning, activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy.

According to Puvanasvaran *et al.* (2010), ISO 14001 EMS has been designed to introduce environmental management improvement into every practice of an organization (i.e., industry, firm or company) by offering an organized approach to manage environmental issues and has since become an administrative tool for corporate environmental management. This approach is regarded as integrated and more systematic (i.e., procedural) covering the life span of an activity from the planning phase to decommissioning phase (from cradle to grave) (NATO-CCMS, 2000).

The decade of the 1980s is discernible by the adoption of the systematic approach to environmental management in dealing with environmental problems. This approach is meant to achieve the main goal which is environmental protection and sustainability of the natural resources. According to NATO-CCMS (2000), both governments and industries during the 1980s began adopting this approach in an effort to replace the *ad-hoc* approach previously used in dealing with environmental problems. The replacement of the *ad-hoc* approach in addressing environmental management issues emanated from the realization that it could not achieve environmental protection and sustainability. Furthermore, to limit and even eradicates the incidences of poor environmental management practices (Trinder, n.d.).

Therefore EMS can be viewed as an assurance by an organization that it is committed to the sustainability of the environment. However, EMS of any organization must comply with and be certified under the ISO 14001 standard. There are three dominant international standards, these include the BS 7750 environmental management standard created in 1992 by the British Standards Institute; in 1995 the European Union developed the Eco-Management and Audit Scheme (EMAS); and International Organisation for Standardisation (ISO) published its environmental management systems (ISO 14001) in 1996, although the organization was established in 1947 (NATO-CCMS, 2000). From this development in environmental management approach, numerous countries formulated their own national standards. South Africa is the only country in Africa that has developed an environmental management standard (NATO-CCMS, 2000).

Literature indicates that for decades proper environmental management have been enforced in industries and other sectors of the society but not the defence sector. These sectors were forced to develop and implement EMS. Therefore, increase in the implementation of systematic approach in the management of the environment in the civil sectors of the society was noted (Tan, 2005; Matuszak-Flejszman, 2009; Puvanasvaran *et al.*, 2010). However, there is a dearth of literature on the integration of environmental management into the defence sector's activities around the world (Ramos & de Melo, 2006). This in a way may show that there is serious resistance by defence forces to develop and implement EMS as required by all the environmental standards. It is also indicative that military spaces and places are viewed and treated as entities existing outside of social practice whereas they are products of social practice (Woodward, 2001).

Although the military sector's environmental impact far exceeds that of most other government departments (NATO-CCMS, 2000; Ramos *et al.*, 2007), in the past the military sectors were not obligated to comply with environmental laws. However, in the last decade or so, there were drastic changes with regard to environmental protection in military sectors. Globally, defence sectors have recognised that sustainable environmental management have positive spinoffs to military activities in the long-term (Wang & Wu, 2013). Recognition protection of the environment resulted in increasing pressure and concern for the military sector to integrate environmental issues in their military training programmes and activities (Smit, 2011; Wu & Wang, 2011). Adoption and implementation of EMS has proved to be essential and required in the defence sectors to ascertain environmental protection and sustainability (NATO-CCMS, 2000; Dawnson, 2004; Ramos *et al.*, 2007; Smit, 2011; Wang & Wu, 2013); thus, this argument is presented in one of the sections below.

Rationale and Benefits of Implementing EMS

Each and every practice, activity and/or programme has its own purpose, benefits and challenges. In the case of adoption of a systematic approach to environmental management the rationale is to ensure sustainability of the environment (or sustainable utilization of the environment). This can only be achieved by developing, implementing and maintaining programmes that reduces harmful effects on the environment, and/or protection of the environment. According to Matuszak-Flejszman

(2009), the major reasons and benefit for implementing EMS in line with ISO 14001 include the following:

- Care for the environment,
- Accepted development strategy of the company,
- Development guidelines for the quality management system in use,
- Influence of any third parties on the activity of the company,
- Possible growth in exports of the company products,
- Compliance with legal requirements,
- Raising pro-ecological awareness of the employees,
- Interest of the local community in the activity of the company,
- Improving environmental impact,
- Planning to increase market share.

Fifty percent of the reasons stated above, are applicable to the military sector. Thus, caring for the environmental must form part of the management of military properties. For instance, degradation of the environmental will have significant negative implications to the training activities of the defence force. Godschalk (1998) discuss the benefits associated with the implementation of EMS in the military (especially in South Africa). These benefits are as follows:

- enhanced operational readiness,
- conservation of input material,
- systematic approach to effective resources allocation,
- provides more confidence to interested parties/authorities/chain of command,
- enhance good public/community relations,
- ensuring ongoing compliance with environmental legislation,

- management of environmental risks and preventing incidents,
- management of environmental incidents,
- liability limitation,
- increase the quality and efficiency of environmental training through standardisation and integration,
- increasing environmental awareness of all levels of personnel,
- facilitate obtaining of permits and authorisations,
- ease of regulatory burden,
- facilitate civilian re-use of former military installations,
- conservation of environmental resources,
- demonstrate improved environmental performance,
- reduction in environmental staff in the long term,
- cost saving, and
- improves cooperation with foreign militaries.

Therefore, collaboration and exchange of expertise between government departments and militaries is very important to assist defence departments to increase their capacity to adequately management the environment. To comply with legal requirements ensures that the organization (defence force in this case) is protected against claims of environmental negligence (Turner & O'Neill, 2007). In addition, this assists the organization to circumvent any financial fines relating to environmental damage (Matuszak-Flejszman, 2009), especially when the polluter pays principle is applied. There are many other benefits associated with the implementation of EMS, some of which falls beyond the scope of this study. In this section below only those that are applicable and/or relevant to the military sector are highlighted. These include identifying all potential environmental risk associated to the planned activity and/or daily activities of the organization as well as preparing appropriate measures to reduce such risk (Matuszak-Flejszman, 2009).

This is very important for defence forces given the aggressive nature of their daily activities. It can also improve the conditions of the natural environment (Matuszak-Flejszman, 2009). In the military sector this can reduce the degradation of training ranges. According to Matuszak-Flejszman (2009), other benefits linked to the implementation and maintenance of EMS include the reduction of the volume of waste and treatment costs, reduction and/or eliminating pollution, health care, increased in capacity and pro-active attitude to the environment. All these benefits are critical to the military sector because it is very important that the conditions of the training ranges do not become hazardous to military personnel.

Furthermore, pro-active environmental attitude is essential towards environmental protection and sustainable utilization of the military properties. It is acknowledged in the NATO-CCMS's (2000) final report that no matter how well an employee's work is planned, managed and measured, the final outcome heavily depends on how passionate the employee is about the activity (i.e., work). Therefore, environmental education and awareness is critical in military organisations to inculcate a degree of environmental responsibility to military personnel (Woodward, 2001).

Environmental Management System in the Military

A paradigm shift in the management of the environment by defence forces is noted in the 1990s. In 1996 the NATO Committee on the challenges of modern society started a pilot project investigating the practicability of introducing environmental management systems (EMS) in defence forces (NATO-CCMS, 2000). According to NATO-CCMS' final report (2000), a total of twenty-nine countries participated in this pilot project and the conclusion was in favour of the implementation of EMS in military organization. The majority of the countries participated in the pilot study are European countries with only South Africa from the African continent. The formulation and adoption of EMS for the defence department is indicative of the efforts to ensure compliance with environmental legislations of the country concerned (NATO-CCMS, 2000) and further to ensure commitment to protect the environment. However, it is imperative to try and trace the recognition of environment protection by military organization.

Wang and Wu (2013) provide a comprehensive review of environmental management systems in global defence sectors. Though Wang and Wu's (2013) article does not categorically state when each country's defence adopted and implemented EMS they have managed to demonstrate that many countries have responded positively to the challenge. The publication of NATO-CCMS's final report in the year 2000 led to all military practitioners realizes that EMS is actually possible and even desirable for implementation in military organisations (Dawnson, 2004). Since the publication of this report many defence forces in different countries started to develop and implement EMS in efforts to protect the environment and ensuring its sustainability as well as complying with legal requirements. Wang and Wu (2013) outline that some of the countries have developed and implemented ISO 14001 based EMS or plan for environmental management in their respective defence forces.

The countries outlined by Wang and Wu (2013) are United Kingdom, the Netherland, USA, Canada, Portugal, South Africa, Slovak Republic and India. The Australian Defence Force adopted its EMS in 2001 for incorporating environmental concerns into the daily military activities (Wang & Wu, 2013). However, Ramos and de Melo (2005) state that the USA started piloting the implementation of EMS in 1997 at 16 military installations. Consequently, the Navy's North Island Naval Air Station was the first military installation in the USA to receive ISO 14001 certification. In 2001 the Portuguese military organisation implemented EMS and also received ISO 14001 certification (Ramos & de Melo, 2005).

However, the NATO-CCMS's final report of Phase II states that 25 countries (representatives from defence organisations of 25 countries) participated in a workshop on issues of environmental aspects of military compounds held in Vienna, Austria in 2006 (NATO/Science for Peace and Security [NATO/SPS], 2015). These countries included nine partner countries which are Albania, Armenia, Austria, Azerbaijan, Croatia, Finland, former Yugoslav Republic of Macedonia, Georgia and Ukraine. The participation of these countries in the workshop reflects commitment to pro-active environmental management of military activities as it has become a global concern (Ramos & de Melo, 2005; 2006; Ramos *et al.*, 2007; Smit, 2011; Wang & Wu, 2013). Thus, countries are sharing ideas, knowledge and experiences on the developed and implemented EMS in the defence forces (NATO/SPS, 2008).

A bilateral partnership on defence and environmental management between South Africa and the USA has assisted the DoDMV (SANDF) to develop its EMS. In addition, other documents produced by this partnership including Conversion of Military Base in South Africa (2001); Military Integrated Training Range Management Guidebook (2002); Partnering to Build a South African Ministry of Defence Facilities Management Web Site (2003); Guidebook on the Development and Implementation of Environmental Education and Training in the Military (2004); and Guidebook on Environmental Impact Assessment in the military (2004) have been developed (ESWG, 2005). Furthermore, a Guidebook on Environmental Considerations during Military Operations was published in 2006 (Finnish Defence Forces, 2008).

All these documents are indicative that the SANDF is committed to protect, reduce its environmental impact and ensuring sustainability of the military training areas. However, the implementation of the pilot project of EMS was terminated in 2007 due to lack of progress (Smit, 2011). Whitford and Wong (2009) argue that adoption of ISO 14001 based EMS is associated with higher levels of environmental sustainability. The collapse of EMS implementation in the SANDF could have serious repercussions in the future. Similarly, if all these other documents developed from the US-RSA bi-nations co-operation are not translated into action they will not serve the purpose they were developed for. It is clear that the SANDF is facing severe environmental management deficiency in terms of structures, lack of qualified staff, and severe lack of funding for environmental services (Smit, 2011; Magagula, 2014). Therefore, the SANDF is facing serious challenges to meet its obligation to protect the environment through implementation of effective environmental tools. This can be viewed as a threat in the medium- to the long-term sustainability of military environment in South Africa (Magagula, 2014).

Conception of the Environmental Considerations in Armed Forces

According to Domingo (2011), Vattel and Locke are regarded as pioneers of the concept of environmental protection in wartime. Vattel (1714-1767)[9] and Locke (1632-1704)[10], were vehemently opposed to military tactics predicated on the destruction of the environment (Hulme, 2004). They were the first people to denounce the destruction of the environment during combat. This mainly focused on the acts intended to have long-term environmental effects (Hulme, 2004). It is imperative to note that this study does not deal with environmental damage resulting from armed conflict but it deals with environmental protection and conservation during peacetime (i.e., during training, weapons testing, disposal of military waste etc.). Therefore, the review of environmental problems associated with warfare has been undertaken to show the chronological development of environmental consideration (protection and sustainability) to military activities.

The environment has always been the major victim of war throughout the history of humankind (Green Cross International [GCI], 1999). For example, the nuclear bombing of Hiroshima and Nagasaki in 1945 led to the contamination of vast land area

[9] Domingo, R (2011) cite Vattel's work of 1758 titled "The Law of Nations or the Principles of Natural Law" as the most influential paradigm. Extract "Thus, the malicious destruction of public assets such as monuments, temples, tombs, statues, paintings, and so on, is unequivocally condemned…, furthermore, …the devastation of the open country, ravaging, setting fire to houses, are measures no less horrible and despicable on every occasion when they are evidently put in practice without absolute necessity*" (http://lonang.com/library/reference/vattel-law-of-nations/vatt-309/; accessed: 15 August 2015)*

[10] Locke's work of 1689, The Second Treaties on Civil Government is viewed as the natural law derives from a theory of justice.

(GCI, 1999). In addition, the environmental effects of the Vietnam warfare are well documented. According to Camacho and Sutton (2007), the US military forces, between January 1962 and January 1971 sprayed approximately 670 million litres of herbicides commonly known as Agent Orange over 60 percent of South Vietnam. This defoliant is a mixture of 15 herbicides and it was used to defoliate forests to eliminate enemy camouflage, incidence of ambush and reduce food supply of the enemy (Camacho & Sutton, 2007). According to Ana *et al.* (2007), Agent Orange destroyed huge tracks of forest ecosystem in Vietnam. It is estimated that 6800 km^2 of forest were destroyed (Camacho & Sutton, 2007). This chemical compound alters the metabolism of plants and cause defoliation (Ana *et al.,* 2007).

Physical Environmental Effects of Military Activities

Military-related activities have led to contamination and physical degradation of large tracks of land areas of ecological significance (values) (Linkov *et al.*, 2001). Linkov *et al*. (2001) rightly points out that activities such as training, testing, and deployment of weapons, which is common in the military, create both acute and chronic disturbances in ecosystems surrounding military ranges. In an effort to reduce the rate of degradation of military training areas, many countries (especially developed and to lesser extent developing countries) have enforced environmental laws and regulations even to the armed forces' activities (Ramos & de Melo, 2006). However, some military personnel perceived the enforcement of environmental restrictions in the Army as a factor that could hamper training of military troops. For example, D'Agostino (2002) reports that the US Air Force cancelled one-third of their scheduled live-firing and bombing exercises in an effort to avoid disturbing the movement as well as harming the Sonoran pronghorn antelopes (which are endangered species in the US). In addition, in some cases troops are restricted from digging defense trenches in protection of desert tortoise (D'Agostino, 2002). The cancellation of training exercises and prohibition of modifying the landscape to ensure military readiness or proficiency may have serious repercussions to military mission in combat. Captain Jason Amerine is quoted by D'Agostino as saying:

> "…we cannot expect soldiers to learn [new combat tactics] during war what we ought to teach them during training."

Clearly this indicates how important training is to military readiness for combat. According to Riefler and Medina (2006), military training greatly improves the performance of soldiers in the actual warfare. The GAO (2005) argues that military readiness hinges on the conditions of the military training ranges. However, the viability and sustainability of military training areas to provide realistic training conditions is essential (Nyakatawa *et al.*, 2011).

Military training exercises are therefore undertaken to teach soldiers tactics of war, usage of weaponry and to a certain extent using the physical environment to one's favor when such a situation arise in combat. Thus, war tactics ought to be taught and perfected during training exercises. But the training activities ought to minimise mechanical disturbances of soil and vegetation on the military training lands (Nyakatawa *et al.*, 2011). Otherwise the training range would not be able to provide optimal training requirements (GAO, 2005). Furthermore, GAO argues that a lack of comprehensive approach to management of military training ranges threatens their long-term viability. It is under such conditions and practices that EMS becomes very important and applicable to military sectors to avoid range degradation. To this end, militaries all over the world are now under intense pressure to perform their activities (during peace or wartime) in a manner in which the environment is not harmed and to comply with national and international environmental regulations (Potgieter, 2000). Therefore it is imperative that environmental considerations are integrated into all military training activities/programmes to save the important national assets (i.e., training ranges) from our own actions (GAO, 2005).

Contamination of the Environment through Military Activities

Various kinds of environmental contamination associated with military activities have been reported in many developed and developing countries. The level of contamination is not uniform even at country level as it varies from one training range to another. Environmental contamination is used in this study to refer to pollution of both soil and water. In some countries, these environmental problems are induced during peacetime training. Obviously, countries that have experienced war or civil war, are characterized by severe contamination levels as a result of years of military combat. There are numerous examples that have been cited in the section below.

The environmental impacts of the Vietnam War are well documented. According to Bertell (2002), huge areas (about a third of Vietnam) were destroyed or turned into wasteland due to the use of chemical weapon during this war. Bertell (2002) further states that 2.5 million craters defaced farming areas of Vietnam and over 80% of its forests were lost. Harmse (2003) states that air-strikes during the Vietnam War created

26 million craters over 171 000 ha of land. Bertell (2002) believes that, the ecological disaster of the Vietnam War will take many generations to recover. According to Harmse (2003), the Vietnam environment has started recovering from the effects of the war. In Harmse’s (2003) opinion, nature is has an extremely huge pollution sink capacity absorbing all kinds of pollutants emanating from human activities.

However, the environmental sink capacity can also reach its threshold. But, the environmental impacts in human history are so extreme. For instance, over three million square kilometres of land areas in Europe suffered serious damage through military activities during World War II (Tikhomirov, 2006). Tikhomirov (2006) also argues that further expanse of trenches and anti-tank trenches stretches over hundreds of thousands of kilometres across the landscape in Europe. All these impacts left the various ecosystems modified to different degrees.

The Gulf War also have had major ecological consequences (Bertell, 2002). According to Bertell (2002), this was caused by oil spillage of between four to eight million barrels of oil into the sea. In addition, after the war vast areas in Kuwait were covered by soot from the burning of 650 oil wells that were set ablaze inland (Harmse, 2003). The long-term environmental impact of the soot has never been studied. Only the short-term environmental impact of this condition could be predicted, that is the decrease in the rate of photosynthesis in plants. Szabo (2003) reported that some areas were covered by crude oil which was gushing out of 76 crude oil wells. Clearly the environmental footprints of this war was bordering on environmental catastrophe. It should be stated that environmental impacts of war are beyond the scope of this study.

The two cases referred to above, are meant to highlight the importance of environmental awareness of military personnel as well as adherence to international law(s) regarding the protection of the environment during wartime (Schwabach, n.d.). Schwabach (n.d.) refer to the International Law and the use of force; and the International Law regarding the conduct of war as the most modern international laws regarding environmental damage during conflict, which denounce unnecessary and unjustified destruction of the environment. Thus, if environmental considerations are incorporated into all military training exercise and military practitioners adhere to international laws of conflict, these ecological disasters would have been avoided. However, commanders of units are the ones who are planning and issuing instructions when the mission is executed.

The plan and approach as well as the military tactics adopted are aimed at defeating the opposition army. In addition to all these, political as well as superiority also comes to the fore. Dorfman (2004) explains that in combat every military force always requires success at any cost, thus, the environment endures the consequence of such determination. As the boundaries have been stated above, this study only focuses on environmental impacts occurring during peacetime military training activities. However, it is also important to incorporate environmental effects of civil war, just to illustrate the importance of environmental considerations into military training programmes. Cases of such contaminations are reviewed in the sections below.

Laurian (2007) states that approximately 58 200 sites in the United State of America have been contaminated by military activities. The pollutants range radioactive substances such as uranium, radon, transuranic waste, uranium mill trailing and so on. Teaf *et al*. (2006) states that day-to-day operations of military bases and together with support facilities, results in environmental degradation and long-term contamination of soil, and surface as well as groundwater. They referred to Valcunai as an example of severe case of contamination resulting from daily activities of the military. Valcunai was a site of underground storage of fuel and rocket propellants. Over 3000 m^3 of fuel leaked and contaminated the ground water reserve (Teaf *et al.*, 2006).

Studying heavy metal environmental pollution in military controlled land areas has been a neglected field of study for decades. Thus, there are few studies reporting on environmental pollution associated with military activities. Environmental contamination by heavy metals is a global concern (Mashi *et al.*, 2005). Therefore, soil pollution by heavy metals is one of considerable environmental problems in recent times (Hu *et al*., 2013). Tabari *et al*. (2010) regards heavy metals as the most important environmental pollutants and its accumulation in the environment requires serious and effective monitoring. Numerous studies have been conducted to explore the impact of this phenomenon on the environment as well as on human health. Some of these studies include Arfsten *et al*. (2001), Pinto and Salgado (2004), Mashi *et al*. (2005), Briner (2006), Andrae *et al*. (2007), Duruibe *et al*. (2007), Chary *et al*. (2008), Khan *et al*. (2008), Lasheen *et al*. (2008), Robinson *et al*. (2008), Peralta-Videa *et al*. (2009), Volpe *et al*. (2009), Singh *et al*. (2010), Badr *et al.* (2011), Mochunong *et al*. (2012), Moo *et al*. (2013) and many others.

However, almost all the studies mentioned here, were carried out in non-military controlled land areas. Only few of such studies were conducted in military training ranges. In addition to the physical disturbance caused by military activities, heavy metals are also introduced into various components of the environment such as the soil, water through to vegetation and the air (in the form of contaminated dust). Diaz and Massol-Deya (2003) argue that trace elements such as lead (Pb) and cadmium (Cd) are some of the many environmental pollutants introduced to the environment during military training exercises.

Besides, Robinson *et al*. (2008) further mention that antimony (Sb), arsenic (As), nickel (Ni), bismuth (Bi), silver (Ag), zinc (Zn) and copper (Cu), strontium (Sr) as well as barium (Ba) are common contaminants in military training areas as well as in areas adjacent shooting ranges. Ahmad *et al.* (2012) argue that shooting ranges are largely contaminated with Pb. In addition to heavy metals pollution, military training range soils are also contaminated with various volatile organic compounds and high explosive compounds (Schmidt, 2004; Siebielec & Chaney, 2012). Kristina *et al.*'s (2007) study established that motor-field of Kairial military range and Gaižiūnai military ground airfield in Lithuanian are mostly polluted with Cu, Zn, and Pb. Bullet shells and ammunition fragments in military training areas can introduce Zn and Cu in the soil (Matias *et al.,* 2009).

Only one article was found reporting on heavy metal soil contamination associated with military activities in the whole of the African continent. This is a study conducted by Nwaedozie *et al*. (2013) which investigated the level of trace metal pollution in three Nigerian military training areas. Therefore, military training areas would have different levels of contamination through heavy metals. The level of contamination depends on the frequency of use of the area as well as effective measures put in place to prevent pollution.

Landmine Environmental Contamination

The impacts of landmines have been studied from the humanitarian perspective as well as from an economic point of view, especially in Africa. This problem has never been adequately addressed from the environmental perspective. There are few studies that have acknowledged the environmental impact of landmines. In this study the problem of landmines is reviewed to emphasize the environmental impact posed by unexploded ordnance. The assumption is that if environmental issues were incorporated into military training programmes and environmental education was an integral part of military activities long enough the situation might be different. However, evidence exists that under no circumstances can environmental protection take precedence over military success (i.e., victory). Countries that have experienced war or civil war have been significantly affected by this environmental problem. Figure 1 below summarizes the extent to which some countries of the world have been affected by land mines. At a global scale, nine countries are showing evidence of being heavily laden by landmines.

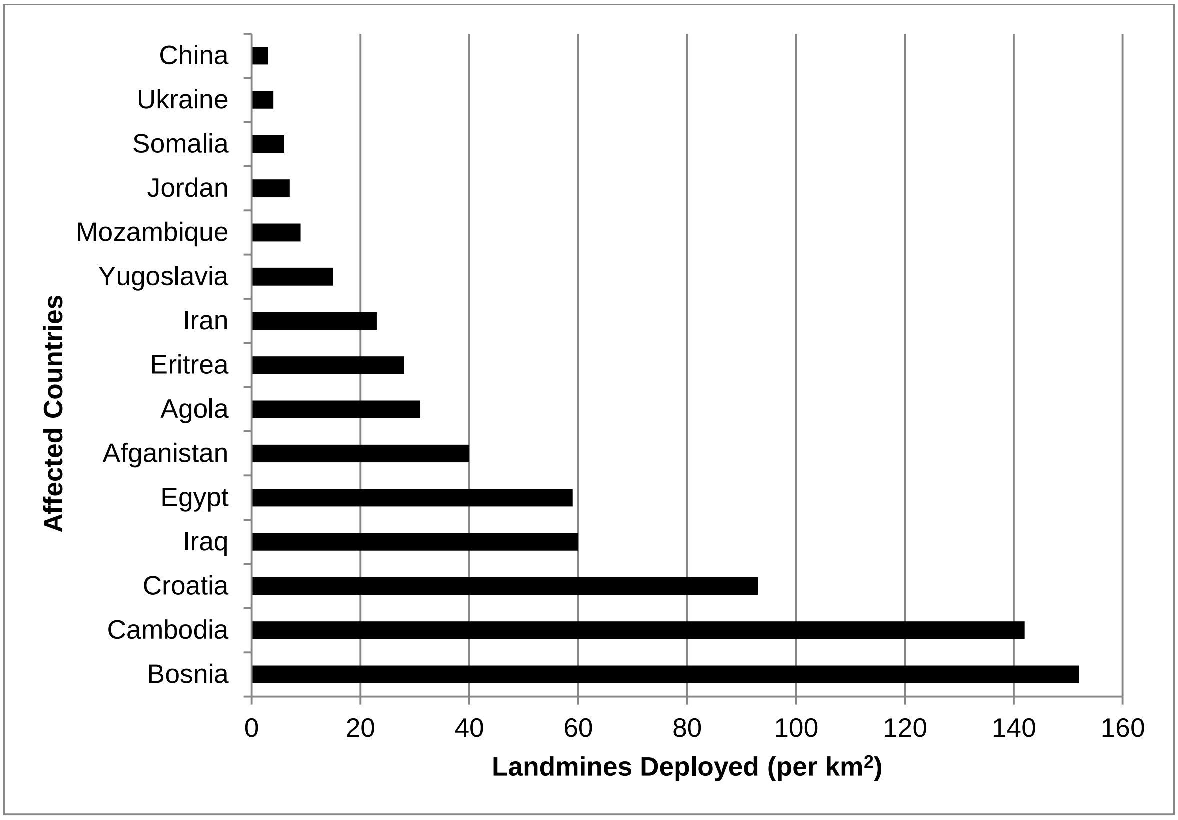


Figure 1. Countries mostly affected by landmines per square area
(Adapted from Bier, 2003)

These countries have more than twenty land mines per square mile. According to Bier (2003), it is estimated that Bosnia has between six hundred thousand to one million landmines in an area of 300 km^2. In Africa, there are many countries that have experienced civil war, and have been seriously affected by landmines. According to Bocchino (2007), landmine contamination has affected about eighty-five African countries. The worst affected countries include Mozambique, Angola, Rwanda, Uganda, Sudan, Somalia, Democratic Republic of Congo to name but a few. Ukabiala (n.d) reports that the United Nations estimated that approximately 44.8 million landmines are buried in eleven African countries. Ukabiala further states that the worst affected African countries are Angola, Egypt and Mozambique.

Bier’s (2003) findings about the extent of minefields in Africa seem to conflict with that of Ukabiala (n.d). Bier (2003) reports that Egypt is the most affected country in Africa, followed by Angola and Eritrea, the least affected in Somalia as Figure 1 indicates. It was estimated that there are about 23 million landmines buried in Egypt and about 15 million in Angola. It is reported that Angola and Mozambique situation is similar, because the minefields were created during the civil war fought over a period in both countries (Ukabiala, n.d). Therefore, the legacy of these civil wars left environmental footprints which will take many years to clear, if ever that is possible. The major challenge with this problem is that the majority of these minefields (i.e., mine laden areas) are unknown (Bier, 2003; Ukabiala, n.d), coupled with this is the fact that landmines remain active for many decades (Ukabiala, n.d).

Although South Africa does not have many of these environmental problems, the Africa Watch (Human Rights NGO) claim that most of the landmines used in Angola and Mozambique came from South Africa (Ukabiala, n.d). In addition, South Africa was also involved in these conflicts in both countries (Ukabiala, n.d). Indirectly, the South African military has contributed to this environmental problem outside its borders. It appears that there are various reasons for the emplacement of the landmines. These vary from fighting for freedom (anti-colonization), protection of strategic important assets, and civil independence warfare (Bocchino, 2007). Huge land areas in these countries have been contaminated with landmines. Mckenzie (1998a) states that unexploded ordnance such as mortars and shells are serious negative environmental impacts of military activities. Whether the mines were laid during conflicts or mortars that did not detonate or shells generated during training have the same environmental effect.

In South Africa, the unexploded ordnance that has contaminated the environment has been left behind after training exercises of the South African National Defence Force (Mckenzie, 1998a). A study conducted by Mckenzie (1998a) on the military and environmental contamination at three military training lands revealed that there is high level of contamination in these areas. All these three military lands were land restitution cases (Mckenzie, 1998a) hence it was important to ascertain the safety of the communities as well as the usability of the areas for community purposes. According to Mckenzie (1998a), the South African Army Combat Training Centre (SAACTC) commonly known as Lohatla in the Northern Cape Province of South Africa is the worst contaminated land area of the SANDF. SAACTC is a combat training centre for the SANDF, where all the branches of the South African Army deploys for intensive training. Therefore, airstrikes (i.e., aircraft bombing), heavy and light artillery, together with infantry training are carried out (Mckenzie, 1998a). This explains the high level of contamination noted by Mckenzie (1998a).

It must also be noted that most of the contamination occurred when environmental considerations were not compulsory into the planning and execution of the defence force activities. One of Mckenzie's (1998a) respondent stated that "…they [i.e., South African National Defence Force] just throw it away where they have exercised. They just throw away what they have not used because they are not meant to use everything up and they do not want to take anything back to the camp". This could be possible because during that time the military did not have environmental issues integrated into their training programmes. They were not aware of the harmful effect such practices have to the environment. At the same time such practice was also putting their own lives at risk and that of fellow soldiers during future training at the same training range. This can also be viewed as waste of resources.

However, Mckenzie (1998a) does not report the views of any of military officials with regard to this claim by the respondents. It is unlikely that military commanders could have allowed this to happen. It does not necessarily mean that any quantity of ammunitions, mortars and rockets that are requested from the arms storages for a training exercise should all be used. There could be surplus which must be returned once the major purpose of the exercise has been achieved. Mckenzie's (1998a) study did not try to quantify the level of environmental pollution, it was just a descriptive analysis based on observable pollutants. The current study tries to identify and quantify pollutants by analyzing both water and soil samples collected from this combat training centre.

Physical Degradation of the South African Military Training Area

There is a dearth of literature on this topic and only two articles dealing with the physical state of the SANDF military training areas were found. EEI (2006) argues that in cases where sustainable operations are not factored-into military training, such land areas are at risk of degradation. According to Harmse (2003), some of the sites used by the SANDF for weaponry testing and vehicle manoeuvre have suffered severe forms of soil erosion. This problem has been noted mostly in training ranges located in the Limpopo Province. The severity of the problem forced the DoDMV to seek scientific assistance from experts to manage the problem (Harmse, 2003). However, Harmse (2003) does not mention the frequency and the intensity or aggression of the military activities. This would give an insight on the resilience of the land areas/vegetation within these areas. In addition, such information could be used towards finding a solution to the problem. The soil erosion that has escalated in these military sites is indicative that vegetation cover has been drastically reduced. Moreover, this part of the country is known to have little annual rainfall. Therefore, vegetation takes a very long time to recover from the destructive activities of military training. Problems like these are the ones that should encouraged the DoDMV to vigorously incorporate environmental considerations into their day-to-day activities.

Environmental Consideration in the South African National Defence Force

Studies (e.g., Sowman *et al.*, 1995; Godschalk, 1998; Rabie & Fuggle, 1992) agree that the 1970s was a decade during which environmental issues were prioritized. This was merely because there was evidence around the world that the environment is deteriorating rapidly. However, the major environmental focus was on other societal sectors rather than in defence forces. In other words the defence forces were not put under so much pressure to reduce their impact on the environment. In South Africa, the first directive to the South African Army to care of the environment under its control was only issued in 1977 (Smit, 2011). In part, this was as a result of the realization of the actual and potential significant impact the defence force activities have on the environment. In 1978 the (then) Department of Defence announced the first environmental management policy (Godschalk, 1998). This was enforced by the promulgation of the Environment Conservation Act, (Act No. 73 of 1989) in 1989 to govern and regulate environmental protection and conservation across all sectors of the society.

Consequently, the directive on environmental care in the defence properties led to the Department of Defence adopting nature conservation within its territories (Smit, 2011). This can also be viewed as a move towards compliance with this legislation. Emanating from the adoption of nature conservation by the Defence Department were a wide range of sub-functions which included ecological management of training areas, base environmental management, cultural resource management, environmental research and education (Smit, 2011). Smit (2011) further explains that these functions were regarded as of little relevance to the core business of the military. This is indicative of the lack of foresight of the role played by the environment on the realistic military training and readiness. In other words military personnel did not recognize that environmental damage induced during peacetime training have long term effects on sustainability of the training ranges. However, Smit (2011) attests that in the 1980s environmental awareness and conservation gradually became central to the day-to-day activities of the South African Department of Defence.

The component of environmental research and education of the nature conservation approach adopted by the DoDMV was the most critical. Research on environmental issues within the defence would have had a positive significant impact on the planning and execution of military activities. This would have guided the defence from avoiding disrupting ecological sensitive land areas or ecosystems as Mckenzie (1998b) reported. The expectations are that military personnel would have been given environmental education. This would have, to a certain extent changed their attitude towards the environment in relation to their day-to-day military activities. According to Smit (2011), environmental education under this approach was more of *ad hoc* awareness campaigns rather than a continuous structured systematic processes.

However literature disprove that the DoDMV adequately incorporated environmental issues into all military related activities during the 1980s. For example, Mckenzie (1998b) discusses cases where military activities were carried out in areas where environmental consideration were disregarded. These cases include the weapons testing sites. According to Mckenzie (1998b), these sites are located in ecologically sensitive areas. Surely if the DoDMV was environmentally aware and mindful of the consequences of military activities in such areas, alternative land areas would have been used/selected for this practice. To make matter worse is the fact that these areas were established in a veil of secrecy (Mckenzie, 1998b) without consultation with affected and interested stakeholders. Affected and interested stakeholders would have been the communities around these areas and experts in environmental matters. Mckenzie (1998b) reports that the establishment of these weapons testing disrupted or negatively affected crocodile, and water-bird breeding grounds. This clearly shows that during peacetime numerous ecosystems can be affected by defence forces' activities, this illustrated the lack of environmental awareness and protection.

This may still continue occurring especially if the attitude of military commanders and those involved towards the environment is negative. For example, soldiers or military personnel who did not receive training in which environmental issues are part of military activities, are likely to think like Renner. Renner as quoted by Mckenzie (1998a) said "A world that wants to make peace with the environmental cannot continue to fight wars or sacrifice human health and the earth's ecosystems preparing for them…". Attitude like this is disastrous to environmental protection and sustainability, as it shows that some military personnel did not envisaged that military activities can be carried out in an environmentally friendly manner. This utterance shows that environmental education in the military is essential. It also shows that some personnel do not recognize the role the environment plays in realistic military training (GAO, 2005; Nyakatawa *et al.*, 2011). The current study has tried to assess attitude and perceptions of military personnel towards the incorporation of environmental considerations into military activities.

The cultural resource management programme of the SANDF necessitates the review of cultural sustainability as a concept of analysing environmental management and development initiatives. Therefore, to effectively analyse environmental problems and economic development activities requires adequate review of cultural issues. Sustainable development emerged to cater for wise utilisation of all natural and cultural resources.

The concept of sustainable development is known to have three pillars which are ecological, economic and social dimension (Soini & Birkeland, 2014). The social components of this concept (i.e., sustainable development) is always viewed or discussed to encompass cultural issues (Soini & Dessein, 2016). However, Rantala *et al.* (2012) argue that the cultural dimension of sustainability has been introduced to sufficiently analyse issues of ecological and economic sustainability as well as utilisation and studying impacts on the natural resources, rather than just dealing with cultural values. The concept of cultural sustainability was first introduced by Hawkes (2001) as the fourth pillar of sustainability exclusive of social sustainability (Soini & Birkeland, 2014). Previously and in recent times, some scholars still analyse cultural related development issues within the ambit of social sustainability (Soini & Dessein, 2016).

To this end, Soini and Birkeland (2014) argue that cultural sustainability has remained under-utilised as a conceptual and theoretical framework to study and analyse development practices. Soini and Dessein (2016) further argue that the omission of “cultural sustainability” as one of the pillars of sustainable development debates might be due to political resistance to the powers that be. The assumption is that, the addition of culture in the sustainability concept might change the status quo in sustainability research as well as policy development (Soini & Dessein, 2016).

Therefore, to disregard cultural sustainability in sustainable development will advance the negligence of what culture stands for and its meaning to the local communities. Accordingly, Alhojärvi (2007) argues that in general, rural and local people are always excluded from participating in planning and decision-making processes regarding the management of the natural resources their lives and livelihood are depending on. According to Ursic (2011), cultural sustainability advocates for the adoption of the principle of inclusive (or inclusivity), thus, give voice to all groups in the population.

Culture is a communal practice within the community, and the common values attached to it are seen in traditions and practices which include recreation, beliefs, religions, rituals as well as spiritual issues (Rantala et al., 2012). This argument is supported by Morelli (2011) that ecosystems provides cultural services and benefits to people through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences, all of which are nonmaterial benefits. Moreover, culture should be viewed as the fundamental underpinning concept for adequate understanding the behaviour of the individuals and their perceptions towards environmental sustainability among other issues (Soini & Birkeland, 2014). Therefore, cultural sustainability is a way of examining or assessing cultural identity that promotes environmental sustainability.

It is only recently that some scholars have used cultural sustainability in variety of research activities to analyse and study development activities as well as environmental problem. Some of the studies that have used cultural sustainability as a conceptual framework include but not limited to studies on sustainability in housing by Chiu (2004), cultural economy and linkages between ecology and cultural sustainability by Throsby in 2001 and 2008 respectively (Soini & Birkeland, 2014). Alhojärvi (2007) argues that cultural sustainability is critical to nature conservation programmes and projects. Consequently, armed forces, the world over, are also expected to ensure that their day-to-day practices and activities in all their training areas are not destructive to any cultural resources (heritage sites such as archaeological sites, artifacts, rock paintings etc.) found in such landscapes.
As Kirke (2009) emphasizes, organisational and military culture plays a significant role in social cohesion within the army.

Soini and Birkeland (2014) mention the distinctiveness of landscapes as one of the values of culture. Thus, culture is perceived to be very important for understanding environmental problems or issues (Soini & Birkeland, 2014). Furthermore, Soini and Birkeland (2014) argue that culture or cultural sustainability seems to be the most appropriate tool to achieve ecological sustainability when linked to conservation policies and debates on environmental management issues. Armed forces must incorporate cultural resource management programmes in their broad environmental management initiatives. The US DoD for example, has ensured that in all its installations both natural and cultural resources are protected and preserved, this being the achievement of their conservation initiatives (US/FY, 2004). Similarly, the DoDMV through the SANDF is striving towards protecting all cultural resources in all its installations through establishing environmental management programmes for ensuring environmental sustainability of military facilities in the long-term (White Paper, 1996).

Thus, the “culture” within an organisation also have its role in shaping the behaviour of all those that are part of it. For example, King (2007), Siebold (2007), Firing *et al*. (2009), and Kirke (2009) noted that in the army there is an existence of what they social cohesion. It is assumed that the secrecy and non-disclosure of information that characterises defence organisations has been maintained through cultural sustainability.

Environmental Management in the Democratic Dispensation

The dawn of democracy in South Africa brought major changes in all the laws governing the country. Some of the legislations which affect the activities of the SANDF have been reviewed in the previous chapter. The democratic dispensation led to the broadening and instilling of environmental values and consciousness to all South Africans. In 1998 the National Environmental Management Act [NEMA] (Act No. 107 of 1998) was promulgated. This Act challenged all organs of the state that might affect the environment to compile Environmental Implementation Plan (EIP) within a year of publication of this law (Smit, 2011). This Act also compelled all government departments to review and update their EIP every four years thereafter to ensure improvement in environmental performance (Jacobs *et al.*, 2002; Smit, 2011). In line with this legislation, environmental consideration took a central position to the daily activities of the South African Department of Defence [DoDMV] (Smit, 2011).

According to Smit (2011), the DoDMV took up this challenge and developed its EIP to indicate its obligation and commitment to environmental protection. At the same time the Department wanted to comply with the new environmental management legislation. To-date, two editions of the EIP have been published; the first edition was published in 2001 and the second edition in 2008. However, having this document is one thing and to translate it into action is another matter. For it to be operationalised, all the necessary resources must be made available. Necessary resources for adequate implementation of environmental programmes and plans include financial resources, qualified and/or skilled personnel. Lack of anyone of these resources will undermine the efforts and commitment to successfully implement environmental protection measures in the defence force.

Military Integrated Environmental Management Approach of the SANDF

According to Smit (2011), in the early 1990s there was a shift in the environmental approach of the DoDMV from a purely conservation to the integration of the management of environmental impacts into all activities of the army/military. The concept has been term military integrated environmental management (MIEM). This means that all military activities and planning must incorporate environmental concerns. Furthermore, this approach assists in identifying environmental impacts of an exercise before it could be executed. This provides a platform or an opportunity for identification and development of mitigation measures for that particular military exercise. This approach would enhance the pro-active rather than the reactive attitude towards environmental management and protection.

Smit (2011) describe this approach as a fully integrated environmental management function. In this approach environmental education is an integral part of all aspects of training and research focused on military environmental impacts as opposed to general environmental issues as was the case in the initial approach (Smit, 2011). According to Ramos and de Melo (2005), to encourage the linkage between military activities and the environment requires extensive research into techniques of developing, measuring, and promoting the integration of environmental concerns at all levels of the military organization, through to decision-making, logistics and operational practices. This is possible through integrating the environment into the whole management process of the defence, rather than maintaining it as an isolated aspect (Ramos & de Melo, 2005).

The suggestion by Ramos and de Melo (2005) is in line with the approach adopted by the DoDMV to deal with environmental management issues while carrying out their day-to-day activities. Both studies by Ramos and de Melo (2005) and Smit (2011) does not emphasize the importance of monitoring, enforcement and auditing of environmental practices in military installations. Lack of these aspects of environmental management tools has the potential to undermine the effectiveness of this approach to improve environmental performance of the military organizations, particularly the DoDMV. Theoretically, this approach (i.e., MIEM) is in line with environmental protection and sustainable principles. Nevertheless, its effectiveness in achieving the intended or desired goal or objectives lies in numerous other factors such as capacity of the SANDF personnel, financial resources and implementation structures as explained in Smit (2011) and Magagula (2014). This study has tried to establish to extent to which environmental performance is monitored and measured in the two SANDF military installations studied.

Summary

This Chapter has reviewed the literature on military activities and environmental management. Various themes have been selected and formulated in line with the objectives of the study. These are core themes in the chapter and include conception of EMS in general, benefits of EMS implementation, EMS adoption and implementation in the military sector, environmental effects of military activities (i.e., various forms of contamination), state of the SANDF's training areas and environmental considerations in the SANDF activities. To this end, the Joint US-Republic of South Africa Environmental Security Working Group Project has developed numerous environmental management documents for the SANDF. Which if adequately implemented, the environmental management profile of the SANDF could be positively comparable to other defence organisations in the world.

It has been noted that there is deficiency of literature on various aspects of military environmental management in the African continent. Thus, most of the available information on these issues is from other continents mainly Europe and America. This is indicative that the military environmental management field of study is somewhat neglected in Africa. The impact of this situation might be dire in the long-term, as it means that military organisations in Africa will have to learn how to integrate environmental concerns to military activities from their counterparts in Europe and America. Consequently, military training areas in African countries will continue to suffer the severe and various forms of contamination and degradation as explained in Bier (2003), Bocchino (2007), Ukabiala (n.d.) and Mckenzie (1998a & 1998b).

It was also surprising to note that only South Africa in Africa participated in the pilot study on the implementation of EMS in the military sector carried out by NATO-CCMS from the year 1996-1999 (NATO-CCMS, 2000). Though the final report of the NATO-CCMS showed that EMS is possible and necessary in the military, African countries are still discreet on adopting EMS and following the global military environmental management approach. EMS is designed for the benefit of the organisation and the environment in the long-term (Ramos & de Melo, 2006; Matuszak-Flejszman, 2009). It seems like military organisations in Africa do not realised the benefits associated with appropriate management of the environment and its sustainability.

The next chapter (Chapter IV) describes the research design and also explains the research techniques adopted in the collection of both the primary and secondary data as well as the analysis of the collected data.

CHAPTER IV

RESEARCH DESIGN AND METHODOLOGY

Introduction

This chapter describes the research design of the current study and presents its study location. It is divided into two parts: the first part describes how the study was designed (i.e., planned), carried out (data collection) and how the collected data was analysed. Thomas *et al.* (2011) argue that the research question influences the research method. The selected methods herein were dictated by the research questions of the current study. Thomas *et al.* (2011) further suggest that a study can be primarily qualitative with a quantitative part or vice versa. A study of this nature therefore warrants a mixed-research method. A decision has to be made to strike a balance between qualitative and quantitative components (Thomas *et al.*, 2011). However, the decision is mainly influenced by the nature of the study, as there are specific methods used within each part of the research (i.e., qualitative or quantitative). To this end, the current study adopted the integrated research method which is explained below.

The second part of the chapter deals with the description of the research study sites. In addition, the challenges the researcher faced during data collection are dealt with in the latter part of the chapter.

Research Design and Methodology

This study has adopted an intensive case study design which allows for a detailed analysis of the conditions and problems under investigation (Sayer, 1992; Creswell, 2003; de Vaus, 2006; Thanner & Segal, 2008). It has adopted combined theory-testing and theory-building data collection and analysis techniques. This approach was adopted to cater for statistical and comparative case study analysis as explained by Alaranta (n.d.) in an effort to explore the issues raised in the specific objectives stated in Chapter I of this thesis. It has adopted an integrated research approach (i.e., both qualitative and quantitative research methods).

This approach is referred to by different names in different articles. Driscoll *et al*. (2007) highlight the different names used to refer to this research approach as a multi-method, hybrid research, an integrated research, combined research, or as a mixed methodology research. Jogulu and Pansiri (2011) call this research methodology a third research paradigm and it is perceived to be a profoundly comprehensive research technique because it integrates both thematic and statistical data. Alaranta (n.d.) recommends an integrated (multi-method) research method as necessary in dealing effectively with the problem investigated. The type of research technique to use in a particular study is primarily determined by the nature of the research undertaken and by the type of data required to adequately answer the question or questions the study is raising.

In the current study, the phrase, “integrated research approach” is used to describe the adopted research method. Every research methodology has its own advantages and disadvantages. The advantages of the integrated research approach, as described in Jogulu and Pansiri (2011) are: it leads to greater depth and breadth in the overall results, it is epistemologically coherent and useful for verification as well as generation of findings, it rigorously integrates statistical and thematic data to expand and enhance the findings, and it leads to a better understanding of a phenomenon. This is exactly the intention of the current study to fully understand the environmental practices in the SANDF. By eliciting perceptions of defence force members (gathered through questionnaires), analysing content of official documents on environmental management, environmental reports, interviewing relevant defence force members and analysing soil and water samples for pollutants.

Initially, the study was designed to be carried out sequentially as shown in Table 1. In the first phase, only questionnaires were to be distributed to all respondents. These questionnaires were to elicit data regarding environmental management in the SANDF, defence environmental programmes, environmental training of defence members as well as challenges of implementing environmental management in the SANDF. The data on these issues would have been more useful to formulate themes for the interview phase (second phase) with selected respondents. Furthermore, the data from both the first the second phase would have been very crucial in undertaking the third phase of the research, which would have been observation and sample collection. As Thomas *et al.* (2011) explain: “in sequential mixed-method research, the results of the first part have a strong influence on what occurs in the second phase of the field research.”

Table 1. Integrated research approach matrix: Initial data collection

Status	Concurrent Approach	Sequential Approach
Equal	QUAL + QUAN	QUAL → QUAN QUAN → QUAL
Dominant	QUAL + quan QUAN + qual	QUAL → quan quan → QUAL
		QUAN → qual qual → QUAN

Notes: "QUAL" stands for qualitative; "QUAN" stands for quantitative; "+" stands for concurrent while "→" stands for sequential. Upper case letters: "QUAN" and "QUAL" denote high credence; lower case letters: "qual" and "quan" denote lower credence.
(**Source:** adapted and modified from Jogulu & Pansiri, 2011)

The third phase would have largely focused on field observation and collecting both water and soil samples from the military training areas. However, due to the nature of the military and its structures, this design had to be changed to the concurrent research approach (Table 2). In the concurrent research design, interviews were conducted simultaneously with the distribution of questionnaires and, to a certain extent, collection of samples. Thus, all data collection methods were used and as such the results of one part could not influence the methods for the second part (Thomas *et al.*, 2011). Both equal and dominant approaches were used because of the challenges encountered during the field research. The dominant qualitative approach was used at the SAACTC where an interview was conducted with the respondent. However, the distributed questionnaires (refer to Table 3) were returned. Quantitative data from this case study was gathered through interviews and analysis of official documents on environmental management practices. The major challenge with the concurrent data collection approach was that of a second round of interviews was required to be conducted with certain respondents. All efforts to secure such interviews did not materialise.

Table 2. Integrated research approach matrix: Alternative combination used

Status	Concurrent Approach	Sequential Approach
Equal	QUAL + QUAN	QUAL → QUAN QUAN → QUAL
Dominant	QUAN + qual	QUAL → quan quan → QUAL
	QUAL + quan	QUAN → qual qual → QUAN

Notes: "QUAL" stands for qualitative; "QUAN" stands for quantitative; "+" stands for concurrent while "→" stands for sequential. Upper case letters: "QUAN" and "QUAL" denote high credence; lower case letters: "qual" and "quan" denote lower credence.
(**Source:** adapted and modified from Jogulu & Pansiri, 2011)

Sampling Techniques

A combination of three sampling techniques, namely the stratified, purposive and snowball samplings were adopted. Gray (2004) describes stratified sampling as a technique that draws the same sample from various strata. However, purposive sampling is a technique adopted to deliberately select the subjects against one or more traits to achieve what is believed to be a representative sample. According to Gray (2004), a purposive sampling technique may lead to the omission of vital characteristics or might be biased in selecting the sample. This shortcoming is compensated for by snowball sampling. Snowballing was used to identify a small number of respondents, who, in turn, identify others within the population who can provide relevant information (Gray, 2004) about the problem being investigated.

Other scholars refer to snowball sampling as link-tracing sampling (LTS) techniques to select research respondents. Félix-Medina and Monjardin (2009) describe LTS as a sampling technique and 'chain referral sampling' approach. Katuu (2012) refers to snowball sampling as a referral form of data collection technique. Using these research methods, the selection of respondents to participate in the study was based on appropriateness and environmental management responsibility within the SANDF at the two selected military installations. Therefore, only those military personnel who were in a position to provide relevant data to achieve the objectives of the study were identified by the initial sample of members of the targeted population. LTS has proved to be appropriate for sampling hidden respondents within the targeted population (Félix-Medina & Monjardin, 2009). Sheng *et al.* (2011) also confirm the that LTS is the only means by which initially sampled respondents lead the researcher to other potential/hidden respondents within the population, which, in turn, may lead to other respondents.

The current study successfully used purposive sampling and LTS (or snowball sampling) to identify relevant respondents within the SANDF members both at GMI and SAACTC. Consequently, only military personnel who were charged with the responsibility to ensure that military activities were carried out in compliance with environmental legislations were selected and interviewed. The targeted respondents were the personnel in the Environmental Management Facilities (EMFs) at GMI and SAACTC, strategic environmental planners, installation managers (range managers), commanders, environmental officers, soldiers and recruits at both military installations. The LTS technique was then used to identify other individuals who could provide relevant data to this study, other than those at the EMF who included the RFIM personnel of the SANDF.

The criteria used to select military installations as study areas were “light military use” and “heavy military use”. In addition, consideration was given to the aspect of military operational aggression in each category. Based on these criteria, GMI was classified as “light military use” and SAACTC as “heavy military use” installation.

Adopted Research Techniques

Questionnaires

Research techniques adopted for the collection of primary data included structured questionnaires. According to Bless and Higson-Smith (1995), these are some of the most efficient tools of acquiring primary data in the social sciences. A structured questionnaire survey was carried out both at Grahamstown and SAACTC to understand the environmental practice of the SANDF, elicit challenges of implementing environmental management system and incorporating environmental concerns into military activities. In addition, the research sought to assess the extent to which the defence force complies with environmental legislations and the attitude of defence force members towards incorporating environmental issues into military activities. Consequently, four types of questionnaires were prepared for the waste management, environmental management facility personnel, commanders and private soldiers (Appendixes . A total of 217 questionnaires were distributed as shown in Table 3. Of the 130 questionnaires distributed at GMI, 30 of them were open-ended questionnaires. Only one of the open-ended questionnaires was returned. Similarly, the same challenge was experienced at SAACTC where only two open-ended questionnaires were returned, but only one usable.

An attitudinal Likert scale questionnaire was prepared to ascertain the attitude of military personnel towards environmental considerations in military activities. At GMI 67 of the attitudinal Likert scale, questionnaires were returned (51.54% response rate) and only 54 were usable, some of the remaining 33 were returned uncompleted while some were incomplete (i.e., other statements were not answered). At SAACTC, 50 attitudinal questionnaires were distributed and only 39 were returned. Of the 39 returned questionnaires, only three were unusable. Overall, a response rate of 50.23% was received (Table 3) despite the fact that authorization to carry out the study within the SANDF territory was secured (Appendix E). This low response rate is associated with the absence of order or directive from high ranking officials in the DoDMV to instruct SANDF members to fully cooperate with the current research. Thus, it was a non-commissioned research; therefore, participation was purely voluntary. For example, Ramos and de Melo’s (2006) study recorded 96% questionnaire response rate because an order from the higher level in the hierarchical chain of command in the Portuguese military was issued. The Likert scale developed and used was a five-point scale ranging from “strongly agree”, “agree”, “neutral”, “disagree”, to “strongly disagree". Similarly, a five-point Likert scale was used by Kulatunga *et al*. (2006) when assessing attitude and perceptions of construction workforce on construction waste.

Table 3. Samples of the questionnaire surveys

Category	Number of questionnaires issued	Number of questionnaires returned	Percentage response
Waste Management (GMI)	3	-	-
Environment Facility (GMI)	4	1	25
Commanders (GMI)	10	-	-
Private Soldiers (GMI)	130	67	51.54
Environmental Managers (RFIMs)	5	-	-
Environment Facility (SAACTC)	5	2	40
Commanders (SAACTC)	10	-	-
Soldiers (none rank personnel) (SAACTC)	50	39	78
Total	**217**	**109**	**50.23%**

Notes: "GMI" - stands for Grahamstown Military Installation and "SAACTC" stands for South African Army Combat Training Centre.

Interviews

A semi-structured interview guide was designed and used to collect data. This guide categorised questions into five sections, namely, financial resources, human resources, legislation, internal policies and environmental management structure and linkages. A total of seven military officials were interviewed. Only one official refused to be interviewed. The first interview was held with the Occupation, Health and Safety officer on 1 July 2011. The health and safety officer referred the researcher to other respondents. An interview was conducted on 12 July 2011 with a non-commissioned staff officer of the Environmental Services Division based in Pretoria, who was visiting the GMI to determine whether appropriate environmental impact mitigation measures were in place before the start of Exercise Shared Accord between the SANDF and the US Marines. This interview took the form of an informal discussion; however, notes were taken during the interview and refined after the discussion. Interviews were also held with the military readiness officer, as well as the acting environmental non-commissioned officer based at GMI. These interviews were held on 13 July 2011. On 14 July 2011, the Occupation, Health and Safety officer was interviewed for the second time for clarity on certain issues he raised during the first interview session. These interviews aimed at gathering data on measures taken to prevent pollution due to vehicles' breakdown and fixing during training exercises. The regional staff officer initially indicated willingness to participate in the face-to-face interview that was scheduled for the 19th of September 2011. However, she later declined due to work commitments.

Another interview with the stand-in environmental management services staffer took place on the 18th of July 2011. Themes covered during the interview included the state/condition of the training ranges, environmental audits, and a restoration of degraded training ranges, waste management strategy, pollution prevention, challenges, collateral environmental damage and environmental footprint of the army. Interviews were also held with the environmental Officer at SAACTC on two occasions. The interviews were on the 10th of January 2012 and 05th of November 2013 at SAACTC complex, respectively. The second interview was meant to gather more data on the themes mentioned above.

The interviews were based on 12 questions derived from certain themes of the questionnaires and a total of ten interviews were conducted between July 2011 and November 2013. The normal duration of these interviews ranged between 20 and 45 minutes. However, one interview was approximately an hour long. In this case, the respondent was voluntarily providing more information on certain issues, especially on the challenges and funding of environmental management programmes of the defence. All these interviews were tape-recorded and transcribed *in extenso* thereafter. Respondents were adamant about not talking 'on record', but were assured that whatever information they provided would be treated as confidential and for research purposes only.

Field Observation

Observation research has been recognised and used as a research tool (Mulhall, 2003). It can be carried out in two discrete ways: firstly, while the observer is participating in the activity and, secondly, when the observer does not participate in the group activities but pretends to be a group member (Bailey, 1994; Fox, 1998). Thus, the observation research technique has been a fundamental method since the beginning of qualitative enquiry (Nicholls *et al.*, 2013). This technique is most preferred when one wants to study in detail the behaviour and actions that occur in a certain setting or institution (Bailey, 1994). Bailey states that observation research technique is more appropriate in studying space use. Therefore, this adequately justifies the adoption of this research technique by the current study as it was interested in knowing how the environment is protected during training activities. However, observation research is rarely used as a single method and is often used in multi-method research (mixed-research design), although there are certain exceptions (Nicholls *et al.*, 2013). In the current study too, this research technique forms part of a combination of other research techniques used to collect various kinds of data to answer the research questions stated in Chapter I.

Mulhall (2003), however, states that there is paucity of information about this research technique. This might be related to the fact that the observation research technique is rarely used as the chief method of data collection. Bailey (1994) argues that the observation method is the primary technique for collecting data that is nonverbal. This means that observation can be carried out to study ways of waste disposal, pollution prevention, clean-ups, mitigation and rehabilitation measures adopted by a particular entity. Therefore, the current study adopted this research technique to ascertain whether the data collected through interviews, questionnaires and documents analysis did indeed tally with what is actually done in the training ranges. In other words, field observations were carried to verify the data collected through interviews and questionnaires and to provide additional explanation of the results (or data already collected) (Nicholls *et al.*, 2013).

The observation research technique can be carried out in two distinct ways, namely, structured and unstructured (Mulhall, 2003). Mulhall (2003) states that structured observations always have predetermined schedules based on known theory or fact about the activities to be observed. In contrast, unstructured observation research is carried out without a list of predetermined schedule and/or theme. According to Mulhall (2003), in most cases, positivistic research always assumed a structured observation approach. However, the current study adopted the unstructured observation research. This type is assumed to be flexible because concentration is given to variables that prove to be important (Bailey, 1994). Thus, observation focused on those practices that were of significance to the study. This included mitigation measures put in place to prevent pollution, waste disposal, back-filling of trenches, refuelling bunkers and so on. During the field observation, detailed field notes were made on the notebook. These notes were theme based and the themes were developed on the basis of the activity. For example, pollution prevention theme incorporated notes on practices such as locations of fuel bunkers and mitigation measures used and so on. Furthermore, where solid waste was spotted, description of the kind of waste and location was noted in the notebook.

Mulhall (2003) explains that access to research sites to carry out observation research can sometimes be problematic for various reasons. Fox (1998) writes that gaining access to research site(s) is a continuous negotiation until the data collection process has been completed. Therefore, it is worth mentioning that the current study encountered serious problems relating to gaining access to research sites especially during active military training exercises. After some negotiations with those in authority, permission was granted before and after the training exercises. This happened despite the fact that authorisation was granted by the DI at national office to carry out this study within the SANDF territories.

Soil and Water Sample Collection

In addition to interviews, questionnaire distribution as well as field observation, soil and water samples were also collected to identify pollutants and assess the level of pollution at these military sites. The heavy metals determined in each sample included lead (Pb) and cadmium (Cd), chromium (Cr), nickel (Ni), zinc (Zn), strontium (Sr) and copper (Cu), which are common contaminants in military training areas as well as in areas adjacent to shooting ranges.

Soil samples were collected randomly inside both training areas. A manually operated soil auger of 15cm height and 6cm core was used to collect surface sediment samples. Therefore, to identify and quantify the heavy metals, surface soil sediment from 0 – 30cm in the two military training areas were collected. A total of 140 surface sediment samples, including control samples, were randomly collected from the GMI and SAACTC. Two samples were collected at each sampling point (0-15 cm & 15-30 cm) and were then mixed together to form one composite sample.

However, due to high costs associated with the analysis of heavy metals in soil, more composite samples were formed, and control samples were excluded from the analysis. To this end, twenty-eight composite sediment samples were from GMI and another twenty-eight randomly collected from SAACTC training ranges. These samples were put into polyethylene ziplock bags and thereafter kept in a cooler box even in the laboratory. Thus, a total of fifty-six sediment samples were used to determine the quantity of each of the heavy metals mentioned above.

Water samples were also collected from the two military training areas. The water samples were collected from any water source identified within the training areas. The water sample bottles were pre-treated with nitric acid (HNO_3) and rinsed with distilled water, a procedure described in Filho *et al.* (2013) to sterilise sample containers. All the samples were kept and stored in cooler boxes after collection (during field sampling and in the laboratory). Twenty-four water samples were collected at GMI training area and only twelve were collected at SAACTC. These samples too were used to identify and quantify the specified heavy metals.

The analysis for the heavy metals in all sample types was carried out by the Council of Scientific and Industrial Research (CSIR) and Natural Analytical Laboratory based in Stellenbosch, Western Cape Province of South Africa. Determination of the heavy metals was done with inductively coupled plasma–mass spectroscopy (ICP-MS). ICP-MS is regarded as a new method for determining multi-element analysis and ideal for soil and water samples analysis, because the majority of target compounds can be detected below 0.1 mg/l (Voica *et al*., 2012). Samples were introduced through integrated samples introduction system (ISIS), where each sample was nebulised using concentric nebulisation to argon based, high temperature radiation frequency plasma. Samples aerosols were atomised and ionised to produce a cloud of positively charged ions which were extracted into the vacuum system containing a quadrupole analyser. Then, the ion concentration of specific mass to charge ratio was measured by an electron multiplier detector (CSIR, email comm. 2013).

Satellite Imagery Analysis

The nature of the current study justified the adoption of both qualitative and quantitative research approaches, adopting an intensive case study methodology. To assess vegetation cover change in the two selected military training areas satellite imagery were used. The techniques of extracting vegetation from pre-processed images are grouped into to two types namely the supervised and unsupervised classification (Lillesand & Keifer, 2004). Supervised classification was not chosen because it requires extensive field survey before classifying the image (i.e., determining land cover classes), and assigning numerical descriptors of various land cover types present in the area of interest (Palmer *et al*., 2009). Extensive field verification of land cover classes is impossible in a military training area due to existence of unexploded ordinance. Thus, the current study adopted unsupervised classification method to classify and define features on the satellite imagery (Zhang *et al.*, 2011; El Gunaid & ElHag, 2013). Congedo and Munafò (2013) refer to this classification as a semi-automatic classification method. It classifies elements of the remote sensing images according to their spectral signatures (Congedo and Munafò, 2013). Poor imagery quality can lead to inaccurate classification of land cover surfaces (Boswell, 2015). Thus, high resolution images are required for this method of classification, and it is useful for assessing land cover (LC) and land cover change (LCC) (Congedo and Munafò, 2013). Therefore, it was appropriate for adoption in the current study since the focus is on determining LC and LCC over a specified period.

The four LC classes defined in the classification for the current study are dense forest, shrub land, grassland and bare land. It must be noted that, in the current study, the grassland class does not incorporate other green surfaces such as agricultural land and gardens (Diallo & Bao, 2010). For the GMI, high resolution satellite imagery for the years 1986 and 2014 were analysed. The 1986 image was for the month of October, while the 2014 data was for the month of January in the same rainfall period. The land cover change at SAACTC was studied from high resolution satellite imagery for the years 1991 and 2014. The satellite imagery for SAACTC analysed were for the months of September and December respectively. Again these images also cover the spring and the summer period.

Analysis of Official Documents

Official documents expected to explain how the DoDMV is planning to deal with environmental protection and ensuring environmental sustainability within its territories were analysed. These documents included two environmental implementation plans (EIPs) (i.e. the 2001 and 2008 editions). The purpose of studying the EIPs was to establish the mechanisms by which the SA DoDMV was planning to deal with environmental issues within its territories. Relevant pieces of legislation were studied to establish the legal mandate for the environmental management of all sectors (including the SA DoDMV) of the South African society.

Guidebooks and other documents such as the development and implementation of environmental education and training in the military: a joint United States-Republic of South Africa Environmental Working Group Project (2003); Department of Defence: Republic of South Africa – Overarching Strategic Statement for 2011; Integrated Environmental Management Information Series: Linking Environmental Impact Assessment and Environmental Management Systems (2004); The Department of Defence Strategic Plan (2010): Republic of South Africa and the South African Defence Review (2012) were studied.

Other official documents analysed include Conversion of Military Base in South Africa (2001); Military Integrated Training Range Management Guidebook (2002); Partnering to Build a South African Ministry of Defence Facilities Management Web Site (2003); Guidebook on the Development and Implementation of Environmental Education and Training in the Military (2004); and Guidebook on Environmental Impact Assessment in the Military (2004). A Guidebook on Environmental Considerations during Military Operations (2006) was also read.

In addition, other secondary data were collected from the monthly magazine of the SANDF called SA Soldier. Further, various environmental reports from SAACTC were also analysed. These reports are Environmental Support Plan for Exercise Para Bellum 2008; Environmental Closure Report (ECR) for Exercise Seboka and Para Bellum 2008; Environmental Closure Report: Exercise Seboka 2009: Lohatla 01 April 2010 to 31 March 2011; Environmental Management Plan: SA Army Combat Training Centre, 2011.

Data Analysis

As explained, this study employs an integrated research approach hence both quantitative and qualitative data analysis techniques were used. Qualitative data analysis techniques used is the combination of narrative and content analysis.

Content Analysis

The current study adopted a simple content or ethnographic content analysis (ECA) over the quantitative content analysis (QCA). Altheide (1987) defines ECA as a reflexive analysis of documents. ECA is embedded in constant discovery and comparison of relevant situations, settings, styles and meaning (Altheide, 1987). Content analysis is regarded by Duriau *et al.* (2007) as a kind of research method that exists at the interface of the qualitative and quantitative research approaches. This research method is a promising rigorous exploration of important yet difficult-to-study issues (Duriau *et al.*, 2007). GAO (1996) regards content analysis as a method which safeguards information against distortion. In this study, ECA was adopted to collect and analyse environmental management procedures, practices, programmes and reports of environmental impacts on the SANDF. Krippendorff (1989) states clearly that the most obvious sources of data for content analysis are texts to which meanings are usually ascribed. These include verbal discourse, written documents and visual representations of situations or experiences. Thus, content analysis is a method used to analyse written, verbal and visual communications (Elo & Kyngäs, 2008).

Narrative analysis is described by Smith (2000) as dealing only with verbal material, usually, accounts of personal experiences. Smith further argues that content and narrative analysis can provide information that other methods cannot extract. Thus, the data derived from the interviews conducted for the current study were analysed using the narrative analysis. Scholars like Coffey and Atkinson (1996), Saunders *et al*. (2003), Liamputtong and Ezzy (2005), Punch (2005) and regard this data analysis method has assisting researchers to retain the integrity of data collected. Understandably, this is what the current study wanted to achieve.

The questionnaires developed for this study had thirty statements on various environmental management issues such as environmental education and training; availability of resources; processes, procedures and practices; enforcement and compliance; and compatibility. The data acquired using the five-point Likert scale questionnaire was then coded as 1 for “strongly agree”, 2 for “agree”, 3 for “neutral” 4 for “disagree” and 5 for “strongly disagree”. After coding the data, average attitudinal scores were calculated for each dimension. Thereafter, the percentage for each response option was calculated. The statements were further classified into five categories as mentioned above. These categories were environmental education and training, availability of resources, processes, procedures and practices, enforcement and compliance as well as compatibility. The responses were also analysed based on these categories.

Moreover, the same data gathered from the questionnaires were analysed using One Way Analysis of Variance (ANOVA). To do this analysis, the responses were further categorised on the basis of the military ranks, namely, Riflemen, Private, Corporals and Sergeants. Before such analyses were performed, averages of the responses were calculated and group variables were numerically coded. Further, the responses were analysed on the basis of military service period. These analyses were performed to determine whether there were any significant differences between the groups.

Analysis of Concentrations of Heavy Metals

Quantitative analysis included the use of selected statistics to analyse the concentration of heavy metals (Cr, Co, Ni, Cu, Zn, Sr, Cd & Pb) determined from soil and water samples. The statistics used includes the analysis of the variance (ANOVA), Pearson’s correlations, principal component analysis and hierarchical cluster analysis (Qishlaqi & Moore, 2007; Sekabira *et al.* 2010; Nazzal *et al.* 2014). ANOVA was performed to determine whether groups of variables have the same means. It was further used to assess the relationship between heavy metal concentrations and chemical interaction. A Correlation Analysis was carried out to analyse relationships between heavy metal concentrations. Dikinya and Areola (2010) adopted this analytical statistical procedure when comparing heavy metal concentration in soil samples collected from crop farm lands in Glen Valley, in Gaborone. The same statistical procedure was used by Naoura and Benaabidate (2011) when analysing heavy metal concentration in sediments collected from Inaouene River.

While the principal components analysis (PCA) was performed to identify different important components accounting for most of the variances (Gajbhiye *et al.*, 2015) in the heavy metals. Further, the cluster analysis (CA) was adopted to classify elements of different sources and identify variables with similar properties. Hu *et al.* (2013) also used PCA and CA to identify possible sources of heavy metals from surface soil samples. Naoura and Benaabidate (2011) also used PCA to show the association of the heavy metals in river sediment.

Discriminant analysis (DA) was also used to determine whether the two military training areas differed considerably in terms of heavy metal concentrations. Nazzal *et al.* (2014) used DA to determine chemical(s) that distinguish one sample from the other. Thus, DA is a tool to classify or group variables on the basis of similarities between that case and the other case(s) (Brown & Wicker, 2000). Qishlaqi and Moore (2007) used DA to contrast the level of pollution with heavy metals in two different sites. DA has the ability to determine contaminants of interest among a group of measured chemicals together with the most important differences between site-related subsets (Nazzal *et al.,* 2014).

Summary

This chapter has outlined the design and methods used in data collection. This study adopted the integrated research design, which implies both the qualitative and quantitative research approaches. Initially, the study was planned to follow a sequential research approach. The first phase was to involve the distribution of questionnaires. The second phase would have involved conducting interviews with respondents. However, due to unforeseen circumstances, the sequential approach was dropped and the concurrent approach adopted. Accordingly, the distribution of questionnaires, interviews and field observation were carried out simultaneously.

Stratified, purposive and link-tracing sampling techniques were used for selected respondents. A total of 217 questionnaires were distributed at GMI and SAACTC. A response rate of 50.23% was achieved. Using semi-structured interview guides, seven SANDF officials were interviewed between July 2011 and November 2013. All interviews were tape recorded, except for the numerous informal interviews. All the recorded interviews were transcribed *in extenso* thereafter.

Furthermore, field observations were carried out within both military installations training areas between July 2011 and November 2013. They were carried out to collect data on various aspects on the conditions of the training areas, perform waste removal after training exercises, pollution prevention measures put in place, rehabilitation efforts to restore degraded training ranges and so on. During the field observation, both soil and water samples were collected. Soil samples were collected randomly from 0 – 30 cm, and then composites samples were created. At the end, fifty-six surface sediments were analysed for the concentrations of heavy metals. Water samples were collected from any water body found in each of these military training areas. Twenty-four water samples were analysed for the heavy metal concentrations. In addition, impacts of military activities were also studied through performing time-series analysis of satellite imagery of both training areas.

Numerous official documents were analysed or studied to gather data on the approach of the SANDF towards environmental management. These documents included annual environmental reports for the SAACTC. Content analysis was used to analyse data collected from the secondary sources, while primary data was analysed using multivariate statistical techniques. The results of the application of the methods explained in this chapter are presented in Chapters VI and VII.

The next chapter (Chapter V) provides a detailed description of the research locations. As it has been explained, this research was designed and carried out through two case studies. One case study is based on the environmental practices of the 6SAI Bn based at GMI and the second case study is based on practices of the SAACTC located in the Northern Cape Province.

CHAPTER V

RESEARCH LOCATIONS

Introduction

This study was carried out in two different military installations, which are located in two different provinces of South Africa. The first site is the Grahamstown Military Installation (GMI) which is located in the Eastern Cape Province. The second is the South African Army Combat Training Centre (SAACTC) located in the Northern Cape Province of South Africa. Accordingly, the climatic conditions as well as the vegetation types in these two military areas are different, as are the geology and soil types. Subsequently, the SAACTC is surrounded by open cast mining activities, while the GMI is surrounded by pastoral farming. As indicated in Chapter IV, the study adopted an intensive case study research approach. Therefore, attempts were made to study each military installation intensively. However, given the sensitive nature of the military, certain sites were not accessible or access was denied. The sections below provide a detailed description of GMI and SAACTC military areas on the basis of the variations between the two, such as the size of each military training area, climate, vegetation and geology.

RESEARCH CASE STUDIES

Case Study I: Grahamstown Military Installation

The GMI was categorised for light military use where minimally aggressive military training activities are carried out. As previously noted, this study site is situated in Grahamstown, in the Eastern Cape Province of South Africa (see Figure 2). This is an infantry military installation hosting the 6 South African Infantry Battalion (6 SAI Bn). This military training area is approximately 70 000ha (Mckenzie, 1998a). According to the Unit's History Handbook (n.d.), the Grahamstown military base was established in April 1812 by the then Governor of Cradock, Lieutenant Colonel John Graham. During that time, it was a military outpost of the Cape Colony. Before 1962, approximately 1 915 volunteers were called up to form a combat unit to execute duties in German East Africa. This military unit had three brigades formed from 12 infantry units. The 6 SAI Bn was one of the two South African Brigades. The military training area for the 6 SAI Bn is about 0.41% of the total landmass of the Eastern Cape Province; and equivalent to 0.06% of the entire landmass of South Africa.

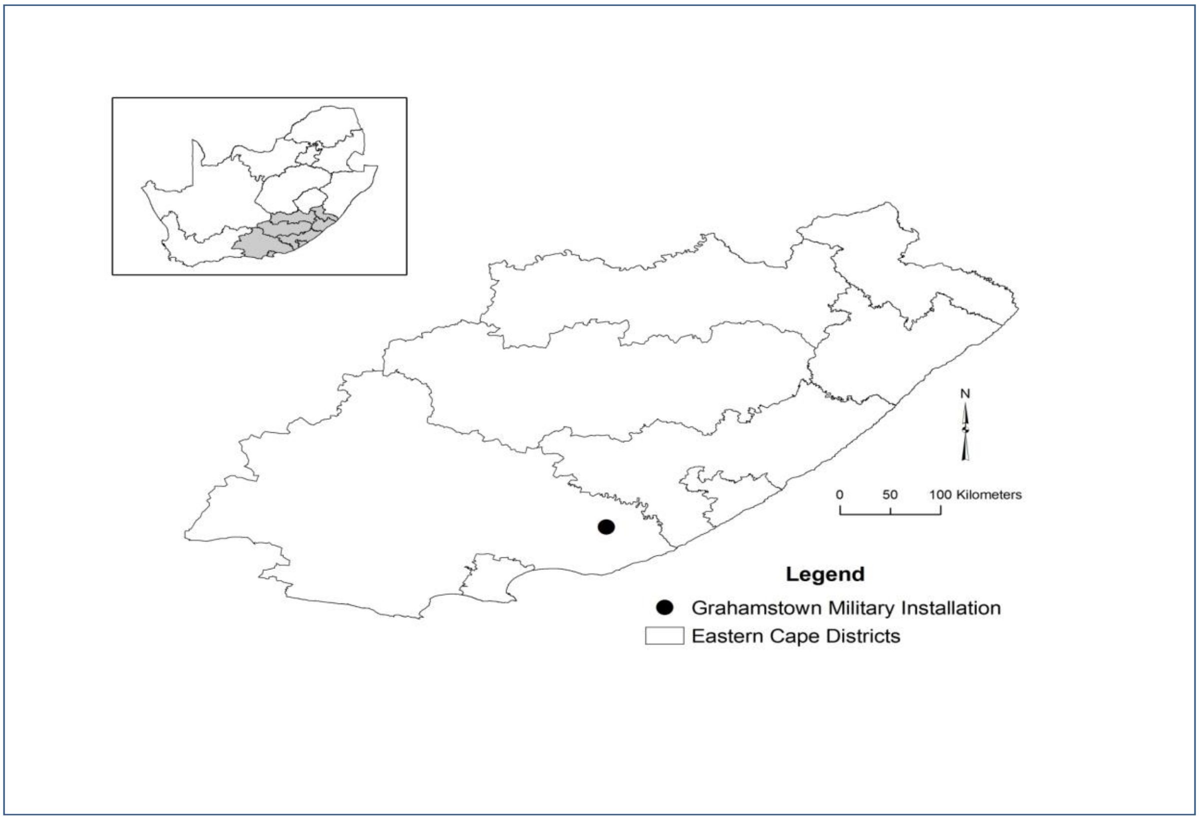


Figure 2. Geographic location of GMI in the Eastern Cape Province

According to the Unit's History Handbook (n.d.), this military unit made its first ever contact with an opposition army in 1916 (the Battle of Salaita Hill). In 1941, the Royal Air Force (RAF) established the 44 Air School in Grahamstown, which was part of the British Government's Training Scheme. The 44 Air School left the Grahamstown base in 1946, after the end of the Second World War. The 6SAI Bn was later formed in January 1962 under the command of Commandant Terblanche, and its first intake of recruits was in April of the same year. In 1993, just over three decades after its first intake of recruits, the 6SAI Bn received its last intake of National Servicemen. From 1994 to 1997, the unit was tasked with conducting bridging training for non-statutory forces (basic training). Members were trained and sent to various units of the SANDF. It is also reported that the unit continued to train soldiers for operational duties during this time.

In 1996, the status of the unit was changed to that of a motorised battalion; it is during this period that extensive training exercises were conducted at the site. During the same period, the unit also participated in internal operational duties. Three years later (i.e., in 1999), the status of the unit was downgraded to that of a light infantry battalion. Two companies from this unit participated in Exercise Iron Eagle in 2001, which is the first time the unit was used in an airmobile role by the South African Army. Despite this, the unit's participation in the exercise was successful. This meant that the unit was retained to become the airmobile battalion of the South African Army. According to the Unit's History Handbook (n.d.), in 2002, the 6SAI Bn became the first composite battalion in the South African Military Force to be deployed beyond the borders of the country. This deployment was part of a peacekeeping mission to Burundi.

Climate of Grahamstown and Surrounds

The GMI is located within the Makana Local Municipality. The southern part of the local municipality experiences the highest rainfall. Grahamstown lies at the intersection of four different climatic zones [Makana Integrated Development Plan (IDP), 2014]. Thus, it is possible that all four seasons can be experienced in one day (Grahamstown Handbook, n.d.). Rainfall is received throughout the year, with mean annual precipitation of approximately 680 mm (IDP, 2014). Contrary, Haigh *et al.* (2008) argue that the average rainfall for Grahamstown ranges between 250 and 500mm spread throughout the year. This area has a Mediterranean climate; it thus receives most of its rainfall during the winter months of the year (SAexplorer, 2014). Figure 3, below, shows that the lowest average rainfall is received in June (33mm) and the highest average rainfall is recorded in March and October (75mm) of each year. Makana's climate is semi-arid and has a bimodal rainfall pattern (Haigh *et al.*, 2008).

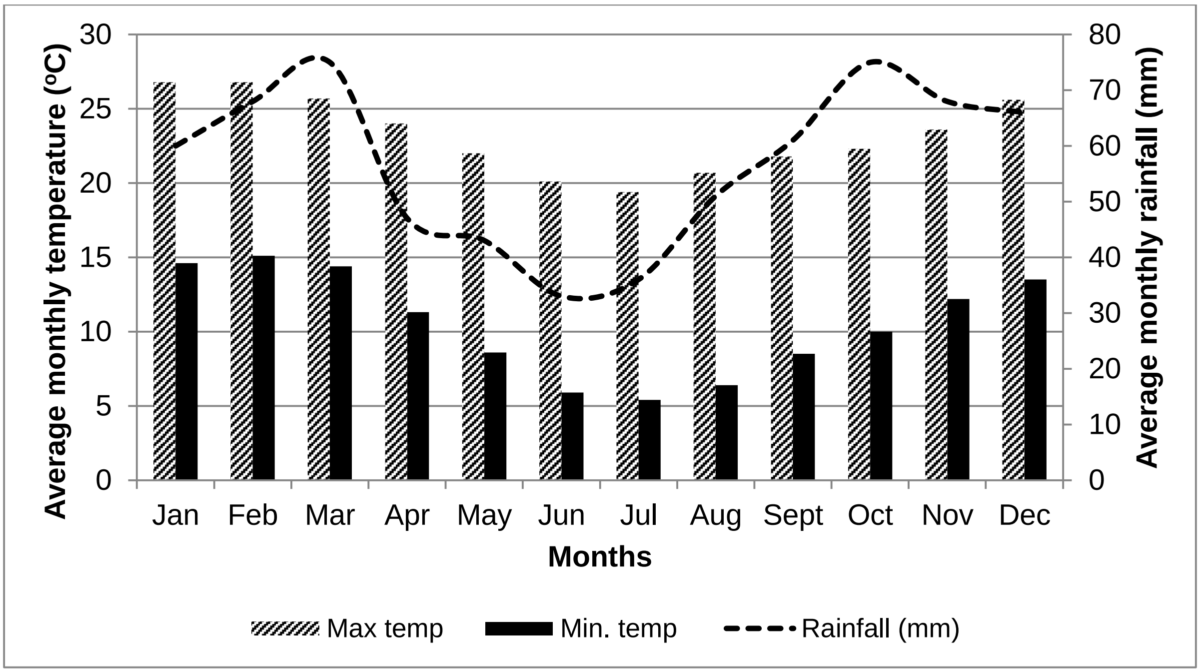


Figure 3. Average rainfall and temperature for the Grahamstown area
(Source: Climate data organisation, 17 August 2015)

Temperatures range from 5.4^{o}C in July to 27^{o}C in January and February. While the hottest and wettest months in Grahamstown are December to March. The maximum monthly average temperature varies from 20^{o}C and above, except for the month of July (Figure 3). The coldest months are June to August.

Geology and Soil

The Grahamstown area is situated in the Cape Fold Belt and underlain by rocks of the Witterberg Group of the Cape Supergroup, and the Dwyka and Ecca Groups of the Karoo Supergroup (Modesto *et al.*, 2001; Outeniqua Geotechnical Services - Civil Laboratories, 2011; Madi *et al.*, 2013; Büttner *et al*., 2015). According to Haigh *et al.* (2008), the geology of the area is complex, with intercalation of sandstone and alluvial coastal shales with large deposits of fine kaolin clay. Smuts (1983) argues that the clay deposits in the Grahamstown area transverse four different lithologies such as Bokkeveld Shale, Witterberg Shale, Dwyka tillite and Ecca Shale. The military training area of the 6SAI Bn is situated over the Silcrete formation, Lake Mentz Subgroup, Witpoort formation and Dwyka Group geological rock formation (Figure 4).

The Makana Municipal area is characterised by its Beaufort group sandstones and shales (IDP, 2014). According to the IDP (2014), soils in the Grahamstown area are described as Glenrosa which are generally shallow and weakly developed, with depths not exceeding 60m.

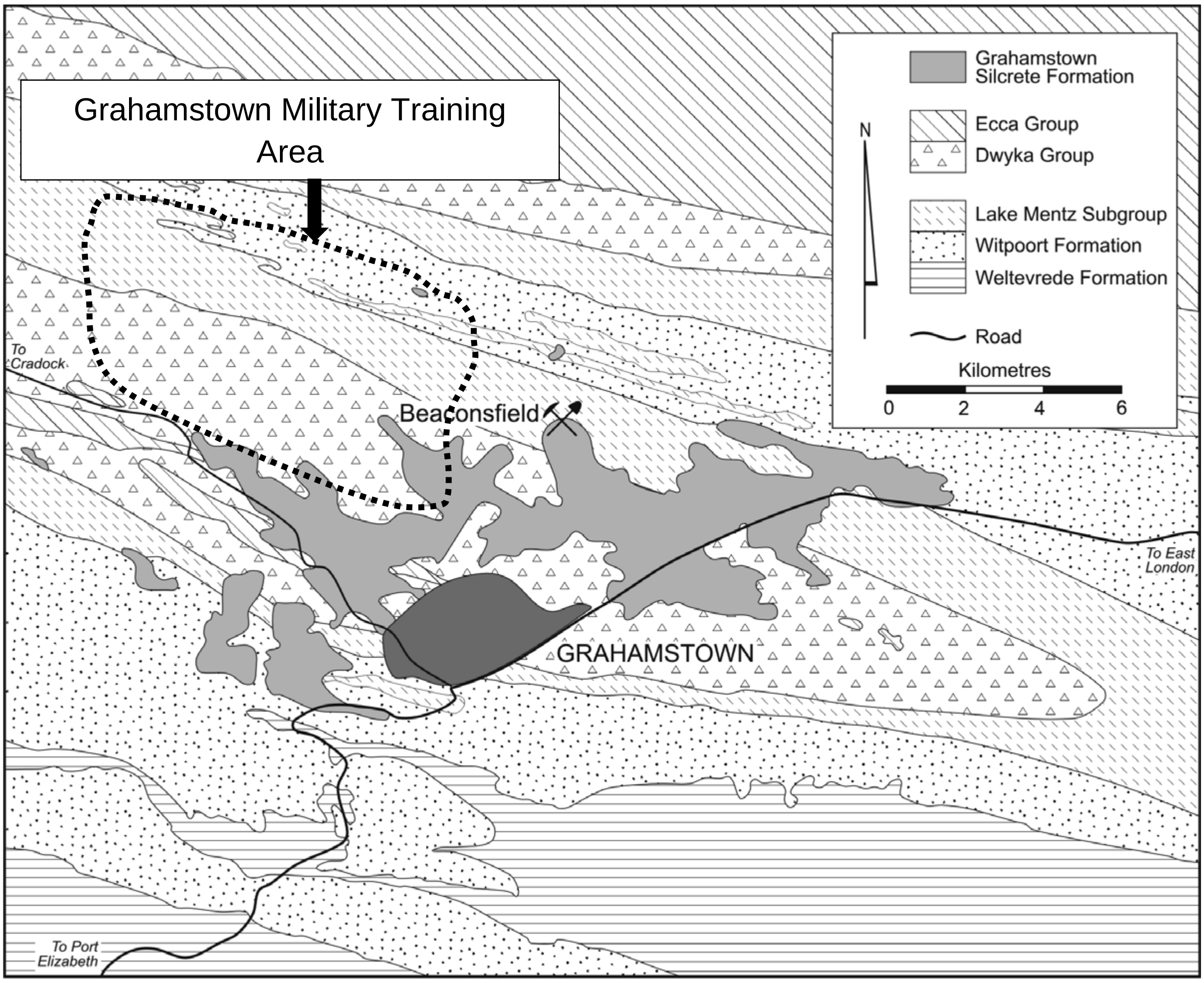


Figure 4. Simplified and modified geological map of the Grahamstown area
(Adapted and modified from Jacob *et al.*, 2004)

The presence of shrubs and scattered bush thickets is indicative of shallow soils. The topography is characterized by shallow and narrow valleys and gentle slopes. The slopes are primarily constituted of flat hilltop with the majority of the area having relatively gentle slopes on the southern and western parts (Brutsch & Zimmerman, 1993). A simplified geological structure of the Grahamstown area is presented in Figure 5. Sedimentary rock types appear to dominate the geological structure of the area.

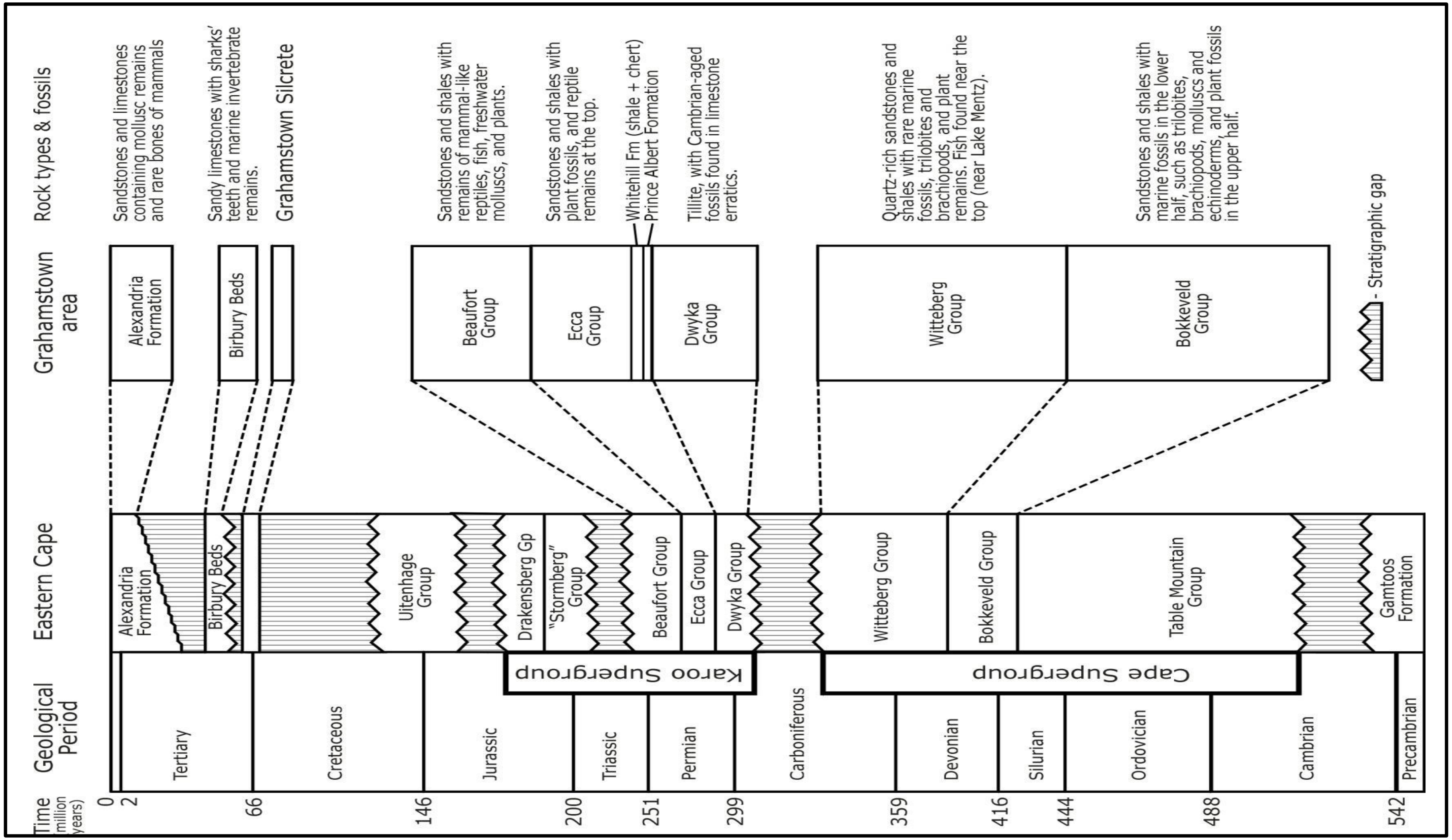


Figure 5. Stratigraphic section of the geology of the Grahamstown area compared to the Eastern Cape Province
(Adapted and modified from Büttner *et al.,* 2015)

The Beaufort Group, Ecca Group, and the Dwyka Group and the subgroups of the Karoo Supergroup also form the geological structure of the Grahamstown area. While the Witteberg Group and the Bokkeveld Group are subgroups of the Cape Supergroup specifically underlies the military training area (Büttner *et al.,* 2015).

Vegetation and Biomes

The Makana district has rich vegetation diversity; this is comprised of ten vegetation types, which represent six of the seven major biomes in Southern Africa. The represented biomes are forest, grassland, succulent Karoo, fynbos, savannah and thickets (Makana IDP, 2012). The Albany Thicket consists of the Great Fish thicket, Great Fish Noorsveld, Kowie thicket, Eastern Cape Thornveld (Mmoto, 2009). Thus, the Grahamstown area is also known as the Albany region and it comprises of two forms of succulent plants: xeric succulent thicket and mesic succulent thicket. However, the xeric succulent thicket is more dominant compared to the mesic succulent. Grahamstown mainly has the Eastern Cape thorn veld. Unlike other semi-arid ecosystems, such as savannah and certain Mediterranean type shrub lands, the vegetation of the area (Albany thicket) is resistant to widespread fire regimes due to its succulent nature (Zimmermann *et al.*, 2006).

There are clusters of *Opuntia ficus-Indica* (prickle pear) which occur randomly across the region at variable altitudes. The 6SAI Bn in Grahamstown is characterised by thick Thickets which are found throughout the training area (Brandt *et al.,* 2011*)*. The herbaceous species in the area are dominated by *Maireana Astrotricha*, open grassland and shrubs. Thorny species, such as *Acacia,* are also present in the area and most of them occur along the low lying water course areas. The grass within the area varies with dense grass occurring near the water sources; this becomes sparse in areas that are away from water sources. The shrub plant occurs all over the site in variable sizes and heights (Kleunen *et al*., 2011). Robertson *et al.* (2004) classified the vegetation of the Grahamstown military site as Eastern Cape Thornveld.

Case Study II: The South African Army Combat Training Centre

The South African Army Combat Training Centre (SAACTC) is situated in the Northern Cape Province (Figure 6). It is some 104km south of Kuruman and 43km to the north of Postmasburg. The Northern Cape province of South Africa is the largest province by land mass in the country and is approximately 372 889km^2 in size and constitutes more than 30% of South Africa's land mass (SAinfo, 2012). This is the province where the SAACTC training area of the South African Army, which is categorised as "heavy military" in the current study, is situated. This military base was initially known as the South Africa Army Battle School until it was renamed as the South African Army Combat Training Centre in October 2000 *(http://www.actc.army.mil.za/,* accessed 04 August 2015). Thus, the second case study was carried out in this training area of the SANDF. It is in this military training area where high calibre weapons are used, including those required for airstrike training exercises of the Air Force.

In the late 1890s, this area was a Nature Reserve called the Ga-Thlose Nature Reserve. This is one of the lands forcefully taken away from their rightful owners by

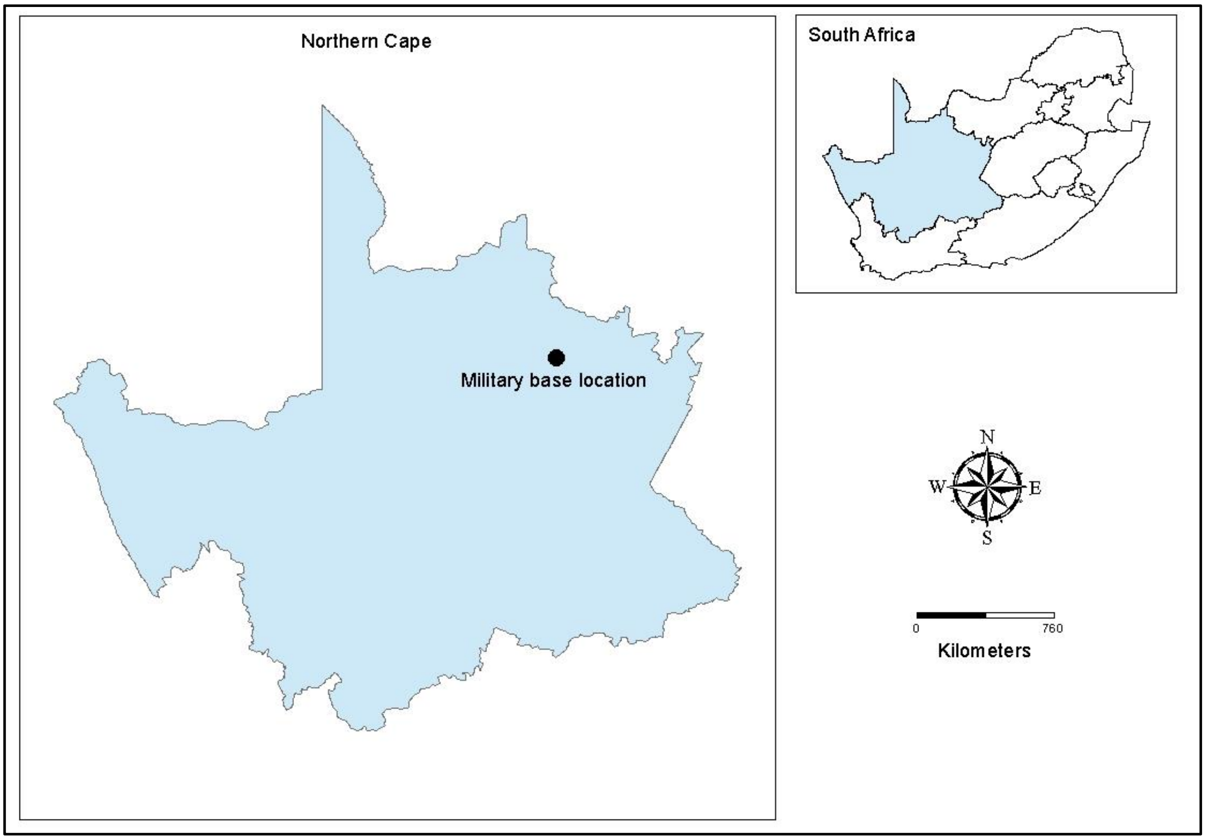


Figure 6. Geographic location of SAACTC in the Northern Cape Province

the apartheid regime. In 1976, the area was proclaimed as a restricted military land (SAACTC, n.d.). Subsequently, the local people living in the area were relocated to another area (Mckenzie, 1998a; SAACTC, n.d.). The size of this military training area is 156 500ha, which is approximately 0.13% of the total landmass of the country. This military training area is one of the largest in the southern hemisphere. Thus, this military land is used for purposes such as the firing of high-explosive weapons, anti-tank and armour weapons, anti-aircraft weapons, fire and manoeuvring military training, small-calibre weapons, target hitting by the South African Air Force (SAAF), and demolition work (DoD, 2005). Therefore, this military training area provides for both conventional and integrated training needs which are applicable to all military forces around the world (*http://kml.inovmapping.com, accessed 26 August 2015*). The training area is divided into ten ranges in which various military training exercises are carried out. The terrain of the area is seen to be providing the specific requirements for different army units to execute modern mobile combat training exercises (*http://kml.inovmapping.com, accessed 26 August 2015*).

Climate Conditions of the Northern Cape Province

The Northern Cape Province is a semi-arid region with little rainfall even in summer (SAinfo, 2012). The greater proportion of the Northern Cape Province falls within the 0.05 – 0.2 aridity class [Northern Cape State of the Environmental Report (NC/SoER), 2004]. Aridity classes were defined by calculating the ratio of the mean annual precipitation to the potential evapotranspiration (NC/SoER, 2004). According to Van den Berg (2010), it is only the eastern part of the Northern Province - from Kuruman southwards to Hanover - that can be described as semi-arid. It is in this part of the province where the SAACTC is situated.

The western to the central parts of the province are relatively dry, with average rainfall ranging from 11 – 200mm per annum, respectively (Van den Berg, 2010). Thus, the weather conditions in this province are extreme; winters are very cold while summer seasons are extremely hot (SAinfo, 2012). The coldest months are June and July; during these months the minimum temperatures are usually below 5^{o}C with maximum temperatures below 20^{o}C (Figure 6). Maximum temperatures of up to 43^{o}C are normally recorded during the summer months (i.e., from November to February) while extreme winter temperatures can fall below 0^{o}C during the months of June, July and August; thus, the area has a steppe climate. (Siyanda District Municipality IDP, 2012/2013).

This area receives very little rainfall throughout the year. The annual rainfall received is approximately 389mm (Climate data organisation, 2013). Most of the rainfall in the Northern Cape Province is received between January and March. The average rainfall recorded during the month of March is 74mm, which is the highest rainfall on record. According to Van den Berg (2010), annual rainfall of the Northern Cape Province increases gradually from the west to the east. Thus, towns such as Kuruman, Postmasburg, Douglas and Kimberley, among others, are in the relatively high rainfall zone of the province. Similarly, the SAACTC is also located within the high rainfall region of the province, where the average annual rainfall is above 230mm.

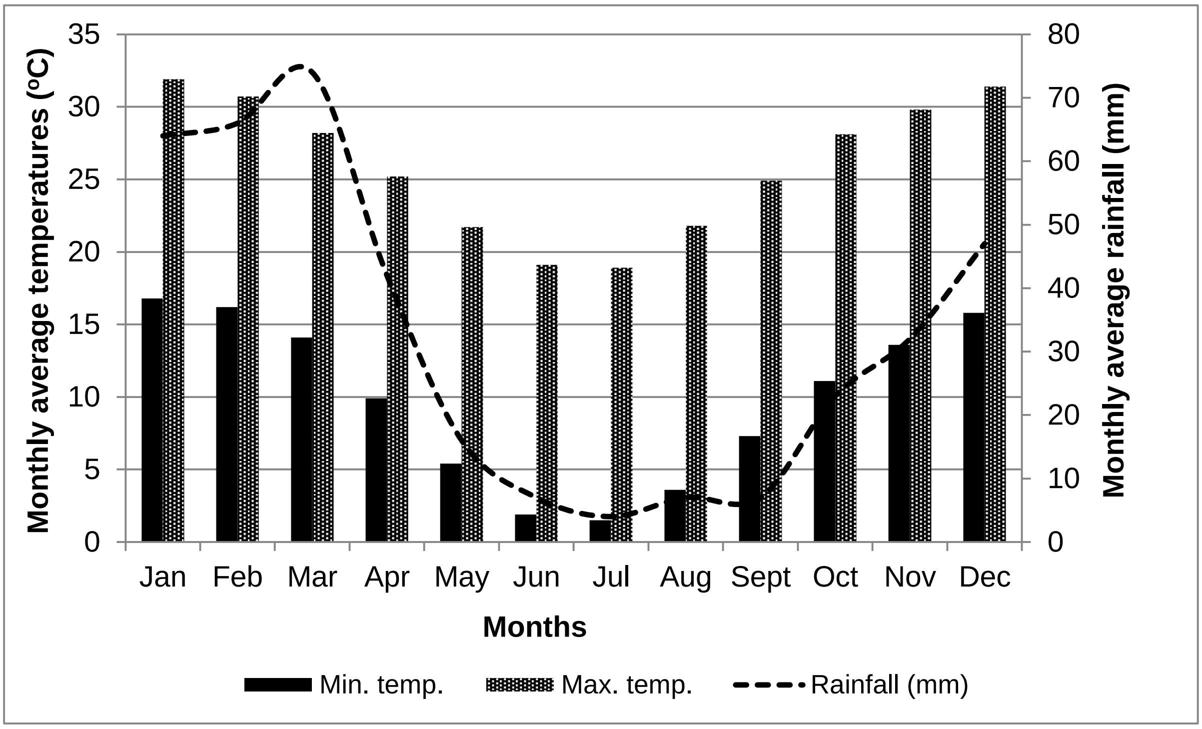


Figure 7. Average rainfall and temperature of Lohatla

Except in March, the effect of temperatures far exceeds the effect of rainfall received. This means that there is always a moisture deficit in the soil and the mobilisation of heavy metals to lower layers of the soil is inadequate. This also affects the rate at which vegetation can recover after aggressive military training exercises.

Geology and Soil

Almond and Pether (2009) describe the Northern Cape Province as comprising of a wide range of sedimentary, igneous and metamorphic rocks, which are rich in evolutionary history of the region. Van den Berg (2010) describes the geology of the Northern Cape as dominated by the Griqualand West Supergroup, Namaqualand Metamorphic Province (Formation), Dwyka, Ecca Groups, and Beaufort Group as well as the Kalahari Group. Figure 7 shows a simplified geological structure of the Northern Cape region, including the study site (SAACTC). According to the Council for Geoscience [CfG] (1997), the Dwyka Group is the lowermost formation of the Karoo Supergroup. Catuneanu *et al.* (2005) state that the Dwyka, Ecca and Beaufort groups in the Northern Cape are a subdivision of the Karoo Supergroup. The Beaufort Group rock formation covers the greater proportion of the Karoo basin (CfG, 1997), while the Ecca group comprises of sixteen different formations within the Karoo Basin (Rubidge *et al.,* 2000).

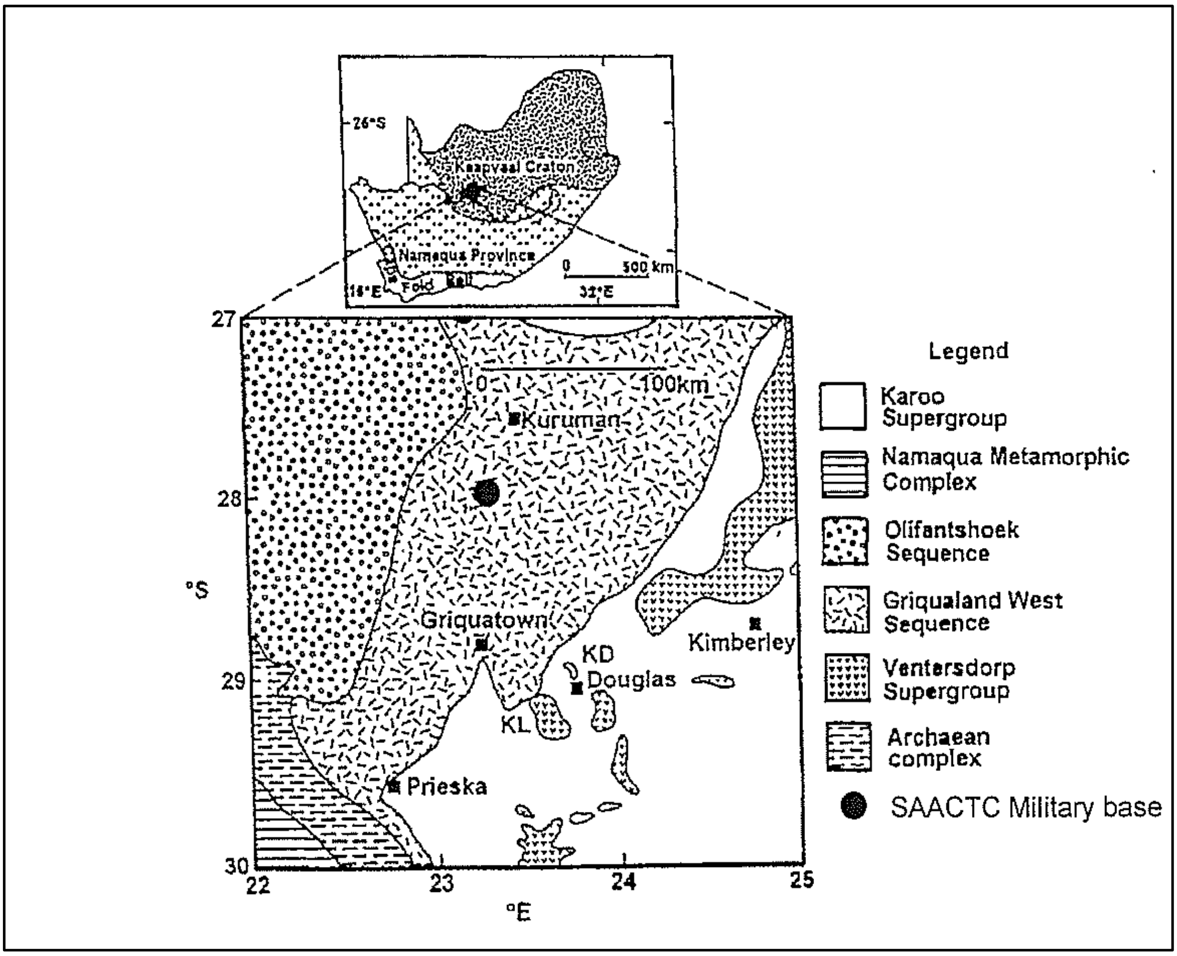


Figure 8. Simplified geological structure of the Northern Cape
(Adapted & modified from de Bruiyn *et al.*, 2002)

The Vryburg rock formation of the Griqualand West Supergroup is the oldest. The Griqualand West Supergroup consists of siltstone with shale, quartzite and andesitic lava (CfG, 1997). Furthermore, the Griqualand West Supergroup comprises of various rock formations such as the Schmidtsdrift subgroup which marks the transition between the Vryburg formation and the Campbell subgroup. The Campbell subgroup consists primarily of grey dolomite (CfG, 1997). Furthermore, the Kuruman and Danielskuil formations also fall under the Griqualand West Supergroup (CfG, 1997). The northern and southern parts of the province are characterised by the Nama Group and the Karoo supergroup. The Kalahari Group is divided into four subgroups, which include the Wessels formation, the Budin formation, the Eden formation and the

Gordonia formation (CfG, 1997). The geology of the SAACTC is described as consisting of hard dolomite, shale stone and calcrete rock formation with pockets of limestone exposed by excavation activities.

The Ventersdorp Supergroup is common in the Northern Cape Province; it is mainly found in the well-preserved volcano-sedimentary sequence on the Kaapvaal Craton (de Bruiyn *et al.*, 2002). According to de Bruiyn *et al.* (2002), the Ventersdorp Supergroup is divided into four major subgroups. These include the Klipriviersberg Group, which is normally at the base of the Ventersdorp Supergroup; the Platberg Group, which is the volcano-sedimentary; the Bothaville Formation, which is largely sedimentary; and the Allanridge Formation, which is andesites and basaltics andesites at the top of the Ventersdorp Supergroup (de Bruiyn *et al.*, 2002). A detailed description of the geology within the military training area is presented in Figure 8. The military training area is dominated by dolomite/limestone geological material. Superficial deposits of gravels, clays, sandstone, silcrete, calcrete and aeolian sand, as well as Gneisses calcrete, also dominate the geology of the area.

Dolomite is described by McKenzie and Vasconcelos (2009), as a common carbonate mineral in sedimentary rocks, especially the Precambrian rocks. However, Robert *et al.* (2006) argue that the formation of carbonate rocks ranges from the Precambrian to the Holocene period. The dolomite rock mineral is highly resistant to chemical weathering, thus, a landscape dominated by it tends to show a rugged high laying areas (McKenzie & Vasconcelos, 2009). Currently, there are two universally accepted analogues regarding the formation of dolomite. The basic consensus is that most dolomites are formed by the secondary replacement of meta-stable calcium carbonate (e.g., aragonite); and, secondly, seawater is an ideal source of dolomite formation because of its high concentration of magnesium ions (Mckenzie & Vasconcelos, 2009). Freas *et al.* (2006) argue that most dolomite is a result of the alteration of calcium carbonate sediments or rock by hyper-saline brines.

Furthermore, dolomite can precipitate directly from solutions containing magnesium, calcium and carbonate ions, leading to the cementation of unlithified sediments (Al-Awadi *et al.,* 2009). According to Freas *et al.* (2006), limestone and dolomite constitute a group of carbonate rocks. These carbonate rocks form approximately 15% of the sedimentary rocks found on earth and are common on all continents (Freas *et al.*, 2006). Both dolomite and limestone are carbonate sedimentary rocks which are extensively used by industries. Most limestone is derived from seawater accumulated in a relatively shallow marine environment (Freas *et al.*, 2006). Al-Awadi *et al.* (2009) argue that most dolomite is formed through the chemical alteration of existing carbonated rock or sediment, such as limestone or calcareous mud. When the calcareous material is subjected to magnesium-rich solutions, then the calcium ions are substituted by magnesium ions, thereby forming a dolomite rock (Al-Awadi *et al.* 2009). It is apparent, from Freas *et al.* (2006), Al-Awadi *et al.* (2009) and Mckenzie and Vasconcelos (2009), that dolomite rock can only form when there is limestone in the vicinity of the area concerned, which has then transformed into dolomite by magnesium solution.

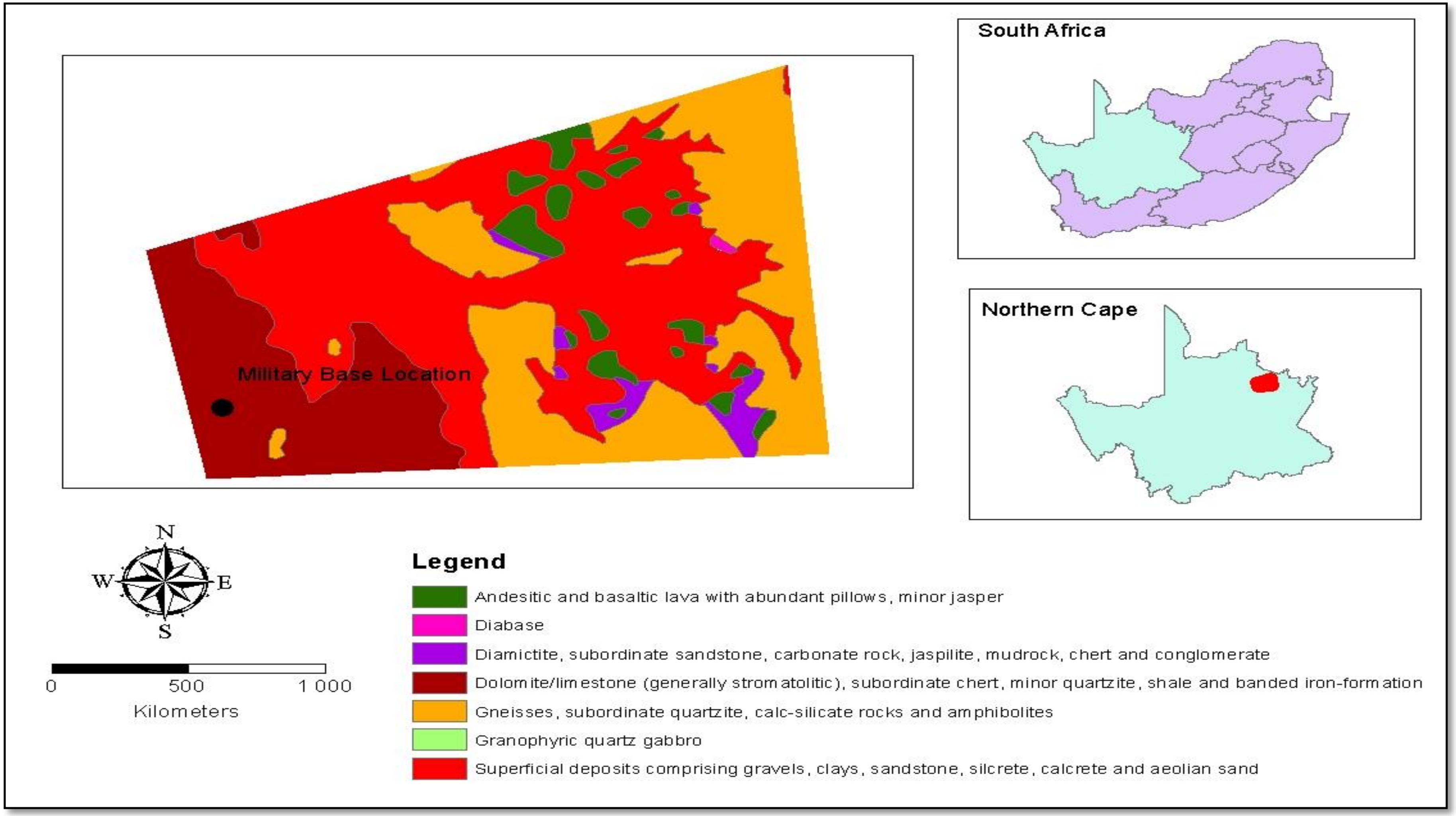


Figure 9. Detailed description of the geological structure of the military training area
(Data source: Council for Geoscience, 1997)

Given the climatic conditions of the region, chemical weathering processes are very slow (Almond & Pether, 2009). This affects the development of the soil in the region. Soil formation begins with the simple process of weathering of rocks and minerals and for this process to be effective, certain climatic conditions must be met; for example, there must be sufficient moisture, adequate temperature, living organisms, and parent material must be available (Verheye, n.d.). Thus, soil depth is associated with humid climatic conditions, while shallow soils are commonly found in dry regions because the effects of chemical weathering and leaching are insignificant (Bridges, 1978). Righi and Meunier (1995) argue that soil is an unconsolidated and restructured materials derived from rock weathering.

In areas where weathering processes are slow and the climate is relatively dry (thereby reducing the effectiveness of chemical weathering), soils tend to be thinner and weakly developed. All sub-processes of weathering play a significant role in the development of soil (Dubroeucg *et al.*, 1998). In general, through observation, the military training area is characterised by red-brown, yellow-brown sandy soils. Apparently, the depth of the soil also varies across the training area. There are training ranges that show high levels of gully erosion while others show insignificant erosion evidence.

Vegetation and Biomes

The SAACTC military training area is situated within the savannah, Kalahari Plains and Mountain Thorn Bushveld Biome (Van den Berg, 2010). The SAACTC training area is characterised by succulent vegetation and other plant species common in semi-arid and arid regions. The most common vegetation in the military training area includes the Camel thorn tree (*Acacia erioloba)*, the shepherd's tree (*Boscia albitrunca*) and the grey camel thorn tree (*Acacia haematoxylon*) (ECR, 2008; 2009). The *Acacia erioloba*, *Boscia albitrunca* and the *Acacia haematoxylon* are endangered plants species found in the training area (ECR, 2009). Their existence is threatened by the frequency of veld fires which ignite during training exercises. According to the ECR for Exercise Seboka (2009), veld fires have destroyed more than 90 000ha of the military training area. Therefore, a veld fire management plan is required to curtail the destruction caused by these disastrous events. Accordingly, veld fire prevention ought to be a crucial programme to the environmental management initiatives of the SANDF, in ensuring environmental protection and the sustainability of this military training area.

Acacia erioloba and *Eragrostis lehmanniana* are sturdily common where the soil is very deep (i.e., >0.8m) and well drained (Bezuidenhout, 2009). These soils are associated with midslopes and footslopes alluvial and colluvial accumulation. Van den Berg (2010) noted that the savannah biome of the Northern Cape Province consists of vegetation types such as Silver cluster-leaf (*Terminalia sericea*), African Olive (*Olea europea*), Umbrella Acacia (*Acacia tortillis),* Buffalo-thorn Jujube (*Ziziphus mucronata),* Blue Guarri (*Euclea crispa*) and Velvet Raisin (*Grewia flava*). Bluebush (*Diospyros lycioides*) and grasses such as Kalahari Coach (*Stipagrostis amabilis),* Lehmann's Lovegrass (*Eragrostis lehmanniana*) and Giant Stick Grass (*Aristida meridionalis)* are found within the biome (Van den Berg, 2010).

The *Acacia tortillis* plants were found to be growing in shallow, but well-drained rocky soil (Bezuidenhout, 2009). However, Bezuidenhout (2009) also indicates that *Diospyros lycioides was* found growing well on moderately deep (i.e., 0.3 – 0.8 m) and moderately drained soil conditions. Therefore, the presence and uneven distribution of vegetation within the biomes indicates a variation in soil depth and moisture conditions.

Summary

This chapter presented a description of the research locations. The research was carried out in two locations: the Grahamstown Military Installation, which is the military base of the 6SAI Bn in the Eastern Cape Province; and the SAACTC, where the 46 SA Bde (46 South African Brigade) is stationed. These two military training areas have been classified for light and heavy military use, respectively. The training area at 6SAI is approximately 70 000ha in size; this equals 0.06% of South Africa's landmass. While the SAACTC, in the Northern Cape Province, is 156 5000ha in size; this is the equivalent to almost 0.13% of the total landmass of South Africa.

The 6SAI base was formed in 1962, as a light infantry battalion of the SANDF. This military installation is situated in the southern part of the province, which has a Mediterranean climate. The average rainfall in this region ranges between 250mm to 500mm, spread throughout the year; thus, rainfall distribution in this region shows a bimodal pattern. The geological structure of the area is dominated by the Karoo and the Cape Supergroups rock formations. The military training area is, however, located in the Dwyka Group and Lake Mentz subgroup rock formation. The region is rich in vegetation diversity: it is characterised by Forests, Grasslands, Succulent Karoo, Fynbos, Savannah and Thickets biomes. The military training area is located in the Thicket biome where patches of grasslands and shrubs are found.

The SAACTC in the Northern Cape Province was declared a military area in 1976. This military area is where the SANDF uses high calibre weapons for training exercises (e.g., airstrike training, anti-aircraft weapons, anti-tanks and armour weapons) and the testing of weaponry. Thus, the conventional military training exercises of the SANDF are carried out in this training area. An arid climate characterises the Northern Cape Province. Rainfall is minimal, even during the summer season; thus, the province falls within the 0.05 – 0.2 aridity classification zone (NC/SoER, 2004). However, the SAACTC is situated within a relatively high rainfall zone where the annual average is above 230mm. The geology of the Northern Cape is dominated by the Karoo, Ventersdorp and Griqualand West Supergroups. Thus, the SAACTC is located in the Griqualand West Supergroup rock formation. Nonetheless, dolomite and limestone dominate the military training area, with other superficial deposits and geological material such as gravel, clay, sandstone, silcrete, calcrete and aeolian sand also found.

The Savannah, Kalahari plains and mountain thorn bushveld biomes characterise the SAACTC military training area. Succulent vegetation and other kinds of plant species commonly found in semi-arid and arid regions are found in the training area. Plant species such as *Acacia erioloba, Acacia tortillis, Boscia albitrunca* and *Acacia haematoxylin,* including grass (*Stipagrostis amabilis, Aristida meridionalis),* dominate the vegetation of the training area. However, many other plant species are also found in the military training land. Soils are shallow to moderately deep (i.e., 0.3 - 0.8m); these are mainly red-brown, yellow-brown sandy soils (Bezuidenhout, 2009).

The next chapter, Chapter VI, presents the qualitative (primary and secondary) data collected using the research techniques described in Chapter IV. The data presented in the next chapter, challenges the objectives and the aims of the current study as stated in Chapter I.

CHAPTER VI

QUALITATIVE DATA PRESENTATION AND ANALYSIS

Introduction

This study seeks to evaluate the SANDF’s environmental protection and sustainability practices. It also intends to assess the challenges and the capacity, as well as the perceptions, of SANDF personnel in regards to effectively implementing environmental protection and conservation measures, without jeopardising the preparedness of the military force. Further, the study seeks to examine the environmental footprints of the SANDF. Thus, this chapter presents the data collected from primary and secondary data sources, through various research techniques, in an attempt to achieve the stated objectives.

Environmental Management Approach at GMI

In the first interview conducted at GMI, on the 12th of July 2011, Warrant Officer 1 (WO1) indicated that an audit of the condition of the training range is conducted prior to any training being undertaken. He also stated that a clean sweep (collection and removal of any form of solid waste) of the range is carried out after a training exercise. This activity involves, primarily, the removal of any waste material such as bullet cartridges and unexploded military ordinances. In cases where trenches have been dug for the purposes of military training, these trenches are backfilled after a training exercise. Thereafter, the military readiness officer inspects the range and issues a clearance certificate to the training company. The certificate is not issued if the training range has not been cleaned.

In an interview conducted on the 18th of July 2011, Corporal “K” (Cpl) (stand-in environmental management services personnel) indicated that an environmental audit, at GMI, is carried out by the “Regional Facility Interface Manager” (RFIM) based in Durban (Lt. Col. “D”). The audits are conducted quarterly, and the base environmental management facility is notified of any environmental management weaknesses that are detected during the audit. He also stated that there are no targets set to be achieved every quarter, except for a verbal report to environmental management services personnel from the regional facility interface manager (RFIM). There was, therefore, no documented evidence that he could produce. He recalled that after one of the audit processes, it was recommended that they had to reduce and recycle waste paper, and that the base was instructed to sort according to waste-type. Thus, monthly reports must indicate progress made in terms of waste reduction. The Grahamstown Military Installation’s Environmental Management Facility (GMI-EMF) is expected to articulate an environmental management plan (EMP) one year in advance. However, in 2011, the GMI-EMF could not provide their monthly internal reports or the EMP for any particular year.

It became apparent, during the interview, that he had never read the EMS for defence despite being involved in the EMF. Cpl “K” stated that, during the RFIM meetings, all military installations were expected to provide feedback on the corrective measures taken to address the problems identified in their previous audit. He was explicit as to whether all parties concerned understand the audit process in regards to environmental management services. Furthermore, all commanders do not sit in RFIM meetings, but are briefed by EMF supervisors.

Reaction towards Environmental Management at GMI

Cpl "K" indicated that, initially, commanders were reluctant to incorporate environmental management practices into military activities. This reluctance was due to the fact that environmental practices in military activities lengthen the planning process and delay the training exercise. Recently, however, many of those involved have since realised the importance of protecting the environment and the sustainability of the national assets (i.e., military training areas).

Environmental Funding at GMI

A Senior Staff Officer in the Environmental Services [SSO Env. Services, Captain (South African Navy) Captain "G"] of the SANDF, in an interview conducted on the 19th of July 2011, stated that the entire DoDMV, generally, does not have a separate budget for its environmental programmes and services. Subsequently, the environmental services at all military installations are funded from a miscellaneous account. Similarly, the SANDF does not have a budget allocation for environmental management services.

Furthermore, Cpl “K” mentioned that there is no funding that is specifically allocated to environmental programmes or made available for environmental management activities at 6 South African Infantry (6SAI). He indicated that the national budget for Defence has been decreasing since 1994. The reduction of the defence budget has led to a decrease in the funds available for environmental management services at 6SAI. Therefore, environmental management activities are financed from the operation budget of the military installation. Cpl “K” added that the EMF does not have its own vehicle to inspect the training area.

Most of the officials involved in the management of the environment at 6SAI (GMI) are also aware that it is difficult to receive funding for environmental management activities. The said interviews reveal that five critical elements need to be considered in the military environmental management planning process. These include financial planning and allocation, the acquisition of skilled human resources, strengthening internal organisational structures for coordination purposes, updating policies in line with the national legal framework, as well as establishing and maintaining external strategic linkages with environmental experts and practitioners.

Another major weakness is that the environmental facility at 6SAI does not collaborate with any institutions of higher learning or research institutions. Collaboration with these institutions can assist the SANDF to stay abreast with the latest developments in the field of environmental management. Furthermore, collaborations assist with the identification of effective mitigation measures for military related environmental impacts.

Challenges to the Implementation of the Environmental Management System at GMI

Cpl "K" highlighted seven major challenges that impede the effective implementation of environmental management measures at GMI:

- A shortage of vehicles to enable the environmental management personnel to make frequent visits to the field and conduct a proper assessment before and after a training exercise;
- A dearth of skilled and competent staff to lead the environmental management task at GMI and develop an environmental management plan for the installation;
- No adequate training of the environmental management services personnel in order to empower them to carry out their duties diligently;
- Inadequate monitoring of environmental management at the installation, stemming from the absence of senior and competent supervisors at the facility (GMI's - EMF);
- Insufficient investment in proper environmental management, for example, the filling of posts in the environmental management facility, and training, is essential;
- Middle management is not adequately informed of and educated on environmental management issues;
- Good plans and policies can exist, but, if not implemented effectively, the goals and objectives of those policies and plans cannot be achieved.

Pollution Prevention Mechanism at the 6SAI (GMI) Military Training Area

During field observation at the 6SAI military training area, it was observed that canvases are used as a secondary containment at refuelling bunkers. Similar canvas material had also been used to prevent soil pollution from oil as well as diesel spillage from the power generating engine installed a few meters away from the makeshift offices. Both the power generating engine and refuelling station are far away from a water source. The United States Armed Forces (USAF) came to the South African shores for joint practice drills and exchange of amphibious doctrine with the SANDF. Both military forces (US Marines and the SANDF) use camouflage nets that fit the environmental conditions of the area. On the one hand, the SANDF put up camping tents that are made out of brown camouflage nets while, on the other hand, the US Marines used their green and white camping camouflage tents. Clearly, this is an indication that both military forces take due consideration of the protection of the environment. In fact, the US army is a renowned leader in environmental management.

Cpl "K" mentioned that there was an incident in which a diesel bunker leaked and contaminated the ground; it was, however, immediately put under control. When there is significant fuel spillage, they use a private oil company, Oil Kol, to treat the affected area.

Existing Collaborations at GMI

Cpl "K" indicated that the GMI is collaborating with the Department of Water Affairs and the Makana Local Municipality in order to learn more about environmental management practices. However, there was no documentation to support this, except for the ongoing alien species eradication project called "Operation Vuselela" (explained in the Eradication of Invasive Alien Plant Species section in this chapter). The limited external linkage could be consequent of the absence of qualified or competent environmental officers in the GMI's environmental management facility. Skilled and competent officers can establish the importance of external linkages.

Physical Land Disturbance at 6SAI Military Training Area

Field observations conducted three weeks after Exercise Shared Accord between the US Marines and the SANDF, revealed that obvious physical damage was inflicted upon the environment by armoured vehicle manoeuvres. Thus, ruts of various depths (e.g., 5cm–45cm and more) on the ground were obviously visible, with vegetation that was destroyed by heavy military vehicles. It was surprising, however, to see that the trenches dug during that exercise were not backfilled, as expected. This contradicts what WO1 had indicated in the interview on the 01st of July 2011, that is, that trenches are backfilled after each training exercise. Much of the surface at the target area was extensively disturbed by the explosions used. Impact points of varying diameters from 12-60cm were clearly visible. WO1 explained that the 81mm mortar causes massive holes in the ground because, when sliding on the ground, the mortar can cause 190cm long furrows that could be about 30cm deep. Moreover, used detonation cables were still lying on the ground, while others were half buried for the purpose of setting off the bomb(s).

Various kinds of military waste (such as links and bullet cartridges) were found lying on the ground, although it had been three weeks since the end of the joint exercise. During this field observation, one unexploded ordinate was spotted “stuck” in bushes and a “1000 feet illumination flare” was found hanging from a tree. This confirmed Cpl “K’s” opinion that, in some instances, the clean-up process is not done properly after a training exercise. He recalled a case where a “1000 feet illumination flare” was set off and, when landing back on the ground, it got stuck and dangled on a tree with its parachute. It later got hooked up on the horns of a springbok (*Antidorcas marsupialis)* covering its face and blindfolding it; this graphically explains the importance of cleaning the training area after each training exercise. Such incidences expose weaknesses in the inspection process and the issuing of range clearance certificates.

Field observations at GMTA further revealed the inappropriate disposal of military waste. Clusters of used mortar shells were observed in certain parts of the training area; these mortar rounds appeared to be hidden in brushes within the training range, possibly where training might have taken place (Figure 9). In addition, a few unexploded ordinances were observable at the GMTA (Figure 10). The observation of these materials at the training area contradicts the information provided by some of the respondents. The presence of this waste in the training area raises concerns regarding the adherence to appropriate ways of protecting the environment from harmful practices. These types of waste corrode and introduce heavy metals into the natural environment over time.

Figure 10. Mortar shells in a secluded area within the 6SAI military training area

Figure 11. Unexploded ordinances dotting the 6SAI military training area

Issuing of the Clearance Certificate

The issuing of a range clearance certificate serves to ensure that the waste material generated during a training exercise has been collected and removed from the training field. According to Captain "L", in an interview held on the 15th July 2011, upon the completion of a training exercise, the commanding officer of the military company that was conducting training is issued with a clearance certificate after confirming that the range has been cleared of any waste material including cartridges, ammunitions and anything of a similar nature. It is apparent that the clearance certificate after the training exercise was issued without any form of verification. A report from the EMF should confirm the commanding officer's report, as it is responsible for ensuring adherence to environmental management regulations and legislation.

Eradication of Invasive Alien Plant Species at 6SAI Training Area

The spread of the *Opuntia Indica* species, commonly known as the prickly pear, threatened the ecological integrity of the Grahamstown military training area (GMTA). As a result, in conjunction with the Working for Water Project under the Department of Water Affairs, the DoDMV has initiated a project called Operation Vuselela. This project aims to eradicate invasive alien plant species (primarily the *Opuntia Indica*) on military properties, by hiring unemployed military veterans to do so. Vast areas of the GMTA were noted to be heavily infested with this invasive plant. Although Operation Vuselela has been implemented for some time, it appears to be failing to control the spread of this plant within the training area. The colonies of this plant are dense in certain areas, especially where military training exercises occur less frequently or are non-existent, particularly in high-lying grounds of the training area. The method used to eradicate this plant species appears to be flawed; this method consists of a combination of mechanical and chemical approaches, but these are not accurately applied. In order to eradicate this plant species, the cladodes of the *Opuntial indica* are chopped down and dissected, then sprayed with chemical liquid while stacked up in piles on the ground (Figure 11). Over time, those cladodes that are in contact with the ground begin to develop roots. Consequently, a treated area will start to show regrowth and become infested with *Opuntia* again. The spread of the *Opuntia Indica* plant species is linked to birds, monkeys and baboons that are commonly roaming within the training area. The *Opuntia* makes certain sections of the military training area inaccessible, thus impeding the movement of soldiers on foot when infantry military training is required to be carried out.

Figure 12. Efforts towards eradication of *Opuntia Indica* within the 6SAI training area

The elimination of invasive plant species at GMTA is regarded as its environmental management programme. There is no other environmental management programme at GMI that is directly linked to the EMF, in line with its responsibilities. The lack of other environmental management plans at GMI illustrates the ineffectiveness of the environmental management facility at this military installation. It is the function of the EMF to ensure that appropriate environmental management programmes are developed for and implemented in the GMTA military installations.

Results from the South African Army Combat Training Centre

Potential Environmental Degradation

An interview with Maj. “R”, on the 10th of January 2012 at SAACTC (Lohatla), revealed that this training area is one of the biggest military training areas in the Southern Hemisphere. Its total area is over 156 500ha (which is approximately 0.4% of the total landmass of South Africa). The SAACTC military training area is divided into ten training ranges of varying sizes. The biggest training ranges are ranges A and C. Both these ranges (A and C) are used specifically for heavy weapons training exercises. Maj. “R” stated that this training range has also been used by the British army, Dutch military force, Singaporean army and the American army on various occasions in the past. Therefore, there is tremendous potential for environmental degradation to occur. However, Maj. “R” indicated that when foreign military forces train in this training area, they bring along their own environmental management personnel to ensure the protection of the environment. The significant environmental risks lie in vehicle manoeuvres and the explosions used during training exercises, as well as veld fires that frequently ignite during training activities. These fires tend to destroy vast hectares of vegetation within the training area and can even destroy sections of the neighbouring farms.

To minimise damage to the environment and to prevent pollution, awareness training is conducted at the base prior to the commencement of training. The awareness training is also replicated and consolidated by environmental workshops that are carried out in the field during training activities. In addition, an environmental representative is appointed in each unit. These representatives ensure that training is conducted in accordance with the environmental management plan for the exercise. The troops' environmental representatives report, to the commanding officer, any environmental problems that were encountered during the execution of the military training exercise.

Contaminations Reduction Programme at SAACTC

Soldiers, at first, held a misconception regarding fuel spillages. As a result, some do not report incidences of spillages. In recent years, however, the attitude of soldiers is slowly changing, and they now report incidences of fuel spillages. Refuelling bunkers in the field pose an enormous threat to the environment and could cause serious environmental contamination. Accordingly, it is always recommended that refuelling bunkers must have a secondary containment as a mitigating and preventative measure for fuel contamination. Maj. “R” indicated that, in cases where 5-100l of fuel has been spilled onto the ground, the soil is dug out and put into a container which is taken to a “laboratory” (shed) where it is treated with a product called “Bio-Curb”. This soil must be kept in the container for 8 – 9 months, during which time it is always watered; after which it is returned to the area from which it was removed once the specified period has lapsed. Currently, the military has a slogan which reads: “*you spill, you dig*”. Consequently, incidences of fuel spillages have decreased. For example, in the year 2011, only nine such cases were reported. Whereas in previous years, as many as 33 fuel spillages were reported and some were not reported but were identified in the field.

All these incidences are recorded in a log book in which all the details pertaining to the spillage are noted, that is, where the incident occurred, how much fuel was spilt, which troop was involved, and so on. Maj. “R” also stated that this form of pollution poses a greater threat because it has the potential to contaminate the ground water reserve, since the water-table in the SAACTC where the training area is located is known to be very close to the surface. He further stated that no depleted uranium bullets and nuclear substances are used in their training areas.

Funding of the Environmental Services and Management Programme

Maj.“R” indicated that funding is the main challenge that he has encountered regarding environmental management at this military installation. He estimated that, in a year, he can only use R10 000 for environmental management services. Although he estimated that R5 million per year would be an ideal budget for effective environmental management at the SAACTC military installation. These funds can be used to maintain effective rehabilitation programmes, where applicable, and to control soil erosion, eradicate alien plant species in the training area and preserve the cultural resources found in the training area (e.g., graves and rock paintings). One training range, called Biessies Pan, has been suspended from all forms of military training due to the high level of degradation that has occurred. The Biessies Pan training range will be allowed to rehabilitate naturally, which could take a maximum period of three years, and after which it is anticipated that it would have recovered.

Moreover, the overall shrinking of the defence budget and the commitment of the SANDF to continental peacekeeping missions further exacerbated the inadequate funding of the environmental programme in the defence force. In addition to environmental management, even the conditions and types of targets used in the training areas are dilapidated. All the old armoured vehicles used in the training areas are now dilapidated. Consequently, conventional metal vehicles are used as targets and, when hit by heavy weapons, fragments of these vehicles are distributed far and wide. As such, these types of targets pose environmental concerns within the training areas. Maj. “R” indicated that he had since recommended that conventional metal vehicle targets should no longer be used for this purpose.

Environmental Management Capacity, Skills and Collaborations

Environmental management challenges in the defence force are discussed during its quarterly meetings. This forum is comprised of environmental officers from all SANDF military installations. It is at this forum that environmentally designated officers are able to share their ideas and experiences. The RFIM also participates in these discussions. One RFIM is responsible for many military installations and they have other military responsibilities, thus, they struggle to carry out the responsibility of environmental management. Skilled and competent environmental personnel are hard to retain within the SANDF, especially since qualified and capable personnel leave the SANDF for better opportunities in the private sector. The remuneration package and upward movement in the job, as far as an environmental officer's career in the army is concerned, is considered a "dead end" by Maj. "R". Most of the current environmental officers in the SANDF are required to attend short environmental management courses. These courses are six weeks in length, and cover concepts ranging from waste disposal to the storage of hazardous waste material. He also mentioned that the environmental management handbook or guidebook they use is based on American conditions rather than the South African context.

Maj. "R" indicated that the SAACTC works in collaboration with many other state departments, including the Department of Environmental Affairs and Tourism, Department of Agriculture, Department of Water Affairs, Department of Forestry and Fisheries, Department of Minerals and Energy, and so forth (refer to Appendix A). These collaborations are meant to provide assistance and advice to the SANDF on environmental management matters, and Maj. “R” regards these collaborations as invaluable.

FIELD OBSERVATION AT SAACTC TRAINING AREA

Environmental Conditions of the Training Area

This training area is vast, therefore, it was difficult to carry out observations in all the training ranges. From afar, one cannot tell that this area is used for strenuous (aggressive) military training exercises. Vegetation cover is estimated at 60 - 75%, as the environment is dominated by short grass vegetation and herbs with shrubs and trees scattered across the area. As expected, however, other sites are completely bare, especially where open public demonstrations are usually held.

However, there are areas where trees show signs of wilting. This could be attributed to high levels of soil contamination or veld fires that commonly ignite during training exercises in the training areas. Soil sample collection was restricted to these sections of the training area, especially towards the target points. Thus, no training range is characterised by overgrown vegetation. Most of the trails in this military training area are in a relatively reasonable condition compared to those at GMI, although they are characterised by loose sandy soil. In all but one training range, there are no marked firing lanes. However, Maj. “R” indicated that some of the targets are fast becoming obsolete. Thus, they have become an important environmental concern. Uncollected mortar shells (used for training) and unexploded missiles were observed to be lying on and stuck in the ground.

Official Environmental Management Documents for the Defence Force

A considerable amount of secondary data was elicited from the analysis of official environmental management documents. Some of the documents used as sources of secondary data have been explained in Chapter IV of this study. It must be noted that the only environmental reports that have been read are those received from SAACTC; furthermore, no environmental report or any such document was obtained from GMI. The various environmental reports from SAACTC are analysed in the sections which follow.

Military Environmental Management Guidebooks

The United States of America (US) and the Republic of South Africa's (RSA) Bi-National Commission on defence and the environment have led to the development of various environmental management documents. Currently, the SANDF has a reference document for EIA for military activities, referred to as a guidebook on environmental impact assessment in the military (2004). This guidebook, in its executive summary, is described as a product that would facilitate and assist military organisations to integrate environmental considerations into their decision-making processes by adopting appropriate EIA processes. The military EIA process outlined in the document is general, which means that it applies to any military organisation. For example, factors that require special attention include the extent of the impact, duration of the impact (temporary, short- or long-term), the frequency of occurrence (annually, weekly or continually) and intensity of the impact.

The guidebook on the Development and Implementation of Environmental Education and Training in the Military (2002) is described as a document intended to assist military organisations in addressing their environmental education and training needs. It is also assumed to be a roadmap for the integration of environmental considerations into the day-to-day activities of military organisations, in order to sustain their missions in an environmentally sound manner. It is further intended to assist military institutions in achieving their overall environmental goals and objectives. This document encourages military organisations to develop an environmental policy framework in which their fundamental principles are outlined. The key principles may include compliance with all environmental laws, pollution prevention to reduce or eliminate pollution at the source, conservation of natural and cultural resources, restoration of degraded military sites, protection of the environment, and the efficient use of resources.

The purpose of the Guidebook on Environmental Considerations during Military Operations (2006) is to assist military organisations to identify procedures that would adequately assess the impact of their activities. This will aid them in meeting their environmental responsibility and accountability objectives, and thereby ensure environmental sustainability. Thus, it is critically important that military organisations implement procedures that would adequately minimise the impact of their activities. In doing this, military institutions would be able to achieve their goal of environmental protection. These guidelines assist military sectors in planning accordingly (as the guidebook identifies and describes all the processes for integrating environmental considerations into military planning and the implementation process) and identifies mitigation measures to offset the potential adverse impact of military activities. In regards to this planning, four stages are defined. Stage 1 signals an intention to stage a military operation; legal frameworks such as international treaties and protocols must be considered for compliance. A critical evaluation of environmental aspects that can constrain the achievement of the military mission needs to be conducted, and key environmental issues that could increase costs and force risks ought to be identified in this stage.

Stage 2, the planning stage, determines that environmental considerations should be integrated into all phases of military planning. The environmental intelligence should be continuously updated with new information through liaison with the relevant agencies, including NGOs. In this stage, operational planning is critical for integrating environmental considerations into operational plans. Planning guidelines integrated with environmental considerations should include, among other concerns, considerations regarding the availability and serviceability of equipment. The equipment that will be used should be serviceable in order to avoid unnecessary environmental maintenance. Environmental reporting procedures must be established and confirmed. The environmental management plan must incorporate an articulation of the processes, roles, functions and responsibilities, including monitoring, assessment and protection of the environment during military operations. The plan ought to be reviewed in order to identify additional measures to address situations that were not provided for in the original plan.

Stage 3 focuses on the execution of the plan, which refers to the roll-out of the plan (i.e. putting the plan into action). This stage includes confirming that the environmental plans have been put in place, confirming environmental intelligence, and thus demarcating environmentally sensitive areas. At the end of the activity, detailed environmental reports must be finalised and submitted to the relevant offices. The last stage is called the post-deployment stage, which is concerned with all the actions to be taken after the forces withdraw from the mission (base area). It is during this stage that rehabilitation and monitoring programmes are designed. Furthermore, the weaknesses of the planning and the subsequent execution of the plans are reflected upon in this stage; this includes reflection on the integration of environmental considerations into the operation or activities. The environmental reports read from the SAACTC adopted some of the processes outlined in the guidebook on environmental consideration during its military operations.

The Military Integrated Training Range Management Guidebook (2000) is aimed at enhancing the defence sector's ability to sustain long-term, cost-effective range operations through formulating appropriate range management practices. It is acknowledged, in this document, that militaries around the world rely on environmental managers and range commanders to provide the essential, although potentially unexciting, service of managing the natural environment. Thus, military environmental managers must ensure the long-term continuation of environmentally appropriate range management practices. This guidebook also outlines the benefits associated with appropriate range management initiatives. These advantages include the long-term military use of the land areas and force preparation, ensuring the long-term and sustainable potential of military ranges and, thereby, reducing the need for land for military activities. Furthermore, the military will demonstrate commitment to custodianship of state resources in their use thereof. Therefore, the purpose of this guidebook is to assist armies anywhere in the world to develop an environmentally comprehensive and viable range management strategy in order to enhance their ability to sustain long-term military use.

Environmental Management Reports from SAACTC

The EIP of 2008 requires that each military installation submits an annual environmental report, as a measure of effective environmental management, and monitors compliance with the country's environmental laws. Therefore, each installation must have or must develop a database of environmental reports. Maj. "R" provided the researcher with copies of some of the environmental management reports that he had prepared. Thus, the section below presents the findings derived from the environmental support plan for exercise Para Bellum, which was undertaken in 2008.

Environmental Support Plan for Exercise Para Bellum 2008

This plan covered a variety of environmental management issues during the training exercise. Its aim was to assist in ensuring that environmental considerations become part of the pre-planning process, together with promoting the environmental sustainability and viability of the training range being used. The key elements of this report are outlined as pro-active preventive actions and the mitigation of environmental damage that is likely to be caused by the military training exercise.

The plan outlines a total of 14 environmental management aspects that are deemed essential and crucial for the future usage of the training range and the training area, as a whole. The environmental management issues outlined in the plan include the following:

- Environmental threats

  The area was at its peak of fire regime which signalled significant environmental risk. Effective plans for the prevention of significant environmental pollution are emphasised (and must be adopted). Necessary precautions ought to be taken to ensure that underground water sources are not polluted by pit latrines and refuelling operations. Furthermore, the management of hazardous material and waste should be addressed at all stages of the exercise.

- Possible environmental manipulation

  The training range in which the training exercise was due to take place had three bulk fuel stations containing various quantities of fuel. Thus, the plan drew the attention of the commander that any act of sabotage during the training exercise would have resulted in severe contamination of the available water sources in a short period of time. In other words, there will not be enough time to contain any spillage.

- Environmental compliance requirements

  It was critical that no harm occurred to the environment because of the exercise. Thus, commanders were to be held liable and accountable for any negligent damage to the environment, including its historical and cultural resources as well as its infrastructure. Therefore, the duty of care principle was given significant emphasis during this training exercise. Accordingly, everyone participating in the training exercise, not only the environmental manager, were expected to observe best environmental practices. In this section, the plan also states that trainers are responsible for mitigating and rehabilitating any pollution spill that would have a considerable environmental impact.

- Environmental responsibility

  Commanding officers have the responsibility to ensure that environmental protection practices are integrated with military activities, as stipulated in the EIP for defence. The EIP for defence states that "[e]very commanding officer is responsible for ensuring that the activities, that are carried out under the commander's supervision are done in a sound and environmentally friendly manner." At the same time, the plan highlights, or acknowledges, the fact that the General Commanding Officer (GOC) of the SA 43Bde cannot be held entirely responsible for environmental damage which occurs during training exercises. Thus, the GOC appoints environmental representatives who will ensure that appropriate environmental practices are adhered to during the training exercise. Some of the responsibilities of these environmental representatives are to:

  - Disseminate and implement environmental instructions during the training exercise.
  - Become the co-ordinator of the unit's hazardous material/waste and spill contingency.
  - Ensure that environmental incidents and spills are reported as per instructions and that the contingency plan can be implemented as soon as possible.
  - Maintain environmental awareness throughout daily activities.
  - Evaluate the implementation of environmental considerations into military activities and note the successes and failures in environmental compliance and practice.

- Preparation of base camps and rear assembly areas

  Before the company departs from the "camp site," the designated environmental officer has the responsibility of conducting an environmental base survey (EBS: referring to the initial environmental conditions prior to deployment) to document the conditions of the site and other environmental conditions. The EBS report together with the environmental reports that are prepared after deployment (environmental closure report) are submitted to the commanding officer (43 SA Bde HQ).

  In addition, the designated environmental officer also considers potential for and evidence of pollution of water sources, solid and liquid waste management, as well as hazardous waste material. All these must comply with the specified waste management and removal plan previously provided to the unit, in training. In cases where hazardous material/waste cannot be removed, the location of the items, types of items and any other critical information that will assist future recovery is recorded. This report must be submitted to the environmental manager.

- Refuelling operations

  The refuelling of vehicles must be done at designated sites. The environmental manager must be consulted if there is a need to relocate the refuelling station. This is meant to ensure that the refuelling station is appropriately relocated, and any potential pollution is avoided. In an attempt to prevent soil contamination from leaking fuel, drip pans or large secondary containments, such as canvas-ground sheeting, are used.

  The secondary containment is placed under the fuel bladders and fuel pumps, and protective sandbags bunds wall are erected to prevent the spread of fuel if spillage occurs. Once spillage occurs, it is mopped up using soil, sawdust or spills orb material. Refuelling and vehicle maintenance are prohibited near or in a wetland or surface water courses. All containers are inspected for leaks every week, and any incomplete, unreadable or obsolete labels must be fixed. Labels must reflect the actual content of the container.

The “Lappies” pump refuelling should be operated by two members of the defence force when filling a container, of any size, with fuel; one member will run the pump, and the other will dispense the fuel. This procedure is meant to ensure that there is adequate monitoring of the pump, for leaks, and to shut the fuel pump in the case of an emergency; it also prevents the overfilling of containers. Fuel storage containers should always be kept in good condition. A spill which occurs during combat refuelling is regarded as unpreventable; thus, the site must be marked, plotted and reported to the environmental manager through the incident report. The unit involved must rehabilitate the site after the training exercise.

- Spill response

  Commanders should maintain spill prevention or control plans, and all forms of spills must be given the necessary attention and must be attended to promptly. The first reaction must be carried out by the Unit involved in the training exercise, in order that they contain the spillage and clean up the site to the best of their ability. The site of the incident is marked, and the incident is recorded and reported accordingly. Spillages that are under 500l and other hazardous waste spills of less than 25l are dealt with internally by the Unit on the advice of the environmental manager. In a case where the spillage exceeds 500 litres, qualified hazardous management response contractors are called in to rehabilitate the site.

- Ecosystem protection

  The clearing of any site within the training range is supposedly done in consultation with the environmental manager and the tactical situation team. All soldiers in action must adhere to the principles of “care” to avoid disturbing threatened and endangered species, habitats and sensitive areas. All individuals involved in the training exercise are expected to uphold the duty of care to prevent vegetation from being stripped during camouflage activities. Soldiers are to use camouflage nets instead of vegetation. Unnecessary damage to vegetation is denounced because it has the potential to destroy the training range, thus leading to a decrease in realistic training.

- Fire hazard

  Veld fires are regarded as a significant threat to the environment and to military personnel. Veld fires are ignited during live fire training exercises and should, thus, be extinguished as soon as possible. The training troop remains responsible for putting out the fire even when fire fighters have arrived on the scene.

- Withdrawal from the deployment area

  The commanding officers should confirm that all fighting positions, trenches and other excavated areas are properly backfilled. All material (such as communication, electricity wires, ammo brass, etc.) should be collected, including waste material. The location of unexploded munitions should be marked and reported accordingly.

- Command and control

  Environmental inspections at all deployment base camps can be conducted at any time by the General Commanding Officer (GOC), Second in Command Officer or the Environmental Manager. Such unannounced inspection visits are meant to ensure that units adhere to the EMP for all exercises carried out by them. However, penalties or punishment for non-adherence are not specified.

The environmental plan emphasises the importance of following environmental management instructions for the duration of the training exercise. It also tries to promote acceptable environmental ethics and invites suggestions and input from everyone involved in order to improve the implementation of environmental protection practices during military training exercises. However, one clause under general considerations makes it clear that no environmental impact can or may lead to the cancellation or suspension of a military training exercise.

Environmental Closure Report (ECR) for Exercises Seboka and Para Bellum 2008

This closure report indicates that there has been a significant impact on vegetation, particularly on endangered tree species such as the Camel Thorn (*Acacia erioloba*), Shepard’s tree (*Bosciaalbitrunca*) and Grey Camel Thorn Tree (*Acacia heamealoxilin*). The impact on these plants was caused by vehicle manoeuvre and by being trampled over by soldiers on foot. Veld fires are reported as having had a significant impact on the Camel Thorn as well as the Wild Olive plant population. The report also indicates that, due to the frequency of fires between 1995 and 2008 in this training range, extensive damage has occurred. Thus, a large portion of the environment has been destroyed, to such an extent that it will only fully recover in a period of 150 to 200 years.

Furthermore, the report states that if the fire problem is not successfully addressed, the characteristics of this training area will be significantly altered such that it will become unsuitable for military activities. It appears, based on the report, that the pollution measures put in place were effective, and that military personnel adhered to the instructions outlined on the environmental support plan. However, spillages did occur during the exercise and the affected sites were rehabilitated accordingly. The rehabilitation was carried out through digging out the contaminated soil to air dry it, mixing it with Bio-Carb, watering it for nine months and then reintroducing it into the excavated ground.

A range clean sweep was carried out after the exercise and all marked UXOs were reported and removed by 2 Field Engineer Regiment. The concluding statements of the report highlight that the main environmental impact identified after the exercise is the adverse effect that the fire has inflicted on the vegetation. It also states that grass and shrubs may recover in three years, if there is no further disturbance due to the training that takes place at this training range. The affected training range is called Biesies Pan. The report, however, notes that the succulents and other trees will not recover within a 20 year period. Thus, the fire problem is likely to render this range open grassland with only knee high shrubs which would not provide sufficient cover for camouflage during military training.

The report also notes that the pro-active prevention of environmental damage and pollution is more efficient and desirable than the reactive treatment approach that is currently adopted to deal with spills and other environmental impairments. The pro-active approach can be achieved by ensuring that only serviceable vehicles and equipment are used during the exercise.

The Spill Register for Exercise Seboka 2008

During Exercise Seboka, in 2008, fuel spills of 125litres in total were recorded in the register. This quantity of fuel spills is a collective total of the various amounts recorded on different dates during the training exercise. Eight of the entries are for diesel spills; one entry is recorded as petroleum, oils and lubricants (POL) spills and one oil entry as well one other entry for the amphibious task force (ATF). Of the eleven entries on the register, six were reported by environmental inspectors, two by the Occupation, Health and Safety representative and two were reported by Commanders. Four of these spillages occurred during a refuelling operation; two were caused by leaking vehicles; one was caused by a leaking diesel bunker, a burst hydraulic pipe and a leaking refuelling generator, as well as leakage from secondary containment. In addition, leaking vehicles and refuelling operations caused one spillage each. In all these cases, actions were taken to contain and decontaminate the ground. The measures taken to deal with these spillages range from “plotted and collected to peat sorb administration.”

Environmental Closure Report: Exercise Seboka 2009

This environmental report provided more details about the findings made when fourteen units were withdrawn from the training area. Half of these units were reported to have complied with the environmental management plan with no environmental impact incident reported. However, the other seven had spillage incidences and other gross environmental malpractice incidents, including not removing the rubbish bins (drum). There was only one Unit that did not have a clean record, which is the 46 SA Brigade Main HQ and BAA Unit. Although this Unit tried to comply with the environmental plan, not all their generators had secondary containment to prevent pollution from leaking fuel. Secondly, their base camp areas were not cleared of rubble of various kinds.

Furthermore, base clearance certificates were not submitted, and the inspection of the unit camp base area was not coordinated by the environmental management facility. However, the Unit was allowed to withdraw from the area before its environmental compliance practice had been audited. Despite this gross malpractice, the report indicates that the impact of Exercise Seboka 2009, in Biesiespan (Range J), did not merit any further investigation.

The remarks of Brigadier General “X”, who was a commandant at the SAACTC (in 2009), regarding this report were that the combat training centre appreciates the compliance by the military Units, but it would be highly appreciated if 46 Bde can warn those units that did not comply and make clear that they should adhere to the environmental management plan.

In keeping with the Guidebook on Environmental Considerations during Military Operations (2006)

- The annual environmental management report, among other issues, lists the personnel responsible and accountable for environmental services at the base. All three persons listed as charged with the responsibilities to lead environmental management are regarded as qualified to carry out this duty. Also, other members who were involved in the management of the environment at this military installation are also listed in the report.

- Section B of the annual environmental report deals with general information, including numerous questions concerning environmental management. One question related to the efforts undertaken to train and empower the personnel responsible for environmental services and another question on the environmental working group at SAACTC were both responded to in a negative manner. A question about partnerships (i.e., external linkages) that the environmental service personnel have with experts concerning the planning and execution of environmental services was answered positively. The answer to this question states that the SAACTC collaborates with nine government departments. These departments are the Department of Water Affairs and Forestry (now known as the Department of Water Affairs and Sanitation) in Upington; the Department of Agriculture in Postmasburg; the Departments of Environmental Affairs and Tourism in Upington, Kuruman and Kimberley; the Olifantshoek Agricultural Union; the Rooiwal Agricultural Union in Smithers; the Kuruman Agricultural Union; as well as the Daniëlskuil Agricultural Union in Daniëlskuil.

Another question on how the base makes use of the environmental services staff officer in the next higher line functional office (i.e., regional facilities officer). Maj. “N” of the RFIM, based at the Bloemfontein military installation, is listed as the liaison officer who is regularly contacted for advice and asked to confirm whether the planned actions and procedures are correct. It is also stated that Maj. “N”, together with other role players, carries out regular inspections of the training ranges. All quarterly environmental working group meetings/workshops are chaired by the RFIM. One of the most important questions in this annual report relates to the problems or challenges associated with the availability of resources (such as manpower, funds, equipment, supplies, etc.) for the implementation and effective functioning of the environmental service at the SAACTC. Surprisingly, the answer to this question focused only on the shortage of manpower, and did not mention the inadequate funding for the environmental services, as revealed by the interviews at both the SAACTC and GMI.

- Ecological Management issues were explained in Section C of the report. The primary components of this section included:
    - Impacts of military and non-military activities
        - The highlighted impacts include pollution of water sources, air pollution caused by fugitive dust, as well as the contamination of soil resulting from the inappropriate and illegal disposal of hazardous substances.

    - Impact on soil
        - This aspect included the loss of top soil due to a loss of vegetative cover, caused by overgrazing and clearing of areas for camping.
        - Erosion due to poor track discipline and compaction caused by military vehicles, as well as the loss of vegetation due to veld fires.
        - However, there is a plan for the management of soil erosion in SAACTC. Gullies have been mapped, and efforts towards rehabilitation have been implemented. Currently, the focus is on identifying and addressing the cause(s) of this problem rather than relying solely on rehabilitation. The identification of causes of the environmental problem is one of the fundamental principles of the sustainable utilisation of natural resources. Identifying the causes

of an impact can assist in devising and implementing mitigation measures to reduce the significance of the impact.

- Air pollution
  - This form of pollution is reported to be caused, primarily, by the burning of wastes at the waste dumping site and, to a lesser extent, by the combustion of fossil fuels and veld fires.

- Water pollution
  - Some of the boreholes in the training area have been polluted or tested as unsafe for human consumption. Those sources that have been affected have since been closed or their use has been discontinued. The report also acknowledged incidences of deliberate and negligent water pollution as still continuing and evidence of this can be found all over the training area. The largest contributor to this problem is military activity, mainly through fuel pollution and the inappropriate disposal of waste.

- Military Integrated Ecological Management (MIEM): the report denounces the overuse of military training ranges, and those that have been overused are closed for four seasons, on the recommendation of the environmental services personnel who have input into the planning of military activities. For example, environmental managers are also attached to all the main training exercises in the training range.

Furthermore, awareness training is also presented to all range users before practical training commences in the training area. The environmental manager always offers suggestions and makes recommendations in all applications for new projects. The involvement of the environmental manager in the processing of the applications to use training ranges is to ensure that the ecological integrity of the training area is maintained, and is sustainable.

- Military Initiated Environmental Impact Assessment (MIEIA) is another measure used to determine the potential environmental impact that is likely to occur due to the execution of military and non-military activities within the military territory. This includes the construction of new facilities in military lands. MIEIA at SAACTC is carried out by Maj. "N", and the most recent MIEIA was conducted in 2010.
    - This section of the report highlights the measures that should be taken to enhance ecological management within the military training area. Some of the actions indicated here are:
        - Maintenance of fire breaks to assist in minimising the area likely to be destroyed by fire which is ignited during a training exercise.
        - The environmental manager is attached to the Brigade during exercises in order to monitor military activities, so as to reduce their environmental impact and to ensure that mitigation measures are put in place and are effective.
        - Future plans include attaching an Environmental Officer to the first part of the practical training phases of all courses.

- Protected species awareness programmes have been incorporated into all lectures for military personnel.
- Another programme includes the cultivation and replanting of *Acacia erioloba* at selected sites. The report states that this programme is proving unsuccessful because of the harsh climatic conditions (i.e. dry winter and spring) as well as the high frequency of wildfires in some years.
- Included in this programme is the management of wetlands, which are areas regarded and managed as anti-pollution sites.
- Management plans for noise, air pollution and water pollution (surface water pollution) are reported to be available at SAACTC. Noise pollution is indicated as occurring during live fire exercises; according to the report, no complaints have been received thus far. Air pollution is primarily caused by veld fires and the burning of waste at the waste dumping site; thus, neighbouring farmers have complained about the smoke pollution from the military ranges. The officers in charge have to certify that waste material is disposed of in a correct manner. In addition, inspections are conducted, and feedback is given within 48 hours of the inspection being carrying out.
- Waste management appears to be the only main threat to surface water pollution at SAACTC. It is clear that the combat training centre is dumping waste in an unlicensed waste disposal site. Moreover,

there is no formal structure in place to manage waste from the SAACTC. However, as of 2013, an application has been made to the Department of Public Works (DPW) to either closethe dumping site or take over the management of waste thereof. The plan to deal with this problem is to close down the waste dumping site and remove waste to the Municipal Waste disposal site in Postmasburg. Should this plan be adopted, the financial cost associated with the removal of waste will be borne by the DPW. It appears from the report that the DPW is responsible for waste management in all other military installations, except at SAACTC.

- Habitat management: sites prone to soil degradation due to military activities have been identified. These sites are monitored and, in areas where soil erosion has become severe, they have been closed to military training. Where possible, the area can only be used once it has recuperated to an acceptable level. In regard to the rehabilitation of disturbed areas, there are certain areas that are not always rehabilitated due to the low success rate and financial viability thereof. Such areas include areas used as base camps. However, if possible, the sites are closed for military training for four seasons.
    - A problem of invasive exotic plants has also been noted at the SAACTC training area. It is, however, reported that a request was made to the Department of Agriculture (DoA) for assistance to eradicate the plant species with herbicides. However, the DoA is said to have indicated that they will not be able to assist, except in an advisory capacity.

- A hazardous material management plan exists: all suppliers of hazardous materials are required to submit the supplier disposal specifications (SDS) for their product(s). Spillage kits, response spill material and cleaning equipment are always on standby to deal with spillages. However, a spillage that is more than 1000l cannot be handled internally, although the Emergency Services personnel were trained accordingly. The worrying issue about the contingency plan, according to the report, is that it was drafted in 2006 and only communicated verbally; subsequently, rehearsals were held. This is not adequate for ensuring that personnel will be well versed in and familiar with a contingency plan. Posters need to be placed in strategic areas where an individual could be in a position to read them at any time.

- The 2010 Annual Environmental Report (AER of 2010) also indicates, under MIEM, that there are no special measures in place for the protection and conservation of particular sensitive habitats. This contradicts the statement, in the same report, that they have a wetlands management programme.

- Section D of the 2010 AER deals with Base Environmental Management (BEM) which mainly covers annual objectives.
    - Thus, each military installation is expected to draw up a BEM every year. It is in this plan that the EMF needs to state how environmental considerations will be incorporated into the planning and execution of military activities.

    - At SAACTC, the report indicates that EIPs were executed since 2000. However, the implementation of EIP cannot be entirely attributed to the Environmental Services (ES), even though most of the information on environmental issues in the defence force is gathered by, and projects are monitored by, the ES.
- Environmental Education and Awareness is described in Section E of the AER (2010).
    - It is clear from the 2010 AER that the installation must develop what is called a Military Integrated Environmental Education Plan (MIEEP). The aim of the MIEEP is to ensure that all members of the defence consider their impact on, and responsibility towards, the environment in their day-to-day activities. This project (i.e. development of MIEEP) is still underway at SAACTC.
    - The SAACTC indicated, in the 2010 AER, that MIEEP is available and it has been reviewed and revised in the year 2008. Amazingly, the report states that this plan was not communicated internally, but is presented to military units visiting the installation for training.
    - The main objectives of the MIEEP were environmental considerations during operations (ECOps) (applicable even during military training exercises) and reducing negligent spillages by 50%. However, the environmental education goals for the year 2009 were not specified, as requested in the report template. Amazingly, it is stated in the report that the objectives were achieved during Exercises Seboka in 2007 to 2009. Most of the questions (11 questions) on environmental education in this section were left unanswered.

- The Integrated Environmental Management System (IEMS) also forms part of the 2010 AER. This section had 15 main issues which focussed on environmental management. These include:
    - Questions regarding the existence of the unit environmental policy and all the related questions were answered negatively.
    - The second question was related to procedures for planning and integration of environmental considerations to military activities. Again all questions regarding the planning and integration of environmental issues to military activities were answered negatively.
    - All three questions on the legal (legislations) and other requirements were left unanswered. All questions related to the processes for determining annual environmental objectives and targets were answered negatively, and the other ten questions were left unanswered.
    - Two questions regarding environmental management programmes, such as progress made in terms of environmental programmes and the existence of procedures or processes for periodic review of these programmes were answered negatively.
    - Furthermore, all questions related to implementation, responsibility and accountability as well as environmental awareness and motivation were not answered.
    - One question about knowledge, skills and training was answered negatively. This question focussed on the development of an environmental training programme. The other three questions related to the execution of the

environmental training programme, documentation and monitoring of the programme as well as the identification of environmental training needs were not answered.

- The question on the issues of the existence of a communication and reporting procedure was negatively answered. Questions relating to the process of receiving and responding to environmental concerns, considering the environmental concerns raised, communication of the results from EMS audits and reviews, as well as the process for developing a Unit/base environmental policy statement were not answered.
- Questions about the existence of procedure for environmental management system documentation control and a question regarding the process of developing and maintaining EMS documentation received negative answers. The remaining five questions were not answered.
- Questions on the existence of procedure for EMS, measuring its effectiveness and monitoring, as well as a question on monitoring significant environmental aspects were all answered negatively. Furthermore, four of the subsequent questions in this category were left unanswered.
- All questions concerning EMS records and information management were unanswered.
- Three questions regarding the management review of EMS were not answered. Only the question on the existence of the procedure for review of the EMS was answered; it was, however, answered negatively.

- Six questions on corrective and preventive action and continual improvement of environmental practice were answered differently. Four of the six questions were answered positively and only one was answered negatively. The sixth question was answered as not being applicable, although it focussed on the utilisation of the expertise of the environmental manager in the rehabilitation of fixed assets. The land resource and its surrounding environment are part of the fixed capital in SANDF territories. It is arguable that the environmental manager can play a significant role in the management of these resources.

Environmental Management Monitoring Mechanisms

An analysis of the first and second editions of Environmental Implementation Plan (2001 & 2008, respectively) reveals that the DoDMV adopted seven measures to monitor the environmental management practices of the SANDF. These measures include the following:

- An Environmental Review Forum (ERF): this forum will execute the function of reviewing the SANDF's environmental performance as well as updating and improving the EMS for defence.
- Steering Groups, Working Groups and Advisory Forums: these are agents that implement and monitor the environmental performance of the SANDF.
- Annual Environmental Management Report: this assists and empowers commanding officers (OCs) to successfully meet the challenges of responsible and accountable environmental management in managing the natural

environment as well as other environmental programmes of the SANDF. This is a compulsory process in which each military installation is provided with a set of environmental management guidelines (questionnaire/template) which become an annual report (such as those analysed in the section above). Furthermore, these guidelines are used as an auditing mechanism to measure the military installation's environmental performance.

- Environmental Awards Programme: this is meant to motivate and reward military installations and individuals for outstanding environmental management initiatives and practices. However, the annual environmental management report is an official determinant.
- Communication and *ad hoc* associations: this mechanism is intended to foster interaction between the SANDF environmental personnel and other national and provincial departments in order to monitor the SANDF's environmental compliance.

- Auditing: there are three levels of auditing to monitor the implementation of all measures for environmental management in the defence force, as well as the monitoring of environmental performance and compliance with the relevant legislation. The three levels that have been identified are as follows:
    - *Environmental management systems audit:* the EMS should be continually audited by qualified personnel. Internal capacity building in the DoDMV began in 1996, and will continue to be expanded to be able to audit environmental performance and compliance in the SANDF. The

implementation of the EMS for the SANDF is reported to have commenced in 2001. However, it has been established that the implementation of the defence EMS was terminated in 2007 due to a lack of progress.

    - *Internal audit*: this is to be carried out by the Defence Inspectorate. However, instruments are still being developed to audit the implementation of environmental management in the SANDF.
    - *External audit:* this task is supposedly carried out by the Office of the Auditor-General. Even though this is an auditing of an environmental management implementation, it relates to the financial spending of the defence. Such audits were carried out in three years (i.e., 1998, 2001 and 2002).

- Guide to Environmental Compliance for Commanding Officers: this mechanism has four principal aims. These are:
    - To provide the commander with environmental management compliance guidelines.
    - These guidelines are utilised as a monitoring measure to ensure acceptable environmental performance.
    - To build capacity through developing an understanding of, and enhancing or advancing, sustainable development through environmental education.
    - To serve as a training manual for the military.

Capacity Gaps and Limitations to Adequate Incorporate Environmental Concerns in Military Activities

Both EIPs highlight a total of 16 capacity gaps and limitations on the part of the DoDMV to effectively implement and incorporate/integrate environmental issues into the SANDF activities and practises. For the purpose of this study, only 12 of these have been selected (i.e., relevant to the study) for elaboration. These are as follows:

- The costs associated with environmental management in the DoDMV have not been sufficiently internalised, but have been integrated with expenditure related to other functions. This obscures the true reflection of environmental investment by the DoDMV.
- Environmental education and awareness training has not been formalised in the DoDMV training policy and has not yet been incorporated into most formal military training and functional training programmes.
- Existing departmental policy is fragmented, some of which has become out-dated and obsolete, with new requirements for such policy arising continuously. The integrity of the DoDMV's environmental policy has a direct influence on the ability of the department to comply with environmental regulatory obligations.
- Enforcement and measurements of environmental compliance with regulatory requirements, as well as measures for environmental performance within the DoDMV, are inadequate.
- Internal structures at base level are not completely operational; thus, there is a lack of capacity.

- At the departmental organisational structure, at all levels, there are poor environmental management structures in place to implement integrated environmental management within the DoDMV.
- More adequate environmentally qualified staff and competent personnel are required to implement effective integrated environmental management within the DoDMV. The capacity gap is further exacerbated by the lack of a career path for environmental management staff in the DoDMV/SANDF.
- A severe lack of funding prevents the DoDMV from complying with international, national and provincial environmental legislation, and the implementation of the necessary environmental programmes within the department.
- There is a deteriorating availability of environmental expertise from other environmental line functions of other departments, in order to assist and advise the DoDMV.
- The formal integration of environmental considerations in the management of training areas, execution of deployments and closure of bases is inadequate.
- The formal EMS for the defence is not yet complete.
- Environmental considerations are not adequately included in the acquisition and disposal systems of products, equipment and facilities.

Defence Environmental Management Programmes

The environmental management strategy of the DoDMV is characterised by six pillar programmes. The broader programme is called military integrated environmental management (MIEM). Six sub-programmes constitute the broader environmental management programme of the SANDF (Figure 12). However, the linkages between these programmes are not specified. Thus, it seems that each programme is a stand-alone offering.

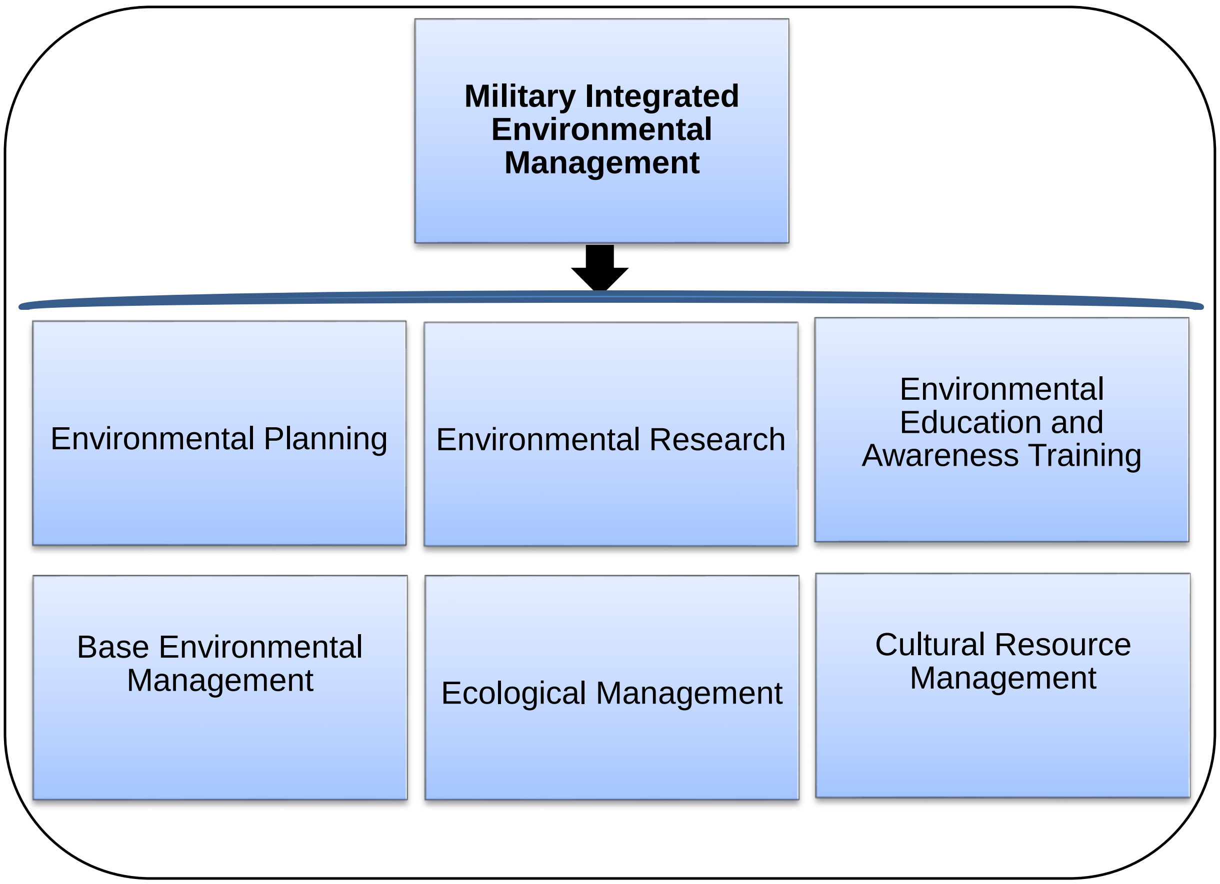


Figure 13. Defence environmental management programmes
(Adapted & modified from EIP, 2001 & 2008)

However, it is noted that these six programmes are relevant to the SANDF's activities. This is especially true for the programme on environmental education and awareness training. It is most critical because the majority of current military personnel have never received formal environmental training. The success of all the other programmes depends on the successful execution of environment education and awareness training. Such awareness training will cause members to understand the necessity of incorporating environmental issues into military planning.

Comparative Analysis of Environmental Practices at GMI and SAACTC

One would expect that environmental practices of the SANDF are relatively the same at all its military installations. Nonetheless, minor variations may occur as a result of the category of the military installation. For example, environmental programmes of a light military infantry base would not be the same as of those of the mechanised and heavy military bases. However, the mechanisms for reporting environmental management practices are expected to be similar.

Nevertheless, a comparative assessment of the environmental management practices at the GMI and SAACTC reveal a different scenario. It appears that two separate defence departments control these military installations. The practices are entirely different for one to say that they are both under the same Department of Defence and one country (Figure 14). This confirms some of the contents of both the EIPs, particularly the information regarding skilled, qualified and competent personnel. Moreover, even the responsible RFIM appears to disregard some of the critical issues and processes that the law stipulates should be carried out or implemented at the installation. Even the DoDMV is wholly responsible for the mal-environmental practice that occurs at GMI. A qualified and competent person is required, and should have been appointed, to lead the environmental management practice at this military installation. This would have improved the performance of the SANDF at this military installation, and would at the very least have shown efforts towards compliance with environmental management requirements and regulations.

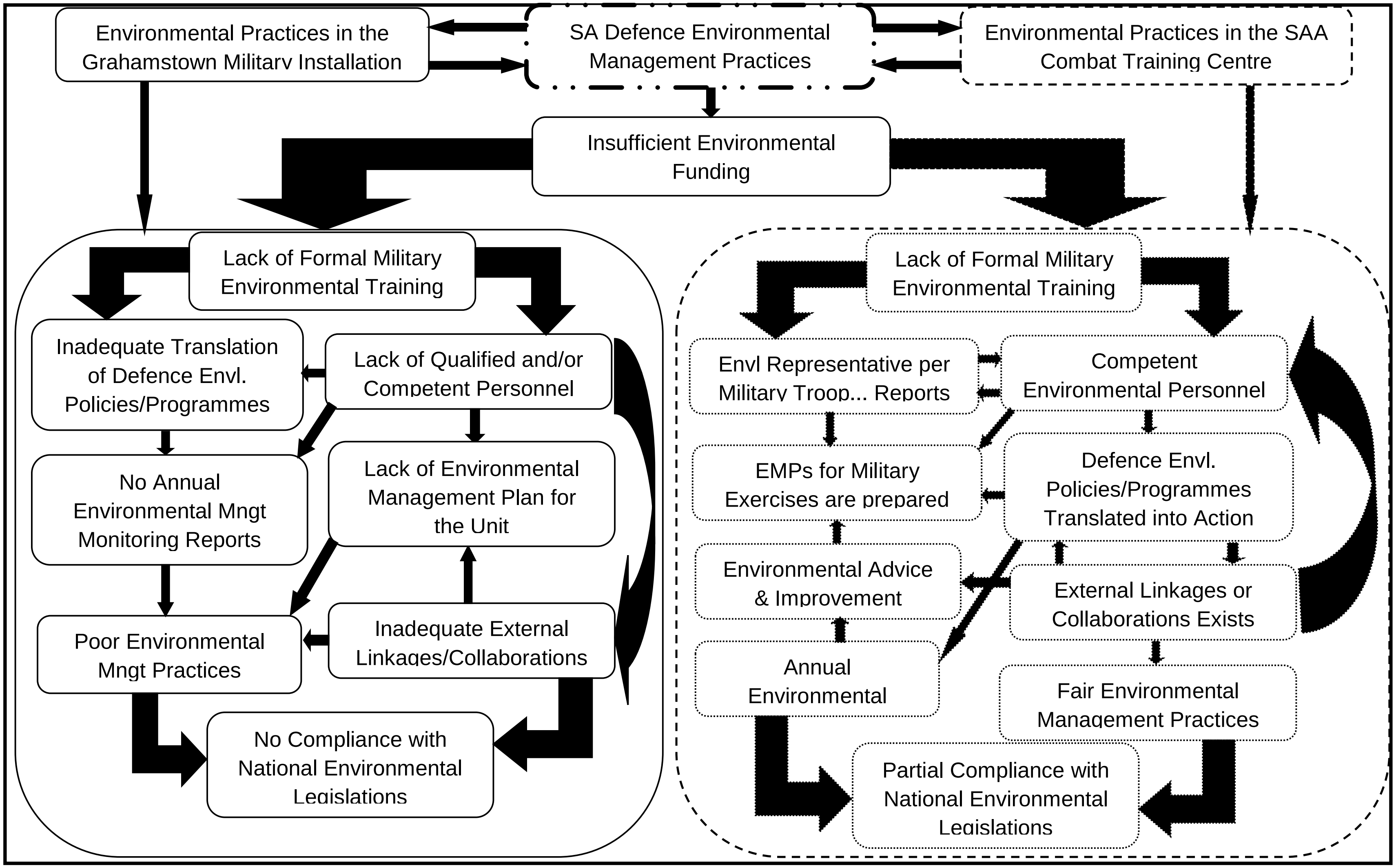


Figure 14. Comparative environmental practices at GMI and SAACTC
Note: 'Envl' stands for 'environmental' and 'Mngt' stands for 'management'

The fragmentation of defence policies apparently affects the environmental performance of these two military installations. The SSO (Env Services Officer) indicated that the preparation of quarterly and annual environmental reports is currently not institutionalised. In other words, there is no policy (as of 2011) that obligates each military installation to submit such reports. Thus, some installations submit these reports while others do not; it is apparent that GMI is an installation that does not prepare and submit its environmental reports.

Most of the staff in the EMF at GMI were not competent enough to effectively deal with environmental management issues. The majority of these staff members had no working knowledge of environmental problems, let alone developing an environmental management plan for the installation. The surprising undertaking of the DoDMV was the appointments of junior defence members, that is, low-rank members (such as Corporals) into positions of designated environmental officers. Due to their low military rank, they cannot challenge a tactical decision that could have a severe environmental impact, if made by the commander.

Summary

This chapter has presented an overview of the environmental management practices at the two military installations studied (i.e., GMI and SAACTC) in this research. It has been noted that, in some cases, what the respondents have said does not correspond or agree with what is taking place in the training area. For example, at GMI, it was mentioned that after every training exercise a clean sweep activity is carried out to remove all waste material. Furthermore, it was indicated that trenches are backfilled immediately after the training exercise. However, field observation proved otherwise. An inspection of the used range, by the military readiness officer, is mandatory at the end of the training exercise; after such an inspection, the officer will issue a clearance certificate to the unit that was conducting its training. This also proved to be inadequately carried out. It also became apparent that effective environmental management is hampered by a lack of funding and the absence of qualified personnel as well as internal organisational structures. Thus, the monitoring of the environmental performance of the unit and its audits are not adequately carried out. To this end, no environmental management reports are readily available. Thus, environmental issues are addressed on an *ad-hoc* basis.

The reaction towards the concerns regarding environmental issues in military planning was resistant at first, because it was regarded as prolonging the planning process and delaying the execution of the training exercise. However, this is beginning to change. Some of the challenges highlighted regarding the implementation of EMS include the lack of vehicles assigned to the EMF, as well as the lack of skilled and competent personnel to lead the environmental management process. Similarly, the inadequate in-service training of the environmentally designated officers, as well as the lack of environmental knowledge and education on the part of middle managers was mentioned as one of the challenges. Only one external linkage was mentioned at GMI, which is inadequate given the diversity of the environmental management field.

The physical environmental damage associated with military activities has also been presented in this chapter. The significance of this impact was observed after Exercise

Shared Accord. After this training exercise, ruts of approximately 45cm were observed. Vegetation also showed signs of being trampled and run over by heavy military vehicles. The target areas also showed various forms of physical disturbances. Three weeks after the military training exercise took place, heaps of used bullet cartridges and links were still lying on the ground, while the rubbish bin overflowed with waste that had not been disposed of. This nullified the statement that the sweep-clean process and range inspection is carried out immediately after a training exercise.

The inappropriate disposal of military waste (two clusters of mortar shells used for training) was also found in different secluded sites within the training area. This also suggested that the issuing of the clearance certificate is somehow flawed. Ensuring better environmental management in the SANDF requires that thorough inspections of the training range are carried out at all times. The 6SAI also battles with alien invasive plant species, namely, the *Opuntia Indica.* The eradication of this species is carried out under the programme called “Operation Vuselela”. The colonies of *Opuntia Indica* show significant infestation in sections of the training area that are infrequently used. The eradication method used is a combination of mechanical and chemical mechanisms; it appears, however, that these means are ineffective.

In the second case study, evidence of the degradation of military training ranges has been noted. One training range has been closed, due to a high level of degradation. The closure of the training range is attributed to the fact that the SAACTC is a heavy artillery military training area; thus, its impacts are significant every time military training takes place. The closure of the training range is indicative of the implementation of environmental management principles and protection initiatives. In addition to the impact of the military activities, veld fires also pose a serious environment threat. These fires are ignited during training exercises and, for now, the SANDF does not have a solution to this problem. However, plans to control or minimise other impacts such as pollution prevention, or reduction, are in place. It should be noted that this installation has a competent and qualified environmental officer. Consequently, each military training exercise has an environmental management plan. Furthermore, annual environmental reports are prepared, as required by the 2008 EIP, for the defence. The spillages which occur during training exercises are recorded, and the affected areas are rehabilitated accordingly. Both military installations have adopted a principle called “you spill, you dig”. This principle is meant to ensure that the contaminated soil is rehabilitated accordingly. Since the adoption of this principle, it is reported that spillage incidences have decreased.

The SAACTC also experiences similar inadequate funding for its environmental programmes. The environmental officer estimated that an ideal budget for environmental services would be approximately R5 million. One other significant threat to the environment at SAACTC is the use of standard metal vehicles as targets. The environmental officer noted that, when high calibre weapons hit these vehicles, they disintegrate into various pieces. This constitutes a significant environmental concern. Skills shortages in the environmental field at SAACTC’s EMF, and the retention of qualified personnel, are also major challenges. At this installation, numerous external linkages have been forged and maintained and are, as such, regarded as invaluable. Hence, this installation has made great strides towards complying with environmental legislation.

The availability of a competent environmental officer has led to the development or preparation of various environmental management reports. Through the environmental reports, six environmental management programmes for SAACTC have been identified. These programmes are the pillars of the military integrated environmental management of the unit. A comparative analysis revealed significant disparities in the management of the environment and compliance with legislation, between GMI and SAACTC.

The results presented in this chapter are further discussed in Chapter VIII. The next chapter (i.e., Chapter VII) presents the quantitative results of this study. Therefore, Chapter VII presents the results of the study of perceptions regarding environmental issues in the defence, as well as the statistical analysis of the concentration of heavy metals detected from both water and soil samples collected from both military training areas.

CHAPTER VII

QUANTITATIVE DATA PRESENTATION AND ANALYSIS

Introduction

This chapter presents the results of the quantitative data generated from questionnaires and the analysis of the concentrations of heavy metals determined from both the soil and water samples. The intention was to explore the variation in the responses from the questionnaires in each case study and between the case studies. Accordingly, this chapter is divided into four parts. The first part (Part I) presents the findings from the GMI case study. While the second part (Part II) of the chapter presents the findings from the South African Army Combat Training Centre (SAACTC). Part III outlines the results of the comparative analysis of the data collected from the two military installations. The last part (Part IV) presents the statistical analysis of the concentrations of heavy metals measured in both soil and water samples from both military training areas.

PART I: Results from Grahamstown Military Installation

Environmental Considerations to Military Training Programmes/Activities

The attitudes and perceptions of the SANDF personnel were assessed using a Likert scale questionnaire containing thirty statements (refer to Table 4). The perception statements are presented in Table 4. Generally, the results from the GMI case study are showing that the majority of respondents have positive perceptions about the considerations of environmental issues to defence activities (Figure 15). The percentage table of the responses is listed as Appendix F.

Table 4. Perceptions and/or attitudinal statements

Statement	Perceptions on environmental related issues in the South African National Defence Force
1	I have received adequate training on implementation of environmental management system.
2	The Department of Defence (DoD) has done enough to enhance skills of military personnel to protect and conserve the environment where it operates.
3	Environmental consideration in military activities affects proficiency of troops for combat.
4	Environmental consideration is not well integrated into military training programmes.
5	The implementation of environmental management system in the DoD has encountered many challenges.
6	Environmental management system cannot be applicable to military activities.
7	Military Integrated Environmental Management can never work in the business of the DoD.
8	Environmental considerations during military training have negative effects on military readiness and weapon testing.
9	Environmental protection and conservation must be enforced into military activities to ensure sustainability of training ranges.
10	The DoD must be granted total immunity from all environmental legislations.
11	The DoD does not have enough resources (i.e., financial & human) to effectively implement environmental management.
12	Environmental education/enlightenment is not part of formal military training programmes.
13	The DoD has adequate and knowledgeable personnel to effectively implement integrated environmental management within military installations.
14	The DoD complies with all international, national and provincial environmental legislations.
15	The DoD has healthy collaborations with environmental experts from other government departments and institutions of higher learning.
16	For the DoD to improve and honour its environmental management responsibilities, it requires to recruit adequate environmentally qualified and knowledgeable personnel.
17	The DoD has a comprehensive environmental audit programme to measure its environmental compliance and performance.
18	The environmental audit programmes of the DoD have led to regularly monitoring and evaluation of activities that can have significant impact on the environment.
19	Environmental audits have instilled environmental consciousness and accountability to all military personnel.

Statement	Perceptions on environmental related issues in the South African National Defence Force
20	Environmental audits have reduced military impact on the environment.
21	The DoD has developed and implemented guidelines and operational instructions manuals on environmental considerations during training.
22	Resources (i.e., environmental advisers, tools and so on) are readily available to assist military personnel implement environmental policy and environmental management system.
23	Absence of environmental advisers in military installations leads to partial implementation of environmental management tools.
24	Environmental consideration must not be enforced to the military because it is the waste of time and other resources.
25	All members of military are encouraged to take initiative, submit suggestions for improvement, and suggest actions or procedures to reduce environmental impact of military activities.
26	Members of the military who carry out tasks that cause significant impact on the environment are adequately trained and experienced.
27	The DoD management has provided adequate resources to implement and maintain environmental management system (EMS) in the military installations where I serve.
28	Identification of all activities which have a significant impact on the environment occurs on an ongoing basis.
29	There is no systematic and documented process describing the methods to identify, monitor and evaluate environmental aspects of military activities.
30	The top-down approach in the implementation of environmental management system in the military is the most effective way of integrating environmental considerations into military activities/programmes.

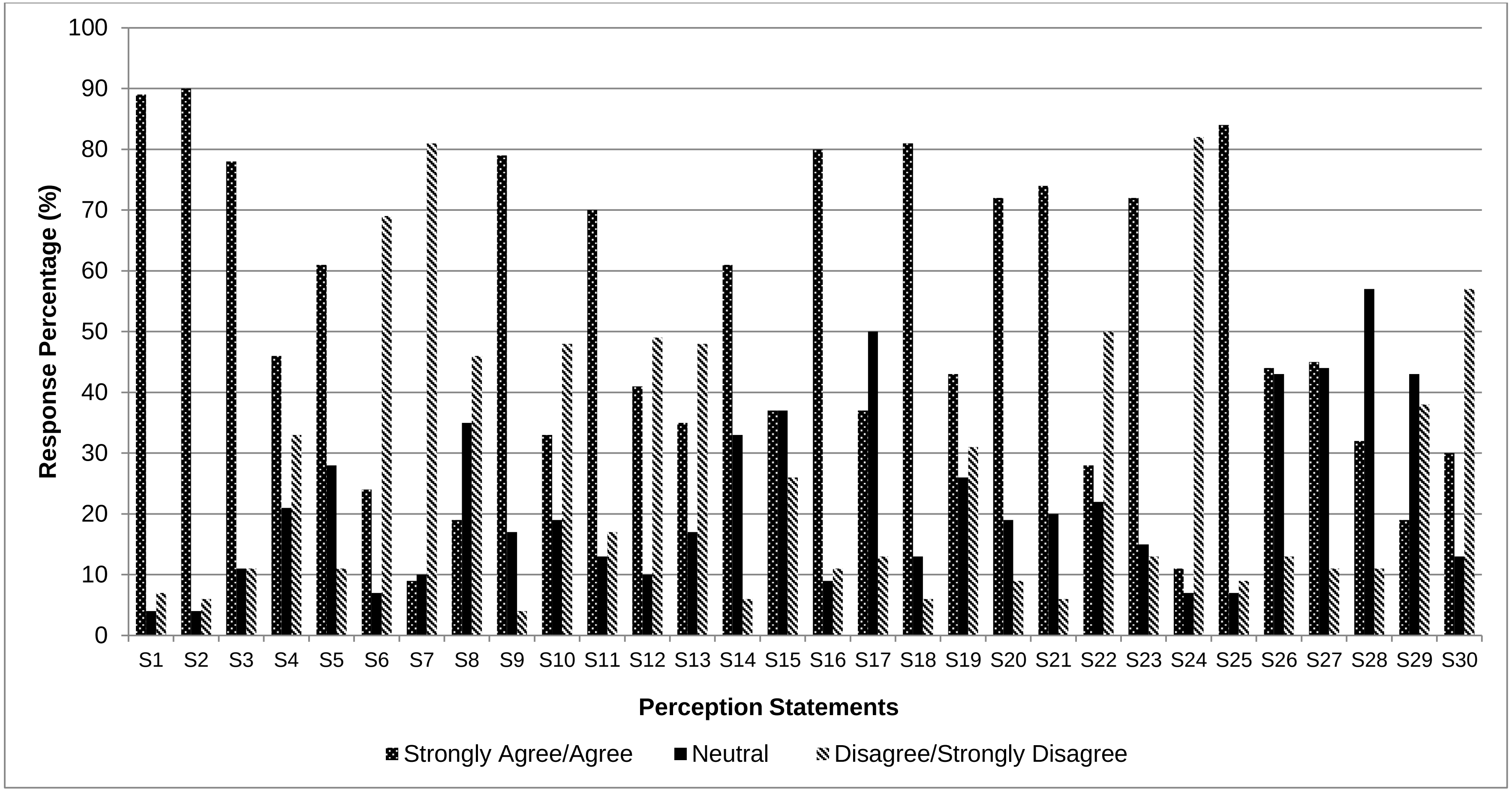


Figure 15. Views on environmental management practices at Grahamstown military installation

The statements in the questionnaire were divided into five categories. These categories were: *environmental education and training, availability of resources, processes, procedures and practices, enforcement and compliance as well as compatibility.* It was noted that some categories have more statements than others. The results of this analysis are presented in Figures 16 - 21. The trends of the responses in first three categories are relatively the same as in the general analysis presented in Figure 15 (revealing more positive responses). The categorical analysis of the responses intended to identify the aspects of environmental management in the defence that is perceived to be lacking or lagging behind those that have been adequately implemented.

Perceptions on Environmental Education and Training at GMI

Most of the respondents (89%) claim to have received adequate environmental training to deal with environmental issues in relation to their defence activities. As many as 90% of the respondents believe that the DoDMV has or is doing enough to improve their skills to be able to protect the environment wherever and whenever an individual performs his/her duties (Figure 16). The results also revealed that environmental education and enlightenment is part of the formal military training of the SANDF.

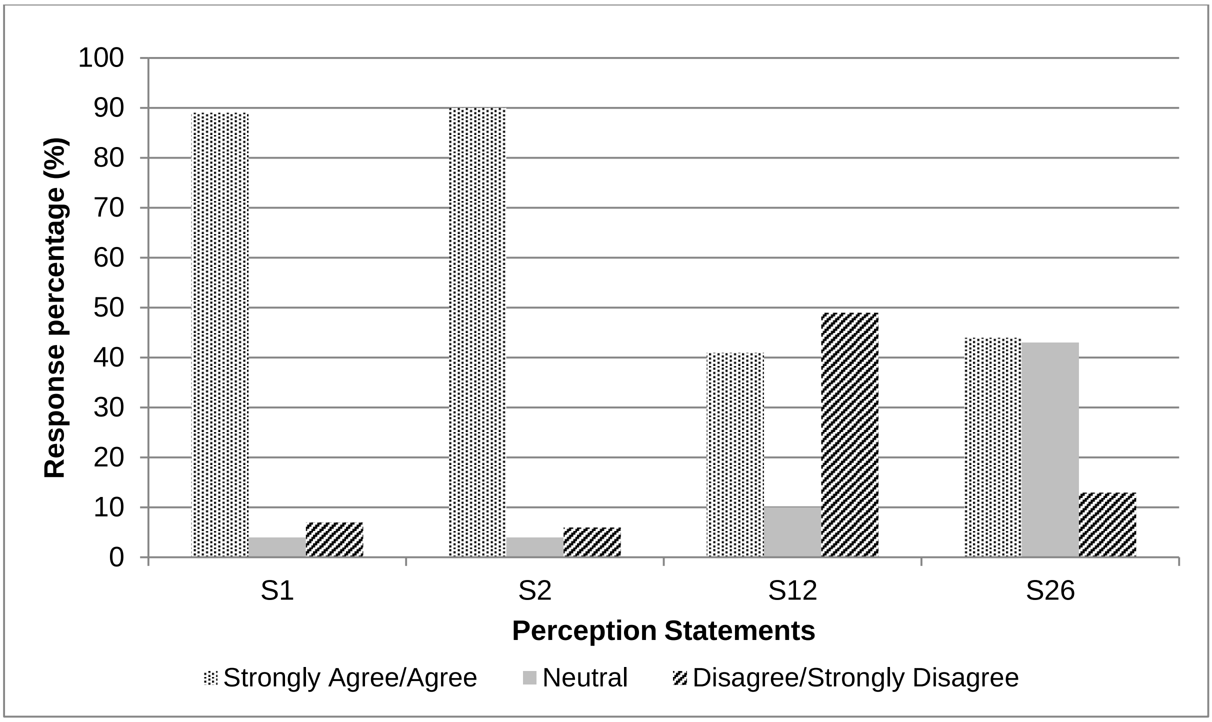


Figure 16. Environmental education and training received as perceived at GMI

Perceptions on Enforcement and Compliance at GMI

Most of the respondents (48%) feel that the SANDF must be totally exempted from environmental protection and environmental management legislations (Figure 17), while 82% consider enforcement of environmental incorporation in defence activities a waste of time and resources. These respondents perceive environmental issues to be incompatible with military activities. This perception does reflect on the extent to which the SANDF has failed to inculcate the linkage between the environment and military activities to defence personnel. Thus, indicating the extent to which environmental management practices has not been adequately integrated into military activities.

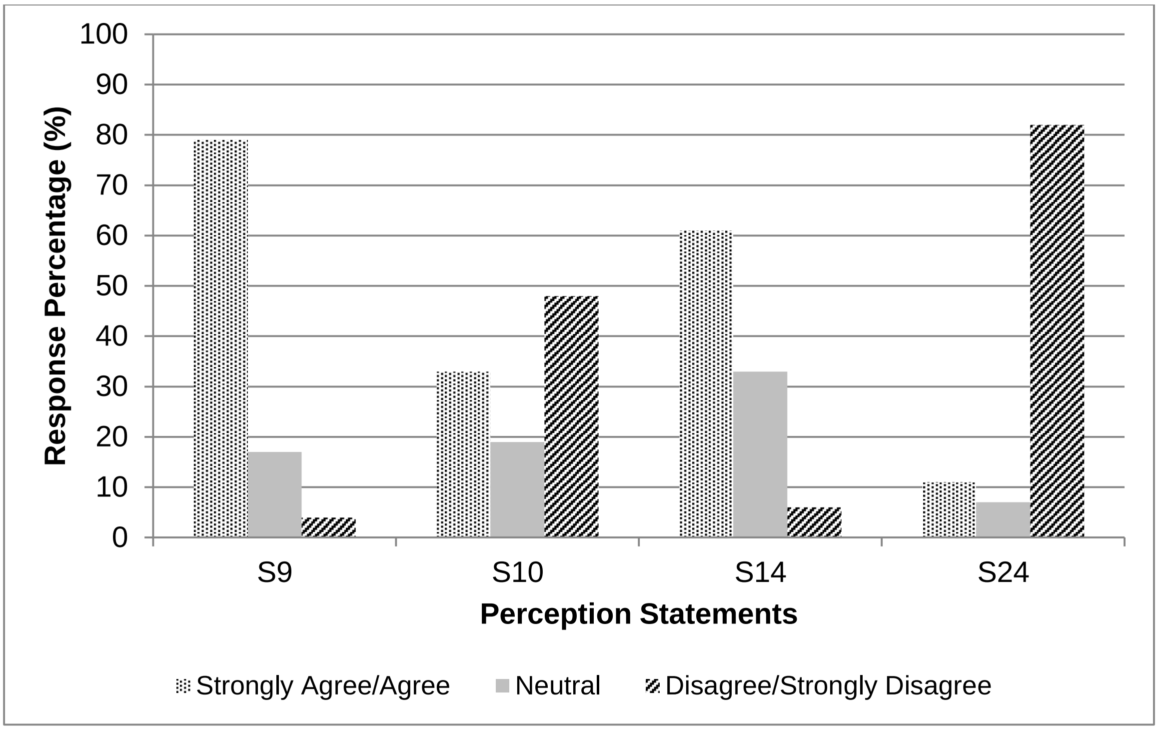


Figure 17. Enforcement and compliance with environmental laws in the defence at GMI

Perceptions on Availability of Resources at GMI

Positive attitudes and perceptions have also predominated with regard to availability of resources (Figure 18). However, only in two statements (i.e., S13 & S24) are the results showing negative perceptions. The prevailing perception is that the SANDF at 6SAI Bn do not have enough environmentally knowledgeable staff/personnel to deal with environmental management issues in relation to the activities of the defence force.

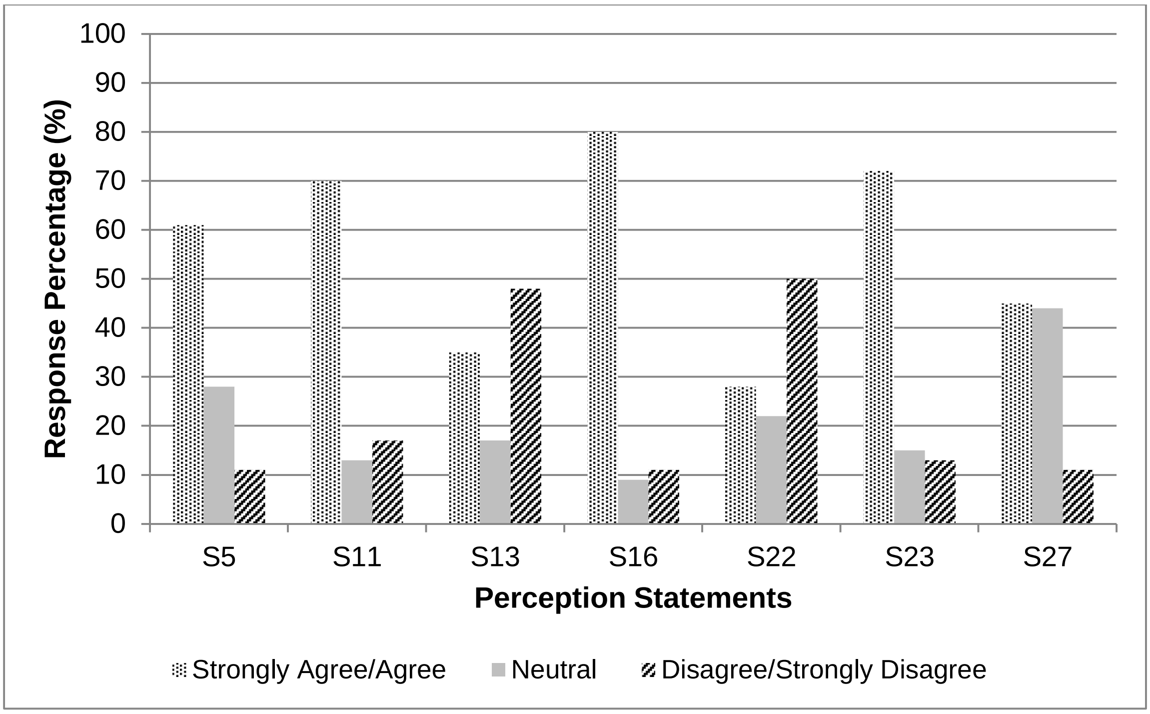


Figure 18. Perceptions on the availability of resource for environmental issues at GMI

This deficit is rightly perceived by the respondents as impacting on the provision of the environmental management leadership required on-site. Obviously this has far reaching implications regarding the environmental protection and sustainability at the 6SAI Bn military installation. This situation has a potential to undo the positive attitudes and perceptions of the defence force members about the protection of the environment. Therefore, the SANDF has to show full commitment towards better environmental management practices within its territories.

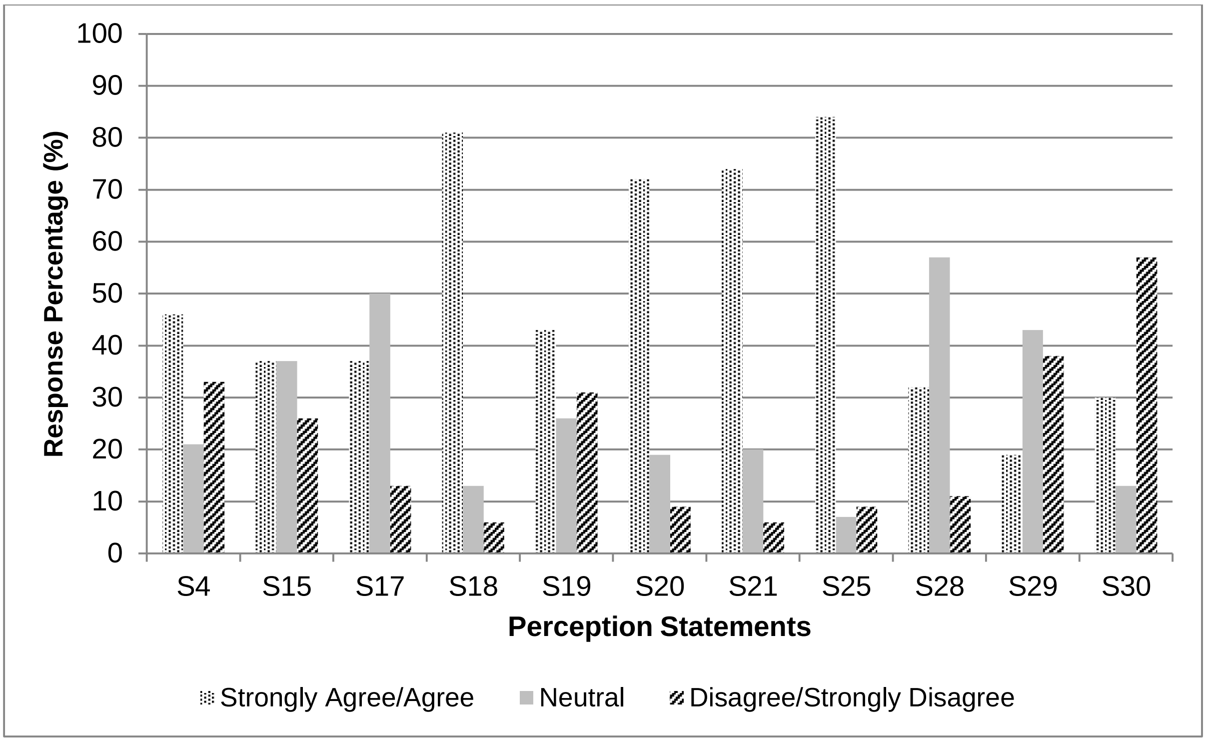


Figure 19. Processes, procedures and practices of environmental management at GMI

Perceptions on Processes, Procedures and Practices at GMI

In this category, yet again the dominance of positive responses are noticed. However, respondents feel that the top-down approach to the integration of environmental issues into military activities is not appropriate (Figure 19). These attitudes and perceptions appear to contradict the defence culture of receiving directives without questioning or contesting instructions (Firing, Karlsdottir & Laberg, 2009). Interestingly, 50% of the respondents chose to be neutral regarding the comprehensiveness of the environmental audit programme of the SANDF to measure its environmental compliance and performance. As high as 57% of the respondents could not share their perceptions on the identification of activities which have significant potential to cause severe environmental impact on an on-going basis. In addition, 48% also reserved their views regarding the availability of a systematic and documented process and procedure to identify, monitor and evaluate military environment impacts at the military installation.

Perceptions on Compatibility of Military Activities and Environmental Issues at GMI

The overall attitudes and perceptions of respondents regarding the compatibility of environmental issues and military activities are negative. The majority of respondents (78%) perceived such integration as posing a threat to the proficiency or military readiness of troops for combat. Most importantly, there is a notable contradiction shown by the results in this category (Figure 20). The majority of respondents have shown positive perceptions towards S6, S7 and S8, which are 69%, 81% and 46% respectively.

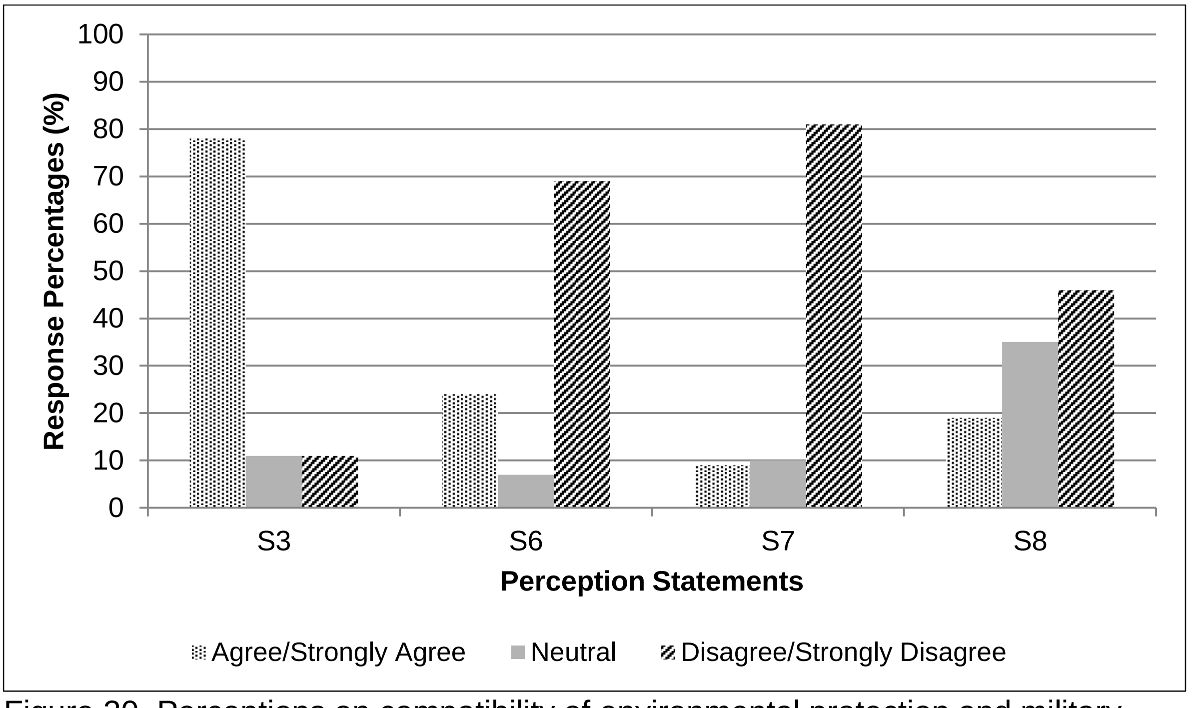
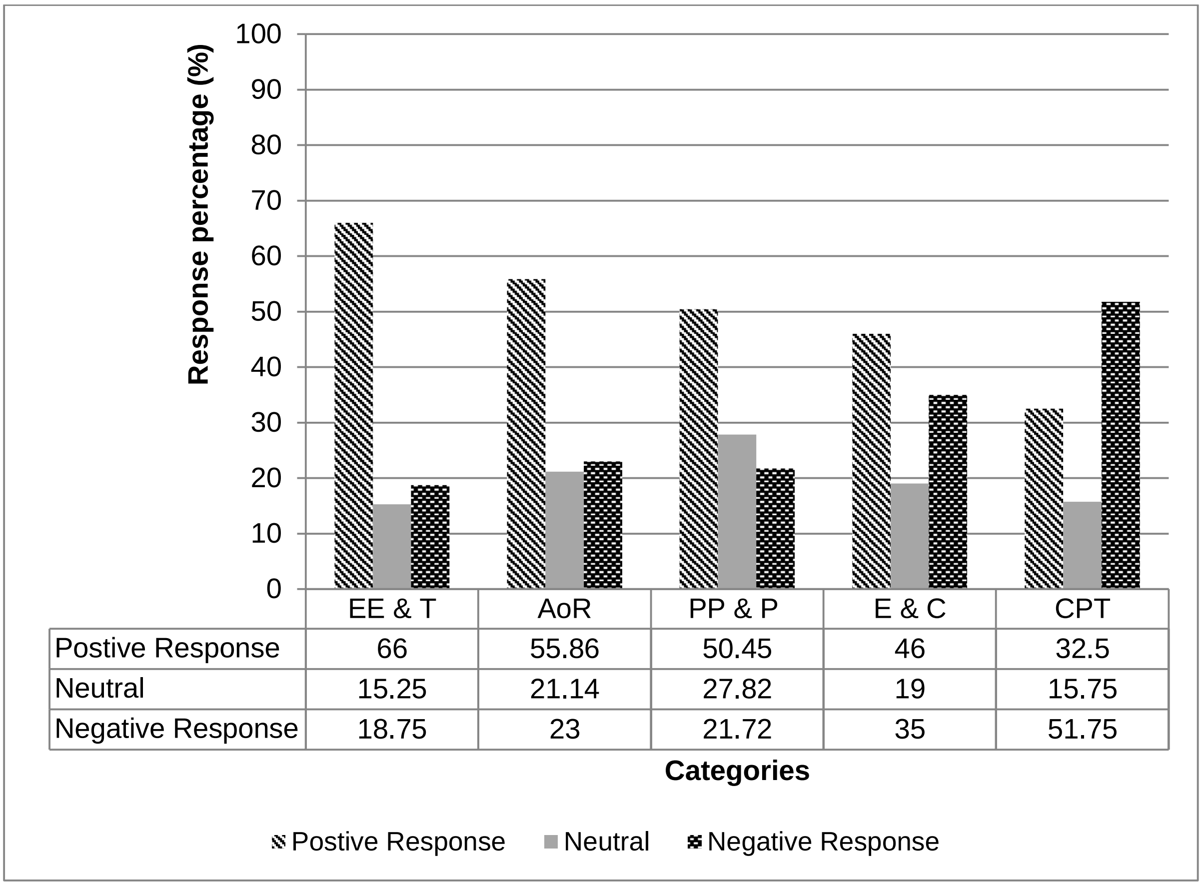


Figure 20. Perceptions on compatibility of environmental protection and military activities at GMI

Overall Categorical Responses on Environmental Management at GMI

The statistical mean of the responses per category is presented in Figure 21. More positive responses were recorded on environmental education and training (66% mean percentage). Least positive responses (32.5% mean) were registered in enforcement and compliance category. The majority of respondents (about 52%) perceived environmental issues as not compatible with defence activities. These attitudes and perceptions might have been created or influenced by certain practises within the defence organisation.



	EE & T	AoR	PP & P	E & C	CPT
Postive Response	66	55.86	50.45	46	32.5
Neutral	15.25	21.14	27.82	19	15.75
Negative Response	18.75	23	21.72	35	51.75

Figure 21. Mean percentages of responses per category for GMI

Note: CPT- stands for “Compatibility”; E & C – stands for “Enforcement and Compliance”; PPP – stands for “Processes, Procedures and Practices”; AoR – stands for “Availability of Resources” and EE & T – stands for “Environmental Education and Training”

One-Way Analysis of Variance in Responses from GMI

This analysis was performed to determine whether there are statistical differences in the responses provided by respondents in different military ranks and periods of service in the defence force. The results in Table 5 reveal that there is no significant difference in the responses of respondents in different military ranks (F=0.309 & p=0.871).

Table 5. Statistical significance between military ranks and responses at GMI

Sum of Squares	df	Mean Square	F	Sig.
.667	4	.167	.309	.871
78.167	145	.539		
78.833	149			

ANOVA and the LSD test were performed to determine statistical differences between five categories (i.e., 1-5 years, 6-10 years, 11-15 years, 16-20 years and 21-25 years) of military service periods. Table 6 presents the ANOVA results, which reveal that there is a significant difference (at $p<0.05$) between military service period and the mean of the responses between groups.

Table 6. Significance between military service periods and responses at GMI

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5.293	4	1.323	2.492	.046*
Within Groups	77.000	145	.531		
Total	82.293	149			

*.Mean different is significant at the 0.05 level.

The LSD test results on Table 7 show that there is a significant difference between 1-5 years and 21-25 years military service group (p=0.014). A significant difference was also noted between 11-15 years and 21-25 years of military service (p=0.005). Furthermore, a significant difference was established between 16-20 years and 21-25 years as well as 1-5 years (p=0.023 & p=0.014 respectively). Two other significant differences were noted between 21-25 years and 11-15 years (p=0.005) as well as 16-20 years (p=0.023) of military service.

Multiple Comparisons from GMI Data

Table 7. LSD tests results of military service period at GMI

(I) Service Period	(J) Service Period	Mean Difference (I-J)	Std. Error	Sig.
1-5yrs	6-10yrs	-.100	.188	.596
	11-15yrs	.067	.188	.724
	16-20yrs	-.033	.188	.860
	21-25yrs	-.467*	.188	.014
6-10yrs	1-5yrs	.100	.188	.596
	11-15yrs	.167	.188	.377
	16-20yrs	.067	.188	.724
	21-25yrs	-.367	.188	.053
11-15yrs	1-5yrs	-.067	.188	.724
	6-10yrs	-.167	.188	.377
	16-20yrs	-.100	.188	.596
	21-25yrs	-.533*	.188	.005
16-20yrs	1-5yrs	.033	.188	.860
	6-10yrs	-.067	.188	.724
	11-15yrs	.100	.188	.596
	21-25yrs	-.433*	.188	.023
21-25yrs	1-5yrs	.467*	.188	.014

(I) Service Period	(J) Service Period	Mean Difference (I-J)	Std. Error	Sig.
	6-10yrs	.367	.188	.053
	11-15yrs	.533*	.188	.005
	16-20yrs	.433*	.188	.023

*. The mean difference is significant at the 0.05 level. Note: "yrs" stands for years.

PART II: Results from the South African Army Combat Training Centre

Environmental Management Approach: SAACTC

A trend similar to that of GMI has also emerged from the findings of the data collected at SAACTC. The respondents at this military installation too perceive environmental protection has the most important aspect which the defence should care about. The responses are summarized and presented in Figure 22 (the percentage table is listed as Appendix G).

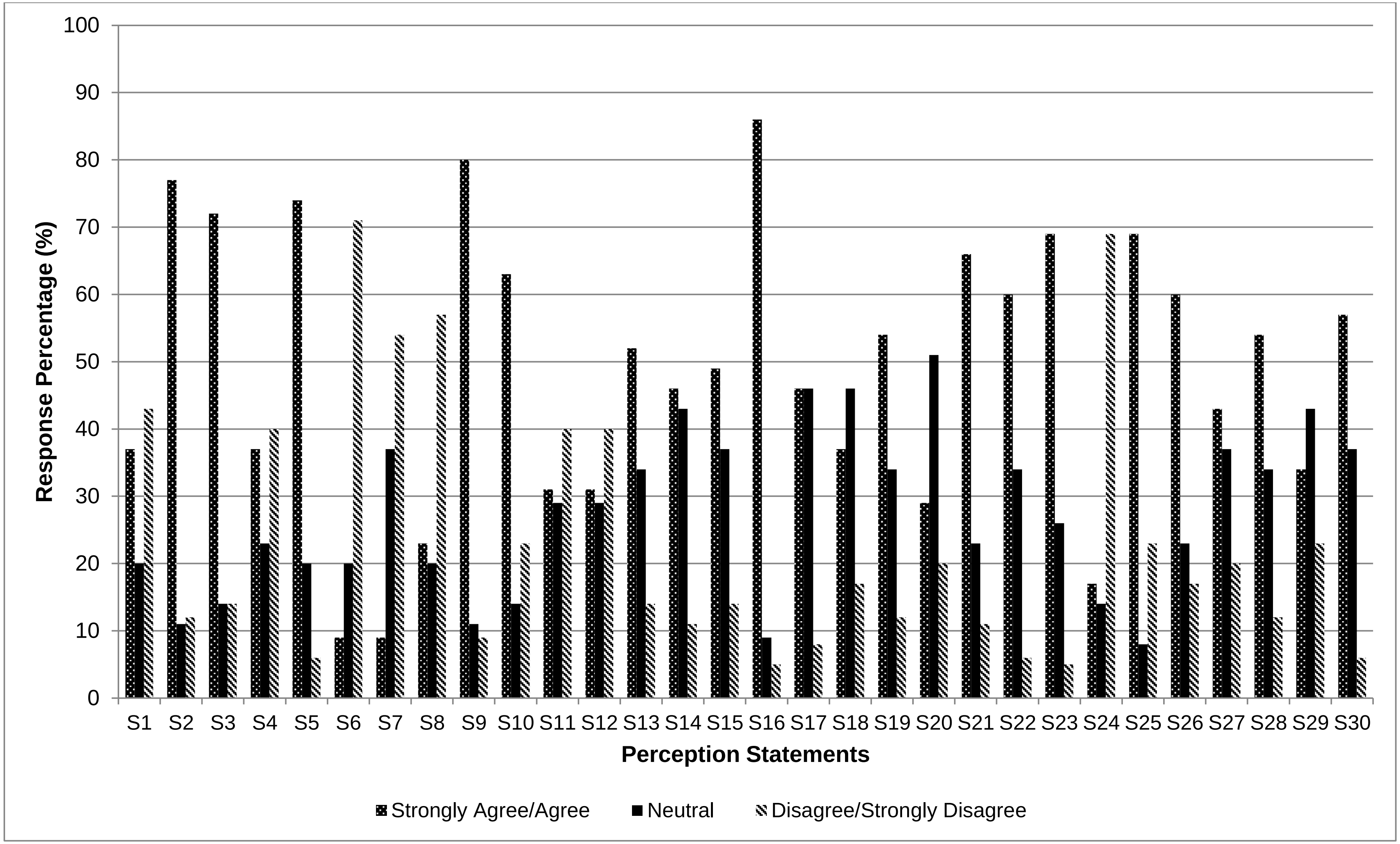


Figure 22. Perceptions on environmental management at SAACTC

The categorical analysis of the data collected at SAACTC more or less depicts the same pattern when compared to the analysis of the GMI data (Figures 23 – 28). This analysis illustrates how the respondents (military personnel) perceive the integration, processes and practices as well as other related and required environmental management tools. These categories were isolated for closer and in-depth analysis on whether the SANDF's attempts to empower its personnel on processes and practices of environmental protection and sustainability are effective or not.

Perception on Military Environmental Education and Training at SAACTC

Most of the respondents (77%) believe that the DoDMV has done enough to skill military personnel to protect and conserve the environment. Thus, 60% consider that the members of the SANDF who carry out tasks capable of causing significant impact of the environment have received adequate training. While 43% of the respondents indicated that they did not received adequate training on the implementation of environmental management, and another 40% indicated that environmental education is not part of formal military training programmes (Figure 23).

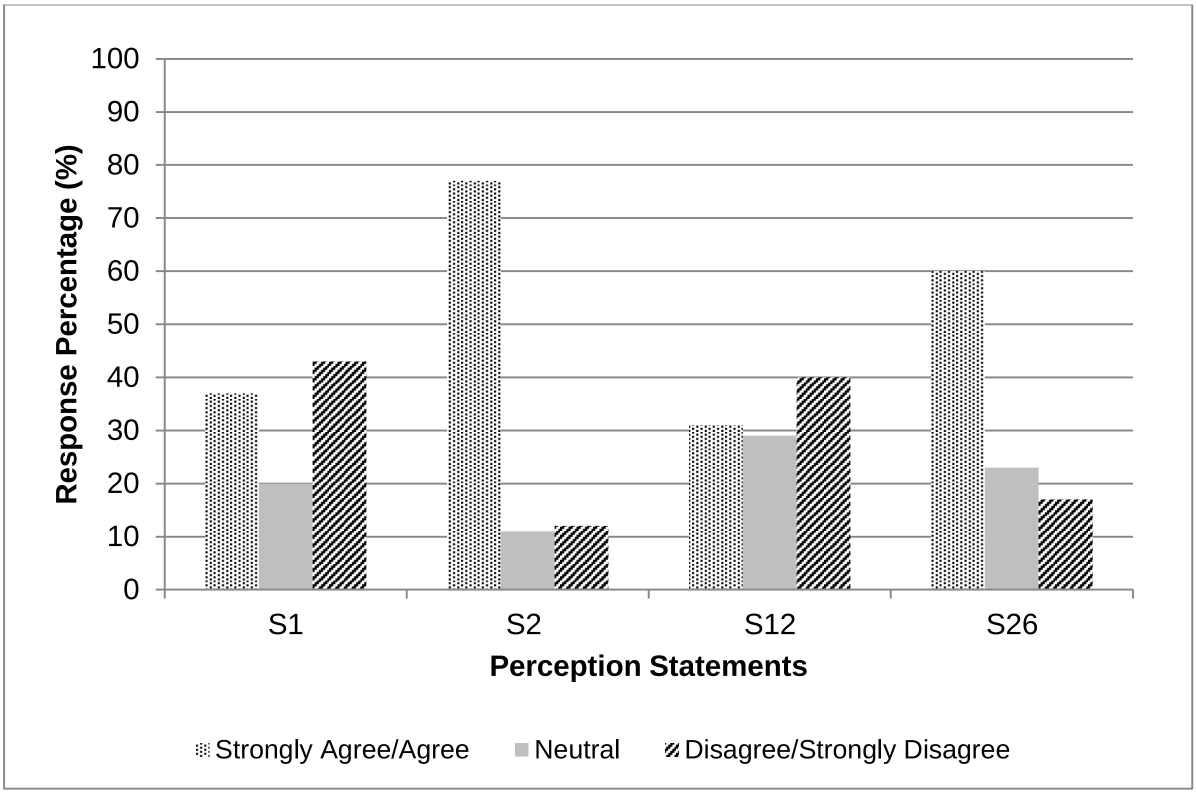


Figure 23. Perceptions on environmental education and training at SAACTC

Perceptions on Availability of Resources from SAACTC Respondents

With regard to availability of resources, 86% of the respondents (Figure 24) believe that for the SANDF to improve and honour its environmental management responsibilities, it ought to recruit adequate and environmental trained and qualified personnel. Furthermore, 74% indicated that the implementation of environmental management system in the SANDF has encountered many challenges. Besides, 69% of the respondents trust that the absence of environmental advisors on-site or in military installation leads to partial implementation of environmental management tools. Moreover, 40% of the respondents perceive that the SANDF have enough resources to effectively implement environmental management system. Likewise, 20% of the participants believe that the SANDF has not provided adequate resources to implement and maintain environmental management system in their respective military installations. While 34% chose to be neutral on the capabilities of those who are charged with the responsibility to lead environmental management in the military. Equal number of respondents (34%) reserved their opinions on the availability of environmental advice on-site whenever required.

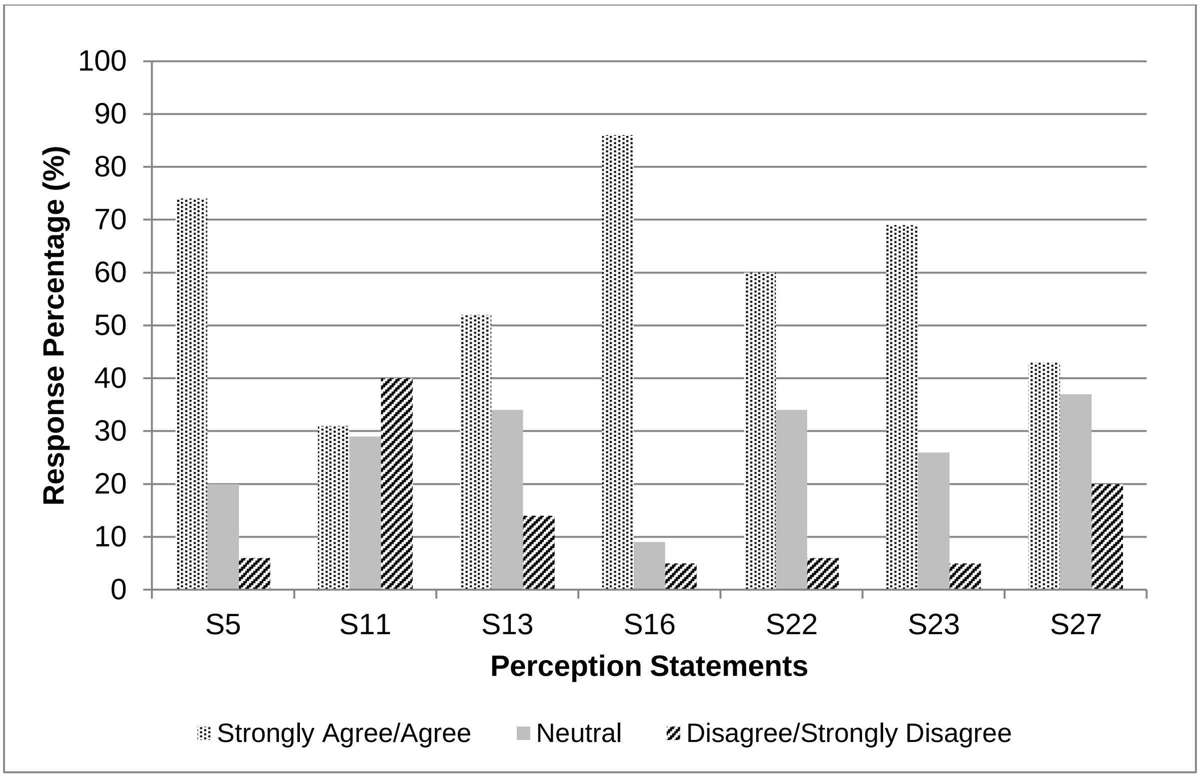


Figure 24. Perceptions on the availability of resources at SAACTC

Perception on Processes, Procedures and Practices at SAACTC

Figure 25 shows that approximately half of the respondents (49%) indicated that the SANDF do not have collaborations with renowned environmental experts from other government departments and institutions of higher learning. Respondents (54%) believe that the environmental audits in their respective military installations have instilled environmental consciousness and accountability to all military personnel. The majority of the respondents (69%) indicated that members of the SANDF are at liberty to take initiatives, make suggestions to improve procedures for environmental impact reduction in military training areas. Existence of environmental management guidelines and operational instructions manuals has also been reported (66%). More than half of the respondents (57%) recommended the top-down approach in the implementation of environmental management system as an effective way of integrating environmental issues into military activities and programmes.

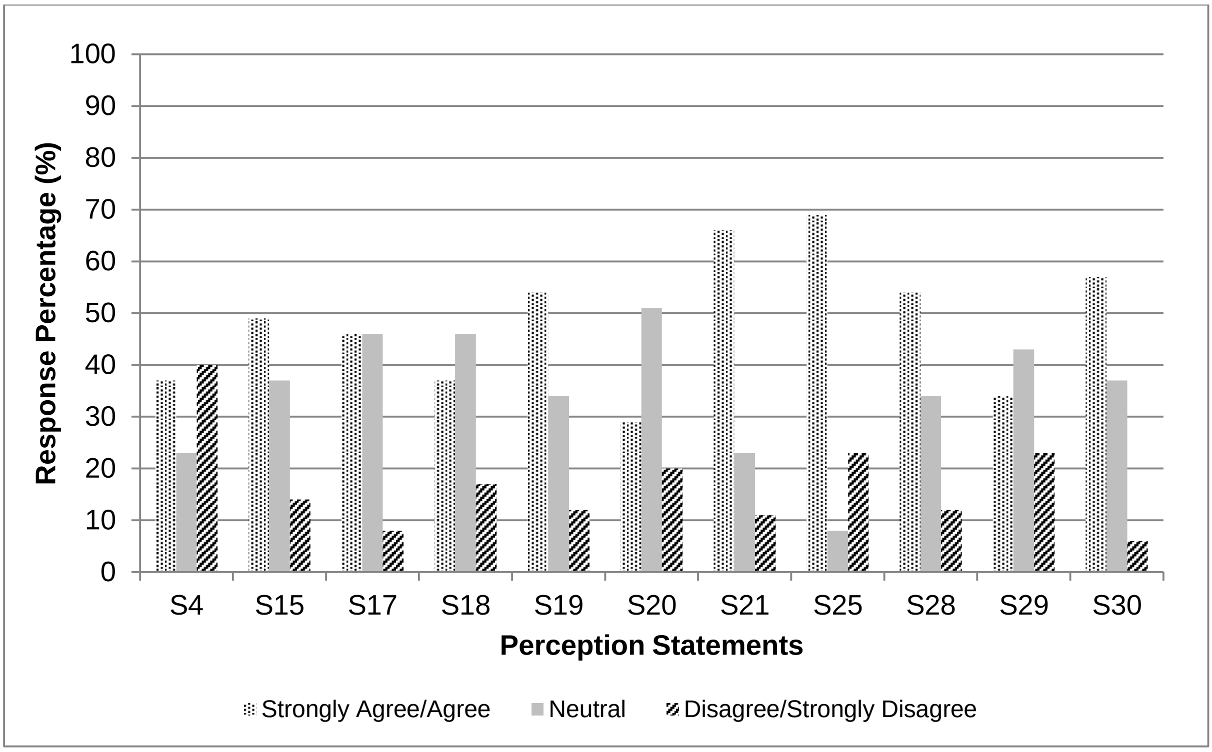


Figure 25. Processes, procedures and practices as perceived at SAACTC

Perception on Enforcement and Compliance with Environmental Laws at SAACTC

Eighty percent of the respondents believe that environmental protection and conservation must be enforced into military activities to ensure sustainability of the training ranges (Figure 26). On the other hand, 63% desires that the SANDF (and DoDMV) must be granted total immunity from all environmental regulations. Contrary, 69% of the respondents believe that environmental consideration must be enforced to the military activities for it is not a waste of time and other resources.

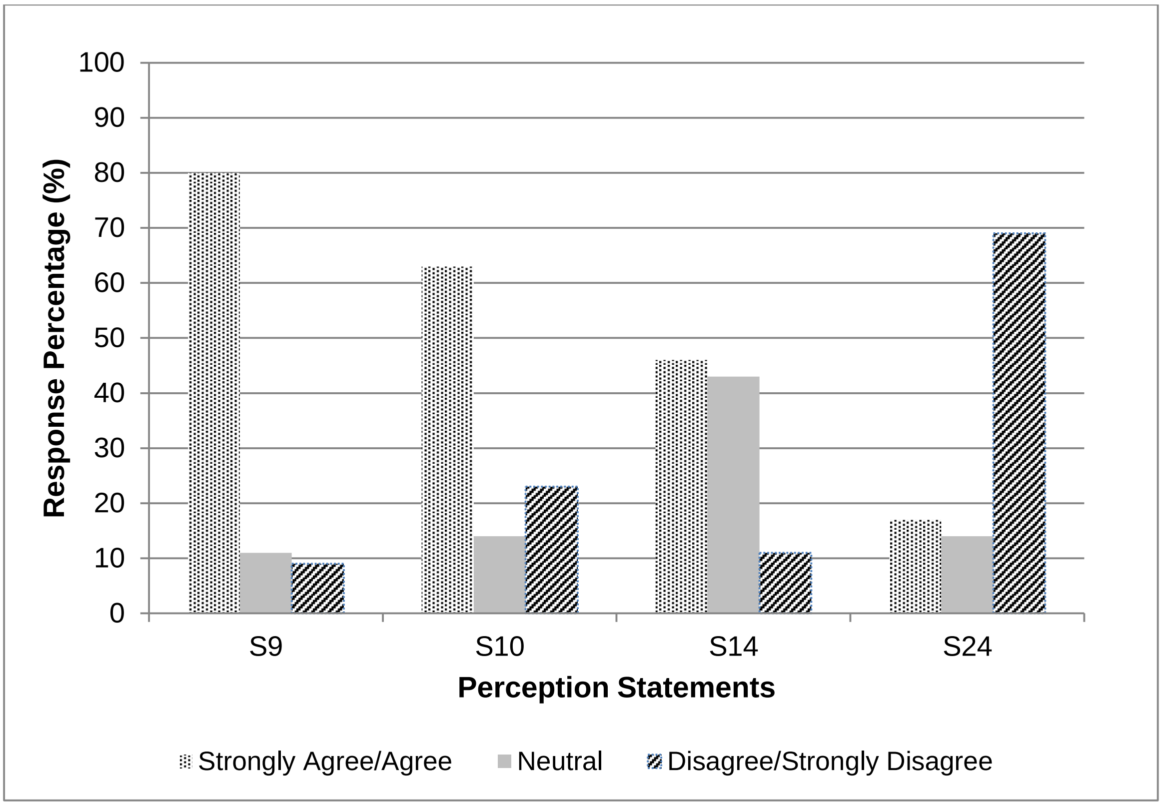


Figure 26. Perception on the enforcement and compliance with environmental regulations at SAACTC

Perception on Military Proficiency and Compatibility with Environmental Management at SAACTC

In Figure 27 it is shown that most of the military personnel (71%) believe that environmental management system can be successfully applied to military activities. With regard to military integrated environmental management (MIEM) 54% indicated that this approach can work well in the core business of the military. While some 57% respondents disagree with the statement that environmental consideration during military training has negative effects on military readiness and weapon testing. Contrary, 72% of the respondents agree that environmental consideration in military activities affects the proficiency of troops for combat.

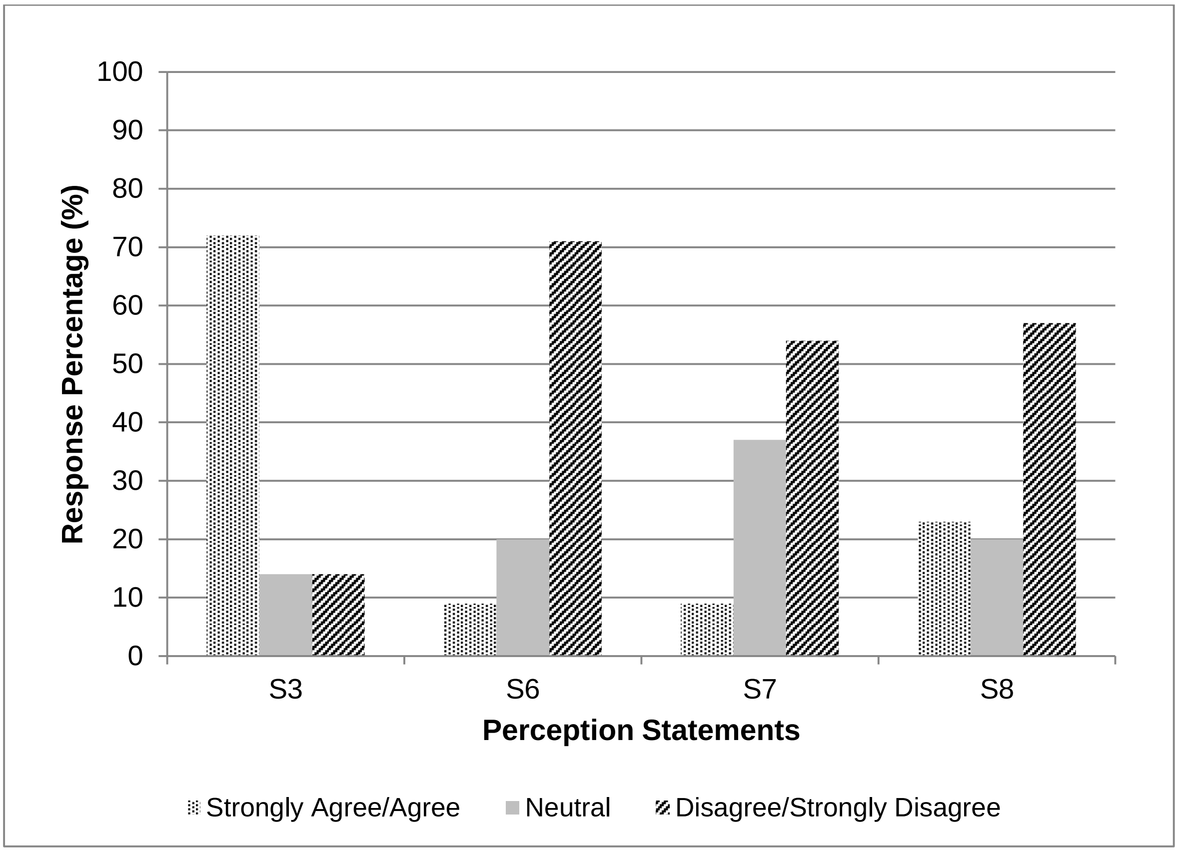
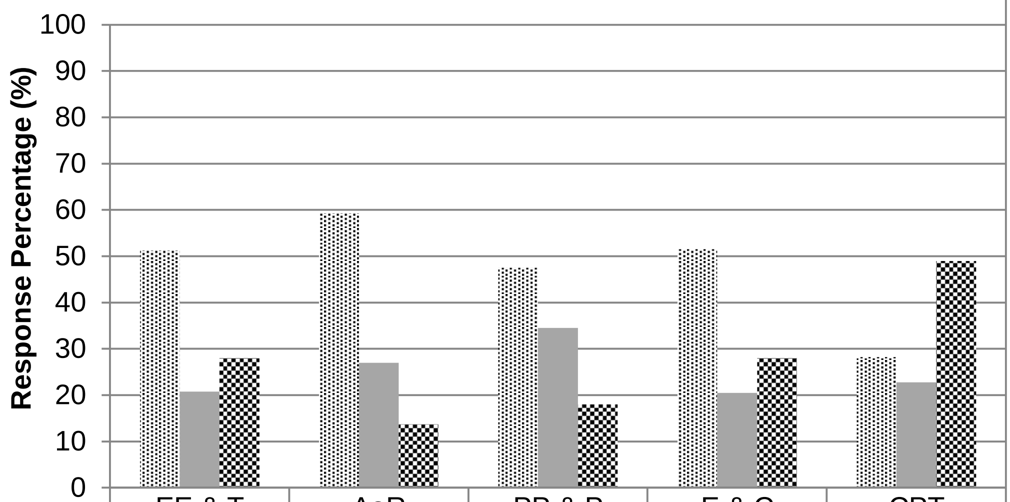


Figure 27. Perceptions on compatibility of environment and military activities at SAACTC

Overall Categorical Analysis of Responses on Environmental Management at SAACTC

Positive perceptions dominate in all but only one category which is compatibility of military activities and environmental protection (Figure 28). This can be attributed to the fact that respondents believe that environmental considerations in military activities have negative influence on troop proficiency for combat readiness.



	EE & T	AoR	PP & P	E & C	CPT
Positive Response	51.25	59.28571429	47.5	51.5	28.25
Neutral	20.75	27	34.5	20.5	22.75
Negative Response	28	13.71428571	18	28	49

Figure 28. Mean percentages of responses per category for SAACTC

Note: CPT- stands for “Compatibility”; E & C – stands for “Enforcement and Compliance”; PPP – stands for “Processes, Procedures and Practices”; AoR – stands for “Availability of Resources” and EE & T – stands for “Environmental Education and Training”

Statistical Analysis: ANOVA Results for SAACTC Responses

In an effort to establish whether there is a significant variations in the responses given of various military the analysis of variance (ANOVA) test was carried out at $p<0.05$.

Military rank was used as one of the variables against the responses provided in the questionnaires. The results of the test are presented in Table 8, and reveal that the responses are not statistically different ($p<0.237$).

Table 8. Significance between military ranks and responses from SAACTC

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.658	4	.164	1.465	.237
Within Groups	3.479	31	.112		
Total	4.137	35			

Further analysis was carried out to test whether there is a significant variation in the responses and military services period. The ANOVA results for this test are presented in Table 9. From the results it is clear that there are no variations in the responses given by the respondents in various military ranks ($p<0.563$).

Table 9. Significance between service period and responses from SAACTC

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.339	4	.085	.754	.563
Within Groups	3.487	31	.112		
Total	3.826	35			

Further from the ANOVA analysis and the LSD test were performed to determine any statistical differences between five categories (i.e., 1-5 years, 6-10 years, 11-15 years, 16-20 years and 21-25 years) of military service periods. Table 10 presents the multiple comparisons results, which reveals that there are no significant differences between military service period and the responses. The statistically significant of the results range between $p>0.125$ and $p>0.920$ which are higher than the 0.05

significance level. In other words, the responses provided by individuals who have served in the defence force for 1-5 years are not statistically different from the responses of those who have served for 25 years or for any other service period.

Table 10. LSD test result of military service period for responses from SAACTC

(I) Service Period	(J) Service Period	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1-5yrs	6-10yrs	.01417	.14030	.920	-.2720	.3003
	11-15yrs	-.12333	.24873	.623	-.6306	.3840
	16-20yrs	.22667	.24873	.369	-.2806	.7340
	21-25yrs	-.23167	.18370	.217	-.6063	.1430
6-10yrs	1-5yrs	-.01417	.14030	.920	-.3003	.2720
	11-15yrs	-.13750	.26515	.608	-.6783	.4033
	16-20yrs	.21250	.26515	.429	-.3283	.7533
	21-25yrs	-.24583	.20538	.240	-.6647	.1730
11-15yrs	1-5yrs	.12333	.24873	.623	-.3840	.6306
	6-10yrs	.13750	.26515	.608	-.4033	.6783
	16-20yrs	.35000	.33539	.305	-.3340	1.0340
	21-25yrs	-.10833	.29045	.712	-.7007	.4841
16-20yrs	1-5yrs	-.22667	.24873	.369	-.7340	.2806
	6-10yrs	-.21250	.26515	.429	-.7533	.3283
	11-15yrs	-.35000	.33539	.305	-1.0340	.3340
	21-25yrs	-.45833	.29045	.125	-1.0507	.1341
21-25yrs	1-5yrs	.23167	.18370	.217	-.1430	.6063
	6-10yrs	.24583	.20538	.240	-.1730	.6647
	11-15yrs	.10833	.29045	.712	-.4841	.7007
	16-20yrs	.45833	.29045	.125	-.1341	1.0507

Note: “yrs” – stands for years

Part III: Comparative Analysis of the Responses from GMI and SAACTC

The trends of the positive responses from the two case studies are relatively similar. However, there are variations noted in the responses from the respondents in the two military sites studied. The results of the comparative analysis are presented in Figure 28. More than two-thirds (37%) of the respondents at GMI believe that they received adequate environmental training on the implementation of EMS. While 43% of the respondents at SAACTC believe that they did not received adequate environmental training. Greater proportion of respondents (78% & 72%) in both case studies (i.e., GMI & SAACTC respectively) perceive environmental considerations in military activities to have negative influence on troops' proficiency for combat. The majority of respondents in both cases (61% & 74%) acknowledge the reality that the implementation of EMS in the SANDF has encountered numerous challenges. A total of 69% of the respondents at GMI perceive EMS applicable to military activities compared to a staggering 71% at SAACTC who disagree with S6. In both case studies the majority (81% & 54%) of the respondents believe that military integrated environmental management can be compatible with the SANDF's activities. It is also clear that the majority of the respondents (46% & 57% respectively) do not view environmental considerations during training activities as having negative effects on military readiness and weapon testing.

As many as 79% and 80% of the respondents at GMI and SAACTC respectively are of the view that environmental protection and conservation ought to be enforced into military activities to ensure sustainability of the SANDF training ranges. Forty-eight percent of the respondents at GMI are of the opinion that the SANDF must comply with all environmental legislations. Contrary, 63% of the respondents at SAACTC believe that the SANDF must be granted total exemption from all environmental legislations. The need for the SANDF to have environmentally qualified and competent personnel is recognised by the majority (80% at GMI & 86% at SAACTC) of the respondents from both case studies. Similarly, 82% and 69% of the respondents at GMI and SAACTC respectively, would appreciate enforcement of environmental considerations to military's activities. The majority (41%) of the respondents at GMI agree that environmental education and enlightenment is not part of the formal military training programmes of the SANDF. Contrary, 49% of the respondents at SAACTC believe that formal military training of the SANDF incorporates environmental education and enlightenment.

Thirty-seven percent of the respondents at GMI and 49% at SAACTC believe that the DoD do have external collaborations with environmental management experts in other government departments and universities. Most (46%) of the respondents at SAACTC opted to withhold their opinions regarding the effects of environmental audit programmes of the DoD in the monitoring and evaluation of activities that have significant impact on the environment. While 81% of the respondents at GMI agreed with the statement (S18). Consequently, 72% of the respondents at GMI indicated that environmental audits have reduced military impact on the environment. However, the majority of the respondents at SAACTC chose to remain neutral in this regard.

The majority of the respondents (57%) at GMI withheld their perceptions on identification of activities likely to induce significant impact on the environment on an on-going basis. Whereas, 34% of the respondents at SAACTC agreed that potential activities likely to cause significant impacts on the environment are identified on an ongoing basis. The majority of respondents (43% respectively) both at GMI and SAACTC withheld their perceptions on the existence of systematic process of identifying, monitoring and evaluation of environmental performance of the SANDF. Surprisingly, 57% of respondents at GMI believe that the top-down approach in the implementation of environmental management tools is not an effective way of integrating environmental considerations into military activities and programmes.

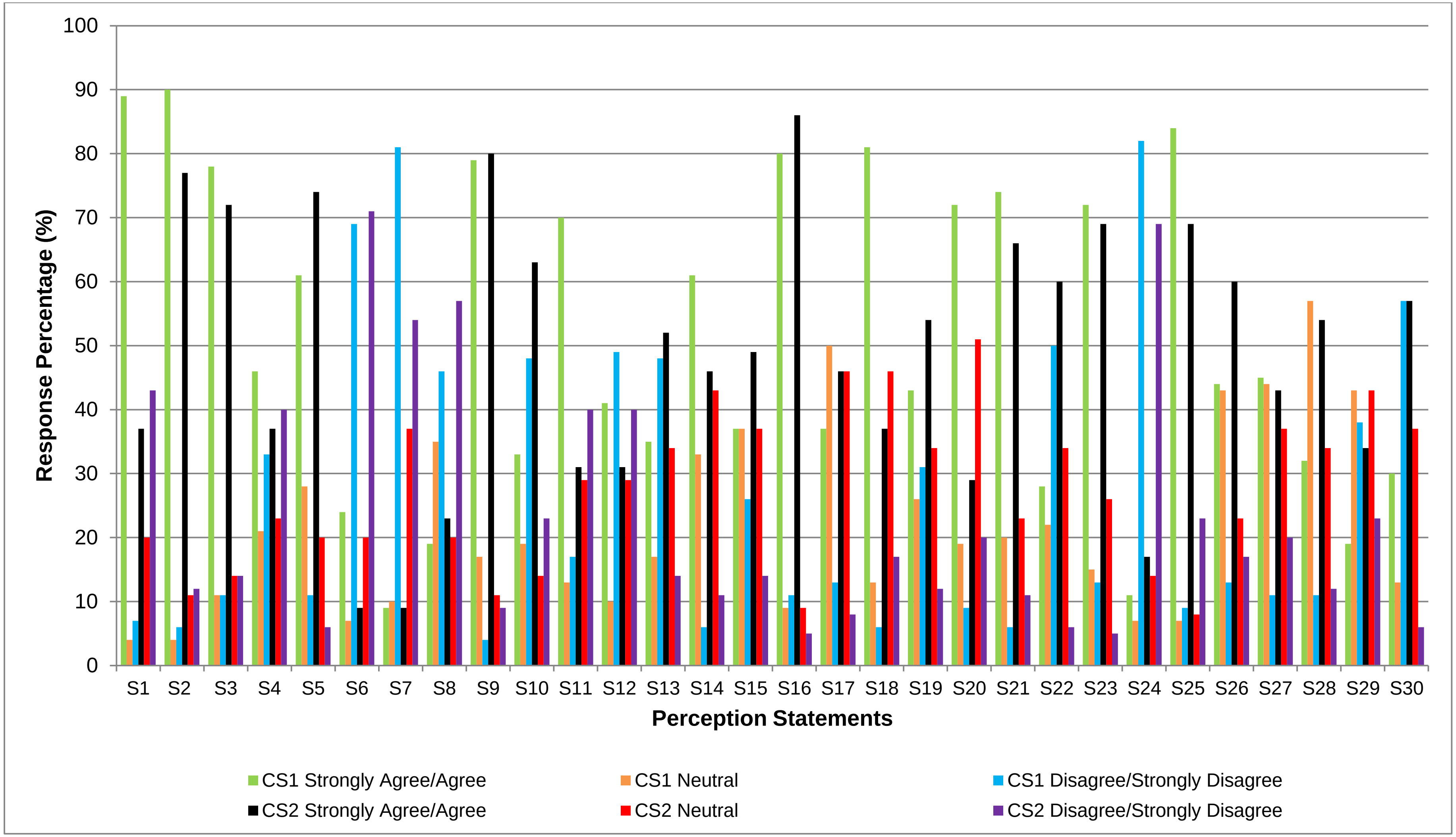


Figure 29. Comparative analysis of data from GMI and SAACTC

Note: CS1 – stands for "case study 1" which is GMI and CS2 – stands for "case study 2" which is SAACTC.

To establish whether the responses from the two case studies are significantly different, the Pearson correlation coefficient was used to analyse the data. The results of this analysis are presented in Table 11. The positive response options were found to be statistically significantly different ($p<0.001$) between the case studies (Table 11). While both the neutral and the negative response options were not statistically different.

The statistical differences noted between the other response options were expected, thus not of importance. Except to note that the positive and negative responses are statistically different at $p<0.05$ confidence level, with the neutral and the negative responses are significantly different at $p<0.01$ level. The descriptive statistical table (not include here) show that there statistical mean value of the positive responses from SAACTC is 50.57 compared to 48.00 for the GMI. The neutral responses at GMI had a statistical mean of 23.73 compared to 21.93 at SAACTC. Whereas the statistical mean value for the neutral responses at GMI was relatively equal to the one obtained at SAACTC (i.e., 27.93 and 27.50 respectively).

The categorical statistical analysis of the results from both military installations also shows that there were no major differences in the results (Table 12). The on statistical significant difference was noted between the neutral response option ($p<0.023$) at 0.05 confidence level. The rest of the results are not significantly different.

Table 11. Correlation coefficients for the results from GMI and SAACTC

		GMI _ Positive Responses	GMI _ Neutral Responses	GMI _ Negative Responses	SAACTC _ Positive Responses	SAACTC _ Neutral Responses	SAACTC _ Negative Responses
GMI _ Positive Responses	Pearson Correlation	1	-.800**	-.412*	.572**	-.021	-.581**
	Sig. (2-tailed)		.000	.024	.001	.912	.001
	N	30	30	30	30	30	30
GMI _ Neutral Responses	Pearson Correlation	-.800**	1	-.216	-.447*	-.290	.641**
	Sig. (2-tailed)	.000		.251	.013	.120	.000
	N	30	30	30	30	30	30
GMI _ Negative Responses	Pearson Correlation	-.412*	-.216	1	-.263	.472**	-.016
	Sig. (2-tailed)	.024	.251		.160	.008	.934
	N	30	30	30	30	30	30
SAACTC _ Positive Responses	Pearson Correlation	.572**	-.447*	-.263	1	-.356	-.820**
	Sig. (2-tailed)	.001	.013	.160		.054	.000
	N	30	30	30	30	30	30
SAACTC _ Neutral Responses	Pearson Correlation	-.021	-.290	.472**	-.356	1	-.242
	Sig. (2-tailed)	.912	.120	.008	.054		.197
	N	30	30	30	30	30	30
SAACTC _ Negative Responses	Pearson Correlation	-.581**	.641**	-.016	-.820**	-.242	1
	Sig. (2-tailed)	.001	.000	.934	.000	.197	
	N	30	30	30	30	30	30

**. Correlation is significant at the 0.01 level (2-tailed),*. Correlation is significant at the 0.05 level (2-tailed).

Table 12.Correlations of categorical analysis results from GMI and SAACTC

		GMI_PTV	GMI_NTL	GMI_NTV	SAACTC_PTV	SAACTC_NTL	SAACTC_NTV
GMI_PTV	Pearson Correlation	1	.051	-.927*	.783	.018	-.675
	Sig. (2-tailed)		.936	.023	.118	.977	.212
	N	5	5	5	5	5	5
GMI_NTL	Pearson Correlation	.051	1	-.420	.310	.928*	-.664
	Sig. (2-tailed)	.936		.481	.611	.023	.222
	N	5	5	5	5	5	5
GMI_NTV	Pearson Correlation	-.927*	-.420	1	-.827	-.364	.861
	Sig. (2-tailed)	.023	.481		.084	.547	.061
	N	5	5	5	5	5	5
SAACTC_PTV	Pearson Correlation	.783	.310	-.827	1	.121	-.904*
	Sig. (2-tailed)	.118	.611	.084		.847	.035
	N	5	5	5	5	5	5
SAACTC_NTL	Pearson Correlation	.018	.928*	-.364	.121	1	-.533
	Sig. (2-tailed)	.977	.023	.547	.847		.355
	N	5	5	5	5	5	5
SAACTC_NTV	Pearson Correlation	-.675	-.664	.861	-.904*	-.533	1
	Sig. (2-tailed)	.212	.222	.061	.035	.355	
	N	5	5	5	5	5	5

*. Correlation is significant at the 0.05 level (2-tailed).

Clearly military personnel do not believe that environmental protection and military activities are compatible. This is very clear in the Figure 30, where the category compatibility has the highest negative response in both the case studies. The availability of resources is also considered by respondents to be relatively adequate under the circumstance. Most (66%) of the respondents at GMI consider environmental education and training to be adequately incorporated into formal military programmes. It is also clear that environmental management processes and practices are known better at GMI than at SAACTC.

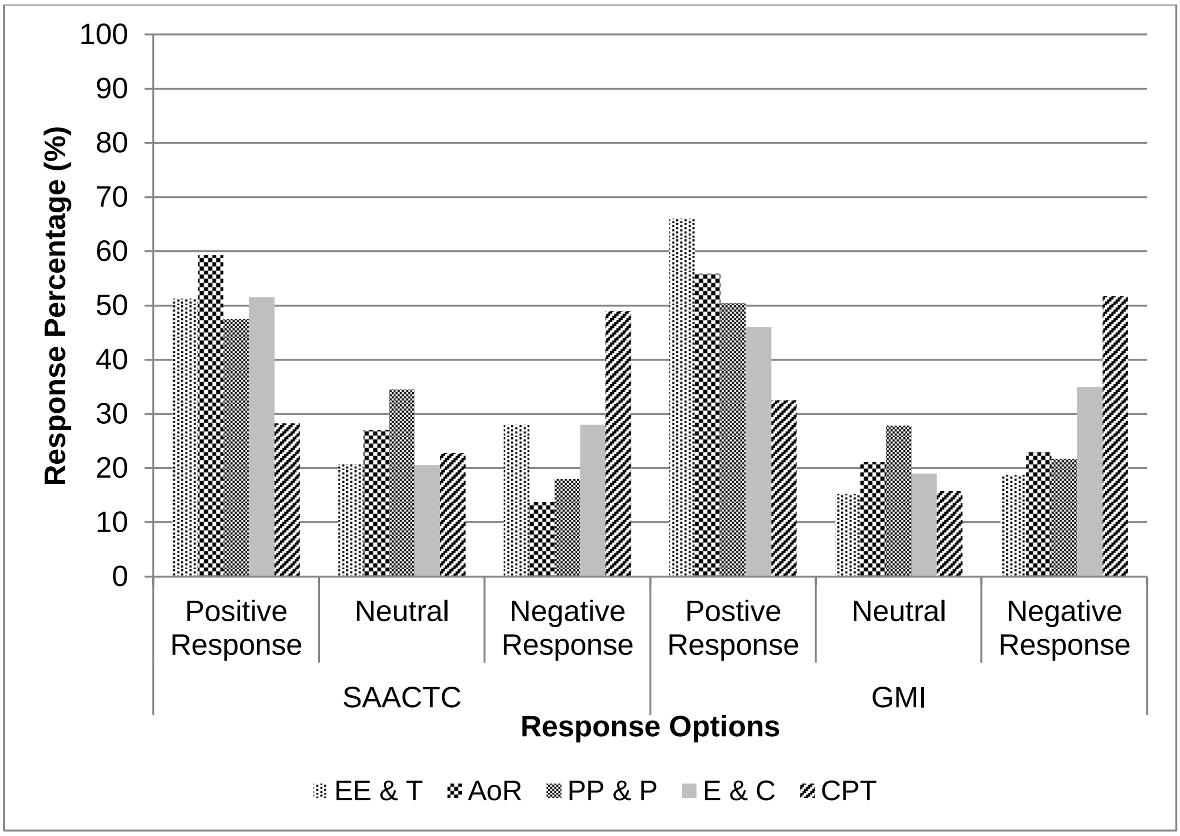


Figure 30. Categorical comparative analysis of data from both study sites

Note: SAACTC – stands for “South African Army Combat Training Centre”; GMI – stands for Grahamstown Military Installation”; EE & T – stands for “Environmental Education and Training”; AoR – stands for “Availability of Resources”; PP & P – stands for “Processes, Procedures and Practices”; E & C – stands for “Enforcement and Compliance” and CPT- stands for “Compatibility”

PART IV: HEAVY METALS IN SOIL AND WATER SAMPLES

Concentrations of Heavy Metals in water bodies

The water samples collected from the GMI and SAACTC were analysed to determine the concentration of selected heavy metals. The selected metals included lead (Pb), cadmium (Cd), nickel (Ni), zinc (Zn) copper (Cu), chromium (Cr) and strontium (Sr). These metals are common contaminants in military as well as in areas adjacent shooting ranges (Robinson *et al.,* 2008).The mean concentrations of the selected heavy metals determined from all the water samples collected from GMI and SAACTC are presented in Figure 31.

The concentrations of all the heavy metals found in the water samples were remarkably low and constant, thus not suggesting significant input by continual military activities. The mobilization and storage of heavy metals in water might account for the low and constant concentration of the metals in this environmental medium. However, it should also be noted that the GMI is a light infantry battalion training area where limited heavy military training is rarely undertaken. Contrary, relatively high concentrations of heavy metals were expected from water samples collected from SAACTC which is a heavy military training area where heavy military artilleries are used (Figure 31). Nevertheless, the concentrations of heavy metals from both training areas were found to be constant (same) except for Sr.

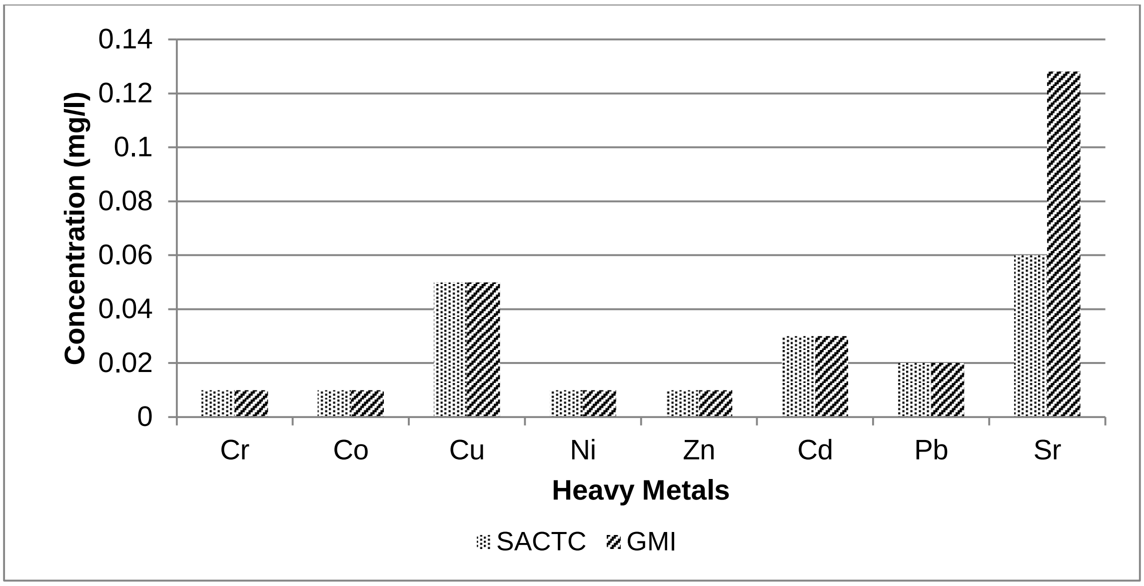


Figure 31. Concentrations of heavy metals in all water samples

Note: SAACTC – stands for “South African Army Combat Training Centre”; GMI – stands for Grahamstown Military Installation”

Overall, the mean concentrations of the heavy metals in water samples were found to be ascending in the order of Sr>Cu>Cd>Pb and all the others equal. No statistical analysis applied to this dataset yielded any meaningful results due to the constant concentrations of the heavy metals in all water samples.

Concentrations of Heavy Metals in Surface Sediments Samples

Heavy metal concentrations were also determined from surface sediments samples collected from Grahamstown military training area (GMTA) and SAACTC. Considerable concentrations of heavy metals were identified from the surface sediments samples collected from GMTA compared to water samples. Military training area around the world have shown high levels of contamination by heavy metals (Diaz & Massol-Deya, 2003; Clausen *et al*., 2004; Greičiūtė *et al*., 2007; Robinson *et al.,* 2008; Matias *et al*., 2009; Ahmad *et al.,* 2012). The concentrations of heavy metals were analyzed using multivariate statistical analysis which included Pearson's correlation. The results of the Pearson's correlation coefficient matrix are presented in Table 13. Only Cr-Zn show a moderate correlation (0.407) significant at $p<0.05$ (2-tailed). In the literature, elemental association is referred to as a pair. This terminology has been adopted in the current study to refer to correlating or non-correlating heavy metals. Twelve pairs have shown correlations at $p<0.01$ significant level (Table 13). These pairs are Ni-Co, Ni-Cr, Ni-Sr, Ni-Zn, Co-Cr, Cr-Sr, Cu-Pb, Cu-Sr, Cu-Zn, Pb-Zn, Pb-Sr, and Sr-Zn. The correlations between pairs range from moderate to very strong (0.465 to 0.880) at $p<0.01$ significant level.

Most of the heavy metal pairs in the soil samples exhibit positive relations; except for Cd/Ni, Cd/Cu, Cd/Pb, Cd/Sr Cd/Zn, Co/Cu and Co/Pb, which means no significant correlation. Whereas Ni/Cr, Ni/Sr, Co/Cr, Cu/Pb, Cu/Zn and Pb/Zn show strong significantly positive correlations (ranging from 0.848 to 0.739) with each other. Clearly, these correlations appear to show a common source; in other words these heavy metals have originated from the same source. Cd shows a very weak negative correlation with Ni, while Co also show weak negative correlation with Cu and Pb. However, Cr shows weak positive correlation with Cu and Pb. In this case, the correlations are suggesting mixed source of origin.

Table 14 presents the result of Pearson's correlation matrix for the heavy metals determined from the surface sediments collected from SAACTC military training area. This analysis was carried out to identify heavy metals that would show strong correlation, thereby indicating that they come from the same source of pollution. While heavy metals that exhibit lack of significant correlation suggests that their sources are different from those of the others (Hu *et al.*, 2013).

Table 13. Pearson correlation matrix of heavy metals in sediments collected from GMI

Variables		Ni	Cd	Co	Cr	Cu	Pb	Sr	Zn
Ni	Pearson Correlation	1	-.090	.543**	.767**	.316	.332	.848**	.623**
	Sig. (2-tailed)		.634	.002	.000	.089	.073	.000	.000
	N	30	30	30	30	30	30	30	30
Cd	Pearson Correlation	-.090	1	.189	.135	-.295	-.107	-.138	-.167
	Sig. (2-tailed)	.634		.317	.478	.114	.575	.467	.378
	N	30	30	30	30	30	30	30	30
Co	Pearson Correlation	.543**	.189	1	.762**	-.003	-.038	.356	.342
	Sig. (2-tailed)	.002	.317		.000	.987	.842	.053	.065
	N	30	30	30	30	30	30	30	30
Cr	Pearson Correlation	.767**	.135	.762**	1	.087	.057	.604**	.407*
	Sig. (2-tailed)	.000	.478	.000		.647	.766	.000	.026
	N	30	30	30	30	30	30	30	30
Cu	Pearson Correlation	.316	-.295	-.003	.087	1	.764**	.465**	.880**
	Sig. (2-tailed)	.089	.114	.987	.647		.000	.010	.000
	N	30	30	30	30	30	30	30	30
Pb	Pearson Correlation	.332	-.107	-.038	.057	.764**	1	.554**	.739**
	Sig. (2-tailed)	.073	.575	.842	.766	.000		.001	.000
	N	30	30	30	30	30	30	30	30

Variables		Ni	Cd	Co	Cr	Cu	Pb	Sr	Zn
Sr	Pearson Correlation	.848**	-.138	.356	.604**	.465**	.554**	1	.713**
	Sig. (2-tailed)	.000	.467	.053	.000	.010	.001		.000
	N	30	30	30	30	30	30	30	30
Zn	Pearson Correlation	.623**	-.167	.342	.407*	.880**	.739**	.713**	1
	Sig. (2-tailed)	.000	.378	.065	.026	.000	.000	.000	
	N	30	30	30	30	30	30	30	30

**. Correlation is significant at the 0.01 level (2-tailed), *. Correlation is significant at the 0.05 level (2-tailed).

Table 14. Correlations matrix of heavy metals in surface sediments collected from SAACTC

Variables	Corr. coefficient	Ni	Cd	Co	Cr	Cu	Pb	Sr	Zn
Ni	Pearson Correlation	1	.265	.988**	.699**	.349	.492**	.899**	.243
	Sig. (2-tailed)		.158	.000	.000	.059	.006	.000	.196
	N	30	30	30	30	30	30	30	30
Cd	Pearson Correlation	.265	1	.273	.095	.173	.200	.169	.838**
	Sig. (2-tailed)	.158		.145	.617	.359	.290	.373	.000
	N	30	30	30	30	30	30	30	30
Co	Pearson Correlation	.988**	.273	1	.643**	.387*	.506**	.911**	.245
	Sig. (2-tailed)	.000	.145		.000	.035	.004	.000	.192

Variables	Corr. coefficient	Ni	Cd	Co	Cr	Cu	Pb	Sr	Zn
	N	30	30	30	30	30	30	30	30
Cr	Pearson Correlation	.699**	.095	.643**	1	.155	.252	.555**	.096
	Sig. (2-tailed)	.000	.617	.000		.414	.180	.001	.614
	N	30	30	30	30	30	30	30	30
Cu	Pearson Correlation	.349	.173	.387*	.155	1	.902**	.297	.457*
	Sig. (2-tailed)	.059	.359	.035	.414		.000	.111	.011
	N	30	30	30	30	30	30	30	30
Pb	Pearson Correlation	.492**	.200	.506**	.252	.902**	1	.366*	.492**
	Sig. (2-tailed)	.006	.290	.004	.180	.000		.047	.006
	N	30	30	30	30	30	30	30	30
Sr	Pearson Correlation	.899**	.169	.911**	.555**	.297	.366*	1	.114
	Sig. (2-tailed)	.000	.373	.000	.001	.111	.047		.548
	N	30	30	30	30	30	30	30	30
Zn	Pearson Correlation	.243	.838**	.245	.096	.457*	.492**	.114	1
	Sig. (2-tailed)	.196	.000	.192	.614	.011	.006	.548	
	N	30	30	30	30	30	30	30	30

**. Correlation is significant at the 0.01 level (2-tailed), *. Correlation is significant at the 0.05 level (2-tailed).

Table 14 show that as many as eleven pairs (Ni-Co, Ni-Cr, Ni-Pb, Ni-Sr, Cd-Zn, Co-Cr, Co-Pb, Co-Sr, Cr-Sr, Cu-Pb, and Pb-Zn) of the heavy metals show positive correlation at $p<0.01$ (correlation coefficient varying from 0.492 to 0.988), while only three pairs have shown correlation at $p<0.05$. The pairs that correlates at $p<0.05$ are Co-Cu, Cu-Zn, and Pb-Sr show a correlation coefficient of 0.387, 0.366 and 0.457 respectively. The correlations of the element in Table 14 can be describe as ranging from moderately weak (0.492) to very strong (0.988). The moderately weak correlated pairs are presumed to be having a mix source of origin. While heavy metals such as Ni/Co, Ni/Sr, Cd/Zn and Co/Sr show strong positive significant correlations. These heavy metals are believed to be originating from the same pollution source.

The same analysis was performed to assess the relationship between the heavy metals from the two investigated military sites. The Pearson correlation coefficients of heavy metals in GMI and SAACTC are presented in Table 15. Most of the correlations of the heavy metals from GMI and SAACTC sediments samples are significant at $p<0.001$. The correlation coefficients vary from moderately weak (0.465) to strong (0.880). The only correlation that is significant at $p<0.05$ is that of Cr and Zn, which is 0.407 indicating a moderately weak association. It is assumed therefore that Cr and Zn do not originate from the same source but Cu and Zn have the same contamination source. From this analysis seven negative correlations between heavy metals are noted. The negatively correlated elements are Ni/Cd, Cd/Cu, Cd/Pb, Cd/Sr, Cd/Zn, Co/Cu and Co/Pb. The correlation between these heavy metals ranged from -0.090 to -0.295. It is clear that these heavy metals do not come from the same contamination source.

Table 15. GMI and SAACTC comparative analysis and correlation coefficients

Variable		Ni	Cd	Co	Cr	Cu	Pb	Sr	Zn
Ni	Pearson Correlation	1	-.090	.543**	.767**	.316	.332	.848**	.623**
	Sig. (2-tailed)		.634	.002	.000	.089	.073	.000	.000
	N	30	30	30	30	30	30	30	30
Cd	Pearson Correlation	-.090	1	.189	.135	-.295	-.107	-.138	-.167
	Sig. (2-tailed)	.634		.317	.478	.114	.575	.467	.378
	N	30	30	30	30	30	30	30	30
Co	Pearson Correlation	.543**	.189	1	.762**	-.003	-.038	.356	.342
	Sig. (2-tailed)	.002	.317		.000	.987	.842	.053	.065
	N	30	30	30	30	30	30	30	30
Cr	Pearson Correlation	.767**	.135	.762**	1	.087	.057	.604**	.407*
	Sig. (2-tailed)	.000	.478	.000		.647	.766	.000	.026
	N	30	30	30	30	30	30	30	30
Cu	Pearson Correlation	.316	-.295	-.003	.087	1	.764**	.465**	.880**
	Sig. (2-tailed)	.089	.114	.987	.647		.000	.010	.000
	N	30	30	30	30	30	30	30	30
Pb	Pearson Correlation	.332	-.107	-.038	.057	.764**	1	.554**	.739**
	Sig. (2-tailed)	.073	.575	.842	.766	.000		.001	.000
	N	30	30	30	30	30	30	30	30
Sr	Pearson Correlation	.848**	-.138	.356	.604**	.465**	.554**	1	.713**
	Sig. (2-tailed)	.000	.467	.053	.000	.010	.001		.000
	N	30	30	30	30	30	30	30	30
Zn	Pearson Correlation	.623**	-.167	.342	.407*	.880**	.739**	.713**	1
	Sig. (2-tailed)	.000	.378	.065	.026	.000	.000	.000	
	N	30	30	30	30	30	30	30	30

**. Correlation is significant at the 0.01 level (2-tailed), *. Correlation is significant at the 0.05 level (2-tailed).

Principal component analysis

Principal component analysis (PCA) is regarded as a powerful tool that tries to explain variance of large dataset of intercorrelated variables with smaller set of independent variables (Gajbhiye *et al.*, 2015). According to Brodziak-Dopierala *et al*. (2010) and Gajbhiye *et al.* (2015), principal component provides information on the most important parameters which describe the whole dataset, while carrying out data reduction with minimal loss of the original information. Thus, PCA was adopted in the current study to facilitate the analysis and interpretation of the variance within the data. PCA with Varimax and Kaiser Normalization rotation was adopted in an effort to identify heavy metals that correlate and thus indicating to have originated from the same source (Qishlaqi & Moore, 2007; Hu *et al.*, 2013). Similarly, Nazzal *et al.* (2014) state that PCA is used to assist in the identification of sources of pollutants. In the present study PCA was used to confirm whether or not the determined heavy metals have originated from the same source.

The basic descriptive statistics of PCA is presented in Table 16. The table shows that Pb has the highest statistical mean followed by Cu then Cr. Furthermore, Table 16 indicates how greatly Pb, Cu and Zn deviate from the mean. Comparing the mean and the standard deviation one could tell that the coefficient of variation in most of the variables is well beyond 100%, except for Ni (CV = 90%) and Cr (CV = 43.79%). The coefficient of variation show how the percentage of the standard deviation deviates from the mean.

Table 16. Principal components descriptive statistics

Heavy Metals	Mean	Std. Deviation	Analysis N
Ni	23.5360	21.18854	60
Cd	1.4687	1.86272	60
Co	9.8100	9.27074	60
Cr	**53.5833**	23.46602	60
Cu	**99.6567**	**497.49361**	60
Pb	**187.2917**	**732.60051**	60
Sr	48.1867	52.43652	60
Zn	**83.6333**	**118.88737**	60

The correlation matrix of the PCA is presented in Table 17. Almost all the heavy metals considered in this analysis showed positive and significant correlation with each other. The correlation coefficients between the variables (i.e., heavy metals) vary from strong to weak. For example, Ni appears to be positively and significantly associated with Co ($r = 0.925$, $p<0.000$) and Sr ($r = 0.884$, $p<0.000$). Conversely, a moderate significant association with Cr ($r = 0.607$, $p<0.000$) is also noted. Cadmium (Cd) show moderate but significant association with Zn ($r = 0.647$, $p<0.000$). While Cu is significantly associated with Pb ($r = 0.769$, $p<0.000$). The association between Cu and Zn appears to be moderately weak ($r = 0.432$, $p<0.000$). Heavy metals showing positive and significant correlations are assumed to be originating from the same pollution source or are having similar characteristics. All the other remaining associations/correlations in Table 17 can be described as very weak especially that of Cu and Co ($r = 0.011$) to moderately weak association noted between Pb and Zn ($r = 0.352$). Negative and weak correlations are noted between Co and Pb ($r = -0.002$), as well as between Cu and Cd ($r = -0.056$). Thus, these heavy metals come from different sources. Therefore, it can be concluded that the correlations in Table 17 indicate the existence of different sources of heavy metals pollution in both military training areas.

Table 17. Principal components correlation matrix[a]

		Ni	Cd	Co	Cr	Cu	Pb	Sr	Zn
Correlation	Ni	1.000	.213	**.925**	**.607**	.145	.150	**.884**	.319
	Cd	.213	1.000	.254	.152	*-.056*	.018	.112	**.647**
	Co	.925	.254	1.000	**.498**	.011	*-.002*	**.855**	.252
	Cr	.607	.152	**.498**	1.000	.116	.120	**.422**	.182
	Cu	.145	*-.056*	.011	.116	1.000	**.769**	.157	**.432**
	Pb	.150	.018	*-.002*	.120	.769	1.000	.175	.352
	Sr	.884	.112	.855	.422	.157	.175	1.000	.215
	Zn	.319	.647	.252	.182	.432	.352	.215	1.000
Sig. (1-tailed)	Ni		.051	.000	.000	.134	.126	.000	.007
	Cd	.051		.025	.124	.335	.446	.196	.000
	Co	**.000**	.025		.000	.468	.493	.000	.026
	Cr	**.000**	.124	**.000**		.189	.180	.000	.081
	Cu	.134	.335	.468	.189		.000	.115	.000
	Pb	.126	.446	.493	.180	**.000**		.090	.003
	Sr	**.000**	.196	**.000**	**.000**	.115	.090		.049
	Zn	.007	**.000**	.026	.081	**.000**	.003	.049	

a. Determinant = .002

Extraction of Principal Components

The PCA procedure extracted four components from the original dataset. It should be noted that PCA is used as a method to reduce data and develop a smaller number of variables that accounts for most of the variability in the observed variables (Jolliffe, 2002). Table 18 list the extracted components with their eigenvalues. According to Hu *et al.* (2013), factor loadings greater than 0.71 in PCA are regarded excellent as opposed to those that are less than 0.32 (very poor). However, Jackson (1993),

Mazlum *et al.* (1999), Kellow (2006), Ledesma and Valero-Mora (2007), Chumney (2012) and many others suggest that only components with eigenvalues greater the 1 be considered in the factor analysis. Mazlum *et al.* (1999) argue that this rule has no theoretical justification. To this end, Dan (2013) included a component with eigenvalue of 0.712 in a study of oil palm. Thus, in the current study, PC4 has a loading value less than 0.71 but greater than 0.32 (i.e., 0.658) and its contribution to the accumulative loading percentage is significant (8.23%), thus it was included in the analysis (Table 18).
Nonetheless, the triviality of the component with eigenvalue less than 1.0 is noted in Figure 32 as its loading was not plotted in the graph. The four extracted components put together can explain 92% of the total variance in the observed variables (Table 18). Even if the fourth component was left out, the analysis would still be carried out because the three components are explaining approximately 80% of the variability. The normally accepted explained variability percentage of PCA is 75% (Brodziak-Dopierala *et al.,* 2010). According to Brodziak-Dopierala *et al.* (2010), the first component produces the most important correlations between the components.

As seen from Table 18, the first component has eigenvalue of 3.469 and accounts for 43.37% of the total variance. The second and the third component respectively accounts for approximately 24% and 17% of the variability. Meanwhile, the fourth component has eigenvalue of 0.658 and explains 8.2% of the total variance. However, under the rotation sums of squared loadings in Table 18, the value of the fourth component is 1 and contributes approximately 12.5% to the variability. The remaining 4 components (components 5 – 8) explain only 7.91% of the variance, thus, they are less important. The 92% variance suggests that there are differences between the characteristics of the heavy metals studied. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy for the study was shown to be 64% in the KMO and Bartlett's Test table (not included in this text).

Table 18. Eigenvalues and variance between principal components

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.469	43.368	43.368	3.469	43.368	43.368	2.791	34.893	34.893
2	1.897	23.712	67.079	1.897	23.712	67.079	1.938	24.219	59.113
3	1.342	16.776	83.855	1.342	16.776	83.855	1.638	20.476	79.588
4	.658	8.230	92.085	.658	8.230	92.085	1.000	12.497	92.085
5	.308	3.849	95.935						
6	.162	2.021	97.955						
7	.115	1.440	99.396						
8	.048	.604	100.000						

Extraction Method: Principal Component Analysis.

The first principal component (PC1) in Table 19 is heavily loaded with Sr (0.954 loading value), Co (0.938 loading value), Ni (0.918 loading value). The second component (PC2) is loaded with Cu (0.943) and Pb (0.920). The third component (PC3) is loaded with Cd (0.939) and Zn (0.834). Lastly, the fourth component (PC4) is loaded with Cr (0.930) and has a significant contribution (8.23%) to the accumulative loading percentage. It appears that the heavy metals are indicative of the source/s of origin.

Table 19 also includes the communalities (i.e., the percentage of variance of the observed variable) of the PCA for the four factor loadings of the heavy metals. The communality range between 0 and 1, the value of 0 indicates that, that particular component explains none of the variance. Whereas, 1 means that the variance is explained by the component associated with that value (Folorunso Olusegun *et al.*, 2010). Communalities that is greater than 0.7 indicates that the variables were described to an acceptable level in the analysis (Mazlum *et al.*, 1999). This is the case in the current study. The communalities varies from 96% for Sr, 90.9% for Co, 94.3% for Ni, 99.7% for Cu, 89.6% for Pb, 85.4% for Cd, 93.10% for Zn to 87.6% for Cr. This means that most of the heavy metals are adequately represented by the four extracted components. Thus, the variability existing between the variables is not explained by a single variable.

Table 19. Rotated principal component matrix with communalities values

Variable	Component				Communalities
	1	2	3	4	
Sr	**.954**	.128	.023	.071	.961
Co	**.938**	-.070	.160	.182	.909
Ni	**.918**	.093	.142	.299	.943
Cu	.048	**.943**	.059	.032	.997
Pb	.047	**.920**	.065	.045	.896
Cd	.088	-.121	**.939**	.066	.854
Zn	.159	.392	**.834**	.033	.931
Cr	.350	.068	.076	**.930**	.876

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 4 iterations.

The PCA loadings for the four rotated components are presented in Figure 32. This Figure (Figure 32) show how these heavy metals are associated in various concentrations in the sediments samples. Clearly, Pb and Cu seem to have similar characteristics. These characteristics could either be common source, concentration or sink. This is also confirmed by their correlation. Furthermore, Cr, Ni, Sr and Co also appears to have strong association thus suggesting to have originated from mixed sources.

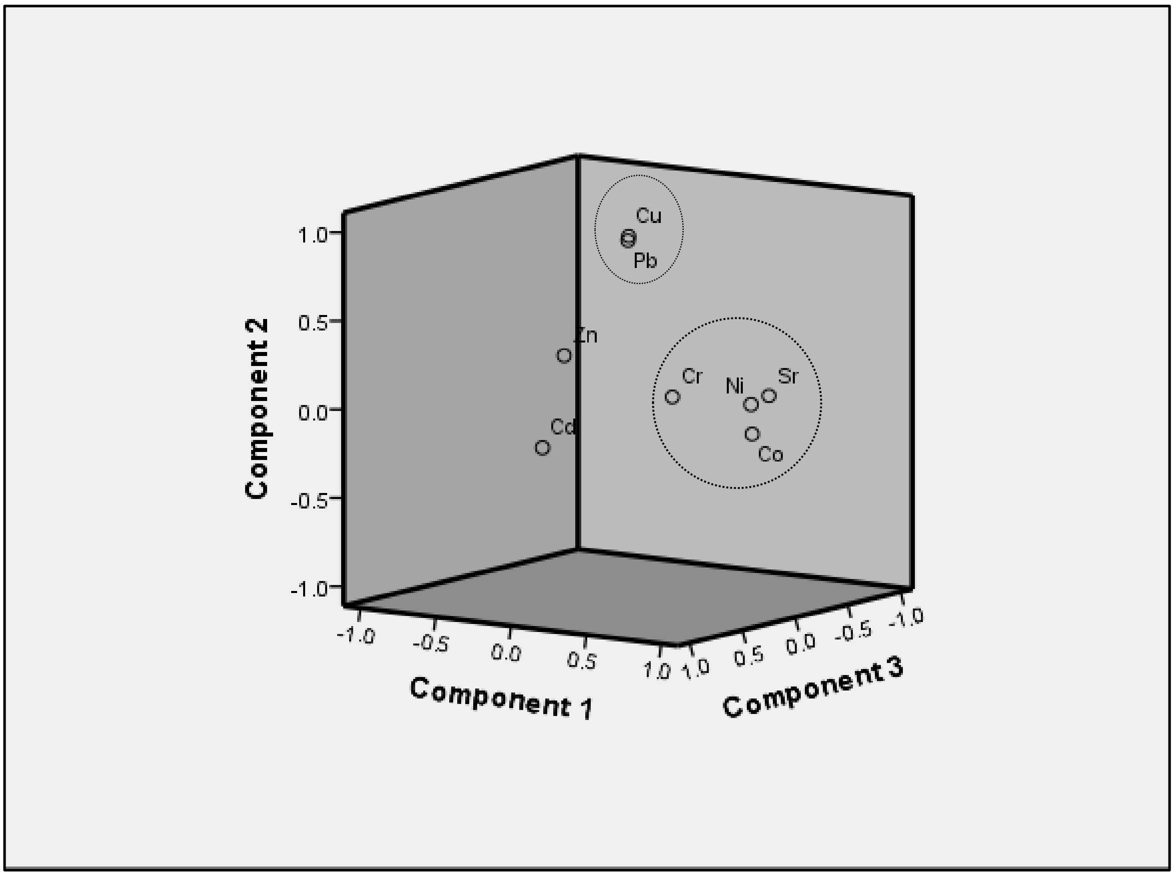


Figure 32. Three dimensional plot for PCA loadings of heavy metals

Hierarchical Cluster Analysis

Hierarchical cluster analysis (HCA) was used to identify similarities and dissimilarities between the concentrations of heavy metals. Adopting the average linkage cluster method, the results obtained from this analysis are presented in Figure 33. These results show three major groups. The first group comprises Ni, Co, Sr, and Cr which appears to come from bullets fragments and cartridges. The second group contains Cd and Zn; the third group includes Cu, Pb showing a very strong association. These clusters too reveal that Cd and Zn originate from the same source which is different from the source of Cu and Pb. These results confirm the association of heavy metals shown in Figure 33. In-depth analysis of these groups shows that Ni and Co are significantly correlated with each other, and Ni also show a strong relation with Sr. These heavy metals are later seen to form an association with Cr. Strong associations are also observed between Cd and Zn as well as Cu and Pb. It is clearly that these heavy metals originate from various sources which may include fuel spillages and bullets shells as well as terrigenous source.

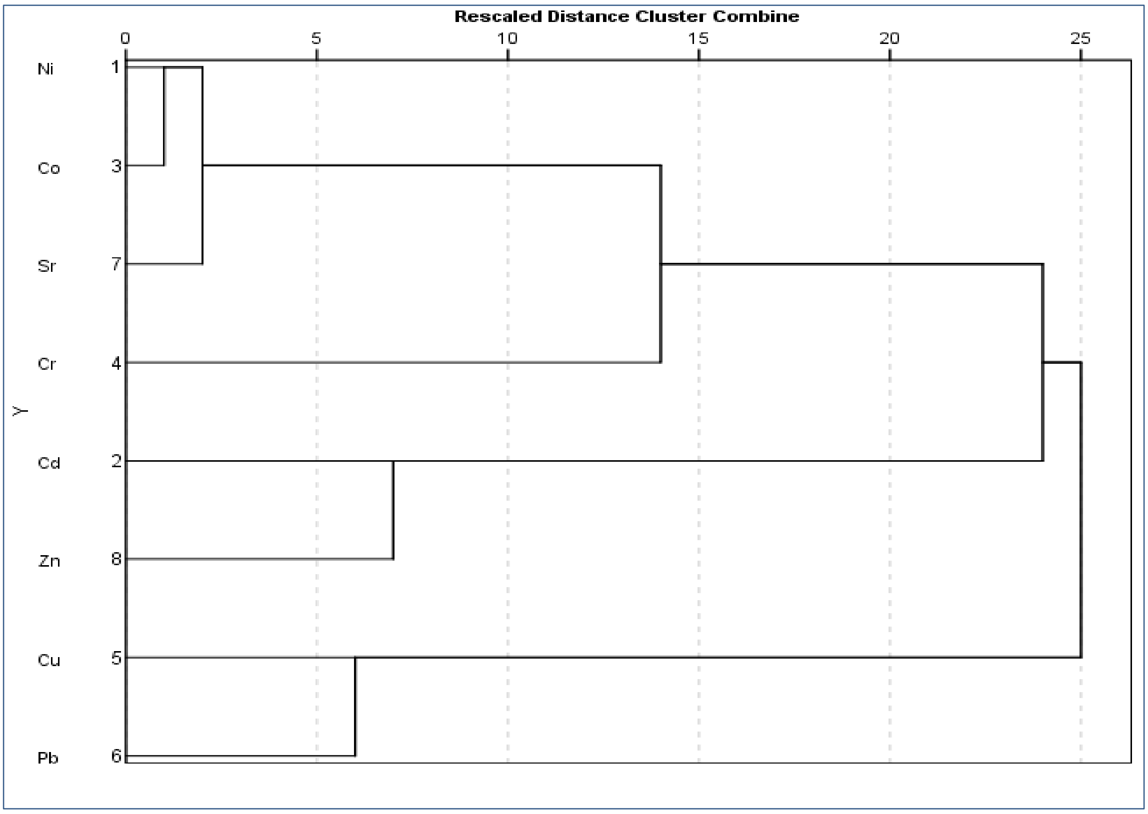


Figure 33. Hierarchical dendrogram of heavy metals concentrations

Discriminant Analysis

This statistical procedure was used to determine whether the concentrations of the heavy metals determined from sediments samples from the two military sites differed significantly. The results obtained from this analysis are presented in Table 20. Clearly the concentrations of heavy metals from the two military sites do not differ much as indicated by the statistical mean for each heavy metal variable. From the results in Table 20, Zn, Sr and Cr appear to be the most important heavy metals to discriminate for the "heavy military" site (i.e., SAACTC). On the other hand, the "light military" site (i.e., GMI) is discriminated by Pb, Cu, Zn and Cr.

Table 20. Discriminant analysis group statistics

Site	Element	Mean	Std. Deviation	Valid N (listwise)	
				Unweighted	Weighted
Heavy Military	Ni	23.3100	27.44630	30	30.000
	Cd	1.0900	2.46204	30	30.000
	Co	10.0567	12.73290	30	30.000
	Cr	**45.7000**	19.19797	30	30.000
	Cu	29.8467	29.31867	30	30.000
	Pb	26.0000	29.10739	30	30.000
	Sr	**52.9067**	**69.88897**	30	30.000
	Zn	**87.8433**	**148.40691**	30	30.000
Light Military	Ni	23.7620	12.64849	30	30.000
	Cd	1.8473	.83713	30	30.000
	Co	9.5633	3.55028	30	30.000
	Cr	**61.4667**	24.96305	30	30.000
	Cu	**169.4667**	**701.84878**	30	30.000
	Pb	**348.5833**	**1018.45111**	30	30.000
	Sr	43.4667	25.75713	30	30.000
	Zn	**79.4233**	**81.82005**	30	30.000
Total	Ni	23.5360	21.18854	60	60.000
	Cd	1.4687	1.86272	60	60.000
	Co	9.8100	9.27074	60	60.000
	Cr	53.5833	23.46602	60	60.000
	Cu	99.6567	497.49361	60	60.000
	Pb	187.2917	732.60051	60	60.000
	Sr	48.1867	52.43652	60	60.000
	Zn	83.6333	118.88737	60	60.000

Table 21 provides statistical evidence of the minor variation with regard to heavy metal concentration between means of the heavy military and light military site. In descending order Cr, Pb, Cd and Cu are showing relatively high F values in comparison to all the other heavy metals. According to Qishlaqi and Moore (2007), the larger the Wilk's lambda value, the greater is the within-group variation. The Wilk's Lambda statistics of the current study are relatively high and therefore suggest that there is a greater within-group variation. The Wilk's Lambda value for Ni in the current study is equal to 1, thus signify that Ni is insignificant in determining group membership (Nasir, 2013). According to Nasir (2013), the Wilk's value is accepted when it is less than or equal to 0.95. Thus, in the current analysis, Cd (0.958), Cr (0.885) and Pb (0.951) have significant role to distinguish heavy metals from heavy military and light military.

The F- value denotes the ratio of variation between and within groups (Sekabira *et al.,* 2010). The higher is the F-value, the greater is the variation from the mean or the means of the variables differ significantly (Sekabira *et al.,* 2010). It is clear from Table 21 that there is greater variation in the mean concentration of Cr ($F=7.520$, $p<0.008$) with that of other heavy metals. This heavy metal also confirms its significance in determining group membership. The other variables show no significant variation between group means of the heavy metals (F- value range from 0.007 to 2.544, while the p-value ranges from 0.935 to 0.116).

Table 21. Tests of equality of group means

Variable	Wilks' Lambda	F	df1	df2	Sig.
Ni	1.000	.007	1	58	.935
Cd	.958	2.544	1	58	.116
Co	.999	.042	1	58	.839
Cr	.885	**7.520**	1	58	**.008**
Cu	.980	1.185	1	58	.281
Pb	.951	3.007	1	58	*.088*
Sr	.992	.482	1	58	.490
Zn	.999	.074	1	58	.786

The results in Table 22 show that Cd-Cu and Cd-Pb pairs are negatively and weakly correlated. Strong positive inter-correlations are seen between Co-Ni, Cr-Ni, Cu-Pb, Sr-Ni, Sr-Co, and Zn-Cd pairs. All other pairs are indicating weak to moderate inter-correlations. Thus, there is no multicollinearity problem in the data.

Table 22. Pooled within-groups matrices

Variable		Ni	Cd	Co	Cr	Cu	Pb	Sr	Zn
Correlation	Ni	1.000	.215	.926	.641	.145	.152	.888	.319
	Cd	.215	1.000	.265	.089	*-.088*	*-.029*	.134	.669
	Co	**.926**	.265	1.000	.540	.015	.004	.857	.251
	Cr	**.641**	.089	.540	1.000	.073	.049	.483	.207
	Cu	.145	*-.088*	.015	.073	1.000	**.765**	.172	.441
	Pb	.152	*-.029*	.004	.049	.765	1.000	.201	.369
	Sr	**.888**	.134	**.857**	.483	.172	.201	1.000	.213
	Zn	.319	**.669**	.251	.207	.441	.369	.213	1.000

The results in Table 23 indicate that there are significant differences between the heavy metals concentrations from the two military sites. This is shown by the variation in the log determinants of these two sites. Furthermore, the value of Box's M is 581.213 with F-value of 13.758 which is significant at p<0.000.

Table 23. Log determinants and test results

Site	Rank	Log Determinant	Box's M		581.213
Heavy Military	8	40.624	F	Approx.	13.758
Light Military	8	48.129		df1	36
Pooled within-groups	8	54.398		df2	11319.368
				Sig.	.000

The ranks and natural logarithms of determinants printed are those of the group covariance matrices.

Since there are only two groups used in this study, namely "heavy military" and "light military" thus only one function is displayed [function is produced by number of groups minus 1(which can be expressed as *k-1*)]. The eigenvalue in Table 24a for the only function is equal to 0.671 (less than 1) and it explains 100% of the variance in the discriminant function. The canonical correlation is a measure of association between the groups of dependent variables.

In the current study, the canonical correlation in Table 24a is 0.634, indicating a moderate degree of correlation between the discriminant functions. It also suggests that the model explains only 40.1% [given by the square of the correlation coefficient, that is $(0.634)^2$] of the variation between-group. The Wilk's Lambda value is between 0 and 1; the lesser the value indicates the strength of the model to discriminate between variables (Verma *et al.*, 2012). Thus, the Wilks' Lambda value of the current study is 0.599 which indicates the significance of the discriminant function (Table 24b).

Consequently, it indicates that as high as 59.9% of the variability is unaccounted for, thus the model is relatively poor in discriminating between the group variables (groups have different mean values). However, the p-value associated with the chi-square function (of 27.714) is $p<0.001$, this denotes that the discrimination criterion between the two groups is significant. Thus, Tables 24a and 24b indicate that there is variation in the concentrations of the heavy metals from the two military sites, and the variation is significant at $p<0.001$.

Table 24. Canonical discriminant function and Wilks' Lambda

Table (a) Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	.671[a]	100.0	100.0	.634

a. First 1 canonical discriminant function was used in the analysis.

Table (b) Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	Df	Sig.
1	.599	27.714	8	.001

The canonical coefficients (unstandardized) presented in Table 25 indicates that Cd (0.635) is an important predictor variable to discriminate between the variable groupings. While all the other variables are far low, ranging from 0.001 (for Pb) to 0.036 (for Cr). Structure correlations are used to determine the relative importance of the variables in predicting group membership (Nasir, 2013). Thus, these correlations are systematic presented in the order of importance of the variables, thus, most important variable are at the top of the table and the least important towards the bottom of the table (Nasir, 2013). Accordingly, the structure matrix of the current study shows that the most important heavy metals are Cr (0.440), Pb (0.278), Cd (0.256) and Cu (0.175) which determines the group membership (Table 25). Therefore, these variables discriminate between the heavy and light military datasets. All the variables showing negative canonical coefficients, discriminants heavy metals from the heavy military grouping and vice versa.

Table 25. Unstandardized canonical discriminant coefficients and structure matrix

Canonical Discriminant Function Coefficients		Structure Matrix	
Variable	Function 1	Variable	Function 1
Ni	-.001	Cr	**.440**
Cd	**.635**	Pb	**.278**
Co	.011	Cd	**.256**
Cr	.036	Cu	.175
Cu	.001	Sr	-.111
Pb	.001	Zn	-.044
Sr	-.012	Co	-.033
Zn	-.011	Ni	.013
(Constant)	-1.703		

Table 26 present the standardized canonical discriminant function coefficients. The canonical discriminant function coefficient is a measure of the relative strength of the variables selected in the discriminant model (Verma *et al.*, 2012). The results of the current study indicates that Cd was the most important predictor variables for the two groupings (i.e., light military and heavy military). The other variables in a descending order that have discriminant power are Cr, Cu, Pb and Co. According to Verma *et al.*

(2012), the variable with a higher coefficient is more powerful in discriminating between groups. The other three variables that have least discriminant power are Zn, Sr and Ni (listed in the order of least important or power).

Table 26. Standardized canonical discriminant function coefficients

Variable	Function
	1
Ni	-.020
Cd	**1.167**
Co	.105
Cr	**.805**
Cu	**.544**
Pb	**.462**
Sr	-.643
Zn	-1.285

This analysis intended to differentiate between heavy metals determined from samples collected at GMI from those of SAACTC. This was performed by using the discriminant function. Thus, the new mean (group centroids) for both sites were generated. The new mean of the heavy military group is -0.805 and for light military group is +0.805 (Table 27). This indicates that the mid-point is zero (Verma *et al.,* 2012). A substantial discrimination between the groups is revealed by the standard deviation values of both groups. The standard deviations are 1.050 and 0.947 for the “heavy military” group and the “light military” respectively (Figures 34 & 35). The standard deviation of 1.05 indicates that the accuracy for the classification of the heavy military group is relatively high compared to that of the light military group with standard deviation of 0.947.

Table 27. Unstandardized canonical discriminant functions

Site	Function
	1
Heavy Military	-.805
Light Military	.805

The means for the transformed groups' centroid are graphically presented in Figures 34 and 35. The purpose was to obtain a model for classifying heavy metals into heavy military or light military groups. It is noted that there is no much overlap between the scores, they produce a normal distribution curves. This indicates that the function does adequately discriminate between the groupings (i.e, heavy military and light military). Accordingly, if the discriminant score of any heavy metal lies on the right of the midpoint (i.e., Z > 0) the heavy metal may be classified into light military group. Whereas, if the discriminant score lies on the left side of the midpoint, it means that the heavy metal may be classified into the heavy military group.

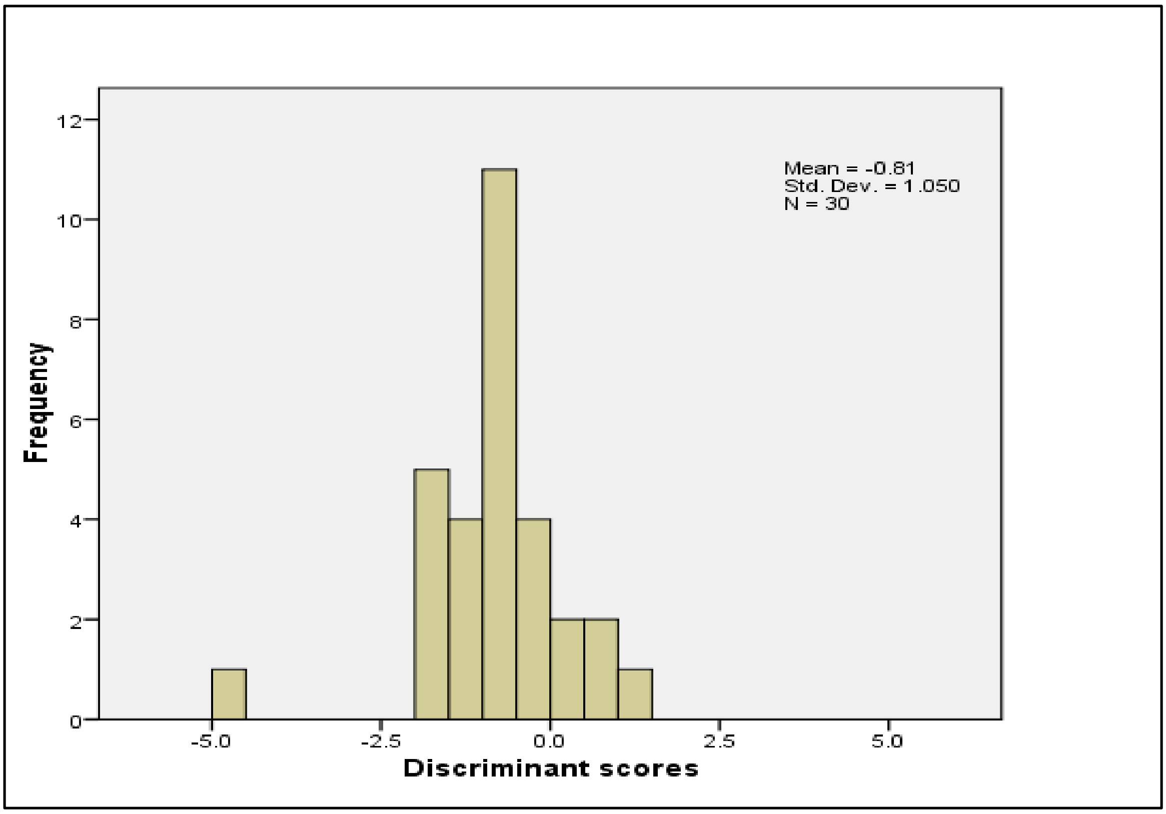


Figure 34. Distribution of discriminant scores for heavy military

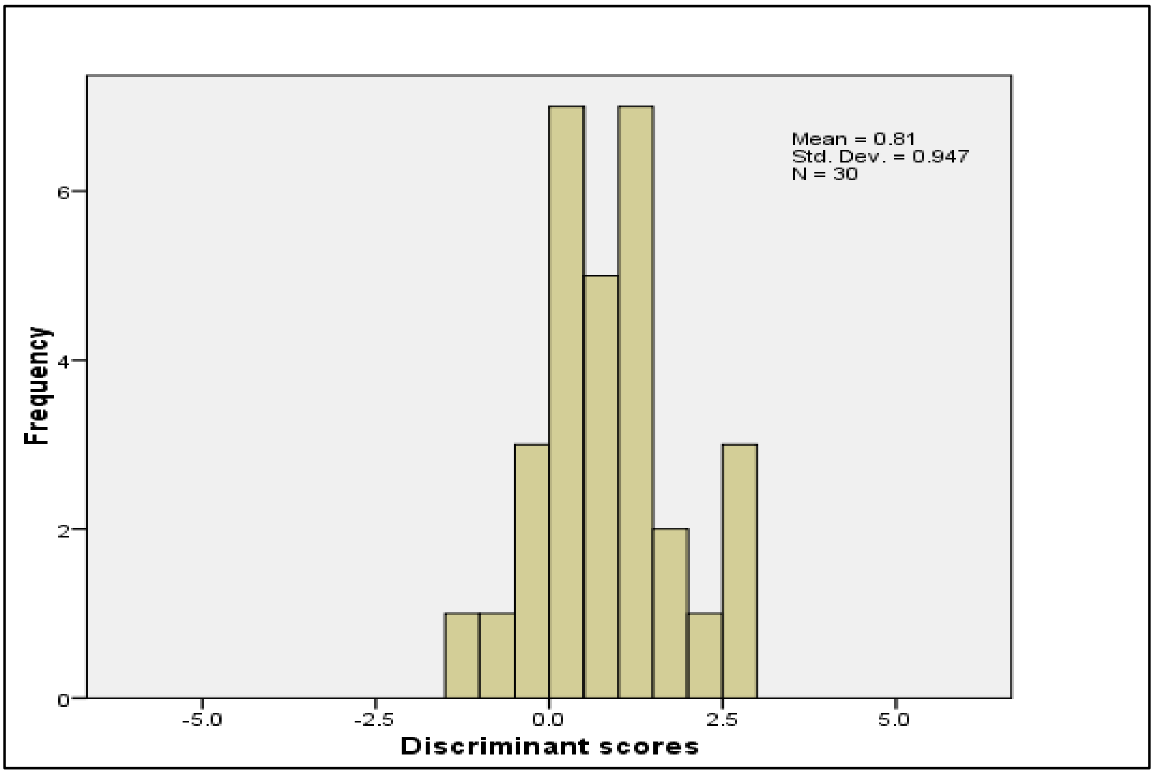


Figure 35. Distribution of discriminant scores for light military

It is clearly from Table 27 and Figures 34 and 35 that the group means are equal but lying in opposite side of the midpoint. The heavy military grouping lies on the negative side of the midpoint, whereas light military grouping lies on the positive side. Table 28 is a classification matrix which provides summary of correct and incorrect classification of heavy metals in both groups through the discriminant model. The classification results reveal that 83.3% of the heavy metals were correctly classified into “heavy military” or “light military” groups. Similarly, the heavy military was classified with better accuracy of 83.3% compared to 76.7% of the light military. The cross-validated classification indicates that overall 80% of the grouped cases were correctly classified. It appears that this is a good classification and thus it can be resolved that the model is efficient.

Table 28. Classification results [a,c]

Grouped Cases		Site	Predicted Group Membership		Total
			Heavy Military	Light Military	
Original	Count	Heavy military	25	5	30
		Light military	5	25	30
	%	Heavy military	83.3	16.7	100.0
		Light military	16.7	83.3	100.0
Cross-validated[b]	Count	Heavy military	25	5	30
		Light military	7	23	30
	%	Heavy military	83.3	16.7	100.0
		Light military	23.3	76.7	100.0

a.83.3% of original grouped cases correctly classified, c. 80.0% of cross-validated grouped cases correctly classified.

Change in Vegetation Cover at the Grahamstown Military Training Area

Satellite imagery for the years 1986 and 2014 for GMI were analysed investigating any changes in vegetation cover. Indeed, changes in vegetation cover over the 28 year observation period were noted (Figure 36). The shrubland show an increase of approximately 1.91%, bareland appeared to have increased by 1.85% from 1986 to 2014. Furthermore, dense forest appears to have decreased by approximately 3.24% during the observation period (Figure 37).

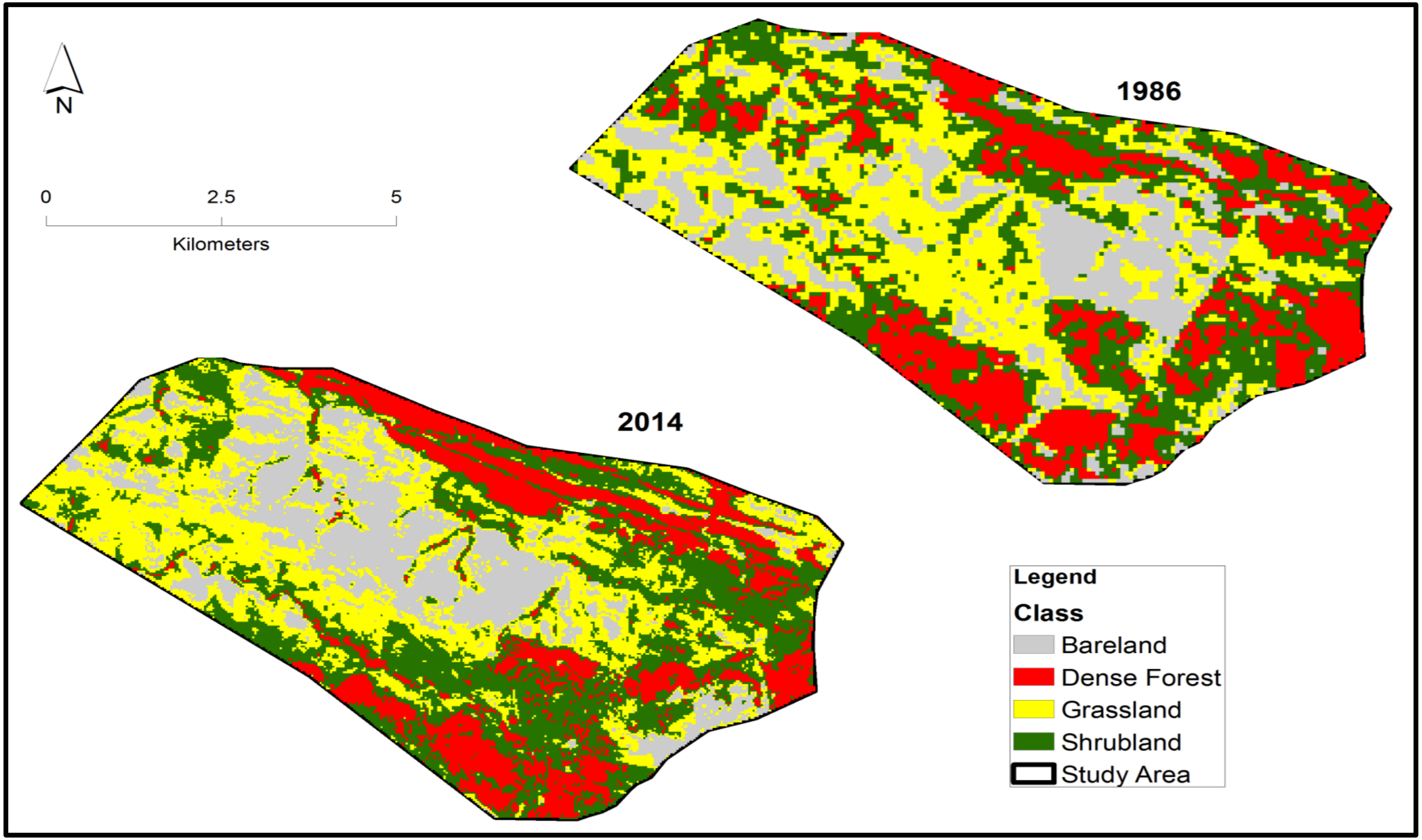


Figure 36. Changes in vegetation within the Grahamstown military training area

The increase in bareland is ascribed to increase in the frequency of military training activities as well as the increase in aggression of such activities. Decrease in dense forest (by 3.24% Figure 38) is attributed the project Vuselela which focusses on eradicating *Opuntia Indica* (commonly known as prikley pear) plant species within the military training area. As shown in Figure 37, the military training area is infested with *Opunita Indica*, thus making some sections of the training area inaccessible. The inaccessibility of certain sites hinders infantry training exercises, thus, the need to eradicate the *Opunti indica* plant species.

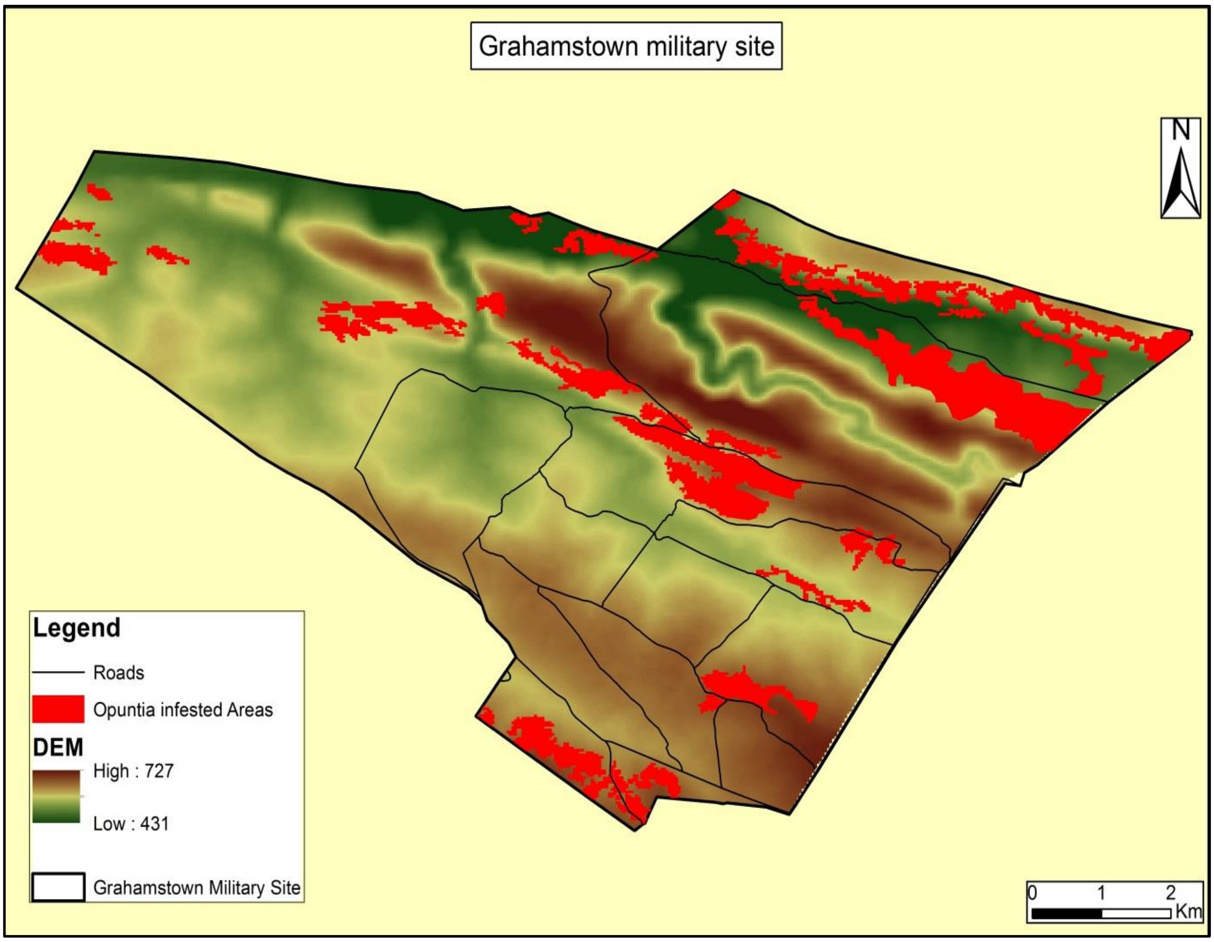
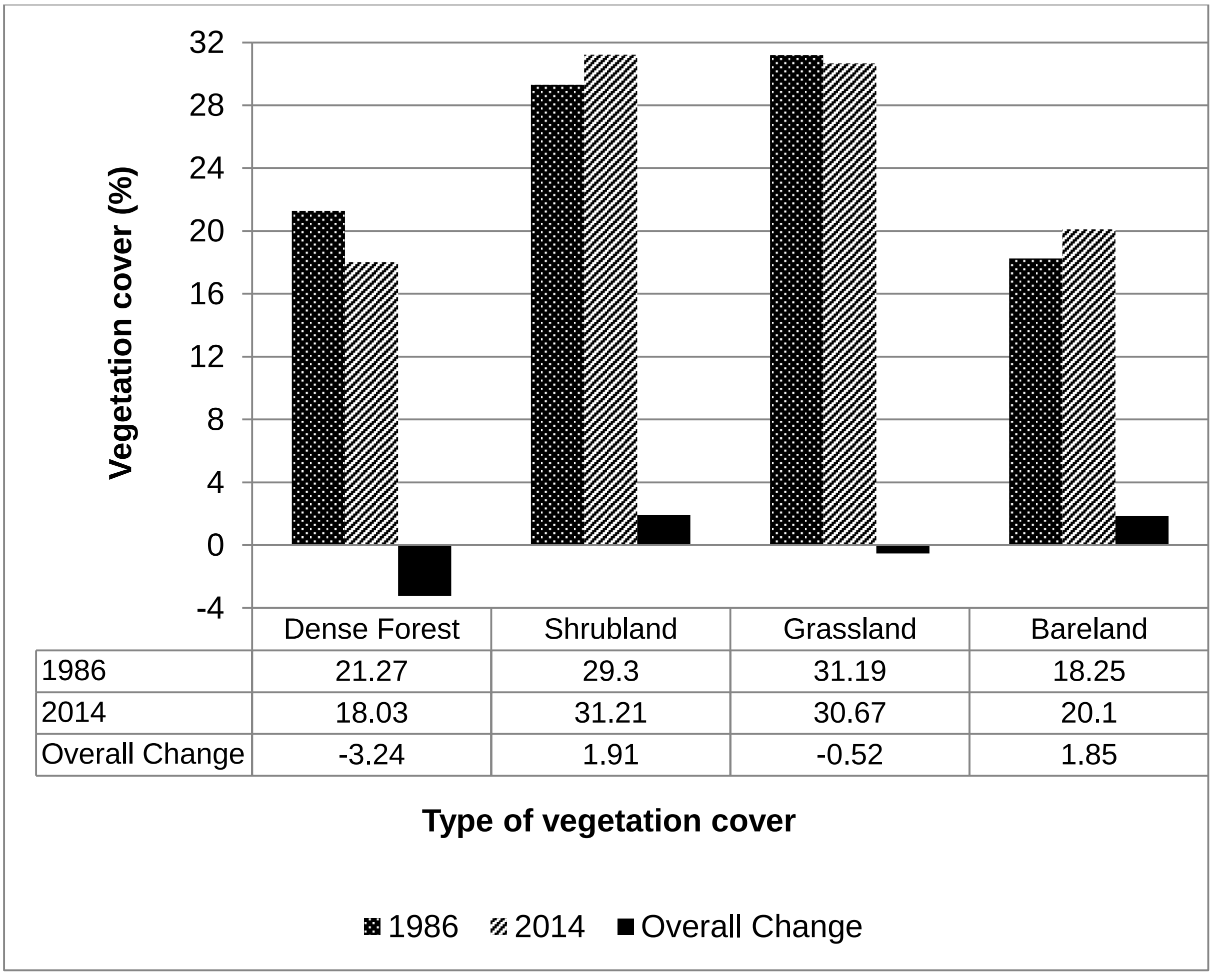


Figure 37. Spatial distribution of *Opuntia Indica* at GMTA
(Source: Adapted from Dyasi, 2015)

The grassland (not including agricultural land use, since the area of study is a military training area) appears to have shrunk by 0.52% (Figure 38). The shrinking of grassland surface is linked to the increase in shrublands which appear to have encroached onto areas which were previously grasslands. Undoubtedly, the greater proportion of the grassland has become bareland given the substantial increase of this ground cover type. It can also be assumed that a certain portion of the grassland have been colonised/encroached by shrubland which also show increase over the period.



	Dense Forest	Shrubland	Grassland	Bareland
1986	21.27	29.3	31.19	18.25
2014	18.03	31.21	30.67	20.1
Overall Change	-3.24	1.91	-0.52	1.85

Figure 38. Percentage change in vegetation cover at Grahamstown military training area

Change in Vegetation Cover at the SAACTC Military Training Area

The change in vegetation cover for the SAACTC training area was assessed from the satellite images for the years 1991 and 2014. This reason for not using satellite images of similar years was availability of the data. Figures 39 and 40 show that in 1991, about 35.7% of the SAACTC training area was dominated by grassland. Thick vegetation (dense forest) constituted 54.43% of the surface area of the training area; while bareland surfaces accounted only for 9.87%. The land cover surface conditions appear to have changed between 1991 and 2014.

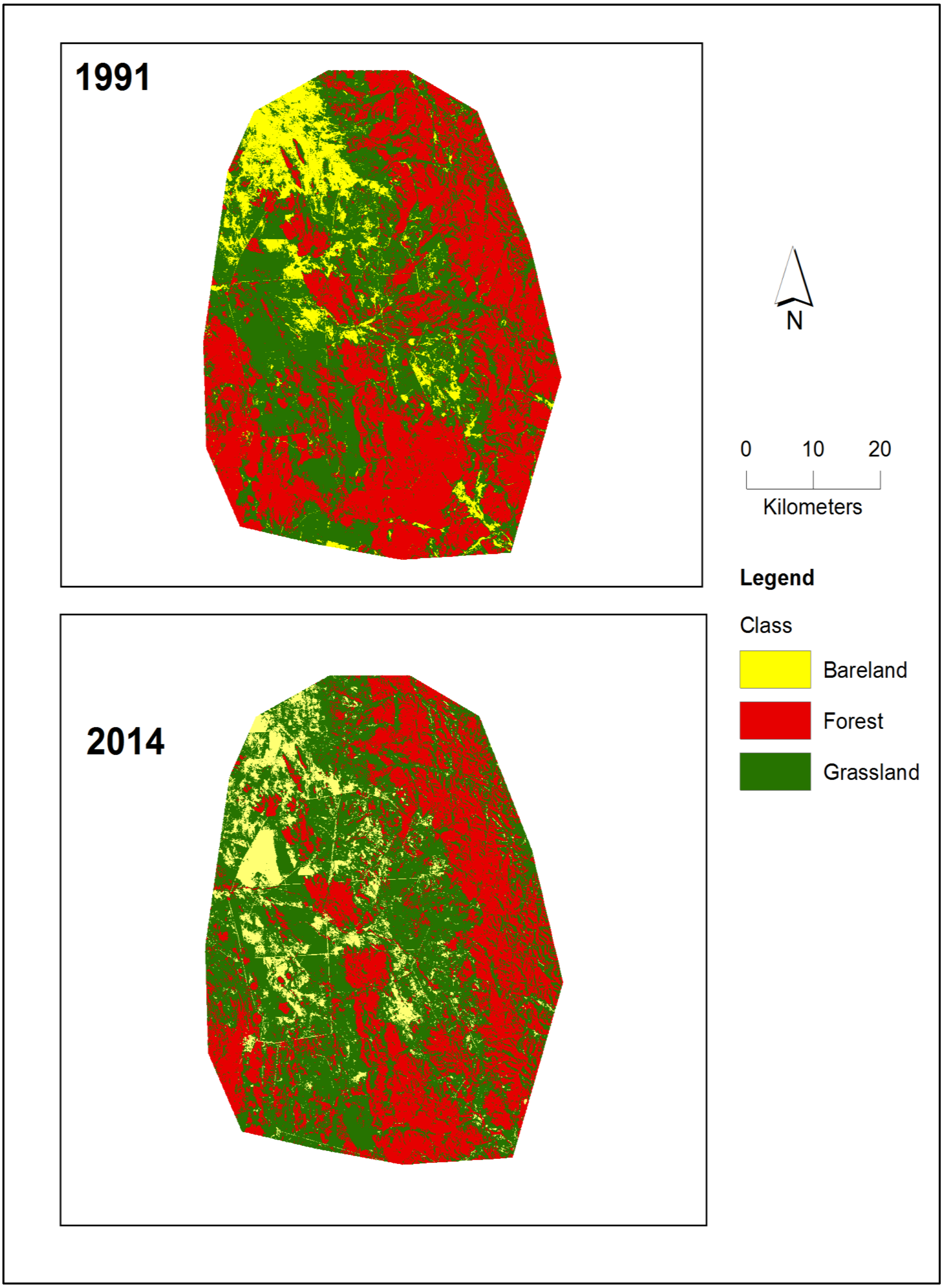
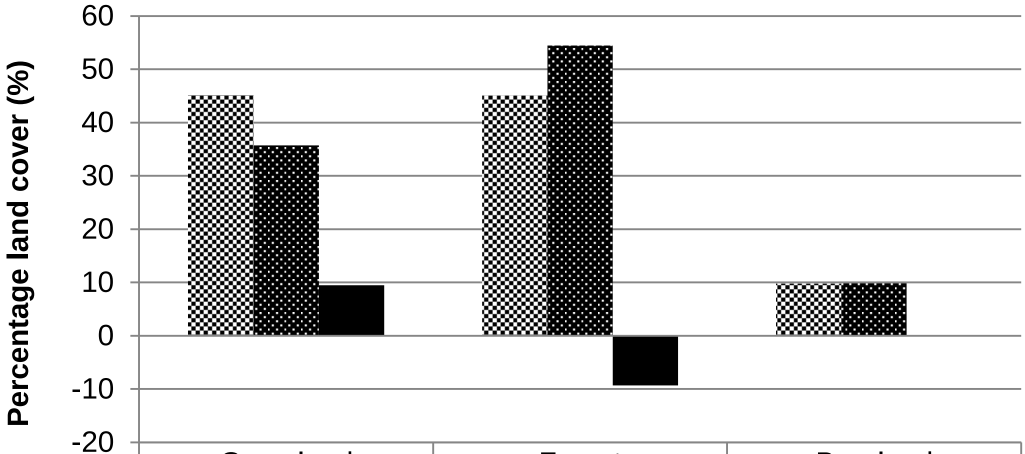


Figure 39. Variation in vegetation cover within the SAACTC

The degree of change in vegetation cover within the SAACTC training area is shown in Figure 40. The dense vegetation cover (forest) decreased by 9.33%, whereas grassland vegetation increased by 9.45%. At the same time the bareland surface decreased by 0.11%, which could be linked to the increase in the grassland vegetation cover. The decrease in dense vegetation can be associated with the increase in the veld fire frequency reported in the environmental reports at SAACTC.



	Grassland	Forest	Bareland
2014	45.15	45.10	9.75
1991	35.70	54.43	9.86
Total Change	9.45	-9.33	-0.11

Figure 40. Magnitude of vegetation in SAACTC training area

Summary

This chapter has presented the analysis of the data collected through the attitudinal questionnaires. These data were analysed by plotting graphs using the percentages of each response option per statement. The attitudinal responses from GMI and SAACTC were further compared to note any trend in the responses provided by the respondents. Variations in the trends were noted. The data were also divided into five categories and analysed. These categories were: environmental education and training, availability of resources, processes, procedures and practices, enforcement and compliance as well as compatibility.

In addition, ANOVA statistical procedure was also performed to ascertain variations if the responses received/provided by the GMI respondents. Furthermore, the same procedure was used to establish whether or not there were any significant variations in the responses given by military personnel in different military ranks as well as between military service periods. No significant differences were found in the responses of respondents at GMI in different military ranks. Significant differences were noted between military service period and the mean of the responses at GMI. From the SAACTC data no significant differences were noted in both cases.

The concentrations of heavy metals were determined from soil and water samples collected from the two military training areas. Water samples from both military training areas were characterized by remarkably low and constant heavy metal concentrations. This was unexpected because the two military training areas are different. The GMI is a light infantry training area where limited heavy military training is rarely undertaken, thus, low concentration of heavy metals may occur. Whereas the SAACTC is a heavy military training area, where high caliber weapons are used, therefore, more concentration of heavy metals could be expected. Consequently, no statistical procedure yielded meaningful results.

Concentrations of heavy metals determined from surface sediments were analysed using multivariate statistics. Pearson's correlation function produced various correlations for different heavy metals. These correlations varied from weak, moderately weak to very strong. All those elemental pairs showing strong correlation with each other were presumed to be sharing the same contamination source.

The principal component analysis (PCA) extracted four components with varying loading factors. The communalities of PCA revealed that the loading percentages for the heavy metals vary from 99.7% to 85.4%. Subsequently, a three dimensional plot for PCA loadings of heavy metals was plotted which revealed how the elements are associated. Moreover, hierarchical cluster analysis (HCA) was used to identify similarities and dissimilarities between the groups of heavy metals. The dendrogram of the HCA confirmed the association revealed by the PCA's three dimensional plot that the heavy metals in both military training areas have different sources.

Results of the discriminant analysis clearly indicated that the two military training areas show differences in the concentrations of heavy metals. Discriminant factors for the heavy military group are Sr and Zn, while Cu and Pb are discriminants for light military group. The heavy military was classified slightly better with accuracy of 83.3% compared to 76.7% of the light military. However, only 40.1% of the variation between-group is explained, while the greater proportion (59.9%) of the variability is unaccounted for. However, it has been established that there is a statistically significant difference between the mean of the heavy metal concentrations ($p<0.001$) from the two military training areas.

Analysis of satellite imagery for the years 1986 and 2014 show changes in vegetation cover over the 28 years period. Bareland appear to have increased by 1.85% within the period of observation. Conversely, dense forest has decreased approximately by

3.24%, and this decrease has been attributed to the eradication of prikely pear within the military training area. However, the 1991 and 2014 images for the SAACTC revealed more increase in the grassland ground surface cover and decrease in both the dense vegetation and bare land surface classes. The increase in grassland is attributed to the frequency of veld fires igniting during training activities. This is a clear indicates that the SANDF need to have a fire management plan. The frequency of veld fire during threatened the ecological integrity of the SAACTC.

It is worth noting that the discussion chapters are divided into two. Chapter VIII, which is the next chapter, discusses the qualitative results presented in Chapter VI. Therefore, the results presented in this chapter are only discussed in Chapter IX.

CHAPTER VIII

DISCUSSION: MILITARY ACTIVITIES AND ENVIRONMENTAL MANAGEMENT APPROACHES IN THE SANDF

Introduction

The discussion of the results has been difficult, due to the overlap between the issues being investigated in the study. The discussion of the results does not follow the sequential order of the specific objectives outlined in Chapter I. Instead, themes were identified under which the results are discussed. The nature of this study and the kind of data collected determined that the results be presented in two different chapters; consequently, this chapter provides a discussion of the results of the qualitative data presented in Chapter V. The discussion of these results is divided into three parts. The first part discusses the results obtained from GMI, the second part focuses on the results obtained at SAACTC. Furthermore, the third part presents the discussion of the results elicited from official documents, which also incorporates the results of the comparative analysis of the case studies.

CONTEXTUAL BACKGROUND OF THE DISCUSSION

The history of environmental management of the SANDF is described by Godschalk (1998) and Smit (2009). Smit (2009) explains that in 1977, national concern for the environment led to the first instruction to the SADF (as it was then called) to care for the environment under its control. In 1978, the first South African Defence policy on environmental management was formulated (Godschalk, 1998; Smit, 2009). Two decades later, after the first instruction to the SANDF to care for the environment was issued, NEMA was enacted and made it mandatory for any entity that might affect the environment to compile an EIP for its operations. To this end, the DoDMV has since developed two editions of its EIP. The DoDMV published its first edition of EIP in 2001 and its second edition was published in 2008. Thus, with the enactment of NEMA, the environmental management approach of the SANDF has changed significantly from conservation to integrated environmental management (Smit, 2009). Therefore, the argument presented in this thesis relates to the extent to which the activities of the SANDF have evolved to provide for the considerations and integration of environmental issues within military activities.

Attempts to Reduce and Prevent Environmental Contamination at GMI

The interviews conducted at GMI provided information that reveals its consideration of pollution prevention practice. The inspection of the environmental conditions carried out before a training exercise commences is noble in assessing the potential impact of military training activities. This creates an opportunity for designing/planning and implementing mitigation measures for the potential impacts that have been identified. Evidence of this practice at GMI was only observed for Exercise Shared Accord. Under normal circumstances, or current expectations, this should be the *modus operandi* for all military planning exercises. This will ensure the sustainability of the military training area by reducing pollution and minimising the destruction of sensitive ecosystems. The growing demand for effective and integrated environmental management in military training exercises is, in part, about reducing environmental pollution (Wang & Wu, 2013). Each military exercise ought to have its own environmental management plan. This would be indicative of compliance with the environmental regulations and laws of the Republic of South Africa. At GMI, no documentations were made available to confirm this practice. The absence of supporting documentation may imply that most of the training activities are carried out without environmental considerations being taken into account. Environmental considerations are regarded as any set of measures or processes put in place to ensure the avoidance or minimisation of adverse impacts likely to occur on the environment during military activities (ESWG, 2006). Thus, Wang and Wu (2013) argue that the consideration of environmental issues, in any operation of an organisation, indicates that the activity is performed in an environmentally responsible manner.

The practice of collecting and removing all waste material (including bullet cartridges and unexploded munitions) after a training exercise is also within the best practices of environmental protection from contamination. Bullet cartridges contain heavy metals such as lead (Pb) and copper (Cu) (Greičiūtė *et al*., 2007). Therefore, removal of cartridges from the ground surface after training exercises reduces the introduction and accumulation of these elements in the soil. These metals (Pb & Cu) can also pollute water sources through mobilisation by wind and surface runoff which eventually settles at the bottom of water sources (Abdullah *et al.*, 2007; Duruibe *et al.*, 2007). This further poses a more serious environmental problem, which is that they are eventually absorbed by plants and bio-accumulates in their cells (Purushotham *et al.*, 2012).

The approach adopted before the start of Exercise Shared Accord, in July 2011, shows attempts towards pollution prevention. Dripping pans and secondary containments were used as measures to ensure that the soil and water are relatively protected from potential pollution. These measures were used specifically where there was significant risk of pollution. High risk areas included the refuelling bunkers and the location of the power generating engine. Furthermore, the bunkers and the power generator were located far away from water sources, thereby reducing the possibility of water contamination through fuel, oil leakages and spillages. These products contain heavy metal pollutants such as Pb and Cd (Greičiūtė *et al*., 2007). Thus, the risk of direct environmental pollution was, to a certain extent, mitigated. The prevention of contamination, resulting from fuel spillages and oil leakages, reduces the rate of heavy metal introduction to the soil and it needs to be prioritised.

Impact of Military Training on Soil and Vegetation Cover

Like any other military training exercise, Exercise Shared Accord left its own scars on the ground surface at the Grahamstown military training area (GMTA). Military training areas are significantly impacted where tanks and other heavy equipment are used, and where foot traffic is high (Whitecotton *et al.*, 2000). Nyakatawa *et al.* (2011) also indicate that the use of vehicular equipment on military lands can have a significant impact on the natural vegetation. Ramos *et al.* (2007) argue that military activities have significant potential to harm the environment in a highly visible manner. Indeed, this was the case during Exercise Shared Accord, after which considerable physical disturbances were discernible on the ground surface.

Ruts as deep as ½ meter were visibly criss-crossing the ground surface in the training ranges where Exercise Shared Accord was carried out. This military training exercise was carried out during rainy days, thus deep ruts were formed. These ruts were formed by military vehicles (i.e., wheeled vehicles) which normally weigh between 55 tons (55 000kg) and 65 tons (65 000kg). Sample *et al.* (1998) argue that these military vehicles are destructive to vegetation, particularly when moisture content is high; this also accounts for the formation of deep ruts on the ground surface. The formation of the ruts, and reduction of vegetation cover, creates conditions for sediment entrainment by surface runoff. Military impacts often result from the direct removal of vegetation through various activities, such as the digging of trenches and foxholes, which disturb the soil, as does heavy infantry traffic (Silveira *et al.*, 2010). The target points, as observed in GMTA, also show high levels of disturbed surfaces. Surfaces such as these could become sediment sources due to the level of soil disturbance and lack of vegetation cover (Quist *et al*., 2003; Tikhomirov, 2006). Garten *et al.* (2003) argues that the disturbance of soil structure and the alteration of the physical properties of the soil is a common impact associated with the use of heavy vehicles in military training areas. Consequently, military training exercises that involve vehicular manoeuvres leads to loosening of soil and destruction of vegetation, which increases the potential for soil erosion (Haugen *et al.*, 2003). High levels of ground surface disturbance also create an easy route for heavy metal pollutants to reach the groundwater (Greičiūtė *et al*., 2007). Studies such as those conducted by Diaz and Massol-Deya (2003), Greičiūtė *et al*. (2007), Robinson *et al*. (2008), Matias *et al.* (2009) and Ahmad *et al.* (2012) have shown that military training areas have surfaces that are contaminated with heavy metals. There are numerous sources of heavy metals, other than fuel spillages and oil leakages, in these areas. Heavy metal contamination in both military training areas is discussed in the next chapter.

Quist *et al.* (2003) and Tikhomirov (2006) argue that typical military training includes manoeuvres by large vehicles that traverse vast areas in a single training exercise, thereby causing various impacts onto the components of the environment. These impacts vary from soil compaction to total loss of vegetation cover. These are some of the impacts that cannot be avoided during military training activities. Nonetheless, military vehicles should be driven through developed roads and trails. This can reduce the impact on vegetation cover and the ecological impact, in general. Studies have shown that an increase in bare soil surfaces in military areas increases with the intensity and frequency of military training activities (Quist *et al*., 2003). This signifies the severity of military activities on vegetation cover.

However, not all types of vegetation are stressed by military activities. There are those that thrive under such constant disturbances and others that are highly sensitive. It was noted during the field observation after Exercise Shared Accord between SANDF and US Marines at GMI that though there was severe disturbance of the ground and damage to vegetation, some were starting to grow and appeared healthy. Vegetation that grows where military training exercises are carried out are disturbance-dependent and/or disturbance-averse species (Warren *et al.*, 2007). Warren *et al.* (2007) further state that disturbance-sensitive plant species normally do not grow where there is constant disturbance of the ground surface on the military training area.

Consequently, disturbance-sensitive plant species prefer to grow, and are found, in high laying sections of the military training area where physical disturbances of the surface are relatively infrequent. Thus, these vegetation found growing after that training exercise are GMI training area, are the disturbance-dependent species. According to Quist *et al.* (2003), the cumulative military disturbances result in the reduction of the abundance of perennial species, but they cause an increase in the abundance of introduced species. Thus, some of the ecological habitats are significantly altered while others are completely destroyed by military training activities.

Furthermore, the disturbance on the surface makes it easier for heavy metal pollutants to find their way to underground water sources (Greičiūtė *et al*., 2007). Likewise, the physical disturbance of the land area on military training ranges provides a habitat suitable for disturbance-averse and disturbance-dependent species (Warren *et al.*, 2007). Certainly, in both military training areas, this became very clear. In sections where there is continuous military activities are carried out, vegetation cover is sparse and characterised by herbaceous species. But highly lying areas, showed very dense vegetation cover comprising of woody plant species.

The backfilling of trenches dug during the military training exercise is commendable. Tikhomirov (2006) reports that certain areas where military training and/or operations took place, fighting trenches, communications trenches and antitank trenches were left open. Thus, to avoid a similar situation, the trenches dug during military training should be back-filled, because trenches that are not rehabilitated would significantly alter the hydrological processes within training areas and training ranges. Military training usually involves large vehicles which tend to increase both surface disturbance and sediment input to stream, due to high levels of soil compaction and increased exposure of the bare soil surface (Quist *et al.*, 2003; Silveira *et al.*, 2010).

Efroymson *et al.* (2005) indicate that tracked and wheeled military vehicles' movement, explosions, infantry movement and creation of a road can enhance soil erosion, thus prompting sedimentation in streams. The study conducted by Quist *et al*. (2003) establishes that there is a strong correlation between the alteration of military land surface and stream degradation through sedimentation. Thus, military activities, such as training, not only have an on-site effect, but can create both severe and prolonged disturbances in ecosystems surrounding military sites (Linkov *et al.*, 2001). Silveira *et al.* (2010) argue that soil disturbance enhances sediment transfer, thus leading to sedimentation problems which aggravate the off-site ecological impacts associated with military activities.

Field observation conducted at GMI show that, in some instances, the backfilling of trenches was not carried out before troops withdrew from the training area. The trenches dug during Exercise Shared Accord were still opened although it was three weeks after the exercise had ended. According to Johnson *et al.* (2011), military training activities inevitably lead to the degradation of natural resources and land conditions, including an increase in soil erosion, the destruction of ecological habitats and fragmentation of the landscape.

Silveira *et al.* (2010) argue that, due to their nature, military activities may degrade and fragment ecological resources and thus put species at risk. Thus, all trenches should have been back-filled before the troops withdrew from the training area. Their existence isolated the population of crawling species and thus interrupted horizontal ecological flows (Forman & Alexander, 1998). The failure to backfill the trenches compromised the ecological integrity of the training range and indicated a lack of environmental protection and rehabilitation. The modification of ecological patterns and destruction of habitats have significant effects on crawling species (Gerlach & Musolf, 2000). The development of roads and new trails in military training areas further fragments habitats between certain species (Froymson *et al.*, 2005).

The failure to backfill the trenches was indicative of the inadequate monitoring and enforcement of acceptable environmental practices during military training exercises. It can therefore be argued that this happened because the environmental officers who inspected the range before the start of the exercise had departed from GMI. Thus, the person left in charge to ensure that the withdrawal process is carried out, as per the guidelines, failed in executing these responsibilities. It is a cause for concern that a clearance certificate was issued to certify that everything was in order, while the trenches and waste had not been attended to. This casts doubt on the credibility of some of the information provided by some of the respondents in this study, especially where supporting evidence was not available.

Removal of Solid Military Waste from the Training Ranges

The inappropriate disposal of military waste is not in line with environmental protection and sustainability. Evidence of inappropriate disposal of military waste was noted at GMI. Numerous solid waste materials, mainly bullets cartridges, were found lying on the ground in one of the training ranges. In one instance, an unexploded munition was observed stuck in the bushes. This situation in the medium to long-term has far reaching implications, which include an increase in the accumulation of heavy metals in the soil.

The long-term impact relates to the contamination of ground water reserves and an increase in the cost of cleaning-up, should the land be returned to civilian use. Accordingly, the various instances of contamination and pollution caused by previous military training activities, by and large, constricts future non-military re-use of former military installations (ESWG, 2000). Furthermore, the inadequate execution of environmental inspection and compliance with the environmental regulations of the SANDF can be attributed to an existing commitment or lack of to improve the protection of the environment by the personnel in the EMF. Other solid waste material included the “1000 feet illumination flare” used in military training, which was hanging on a tree, and detonating wire cables that were not collected during the sweep clean after Exercise Shared Accord. This can be described as poor - or lack of - environmental protection practice, which is not in line with the pro-active approach to environmental management.

In addition, the unit or company that was training is issued a certificate in order to ensure that no environmental hazardous materials are left in the training range. For some reason, this process is carried out without the inspection of the training range, thus making a mockery of the attempts to protect the environment from harmful military waste disposal. Logically, the clearance certificate must be issued once the personnel in the EMF, together with the military readiness officer, have inspected the range and are satisfied with the sweep clean process carried out by the out-going training troops after using the training range. The military readiness officer also has the responsibility to ensure the long-term continuation of environmentally appropriate range management practices (ESWG, 2000).

Therefore, stringent monitoring efforts can significantly assist in inculcating accountability to unit commanding officers and trainers. Such efforts will enhance the long-term military use of the training area and force preparation. Furthermore, it will also ensure the long-term sustainability of military ranges, thereby reducing the pressure for the need for new military land (ESWG, 2000). However, the criticism cannot only be directed to the designated environmental officers (DEO). The Department of Defence and Military Veterans also has to play its role fully and adequately by providing all the necessary facilities to the EMF for the effective enforcement of environmental management practices in military activities. The basic facilities required by the EMF to execute its responsibilities effectively include adequate financial support, suitable vehicles and sufficient environmental training.

Major Challenges in the SANDF Environmental Management

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For the SANDF to effectively integrate environmental protection practices into its activities, and to improve its environmental performance, it needs to plan and budget accordingly. It became evident, from the interviews that five critical elements needed to be considered in the military environmental management planning process. These included appropriate financial planning and allocation, the acquisition of skilled human resources, strengthening of internal organisational structures for coordination purposes, updating internal policies in line with the national legal framework as well as establishing and maintaining external linkages with environmental experts and practitioners. These issues are discussed in the sections below.

Funding for Environmental Management Services

Environmental funds are one of the most important tools for the effective implementation of environmental management in any organisation. According to Wang (2011), the availability of financial resources is a cause of effective environmental management. Thus, private organisations have what they call 'social responsibility funds' which are used to finance external environmental management programmes. The democratic government of South Africa has promulgated numerous laws for the protection and sustainable utilisation of the country's natural resources. Some of these legislative provisions governing the daily practices of defence force are discussed in the section on the legislative framework, below.

The interview with the senior staff officer for Environmental Management Services and the analysis of both EIPs (2001 & 2008 editions) revealed that, generally, the entire DoDMV does not have a specific budget for its environmental programmes and services. As a result, even the SANDF does not have a budget allocation for environmental management services. Environmental services at the GMI are funded from a miscellaneous account. This practice does not promote effective and adequate environmental management by the defence force. In addition, it does not encourage sustainable utilisation of the natural resources within defence installations, as can be seen at the GMI.

Defence forces in other countries have an environmental budget. For example, the US Department of Defence (USDoD) spends billions of dollars on environmental programmes every year (USDoD, 2004). Similarly, countries such as Portugal, Australia, the United Kingdom, Spain, Sweden and Canada adequately fund the environmental management efforts of their respective defence forces (Ramos & de Melo, 2006).

In the SANDF, the costs associated with environmental management in defence activities have not been sufficiently internalised and are integrated with the expenditure associated with other functions. As a result, this has obscured the true environmental expenditure of the SANDF (RSA DoD, 2008). Indeed, the GMI could not show evidence of environmental expenditure for its environmental management services. Moreover, there should be specific environmental management programmes at each installation linked to the EMS or advancing the corporate environmental statement of the DoDMV. Officials involved in the management of the environment at the GMI stated that it is very difficult to get funding for activities related to environmental management. This obviously discourages defence force members who are responsible for the environment. These people cannot be expected to provide leadership in ensuring that the environmental impact of defence activities is minimised to an acceptable level, if the necessary resources are not made available.

This lack of funding is astonishing because the first directive to the SANDF to care for the environment under its control was issued in 1977 (Godschalk, 1998; Smit, 2009 & 2011). This instruction led to the development of the first environmental policy for the South African Defence Force (SADF) in 1978 (Godschalk, 1998; Smit, 2009 & 2011). By now, all environmental facilities of the SANDF should have been fully operational and well resourced. For more than three decades, the SANDF has failed to design a proper plan to finance environmental management programmes. Consequently, the GMI did not have an ongoing environmental management programme linked to the implementation of the EMS for defence. This indicated that the SANDF was facing serious challenges in the implementation of the EMS at the GMI, mainly due to insufficient resources to sustain the environmental services, which is a critical factor in the successful implementation of environmental management tools.

Abrahams (2008) points out that the defence budget has gradually decreased every year. This could be associated with other priorities of government, including building houses, schools, clinics, infrastructure (water, power supply to rural areas, roads), and so on. Considering the importance and urgency of these challenges, it makes sense to rank them high on the priority list, over and above environmental protection from military activities. It will only be after all these necessities have been addressed that focus can shift towards environmental protection (Harmse, 2003).

Wang (2011) points out that financial resources are the foundation of effective environmental management. It is therefore imperative that the DoDMV find an alternative source of funding to make sufficient funds available in order to finance its environmental needs and programmes for the protection and promotion of environmental sustainability. For example, Poland has developed what is called Environmental Funds, which are aimed at improving the implementation of its National Environmental Policy (Unido.org, 2012). The revenue sustaining these funds comes from various sources, including environmental fees, fines for breaching environmental regulations and non-compliance, banks, the Global Environmental Facility, and so on.

According to the Organisation for Economic Co-operation and Development (OECD, 2005), finding additional sources of funding for environmental policy implementation is very important to offsetting budgetary cuts in the short to medium term. The South African government can also develop a similar scheme to offset setbacks created by budgetary cuts, to assist the SANDF, particularly in its quest to meet its environmental management obligations. Defence force activities are by nature aggressive; therefore, it is important that the SANDF must have an effective environmental management strategy. Moreover, the implementation of the strategy hinges strongly on the availability of all forms of resources.

Qualified and Competent Personnel in EMF

As of July 2011, the GMI did not have environmentally qualified and competent staff in its environmental management facility. The majority of the personnel at the facility did not even have working knowledge of environmental management issues. These are the people who are expected to provide guidance on the incorporation of environmental concerns into military activities at all times. Smit (2009) reports that the national service system had been terminated and that the present environmental services personnel structure consists of permanent force members. This has provided much-needed continuity in dealing with environmental issues in defence (Smit, 2009). However, it was established that the GMI has been without a permanent environmental officer for approximately two years. Clearly, there is an urgent need for the SANDF to develop and/or enhance the competence of its environmental management staff if it is to succeed in honouring its environmental obligation.

It must also be noted that the successful implementation of EMS within the SANDF depends largely on the environmental capabilities of the members of the defence force. The members are the most important resource upon which the success or failure to translate environmental policies, plans and programmes depends. Without environmentally qualified and competent staff, the SANDF will not be able to achieve its aim of implementing EMS and adequately incorporating environmental concerns into all its activities. Competent staff can positively change the attitude of all defence force members to a purposeful and resourceful attitude towards environmental issues and challenges.

Environmentally informed defence force members can also change the general reactive attitude, held by most defence force members regarding environmental issues, to a proactive one. Given the current situation at the GMI, it is important that personnel attached to the environmental management facility receive training in environmental issues in order to capacitate them. Alternatively, the defence force could embark on a recruitment drive in order to draw in environmentally qualified individuals to assist in the establishment and strengthening of the EMF. It is only then that these defence force members can provide genuine leadership on environmental matters, across the full spectrum of environmental issues at the military installation. The current state of affairs indicates that there is a lack of commitment to the effective management and protection of the environment from military activities at this installation. Above all, this affirms Rao's (2005) statement that environmental management is not one of the primary concerns of military forces. This is the attitude that the military sector gradually needs to change. In addition, the military sector needs to have its activities streamlined with environmental protection and sustainability in mind. Moreover, environmental management may prove critical in land used primarily to support field training requirements for combat readiness (Ramos & de Melo, 2005). This is vital because effective military training requires a landscape with natural land features (Ramos & de Melo, 2005). Degraded training ranges may adversely affect the potential for diversified military training. Lewis argues that access to high-quality training areas serves as a third factor (in addition to time and money) in troops' readiness (Lewis, 2010). The DEO must be given adequate commanding powers to enhance adherence to the appropriate environmental approach by commanding officers. The appointment of low ranking officers as environmental officers creates serious problems regarding the consideration and enforcement of environmental issues in military activities.

As the results show, there are various capacity limitations within the SANDF at 6SAI Bn, in terms of efficient environmental management. This was further consolidated by the findings obtained from the 2001 and 2008 EIP editions. The recruitment drive to bring in environmentally qualified individuals to assist in the establishment and strengthening of the EMF cannot be over-emphasised.

In an attempt to remain up-to-date with environmental legislative provisions, the department has acquired the services of an external consultant to establish and maintain a corporate database on all international, national and provincial environmental legislation, as well as any relevant norms and standards (EIP, 2008:32). The weakness in this approach is that the actual persons expected to implement the programmes and plans in order to ensure compliance are, in some instances, not well trained and/or competent enough to carry out the relevant and necessary processes. Thus, it is important to develop skills and competency from within the SANDF at GMI. The development of skills from within will ensure that programmes and policies are implemented or translated into action.

Structural Organisation for Effective Environmental Management in the SANDF

When the research for this study was conducted in 2011, the GMI did not have any environmental management or performance monitoring mechanisms. There were no environmental audits and/or annual environmental management reports. This suggests that the SANDF's operating procedures at this installation have not evolved sufficiently to incorporate environmental protection practices. It also shows that the impact of military activities at this installation was not satisfactorily monitored and evaluated. This was still the case in 2011, which is more than a decade after the SANDF participated in a pilot study on the implementation of an EMS in the military sector; this study was conducted by the North Atlantic Treaty Organisation's Committee on the Challenges of Modern Society (NATO-CCMS) in 1996-1999. The final report of the NATO-CCMS's pilot study on the implementation of systematic environmental management in defence forces concluded that it is possible and even desirable to implement EMS in military organisations, given the destructive potential of military activities (NATO-CCMS, 2000; Dawson, 2004).

The environmental practice, or lack thereof, at the GMI also contradicts both the first and second editions of the EIP of the SA DoDMV, published in 2001 and 2008, respectively. Both the EIP documents state that the implementation of environmental management and performance by the defence force and its compliance with legislation will be monitored (DoD, 2001 & 2008; Lewis, 2010). The monitoring mechanisms suggested in both EIP editions include an environmental review forum (ERF); steering groups, working groups and advisory forums (WG/AF); annual environmental management report (AEMR); environmental awards programme (EAP); communication and ad hoc relations; as well as environmental audit (EA) (DoD, 2001 & 2008). All these mechanisms were established to monitor and improve the environmental performance and profile of the SANDF. However, for all these mechanisms to yield the desired outcome depends significantly on the capacity of the SANDF military installations in this regard. Conversely, punitive measures for non-compliance with EIP and NEMA requirements in particular are not mentioned anywhere in both the EIP editions.

However, it is important to note that environmental problems in South Africa are both First and Third World in nature (Glazewski, 1993). The First World environmental problems characterising South Africa include acid rain, which emanates from pollution of the atmosphere through industrial emissions of greenhouse gases (GHGs), such as sulphur dioxide (SO_2) and nitrogen oxides (NO_x), as a result of the combustion of fossil fuel in coal power generating plants. Contamination and/or pollution of water through acid mine drainage (AMD) is another environmental problem common in First World countries, which has also become one of the major environmental problems in South Africa. AMD has affected numerous ecosystems and polluted many major rivers and other water sources in the United States, England, Wales and Spain, all of which are First World countries (Caraballo *et al.*, 2011). Similarly, AMD from defunct mine shafts has also become a major environmental threat to South Africa since the turn of the century (Davies & Mundalamo, 2010).

The Third World environmental problems in South Africa relate to solid waste management. Waste management challenges in South Africa range from strategic waste management issues at national government level to basic operational challenges at local government level (Godfrey, 2008). Large metropolitan municipalities provide a relatively complete waste management service, including collection and appropriate disposal. However, the same cannot be said about many smaller municipalities in rural areas, which lack the capacity to deliver any waste management services to their residents (Friedrich & Trois, 2010). Furthermore, South Africa is still grappling with social problems associated with the provision of clean and safe drinking water and sanitation facilities to thousands of people, as well as environmental problems.

Thus, the government is unable to deal effectively with environmental problems by enforcing environmental regulations at the expense of human welfare (Glazewski, 1993). The government does not have adequate resources to monitor compliance with existing legislation, given the abovementioned challenges. Thus, at the time of the study, the GMI had never been audited by an 'external' environmental management monitoring agency such as the Environmental Management Inspectorate (EMI). Even the proposed internal environmental management mechanisms suggested in the 2008 EIP were not adequately adhered to.

Legal Framework for Environmental Management affecting the SANDF

In 2005, the Department of Environmental Affairs and Tourism (DEAT) formed the Environmental Management Inspectorate (EMI). The EMI units were formed with the aim of monitoring compliance and the enforcement of environmental legislation and regulations, including authorisation issued under legislation in their mandate (Fourie, 2005). These units were given the power to enter any property unannounced in order to conduct environmental inspection. Such inspection is carried out to enforce the following legislation:

- Firstly, the Environment Conservation Act (ECA) (Act No. 73 of 1989) which, although promulgated during the apartheid era, is still relevant; it requires that the environment be adequately protected, environmental pollution prevention be prioritised and waste be properly managed (RSA, 1989).
- Secondly, the Constitution of the Republic of South Africa (Act No. 108 of 1996), particularly Section 24 of the Bill of Rights, makes provision for the protection of the environment. In part, this section states, “[E]veryone has the right –
  - (a) to an environment that is not harmful to their health or well-being; and
  - (b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that –
    - (i) prevent pollution and ecological degradation;
    - (ii) promote conservation; and
    - (iii) secure ecologically sustainable development and use of natural resources while promoting justified economic and social development” (RSA, 1996).

- Thirdly, in the National Environmental Management Act (NEMA) (Act No. 107 of 1998), the principles under Section 2 of this Act describe how policies, plans and programmes of any organisation should comply with the NEMA (RSA, 1998).
- Fourthly, the National Environmental Management: Biodiversity Act (Act No. 10 of 2004) (RSA, 2004). Under this Act, the SANDF must have an ecological management plan for all its military installations (RSA, 2004). Without such plans, the protection and maintenance of biodiversity within military areas cannot be guaranteed.
- Fifthly, the National Environmental Management: Protected Areas Act (Act No. 57 of 2003). Under this Act, the defence force must have guidelines and procedures to promote, protect and conserve the ecological integrity of ecosystems in military sites (RSA, 2003).
- Finally, the National Water Act (NWA) (Act No. 36 of 1998) was promulgated to protect the water resources in the country. Under this Act, the defence force must have and implement water pollution prevention measures to ensure that this scarce resource is not degraded through various forms of pollution (RSA, 1998).

These Acts all advocate for the protection, pollution prevention and sustainable utilisation of the country's natural resources. Ideally, the defence force is expected to comply with all these legislative provisions. The principles of NEMA, together with all the other legislative provisions, do not exempt the DoDMV from adequately managing the environmental within its territories, and no clause(s) in any of these provide such exemption to the DoDMV/SANDF. At the time of the study, in July 2011, the practices at the GMI appeared to be non-compliant with these legislative provisions.

The integrated environmental management (IEM) concept was adopted in South Africa in 1989, as a tool to be used to assess environmental concerns (Sowman *et al.*, 1995). The IEM was adopted because its primary objectives were to promote environmentally sound utilisation, and to link the opposing concepts of utilisation of natural resources and conservation, thus placing emphasis on saving the resource base for future generations (Avis, 1994). In other words, the IEM emphasised a reduction in severe environmental impacts through eliciting information from diverse stakeholders, thereby promoting the sustainability of natural resources. This principle applies across the board and to diverse sectors of South African society.

Every sector in South Africa is expected to conduct its business within the ambit of the abovementioned legal frameworks and many others that are not mentioned here. However, it appears that the SANDF is exempted from such inspection, or the EMI units do not exercise their powers to audit the environmental performance of the defence force. Bertell (2002) rightly points out that states tend to operate according to a double standard. They are not willing to subject their defence forces to the level of transparency and accountability that is required of other organs of state and civil society (Bertell, 2002). If this is true, the lack of transparency and accountability is unacceptable because all sectors of society must abide by the laws and regulations of the country, in an effort to promote the environmental protection and sustainability of natural resources.

Avis (1994) correctly points out that, in South Africa, the private sector is fairly controlled but the public sector is not. Given the political nature of the defence force, the enforcement of environmental regulations and compliance with legislations are not stringent. This means that the agencies charged with the responsibility of monitoring environmental performance, and compliance with legislations and regulations, were not assessing and evaluating the practices of the SANDF at the time of the study, at least not at the GMI.

Glazewski (1993) argues that South Africa is a typical example of a country where there is significant discrimination in the enforcement of environmental management legislations and regulations. This implies that environmental performance and the practises of the private sector are strictly monitored. However, in most cases, the activities of government departments are not rigorously compelled to comply with the same legislations and regulations.

In addition, at the time of the study, Defence force's institutional framework on environmental matters appeared to be weak. The senior staff officer in the environmental management services of the SANDF stated that it was difficult to enforce environmental compliance within the defence force due to policy-related challenges or weaknesses. The existing environmental policy of the DoDMV was still fragmented (DoD, 2008). This did not promote the integration of environmental management and concerns in all the activities of the defence force, at all installations. It also indicated the failure of the DoDMV to comply with environmental legislation. Moreover, this also reflected the failure of the South African government to enforce its environmental management law indiscriminately across all sectors of society. The worst of all was the lack of environmentally competent staff at the GMI. This was a serious weakness and a significant drawback for attempts by the defence force to improve its environmental management practice profile. Consequently, the absence of competent staff at GMI had a negative effect on the translation of DoDMV plans/programmes into action.

Good policy documents and plans are meaningless if not implemented. The study found that DoDMV was failing to lead by example on environmental management issues, yet it was one of the major landowners in South Africa. This department controls approximately 0.4% of state-owned land (DoD, 1996). The Portuguese military sector owns more than 0.25% of the country's land (Ramos & de Melo, 2006), the United States Army manages approximately 1.25% of its nation's land (Johnson *et al.*, 2011), and the Australian defence force is also the largest landowner (1.69%) in Australia (Australian Government Department of Defence [AGDoD], 2010). Defence forces in all these countries have successfully implemented an EMS to ensure that they comply with the environmental laws and regulations of their respective countries (AGDoD, 2010), thus mitigating their impact on the areas under their control. At the GMI, the SANDF failed to accomplish this at the time of the study.

Compliance with environmental management legislation is an assurance that future generations will be able to continue utilising the same land area for the same purposes. Therefore, all South African government departments which have the potential to harm the environment through their activities are expected to be exemplary in environmental protection and the promotion of sustainable utilisation of natural resources by being proactive rather than reactive (i.e. to comply fully with environmental legislation and regulations). This will also give the government the moral high ground to force private companies and firms to comply with the legislation and regulations. Laws and regulations should not be implemented selectively, but should be enforced uniformly across the broader spectrum of society, whether the activity is carried out by a government department or by a private firm/company. Accordingly, Ramos and de Melo (2005) as well as NATO-CCMS (2000) underscore that the military sector must comply with the environmental policies and laws established for the rest of society.

There are however exceptions, especially when the sovereignty of the nation is at risk (Ramos & de Melo, 2005). Furthermore, Lewis (2010) states that the military in Canada is also held to the same environmental laws and regulations as any other organisation operating in Canada. Thus, the non-enforcement and compliance by government departments in South Africa may create a situation where the entire concept of environmental sustainability, especially within defence territories, becomes a myth or mirage.

Thus, the SANDF's non-monitoring of environmental performance and non-compliance with legislation and regulations violates Section 28 of the NEMA (1998), which requires that every person causing significant impact (pollution or degradation of) on the environment takes all reasonable measures to prevent it from occurring, continuing or recurring. Defence activities have a great potential to harm the environment. It was therefore recommended that the GMI develop programmes and plans that are in line with the mitigation of environmental impacts and performance monitoring mechanisms, as required by the environmental management law (i.e. NEMA of 1998) and the second edition of the EIP for the defence force (i.e., SANDF).

Critical Factors for Environmental Considerations in Military Activities in the SANDF

Another major weakness, which has been noted in this study, was that the environmental facility at the GMI did not collaborate with any institutions of higher learning and/or other research institutions. This lack of collaboration with universities and research institutions, as well as other environmental experts, severely hampered the implementation of effective environmental management measures at this military installation. Moreover, it was found that interaction with other stakeholders could even improve the defence force members' understanding of environmental issues.

Stakeholders also play a significant role in environmental management processes in the private sector. This role needs to be recognised in the public sector, including defence activities (Ramos & de Melo, 2006). This can only be realised if the defence force could be more transparent and inclusive regarding environmental management issues. The ADoD prioritises external linkage with environmental stakeholders and maintains transparency on environmental issues (AGDoD, 2010). Collaboration has the potential to assist the defence force to develop effective management tools, and in terms of the evaluation of defence environment management practices and performance (AGDoD, 2010).

The interaction between defence force members and external environmental experts and practitioners could have a variety of other benefits. These may include the accurate interpretation of policies and directives, and keeping abreast of the best environmental practices (AGDoD, 2010). The adequate interpretation of documents and directives will mean that these are easily translated into plans and action. It was clear that the lack of adequate funding, the lack of competent staff and the lack of external linkages posed a significant challenge to the protection of the environment at this installation.

As indicated in Figure 41, the other critical issue in the implementation of EMS and the effective management of the environment in the defence force is maintaining external linkages. The non-availability of financial resources and the absence of interaction with external environmental experts and practitioners could lead to poor environmental practises and the failure or collapse of the whole effort to implement an EMS within SANDF military activities. The collapse of the implementation of EMS would be a major setback for the DoDMV in its quest to honour its environmental obligations.

There was evidence that some military training areas of the SANDF show signs of degradation. Harmse (2003) also reports that military training areas in the province of Limpopo (one of South Africa's nine provinces) have been affected by severe soil erosion. The severity of the problem has prompted the SANDF to seek scientific assistance from experts in order to deal, effectively, with the problem (Harmse, 2003). This would not have happened if the SANDF had been well-resourced enough to deal with integrating environmental issues into military programmes and practice (Harmse, 2003).

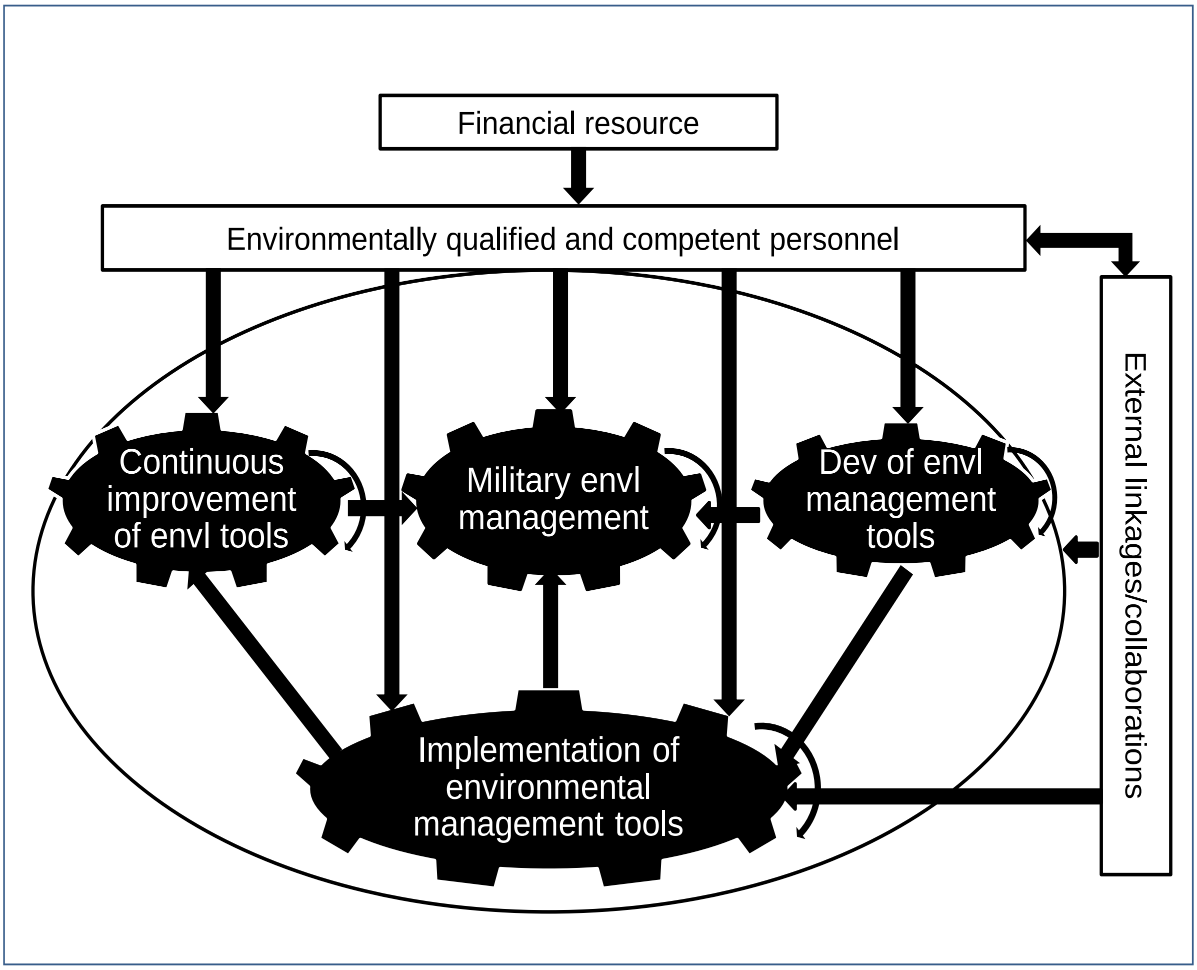

Figure 41. Proposed model towards the implementation of the EMS in the defence

Note: "envl" – stands for 'environmental'; "Dev" – stands for 'Development'; "curved arrows" denote 'continuous improvement or update'

Figure 41, illustrates the essential components of a realistic process towards the implementation of an EMS. Finances are critical towards the successful implementation of any project. When there is adequate funding for any programme, it becomes easier to attract, hire and retain skilled and competent personnel. These are the people who should interpret defence policies and programmes, and translate them into action. Furthermore, their primary function should include developing various environmental management programmes/plans and providing leadership in the implementation of environmental management programmes, in their respective military units/installations.

In addition, defence force's environmental officers must carry out environmental management audits and measure the performance of their respective units against the set objectives and targets. This will ensure the continuous improvement of environmental performance (indicated by the curved arrows in Figure 41). Qualified personnel have to foster a sense of environmental accountability among defence force members. Most importantly, qualified and competent personnel need to establish and maintain external linkages and/or collaborations with experts, practitioners and other institutions. This is crucial in the formulation of best practices, which are applicable to and compatible with military activities. Moreover, external stakeholders could also assist in the formulation and implementation of environmental management techniques and the evaluation of adopted tools.

External stakeholders could provide an objective assessment of the environmental performance of the SANDF. A continuous evaluation of environmental management programmes should be carried out to ensure their relevance in working towards achieving the sustainability of all military training areas and environmental protection from aggressive military activities. These exercises are meant to identify the strengths and weaknesses of the management tools. The other positive aspect of networking with experts and practitioners is accessibility to cutting-edge information and current developments in the environmental management field. An adoption of this model could lead to the successful implementation of the EMS for defence, which will significantly improve the SANDF's environmental practice and performance at all military installations.

The SANDF is not taking its obligation to protect the environment seriously enough. Although the directive to manage the environment within its territories was issued more than thirty years ago in 1977 (Godschalk, 1998; Smit, 2009), it was clear that the GMI had not yet responded positively to this call at the time of the study, in 2011. This was in conflict with the environmental legislation of the country and the stated objectives of the DoDMV environmental policy statement.

If the SANDF had been serious about incorporating environmental issues into its activities, it would have planned and developed an environmental management budget for all its environmental services over the years. However, it is also imperative to acknowledge that the defence budget has been shrinking over the years from R19, 6bn (4.3% of GDP) in 1989 to R10, 5bn (2.2% of GDP) in 1995 (Batchelor, 1998). However, the defence budget started increasing from the year 2000 onwards. In the 2000/01 financial year, the defence force was allocated R13, 8bn, and R37, 5bn in 2012/13 financial year (Sisulu, 2012; Parliamentary Monitoring Group, 2000; RSA National Treasury, 2011).The increase in the defence budget is linked to the African Agenda that the South African government is pursuing (i.e. the peacekeeping mission in the African continent).

This being said, it does not forestall the obligation to secure funds for the implementation of the EMS for defence. To offset the budgetary cuts which have characterised the past years' budget allocation by approximately 11.4% in 1990 to 14.6% in 1995 (Batchelor, 1998), and to sustain its environmental funds, the DoDMV could approach the Global Environmental Facility (GEF) and the Development Bank of Southern Africa (DBSA) through government in order to seek additional funds. The lack of such funds implies that the environment has not received the high priority it deserves from this department. Government itself has also failed to establish a similar fund from all the taxes, environmental fees and fines that are collected from environmental defaulters. Such a fund could have helped the SANDF to meet its environmental obligations more effectively.

South African environmental laws emphasise the 'polluter-pays' principle. Adequate enforcement of these laws would generate sufficient funds for government to establish an environmental fund. This fund could then be used towards financing the implementation of environmental legislation and regulations within departments that are struggling to finance environmental programmes from their allocated budget. Adequate financial resources are crucial to all efforts to implement environmental management tools.

Environmentally qualified staff/personnel can only be attracted and retained when adequate funding is available. These are the people who must be able to interpret policies and directives and translate them into action plans. They also have to interact with experts and practitioners outside the defence force to keep abreast with developments in environmental management matters. This interaction will also assist them to develop effective impact mitigation measures for each installation. Staff at the military environmental management facility of the defence force must provide leadership on environmental management issues at all times. Therefore, extensive environmental awareness training and education for SANDF members are imperative to instil a proactive and can-do attitude. Environmental education is important in the implementation of environmental management policy (Spricis, 2001). The study found that the environmental practices at GMI nullified what the 2001 and 2008 EIP documents articulate, and violate environmental management legislation. The SANDF must therefore engage in collaborations and partnerships with relevant institutions and practitioners in order to improve its environmental performance and management practice profile.

Environmental Management Programme at 6SAI

The greater Grahamstown area is heavily infested with the invasive *Opuntia Indica* plant species. Consequently, the GMTA is also infested with *Opuntia Indica* plants (Figure 37). Due to this problem, project Vuselela has been established in conjunction with the Department of Water and Sanitation in order to eradicate this invasive plant species (as shown in Figure 12). However, active defence force members do not participate in this project, only retired (i.e., military veterans) defence force members are able to participate. The density of the *Opuntia* in the GMTA makes other sites of the training area inaccessible, thus impacting negatively on infantry training activities.

According to Beinart and Wotshela (2011), *Opuntia* was brought into the then Cape Colony in South Africa in the seventeenth century by the earliest white settlers. It was later introduced to Graaff-Reinet in the eighteenth century for commercial purposes. Since then, the invasive plant species has spread across the province. Mmoto *et al.* (2009) state that *Opuntia Indica* is one of the most dominant alien plants in the Camdeboo Municipality in Graaff-Reinet and surrounding areas in the Eastern Cape Province. The species was originally introduced as fodder for sheep and cattle (Milton & Dean, 2000). Thus, *Opuntia* has been grown widely in the drier areas of South Africa as fodder crop, particularly during times of serious drought. It has also been cultivated as a source of fresh fruit for local and export markets (Cocks *et al*., 2003).

It has been noted that people are not the only agents that disperse *Opuntia* to new habitats, but that the plant can also be dispersed by animals and water (Mmoto *et al.*, 2009). Accordingly, Milton and Dean (1998) note that *Opuntia* is quite common along the roads and telephone lines in some parts of Cradock, Cookhouse and Bedford. Thus, this undoubtedly shows that birds (e.g. crows) feed on *Opuntia* and deposit the hard seeds along the road. Baboons have also been cited as one of the agents that spread *Opuntia* in the region (Thuiller *et al.*, 2006). It can therefore be argued that birds and animals within the GMTA are the major vectors for the spread of this plant. At the GMTA, baboons are also playing a major role in dispersing the seeds of this plant across the training area. However, the major threat posed by this plant species within the training range includes making certain sites unusable, especially for infantry training.

There are several ways to control the distribution or spread of *Opuntia*; these include biological, herbicidal and mechanical mechanisms (Bowers, 2005). The control method adopted at GMI includes the combination of physical and chemical mechanisms. Nonetheless, the eradication process is failing to completely eradicate the plant colonies of *Opuntia*. Sites that were previously treated would, after some time, show signs of new colonies redeveloping. The possible reason why the colonies re-establish themselves is because the cladodes are stacked-up after being "dismembered" and sprayed with chemicals called Timera and Monosodium Salt of Methanearsonic (MSMA). This might be one of the weaknesses of the operation/practice. The cladodes of *Opuntia Indica* should not be in contact with the ground, otherwise it develops roots, thereby re-establishing a new colony. Other options need to be explored on how to completely eradicate the invasive plant. Biocontrol remains an ideal control measure for project Vuselela because it is sustainable, cost effective and has relatively safe ecological attributes (Phiri, 2011).

Considerations of Environmental Issues at SAACTC

The results obtained at SAACTC show that environmental consideration is, to a certain extent, incorporated into military training activities. This is attributed to three major factors. Firstly, there is greater potential of degradation of the training area due to the aggressive nature and frequency of military training activities carried out within this training area, as military activities have significant adverse effects on ecosystems in the training areas (Silveira *et al.*, 2010). Secondly, a competent environmental officer/manager at the military rank of Major was appointed to lead the EMF. Thirdly, there is no chance of acquiring additional land for use for military training purposes in

South Africa. The recognition, by Daniel (2007), that there is no chance of acquiring alternative land for the SANDF in South Africa indicates that the current military lands must be managed sustainably.

Smit (2009) argues that, for the SANDF to be able to execute all of its responsibilities, it has to maintain a wide range of environmentally diverse training areas. Therefore, the SANDF has realized that the effects of its activities on the environment are likely to lead to environmental degradation which will, in turn, lessen the value of military training in such areas if not properly managed (Smit, 2009). Thus, environmental management within military training areas is one of the major challenges to the future of realistic training for the SANDF (Daniel, 2007). In other words, all military training areas must be used and managed in a sustainable manner.

Nyakatawa *et al.* (2011) argue that the viability and sustainability of military training areas depends on their ability to provide realistic training landscapes. That is the reason why significant efforts are made to ensure that the SAACTC is utilised sustainably so as to ensure long-term utilisation of this national asset. It is through the recognition of this reality that the DoDMV is now more conscious about environmental protection and sustainability in the utilisation of this training area. The fact is that the importance of training exercises is negatively affected (decreased) when the training area does not provide the required terrain (Lewis, 2010).

Other countries come to train on this training area (i.e., SAACTC) and bring along their own environmental planners. This creates opportunities for the environmental management team of the SANDF to learn more about how to adequately integrate environmental considerations into military training plans. For example, the American and British armed forces are known to be leaders in the incorporation of environmental considerations in military activities (NATO-CCMS, 2000). The armies of these countries have, at one point or another, used the SAACTC for military training. Komar *et al.* (2009) state that an allied exercise is preceded by thorough planning to ensure that environmental protection regulations and laws of the host country are abided by in the proposed environmental management plan.

The environmental briefing carried out prior to the commencement of training activities is commendable and can have significant positive outcomes. Thus, commanders, soldiers and non-combatant personnel should receive environmental training before deployment and in the field (RAC, 2008). This is done to improve environmental stewardship and awareness. Komar *et al.* (2009) also state that commanders and training troops should be informed of operational rules and the system of environmental protection during deployment. It is assumed that this is meant to maintain the environmental awareness of all involved in the training exercise, in order to prioritise environmental protection and avoid unnecessary environmental damage. In cases where this is not possible, the impact should be minimised. Furthermore, the briefing at the base and at the training range should emphasise that all training activities must be carried out in accordance with the environmental management plan of that military exercise. This is important in ensuring that the desired outcomes (such as environmental protection, pollution prevention and no unnecessary vegetation damage) are achieved and that the environmental awareness of defence members is enhanced.

The environmental representatives appointed by the SANDF become responsible for overseeing, maintaining and monitoring environmental protection. Environmental problems encountered during the training exercise are reported to the relevant commanding officer and the designated environmental officer. Ramos and de Melo (2006) state that environmental performance communication and measurement is a critical component of the environmental management process. Thus, it is critically important that the defence force's environmental official (DEO) of the military installation compile a final report and develop a database of military environmental impacts. This would enhance environmental management audit processes, as information is appropriately organised and managed. The DEO should take full responsibility for environmental issues in military installations (NATO-CCMS, 2000).

According to Ramos and de Melo (2005), the DEO should take a leading role in EMS, its implementation, development of environmental programmes, establishment of environmental cooperation with stakeholders, and so on. This means that such individuals need specialised training on EMS and related issues (NATO-CCMS, 2000). It is also important that environmental management records are organised and kept. In cases where reports are scattered, it becomes difficult for other members to access environmental information when required.

The NATO-CCMS (2000) report also emphasises efficient document control and the provision of information to the right people at the right time and place. Documents are also kept to demonstrate compliance with legal requirements, as they provide evidence of ongoing progress made with regard to EMS implementation (NATO-CCMS, 2000). Therefore, the environmental reporting and communication framework must be made clear to every defence force member. It is important for the military to have an environmental reporting framework (ERF) and performance indicators (Wu &

Wang, 2011); the SANDF does not have any of these essential environmental management tools. It can therefore be argued that the absence of an ERF is linked to the collapse, or withdrawal, of the EMS for the SANDF. An ERF is developed in line with the EMS (Wu & Wang, 2011). Wu and Wang (2011) explain that it is imperative for the military to implement environmental reporting using an indicator framework. Problems encountered during one military training exercise ought to inform the environmental management plans (EMPs) for subsequent training activities. Challenges noted during the implementation of EMP simply indicate that the next plan must be improved to ease its implementation and incorporate impacts that might not have been thought of and/or included in the initial plan (ESWG, 2006). Appropriate reporting of environmental impacts, especially those that arose during the execution of training activities and/or were not initially thought of, will reduce the temptation to recycle EMPs.

Disturbance to Soil and Damage to Vegetation Cover

Military training activities cause a variety of impacts on the physical land, water bodies and air (ESWG, 2000). Thus, physical disturbances of the ground in a military training area cannot be avoided (Marlaer & Moore, 2011). Triender and Cole (n.d.) argue that adverse impacts have generally been unavoidable, as some result from accidents while others arise through ignorance because of lack of knowledge. Thus, improperly and poorly planned training exercises may induce severe environmental damage to the training area, thereby causing significant ecological damage (Komar *et al.*, 2009).

It is this aspect of military activities that constitutes an aggression on the part of most training activities, thereby resulting in a loss of vegetation cover (van Donk *et al.*, 2003). Military training activities have, by their nature, considerable effects on the environment (ESWG, 2006). The movement of armoured vehicles destroy vegetation and alter ecological habitats (Linkov *et al*., 2001; Harmse, 2003; Warren *et al.*, 2007; Wang & Wu, 2013). The firing of live ammunitions through bushes causes significant damage to the trees in the line of fire. In the army, bushes are also very important depending on the military tactic being taught.

The firing of missiles and other high calibre weaponry blasts the ground surface and disturbs the soil structure. Greičiūtė *et al*. (2007) argue that the impact of explosions induces a thermal impact through the heat generated by the bomb. This tends to impoverish the soil because the heat that is generated burns out all the organic remnants in the soil (Greičiūtė *et al*., 2007). This too has a severe negative impact on ecological habitats because, in some instances, the explosion kills, injures and/or displaces other living organisms from their habitats. It further creates routes for heavy metals to quickly reach the underground water. As Greičiūtė *et al*. (2007) argue, damaged soils are more permeable and thus allow pollutants to move easily in order to reach groundwater.

In some instances fire can ignite during training exercises and destroy thousands of hectares of vegetation within the training area, and sometimes even beyond it. The destruction of vegetation through veld fires can also degrade military training range conditions. Veld fires are inherent to military training exercises, since many of the munitions that are used are ignition sources (CEMML, n.d.). Therefore, military land managers, range operators and environmental officers of the SANDF must develop plans to effectively deal with this problem. Training ranges that are devoid of vegetation may not be suitable for certain military training exercises. Each military training exercise is carried out to teach and even perfect certain tactics; therefore, they ought to be carried out under specific environmental conditions. Vegetation in a military training range also provides camouflage which a desert-like environment cannot provide. However, the use of vegetation as camouflage during training exercises is prohibited. This prohibition is meant to maintain the ecological integrity of the training area, and ensure the sustainability of these areas. Deserts are, however, important to teach other military tactics, but cannot be deliberately created within a humid military training area through destructive military activities.

The veld fires that ignite during training exercises have severe ecological effects on the SAACTC training area. This problem has proven to be one of the major challenges to threaten the ecological integrity of the entire SAACTC training area. It has also been acknowledged in the ECR of Exercise Seboka (2009) that veld fires have led to serious ecological damage which could take up to a maximum of 200 years to restore. The region in which the SAACTC is situated is a dry climatic zone. Thus, grasses are almost always dry, rainfall is very scarce and temperatures are normally very high (e.g., 37^{o}C maximum average) on most days. The drier the grass, the higher the chances of veld fires starting and getting out of control. The ECR for the year 2009 indicates that veld fires have destroyed vegetation in numerous training ranges to-date. It appears that the SANDF does not have an emergency response plan for this problem. The only possible solution would be that the SANDF keeps its own fire-engines on stand-by whenever training takes place. Fire-fighting without fire-engines, while waiting for the Fire-Fighting Department to arrive to put out the fire, will never reduce the detrimental effects that fires have on the environment.

Evolution of Defence Environmental Management Practices

The results of the study indicate that the lack of environmental education in the formal military training programmes of the SANDF creates serious challenges for the protection of the environment from military activities. Therefore, it is essential that the SANDF changes from its orthodox operational procedure, which has been used for many years, to enhance its environmental management profile. This is, however, not unique to the SANDF; for example, the Portuguese National defence policy was, for many years, far removed from encouraging environmental considerations and environmental management practices (Ramos & de Melo, 2006).

Military planners and trainers were not concerned with environmental considerations in their planning and training activities. They now find themselves having to deal with this aspect. There are those who still resist change, and who perceive the consideration of environmental issues as delaying the execution of the training exercise and lengthening the planning process. To soldiers, environmental protection may appear as a waste of time and resources. This attitude stems from the lack of environmental education and awareness training, which ought to be provided to soldiers on a continuous basis. According to Woodward (2001), environmental education and awareness is critical in military organisations in order to infuse a degree of environmental responsibility among military personnel, thereby promoting the sustainability of training areas.

It should also be remembered that, before the 1970s, not much attention was given to environmental protection, conservation and sustainability. However, when major environmental problems emerged after the 1970s, attitudes and perceptions about the environment changed. From that period to the present, environmental awareness and interest has increased significantly (Trinder & Cole, n.d.). People have realized that the environment has its own capacity and resilience to withstand the harm inflicted upon it. Since then, numerous environmental management philosophies have emerged. These include, among others, environmental conservation and environmental protection as discussed by Li *et al*. (2011); environmental ethics and sustainable development (or environmental sustainability) as discussed by Brennan (2009 & 2014); and, integrated environmental management as discussed by DEAT (2004). Furthermore, van Eeden and Brink (2007) used environmental justice as another philosophical approach to understand and analyse environmental management problems.

The environmental enlightenment of the 1970s led to the very first instructions, in 1977, to the SANDF to care for the environment under and within which it operates (Godschalk, 1998; Smit, 2009 & 2011). This directive, according to Godschalk (1998) and Smit (2009 & 2011), led to the formulation of the very first defence environmental policy in 1978 which focused primarily on environmental conservation. However, a major paradigm shift in the management of the environment by defence forces emerged at the turn of the century, through the publication of the NATO-CCMS report in the year 2000. This report indicated the practicability and desire to introduce EMS in the activities of defence forces (NATO-CCMS, 2000).

Since then, many defence forces in different countries began developing and implementing EMS in efforts to protect the environment and ensure the sustainability of military training areas as well as compliance with legal requirements. As such, the SANDF/DoDMV has followed suit. Disappointingly, the two editions of the EIP (2001 & 2008) state that environmental training has not been formalized in the defence training programme. By now it is expected that the SANDF's activities would adequately incorporate environmental issues, thereby promoting sustainability and preventing long-term degradation of military training areas. According to Trinder and Cole (n.d.), sustainable environmental management ought to be the main aspect of interest for defence forces, given the aggressive nature of military activities.

Therefore, if the emphasis on environmental protection started earlier, it is assumed that the SANDF should be comparable with their Portuguese, Australian, Canadian, American and British counterparts. Nonetheless, the social and economic conditions would have had their own influence, to the extent of funding of the defence force's environmental initiative and, subsequently, the level of compliance with environmental laws and regulations. The influence of these issues on the budget of the SANDF has been discussed in the sections above. Furthermore, the remoteness of the military, as an entity which is isolated from the entire social structure, has significantly influenced the monitoring of the SANDF environmental practices over the years. As Dorfman (2004) states, the defence forces must be held accountable for their impact on the environment. Woodward (2001) rightly pointed out that the space and place where the military operates should not be viewed as entities existing outside of social practices, but as the product of social practice.

Thus, the military sector should also be held accountable for their actions on the environment, just like any other social entity. Bertell (2002) attests that governments tend to avoid subjecting their defence forces to the level of transparency and accountability required of other entities of their society (be it government or the civil sector). To a certain extent, this accounts for the poor environmental management in some of the military training areas, as observed at 6SAI. Due to the recent changes regarding environmental concerns, militaries are no longer institutions which are untouched or should be ignorant of events that affect the wider society (Vreÿ, 2001). Instead, they should conform to the environmental management norms set out for society in general.

The SANDF shows signs of gradual change from being an ‘island’ and/or detached from the greater social structure. These changes are observed in regard to its attempts to improve its environmental performance and compliance with environmental legislation, as limited as this may be. Previously, spillages of fuel and the disposal of military waste and clean-up operations were not perceived to be important. As Trinder and Cole (n.d.) argue, many years ago, environmental issues were hardly recognised in the management priorities of the military. Currently, the laws compel the SANDF to change its practices towards protecting and managing the environment through pollution prevention, maintenance of the ecological integrity of military training areas, and the restoration of degraded areas. The attempts made by the SANDF towards honouring these obligations are mostly appreciated and encouraged.

Contamination Reduction Programme at SAACTC

Military training areas are characterised by various forms of environmental problems, such as wastewater effluent, air pollution, hazardous wastes and soil contamination (Ramos & de Melo, 2005). At SAACTC, attempts are being made to reduce and prevent avoidable environmental contamination. Thus, incidences of fuel spillage are reported, as expected. ESWG (2006) states that spillage incidences should be contained in the environmental closure report (ECR). The ECR must indicate the location where the spillage had occurred, the type and quantity of the contaminant(s), the level of clean-up done and any additional clean-up required (ESWG, 2006). Clearly, the reporting of these incidences should allow for the rehabilitation of the affected site or the decontamination of the affected ground surface. However, it has been noted that reported cases of spillages decrease from one year to the next. The act of reporting these incidences has increased, which shows that defence personnel are beginning to work towards promoting environmental protection and sustainability.

On the contrary, lack of action, both through the non-reporting or treatment of affected areas, would in the medium- to long-term affect the flora and fauna of the training area. If contaminants continue in the soil, it then becomes toxic, thus affecting soil biota and wildlife alike (Siebielec & Chaney, 2012). Siebielec and Chaney (2012) further argue that the contamination of military sites which have been used for a long time is far more complex, as is the case in SAACTC. This is attributed to the fact that there is also indirect contamination of soil by fuel compounds that are introduced by engine combustion (Certini *et al.*, 2013). This shows that soil contamination in a military training area can never be completely eliminated or prevented.

The measures adopted to prevent direct pollution from other activities associated with military training appear to reduce direct pollution of both soil and water. The use of dripping pans and secondary containments placed beneath any potential source of liquid pollutant (i.e., refuelling bunkers and power generating engines), for instance, are meant to prevent environmental contamination. This is one of the pro-active approaches to environmental protection and sustainability. Thus, refuelling operations are prohibited near water sources. This is meant to minimise the risk of contaminating the water source. However, the reactive approach is still being used in cases where spillages have occurred accidentally. This is more appropriate when dealing with accidental incidences and the restoration of over-utilised training ranges.

As stated in the environmental plan for Exercise Seboka (2008), the pro-active approach can further prevent environmental pollution through the use of military vehicles that are in good condition (i.e., serviceable vehicles). Therefore, vehicles leaking fuel, oil, grease and other fluids such as break-fluid and other lubricants have the potential to cause serious contamination and defeat the purpose of caring for the environment. Thus, all equipment used during military training should be serviceable in order to avoid environmental maintenance caused by avoidable environmental pollution (ESWG, 2006).

Spillages of fuel and other substances have proved to be a challenge for the SANDF, in terms of the complete prevention of contamination of the environment during training exercises. Refuelling activities in the field remain the major cause of these spillages and they have led to widespread contamination of soil and water on military training areas (Teafy *et al.,* 2006). The proper inspection of all facilities prior to the commencement of the training exercise would be ideal practice. Only vehicles and fuel tanks that are in good condition should be allowed to enter the training area. The direct contamination of soil through military activities is, by and large, associated with the use of explosive compounds (Certini *et al.*, 2013).

The SAACTC became military training land in January 1978. Since then, all sorts of military exercises and activities such as bomb-dropping, weapon testing and tank shooting have been carried out in this training area; thus, these activities have resulted in a different sort of environmental pollution. Thus, the training area is expected to exhibit widespread contamination from munitions, as well as petroleum products from fuel for motor vehicles and aircrafts (Teafy, *et al.*, 2006, Greičiūtė *et al.,* 2007). It is no surprise that some of the water sources are no longer fit for human water consumption. Soil and water (both surface and groundwater) are always contaminated by the residue from various types of explosives (Teafy *et al.*, 2006). It must be borne in mind that it is only recently that the military sector is compelled to fully comply with environmental laws. In the past, some incidences of pollution were deliberate and caused through negligent behaviour.

Furthermore, the types and conditions of the military targets used at SAACTC have deteriorated. Consequently, as of November 2013, normal metal vehicles were used as targets. This has serious negative environmental consequences because, when hit by heavy or high calibre weapon, debris is scattered all over the area. Thus, the use of these kinds of vehicles poses a greater environmental pollution risk. Armoured military vehicles are the most appropriate types of targets to be used in training areas, so as to reduce environmental contamination. It is surprising that the SANDF could use normal metal vehicle whilst there are many unserviceable armoured vehicles stored at the SAACTC depot.

Funding for Environmental Management Facilities and Environmental Management Programmes of the SANDF

The lack of financial resources appears to be a major challenge faced by the EMF at both military installations. Environmental management programmes are funded from miscellaneous accounts. At SAACTC, it was indicated that in any particular year the maximum amount that can be made available for environmental management projects is approximately R10 000. Both the 2001 and 2008 editions of the EIP acknowledge that expenditure on the environmental management programme is inadequate. Thus, insufficient funding prevents these facilities from operating at their optimal levels. These facilities are expected to lead the implementation and maintenance of all six environmental management programmes constituting the MIEM. Without adequate and sufficient funding, the objectives of establishing these facilities would not be achieved.

The environmental manager at SAACTC estimated that for the facility to operate at its full potential an ideal budget of five million rand is required. This will ensure that the duties associated with this facility, at SAACTC, are carried out effectively and efficiently. All the programmes need to be implemented and/or maintained every year. These programmes are environmental protection, as well as the restoration and sustainability of the ecological integrity of the training area. All these programmes require financial injection in order to be successful. The US DoD, for instance, finances its defence environmental programmes relatively adequately. For example, during the 2010 financial year, the defence environmental programme was allocated $4.5 billion [US Fiscal Year (US/FY), 2010]. According to the US/FY (2010), this money is spread across the six defence environmental programmes which run in all US military installations. However, each programme has its own unique focus and funding needs (US/FY, 2010).

These programmes are Natural and Cultural Resources (is allocated $437.4 million/year), Compliance (is allocated $1.5 billion), Pollution Prevention (allocated $91.2 million), Environmental Restoration for both active and non-active sites (budgeted for $1.6 billion), Base Realignment and Closure (BRAC) (allocated $666.7 million) and Environmental Technology (allocated $255.8 million) (US/FY, 2010). Given this kind of financial support, the US defence environmental programme is far better financed in comparison to the SANDF's environmental services. Thus, the restoration programme that has already been implemented in one training range at SAACTC cannot be improved in any other way, except to suspend it from all military activities. This will only ensure that the training range recuperates naturally, rather than the replanting of vegetation which will require substantial funding.

It is also doubtful that the training range will sufficiently recover within the three or four year period indicated on the AER. The question here is, was the recovery period determined based on empirical evidence or was it just an assumption that three years is long enough for the area to recover? The absence of this information is attributed to the insufficient funding that characterises the SANDF's environmental programme. The uncertainty about the time required for degraded training ranges to recover demands that the environmental research programme of the SANDF be actively engaged, so as to generate information that would guide the restoration programme of the SANDF. Given the insufficient environmental funding, the research unit could not operate and produce the necessary information.

Nonetheless, the reduction of the defence budget and commitment of the DoDMV to continental peacekeeping affects many national defence related programmes. This commitment further exacerbates the inadequate funding of the defence force's environmental programmes.

A military environmental management plan (MEMP) is developed for the purpose of implementation and needs to be adhered to during training exercises. Thus, non-compliance with the MEMP must carry some kind of punishment. As Henckaerts (2000) indicates, training programmes that specifically address the protection of the environment and prohibit widespread, long-term and severe damage to the environment must be adhered to. Thus, the unjustified destruction of the environment ought to be punishable (Henckaerts, 2000); this is, however, an international perspective. The punishment must fit the offense committed. For example, a warning for not complying with set regulations and guidelines does not equate to environmental protection and sustainability. Heavier punishment for disregarding the MEMP will inculcate the consciousness of environmental protection and sustainability to individual defence force members and units.

Eventually, this will also translate to the adherence of environmental management plans for military missions that are carried out beyond the borders of South Africa, when SANDF troops are deployed for peacekeeping missions in Africa or elsewhere in the world. Chartier (2003) stresses that joint forces commanders have to demonstrate proactive environmental leadership and promote environmental awareness for the duration of the mission. Thus, SANDF members should not be caught unprepared for or uninformed on environmental issues when situations such as these arise.

External Collaborations at SAACTC

It is clear that the SAACTC takes environmental management and compliance with the relevant legislation seriously. The existence of numerous external linkages at SAACTC is in line with environmental management concepts, such as integrated environmental management. This concept advocates for the wise use of natural resources without jeopardising the ability of future generations to meet their own needs. For this to be realised, experts from various fields must work together towards achieving the sustainable utilisation of natural resources. In light of this, the SANDF should seek assistance from other government departments, non-governmental organisations, and experts in the field in order to learn more regarding the management of the environment under their control and within which it operates.

Moreover, the DoDMV established a relationship on defence-related matters with the USDoD. Under this bilateral initiative, numerous documents on defence and environmental management have been produced. This is intended to assist the SANDF with the process of integrating environmental considerations into military activities. Smit (2009) indicates that South Africa (DoDMV) became part of the quadrilateral initiative (involving the United States, Canada & Australia) to develop guidelines for the integration of environmental issues into military planning and execution.

Ramos and de Melo (2006) also explain that many countries have formed collaborations through which they share defence environmental management information. These countries include nine partner countries, which are Albania, Armenia, Austria, Azerbaijan, Croatia, Finland, the former Yugoslav Republic of Macedonia, Georgia and Ukraine. Representatives from these countries have participated in various workshops on environmental management in the military (NATO/SPS, 2008). Thus, countries are sharing ideas, knowledge and experiences on the developed and implemented EMS in their defence forces (NATO/SPS, 2008).

These linkages are established in order to empower and enhance the abilities of the designated environmental officers in their respective defence forces to adequately and effectively deal with various aspects of environmental management. Thus, these collaborations established by the SANDF at SAACTC will, over time, significantly improve the environmental performance of the SAACTC military installation. Furthermore, the environmental practice at SAACTC may have a positive ripple effect on other units/installations of the SANDF anywhere in the country.

Capacity Building and Information Sharing Through Regional Facility Interface Managers Forum

The quarterly meetings for all DEOs within the SANDF, together with their RFIMs, should be beneficial to all involved. During these meetings, officers are expected to present their successes and challenges in terms of environmental management and the monitoring of environmental impacts in their respective military installations. These meetings can also be regarded as creating environmental teamwork within the SANDF. The importance of teamwork in environmental management is described, by Massoud *et al*. (2011), as effective in improving problem solving and cooperation. The RFIMs are expected to advise and provide solutions to problems that the DEOs face with regard to environmental management in the defence force. In other words, the RFIM are expected to empower (capacitate and skill) the DEOs and learn from each other's experiences. Environmental teams can make a significant contribution towards improving environmental management (Massoud *et al.,* 2011), which the SANDF needs. This approach is similar to the workshops organised by European countries for sharing ideas, knowledge and experiences on developed and implemented EMSs in the defence forces, as reported by the NATO/SPS (2008). Thus, information sharing is one of the most important tools to capacitate and empower the DEOs.

This is another indicator by which the SANDF shows commitment to effectively dealing with capacity, and competency deficiency, in its environmental management. However, the criteria of appointing the DEO are critical. A person to be appointed to this position must be passionate and demonstrate interest in environmental management issues, otherwise all these programmes may not make any difference and thus become futile exercises. In addition to these meetings, further environmental training is also necessary and important to adequately bridge the capacity gap that was noted during interviews and acknowledged in the EIPs (2001 & 2008). Environmental training is underscored by Ramos and de Melo (2005) as well as Massoud *et al.* (2011) as an integral part of effective environmental management.

The retention and attraction of skilled, environmentally qualified and competent (DEO) personnel within the SANDF requires extensive investment by the DoDMV toward environmental sustainability and establishing a career path in environmental management. The environmental profession in the SANDF must not appear to be a dead-end. Moreover, serious improvement of the EMF is required to make these divisions attractive to even non-military persons (civilians) who are environmentally qualified and competent. A qualified person will not be prepared to struggle as a result of lack of facilities and other necessary resources, in order to execute duties. Policy documents and EIPs can exist, however, they are as good as being non-existent if they are not translated into action. However, collaborations between the SANDF and the US military, concerning environmental management and its considerations in military activities, are a good undertaking for empowerment.

The Impact of Military Activities on Ecosystems at SAACTC

The impact of aggressive military activities and the high frequency of veld fires were evident throughout the training ranges that were visited during the course of this study. The impact of veld fires was most obviously noted on vegetation. Vascular vegetation tends to grow sparsely throughout the affected area, however, this is also ascribed to the military training activities carried out within the training area (Linkov *et al*., 2001; Bertell, 2002; Garten *et al.,* 2003; Haugen *et al.*, 2003; Quist *et al*., 2003; Ramos & de Melo, 2005; Tikhomirov, 2006; Warren *et al*., 2007; Silveira *et al*., 2010; Johnson *et al.,* 2011; Nyakatawa *et al.*, 2011; Wang & Wu, 2013).

Grass vegetation also becomes relatively short and younger owing to constant burning. There were patches of bare surfaces within these training ranges. None of the five training ranges visited had overgrown grass vegetation, thus indicating constant disturbances. Therefore, vegetation cover in all five training ranges could be estimated to be between 45-65%. This creates conditions which are conducive to considerable soil erosion (erosion by both wind and water). Nyakatawa *et al.* (2010) argue that the mechanical disturbance of ground surface soil and vegetation in military training areas creates conditions which are conducive to excessive runoff and erosion.

Numerous unexploded ordinances (munitions) were observed within the training ranges, and many other solid military wastes were lying on the ground surface. These were indicative of poor sweep clean processes after training exercises. These solid military waste materials contribute to environmental pollution, as the material weathers in the soil and thus contributes various types of heavy metals to it (Siebielec & Chaney, 2012). Bullets and bullet fragments (solid military waste) are also susceptible to weathering; they gradually oxides through air, water, organic acids and microbial activities (Robinson *et al.*, 2008). Environmental management reports indicate that the locations of UXO are marked and reported to the environmental manager and the Engineer Regiment. Even though the sweep-clean activity is carried out, not all of these are removed or recovered. The argument presented is that there is not enough time and manpower to recover them all. This validates the argument presented by Siebielec and Chaney (2012) who propose that military sites used for a long time are characterised by a variety of contaminants.

The environmental report suggests that the army cannot be solely held responsible for all the ecological impacts within the training area. This is true because there are numerous mining activities (mainly open-cast) which occur adjacent to the military training area. For example, dust can be mobilised from the mining sites and deposited in the training area. This would have a significant effect on the ecological integrity of the military training area. At a high level of toxic, plants can begin to change; they are thus good indicators of soil conditions (Díaz & Massol-Deya, 2003). Ahmad *et al.* (2012) indicate that military shooting ranges are the second most lead (Pb) contaminated land areas (Pb).

However, soil erosion has also been identified as one of the major problems in the training area. In military training areas, soil erosion is associated with bomb-dropping, off-road driving of wheeled military vehicles, trench and foxhole digging (Linkov *et al.*, 2001; Harmse, 2003; Silveira *et al.*, 2010). The causes of this problem have been identified as loss of vegetation cover, overgrazing and the clearance of vegetation for the establishment of temporal base camps. Furthermore, the poor track driving discipline of military vehicles leads to the trampling of vegetation and thereby induces the compaction of the soil (Harmse, 2003; Wang & Wu, 2013); this results in reduced infiltration and increased surface runoff. Nyakatawa *et al*. (2010) correctly point out that the removal of vegetation and soil compaction can lead to the loss of habitat for animal species.

Due to the serious nature of the erosion problem within the training area, a restoration initiative has been implemented on the heavily gullied training range. However, according to Nyakatawa *et al.* (2010), the restoration of degraded land through gullies, which have resulted from erosion in military training areas, is expensive. Thus, it is important to address the cause of the problem rather than to deal with the consequences. In other words, there should be a paradigm shift in the SANDF at SAACTC from a re-active to a pro-active approach. Furthermore, gullies can have a negative impact on the effectiveness of training activities, as well as jeopardize the safety of military personnel and equipment (Nyakatawa *et al*., 2010).

The collaboration with the Department of Agriculture would be more beneficial to the SANDF with regard to controlling soil erosion and the rehabilitation of affected sites. The degradation of soils in military training areas can cause significant reduction in plant diversity (Nyakatawa *et al.*, 2010). Thus, the reduction in plant diversity negatively affects the ecological integrity of military training areas. The Department of Agriculture, more often than not, deals with this kind of problem. However, the lack of involvement of academic and research institutions is a significant omission as these are centres where long-lasting solutions could be found. The ADF have formed partnerships with universities, research institutions and relevant industry in order to improve its delivery of environmental management and services to the defence force (ADF, 2010). According to Schmidt (2004), the US DoD is working closely with external experts to study the environmental impacts of bombing.

Soil erosion has both on-site and off-site impacts. On-site impacts involve soil loss and the degradation of soil together with nutrients. Alternatively, off-site impacts include sedimentation and siltation of water bodies, thereby degrading aquatic water quality and its ecological integrity (Silveira *et al.*, 2010). Froymson *et al.* (2005) state that aquatic biota is highly susceptible to sedimentation from soil disturbance associated with tracked military vehicle movement and infantry training.

The SAACTC has a programme known as military integrated ecological management (MIEM). This programme is aimed at safeguarding training ranges against over-utilisation. Any training range that might have been overused in a year is closed for four seasons. However, the exact meaning of the word “season”, as used in the context of the report, is not clear. Consequently, it is interpreted here to mean training years. Thus, any training range appeared to have been overused, is closed for four years. To this end, the Besiespan training range was, as of 2013, suspended from military activities for 3 years. The decision to close a training range is taken by the environmental manager after a thorough assessment of the range. The environmental manager also influences the outcomes of applications for use of any training ranges.

This is an assurance that a suspended training range may not be mistakenly used before the required recovery period has lapsed.

Environmental Management Plans and Environmental Reporting

Stringent environmental compliance requirements must also be put in place, at both installations, to closely monitor the environmental performance of the SANDF. The monitoring of adequate implementation of the EMP creates opportunities for additional measures for impacts that are not provided for in the initial plan (ESWG, 2006). This will ensure that no environmental impact occurs as a result of negligence or weaknesses in the EMP. Yet, it should also be noted that not all forms of pollution can be avoided, especially since vehicles and humans constantly move around the area for the duration of the training exercise, and this has a significant impact on the environment. Accordingly, the mass movement of troops have large and unavoidable impacts on the environment (ESWG, 2006). This is one of the unavoidable and unmitigated environmental impacts of military training activities.

Most of the environmental reports that have been analysed show both appropriate environmental practices and expose vast weaknesses. For example, the refuelling of military vehicles can only be carried out at designated sites. Protective sandbags bunds walls are erected at the edge of fuel pump(s) to prevent the contamination of large ground areas due to a malfunction; this is pro-active planning for possible spillage. Refuelling and vehicle maintenance are not allowed near water sources. This shows some level of consideration of environmental concerns in the planning of the military training exercise. Indeed, these practices can significantly reduce environmental contamination and enhance the protection and sustainability of the training ranges. The prohibition of vehicle maintenance in the training area is also commendable because this can contaminate the environment with various harmful fluids. Environmental contamination, through fuel spillages which occur during “combat training”, is regarded as unavoidable; however, the affected sites are marked and reported to the environmental manager in order for rehabilitation action to be taken. This practice is encouraged by the ESWG (2006). This information is then used to design a post-deployment environmental management plan or rehabilitation plan (ESWG, 2006).

The surprising statement that no military training exercise can be cancelled or suspended on the basis of the significance of its environmental impacts (Environmental Support Plan, 2008), simple means that even if the environmental impacts are severe, but the training exercise will continue as planned. This utterance implies that environmental protection is not adequately entrenched in the activities of the SANDF. The US Air Force is reported to terminate over 30% of their scheduled live-firing and bombing exercises in an effort to avoid harming or disturbing the movement of Sonoran pronghorn antelope (D’Agostino, 2002). Further, in some cases, troops are restricted from digging defence trenches, for the protection of the desert tortoise (D’Agostino, 2002). Furthermore, the environmental support plan of 2008 simply indicates that the breeding periods of wildlife are constantly disrupted or are not known. This approach is in conflict with the ecological management programme of the SANDF.

Environmental reporting at SAACTC is not as weak as it is at GMI, although the ESWG (2006) provides a template or format for environmental reporting. The lack of environmental reporting at GMI indicates a weakness in the defence policies. At SAACTC, the previous environmental report becomes the environmental baseline survey (EBS) for the subsequent training exercise. The most appropriate way to do this is to have an environmental conditions report (or site closure report) prepared after the training exercise (ESWG, 2006) so that the impacts can be measured and their aggression noted.

The EBS is then used for comparison against a site closure report (SCR), which details the state of the training range at the end of the military training exercise (Chartier, 2003). Therefore, the environmental representatives of various units must be selected on the basis of their environmental competence. The competence of the ER determines the integrity and accuracy of the field environmental report on the problems encountered. The DEO must also act on all the incidences reports, and make the necessary arrangements for the removal of any hazardous material that may have been left on the training range. Likewise, the DEO can develop a database of all UXO marked and left in the field, this information is very important to the clean-up process. Similarly, the SCR is as critical a document as the EBS (Chartier, 2003), therefore, it needs to be kept on record.

The constant inspection by ER, and the unannounced visit of the GOC or the second in command officer, to assess the effectiveness of all mitigation measures during the training period is appropriate and in line with proactive measures towards the prevention of pollution and damage to the environment. Such inspections are conducted to ensure that activities are carried out in adherence of EMP and to make certain that any non-compliance with the EMP for the military exercise is rectified immediately.

However, inadequate reporting or inaccurate reporting was noted in the 2009 environmental closure report. The challenges related to the implementation and monitoring of environmental management at SAACTC will undoubtedly have severe consequences. This report (ECR, 2009) did not indicate that insufficient funding of the EMF is one of the major challenges to executing these duties more efficiently. This gives the impression that the funding for environmental management is adequate or sufficient, yet it is not.

Environmental Management Tools Adopted in the SANDF

Dawnson (2004) states that military practitioners around the world have realized that EMS is possible and desirable for implementation in military organisations, in order to minimise the environmental impacts associated with military activities. The SANDF attempted to implement EMS in 2001. The current study, in addition to that of Smit (2009), has established that the implementation of EMS in the SANDF collapsed six years after it was piloted (i.e., in 2007). Obviously, the reasons that led to the collapse of the EMS within the SANDF territories are related to funding, lack of adequate skills, lack of capacity and competent permanent human resources as well as poor internal coordination of the SANDF's environmental management (Smit, 2011; Magagula, 2014).

In addition, the lack of appropriate external collaborations with relevant government departments has also played a significant role in this (Magagula, 2014). As of 2013, it was not clear whether all the forums mentioned in Chapter VI were functional, and the extent to which these agencies are working towards resuscitating this important environmental management tool, as reported by Smit (2011).

Similarly, challenges and problems have been identified and linked to the failure of the implementation of EMS, and the corrective measures that have been proposed to avoid the repetition of the initial attempt to implement the programme. It is not clear how the General commanding officer and Unit commanding officers are empowered in terms of environmental management skills and knowledge. All commanding officers refused to participate in the current study, and did not return the questionnaire; subsequently, it was impossible to measure their knowledge and level of environmental empowerment. Environmental empowerment is critical in the successful implementation of environmental management systems in any organisation (Massoud *et al.*, 2011). Based on the passive attitude towards participating in the current study, it can be assumed that they have little knowledge and lack the capacity to oversee the management of the environment in their respective Units.

At GMI, no annual environmental management report was made available on request. Record keeping is evidence of ongoing progress in respect of environmental management (NATO-CCMS, 2000). The lack of records may indicate that the annual audit suggested in the two IEP documents is not carried out as expected. Nevertheless, the EMF at GMI does not have a qualified or competent person leading its environmental management. This situation does not make it possible for adequate incorporation of environmental concerns into military activities. Thus, environmental management practices are not monitored and compliance with NEMA is lacking entirely (Figure 14 in Chapter VI).

However, the situation is different at SAACTC, since environmental reporting is carried out as required by the EIP for the defence force. The environmental practice at SAACTC is somewhat monitored, as the results have indicated (Figure 14); this is attributed to the existence of a competent environmental officer (designated environmental officer). Furthermore, this military installation cannot afford not to have a competent environmental person because it is where the high calibre arsenal is used; therefore, there is a high risk of environmental degradation.

Consequently, various environmental management tools are applied and varieties of environmental programmes have been developed and are being implemented. This is in support of NATO-CCMS (2000) and Ramos and de Melo’s (2005) view that designated environmental professionals take full responsibility for environmental issues within a defence force. This case study shows the SANDF’s commitment to comply with environmental management legislation. Thus, it is well within the best environmental management practices although there are still more weaknesses within the environmental management system.

The environmental monitoring mechanism of the defence (DoDMV) includes an environmental awards programme. This programme is commended in that it recognises the efforts and initiatives of individuals and groups towards environmental management protection and sustainability in different installations. This approach makes members of the defence force see themselves as making as significant contribution to the environmental management process of the defence. It is through this programme that senior environmental managers of the SANDF can identify individuals who should be recruited and trained as additional environmental officers, in order to fill the skills capacity gap.

This programme can identify persons who are passionate about and interested in environmental management issues. However, the career path in environmental management in the defence needs to be broadened so that it is not regarded as a "dead-end". It is only then that defence members can be interested in and attracted to this career in the defence. It should also be noted that people are attracted to divisions where there are fewer problems and where all the required facilities and resources are available or made available when needed.

In both the military installations studied in this thesis, the communication on environmental management issues has been flawed. This can be attributed to the collapse of EMS, as it serves as a beacon for environmental practice in the organisation. The GMI's situation is worse because, as of July 2011, no one was leading its environmental management process. As such, no collaborations or external linkages existed, except for one with the Department of Water and Sanitation. This programme is aimed at the eradication of invasive alien plant species, especially

Opuntia Indica (commonly known as prickly pear) within the training area. The absence of an environmentally qualified and competent person has led to a lack of environmental management programmes and plans. Consequently, environmental management is practiced on an *ad hoc* basis rather than on a continuous basis. The Rand Arroyo Center [RAC] (2008) denounced this tendency, where environmental considerations are addressed on an *ad hoc* basis in the military forces.

The absence of an appropriately qualified person at the GMI has resulted in the failure to implement the monitoring mechanisms recommended in the EIP documents. Therefore, the internal audits have also not been carried out. However, the EIPs state that the internal audit capacity within the defence will continuously be expanded to ensure adequate environmental protection and sustainability (Figure 21). Moreover, the internal audit capacity will improve the environmental performance and compliance with legislation within the SANDF. The DoDMV's failure to equip the EMF, and thereby improve policy implementation, accounts for this situation. Some organisations tend to pay less attention to the organisation's environmental reporting when they are not forced to do so (Leszczynska, 2010). This is the culture that seems to be developing at the GMI.

On the contrary, the situation at SAACTC is different and shows promise that the SANDF will at some stage reach the desired level of compliance with environmental management. Nevertheless, the lack of internal audit instruments hampers progress in this regard. Thus, the adequate evaluation of environmental performance and monitoring has not been appropriately done. The lack of formal environmental education programmes and activities at both installations is a major drawback from empowering defence members in regard to environmental issues (Figure 30).

In addition to the seven environmental management monitoring mechanisms outlined in the first and second editions of the EIP (2001 & 2008), the SAACTC also uses an environmental management tool called the military initiated environmental impact assessment (MIEIA). This tool is used to determine the environmental impact that is likely to arise from the clearance of vegetation for base camps, camouflage and wildfire control procedures as well as execution military activities (ESWG, 2006). It is through this tool that military environmental impacts are identified and mitigation measures suggested and incorporated into the EMP for a particular military training exercise.

Thus, the application of this tool highlights the defence's attempt to integrate environmental planning and its compliance with the principles of environmental protection and sustainability (ESWG, 2004). The MIEIA is carried out by the RFIM attached to this military installation. This gives creditability to the impact identified and mitigation measures suggested. The ESWG (2004) underscores the reality that focus must be placed on those that are practicable, for example, efforts should be focussed on controlling soil erosion that is likely to arise due to the construction of temporary structures.

The requirement that each military installation develops an annual environmental management plan is indicative of the DoDMV's willingness to ensure that military training areas are sustained. The compliance with this requirement (defence policy) can only be possible when all the necessary resources are made available. In a military installation where the very basic resource(s) are not available, as is the case at GMI where an environmental officer has not been appointed in more than two years, the achievement of environmental protection will remain an elusive goal. In addition, non-compliance with the defence policy will continue. At GMI, it is only the OHS officer who, to a certain extent, acts as an environmental advisor; however, his main area of operation is to ensure the safety of defence force members from hazardous environmental working conditions. The OHS is not responsible for environmental protection and sustainability per se.

Thus, the optimum functionality of the EMF in a military installation has valuable benefits. These benefits stem from the development of an environmental management plan for that unit/base. This plan should provide guidelines for each activity that takes place within the training area of that base, including the following: gathering environmental information, implementing impact evaluation and monitoring environmental impacts of the defence training activities. The disposal of any kind of waste and the improvement of the environmental management profile depends on the optimum functioning of the EMF. Thus, the environmental protection and sustainability of military training areas depend primarily on the commitment to empowering defence force members.

The EMF at SAACTC, through the RFIM, is developing a programme called the military integrated environmental education plan (MIEEP). The aim of the MIEEP is to ensure that all members of the defence consider their impact on and responsibility towards the environment in their day-to-day activities. This programme is meant to improve the environmental understanding and knowledge of all defence members stationed at SAACTC. This is the most important step towards improving environmental management at this military installation. Knowledge is power, thus, defence force members will know exactly why the environment must be protected at all times during the execution of their day-to-day duties.

However, the achievement of the desired outcomes associated with this programme lies in the manner in which it is communicated within the Unit. There are various effective ways of disseminating information and, thereby, educating and empowering people. Some of the approaches to be adopted may include seminar presentations, the distribution of pamphlets, and environmental day(s). Therefore, effective communication and the accurate packaging of information is critical to the success of this programme, when implemented. Otherwise, the purpose of this programme will be nullified.

One of the major weaknesses revealed by the results of this study is that the process of environmental management monitoring is severely flawed. Too many critical questions related to environmental management monitoring were left unanswered. Worse still, no reasons were provided to justify why environmental education training has not been carried out or implemented and why there has been no observation of environmental days. Such reasons should have shed light on the existing challenges or problems encountered in carrying out these activities, as this would assist in planning for the future. Furthermore, the SAACTC does not have a procedure to effectively communicate and report on environmental management matters. This means that communication and reporting on environmental issues is not done in a coordinated manner.

The Integrated Environmental Management System (IEMS) mentioned in the AER (2010) revealed that the SAACTC is still not ready to adequately and effectively implement environmental management. Amongst the issues that are of concern include the severe shortage of human resources within the EMF (understaffing), the knowledge gap in environmental management, internal policy development ability/skill, the lack of adequate communication between hierarchical levels, insufficient environmental funding (financial resources) and record keeping (information management).

West (1997) states that for the defence to succeed in its quest for ensuring environmental protection and compliance with the applicable and appropriate laws of the country, it ought to have adequate personnel to coordinate environmental programmes for the defence. A budget for resources with which to execute the environmental management programme in the defence is one of the crucial factors in this regard (West, 1997). Furthermore, West (1997) indicates that environmental coordinators (personnel) at installations must be trained to adequately perform their duties. Moreover, all defence members must be trained to ensure that they also perform their duties in an environmentally responsible manner (West, 1997). Environmental training will foster a proactive attitude towards the protection of the natural environment (Massoud *et al.*, 2011).

From the results obtained in this study, it can be argued that the SAACTC does not have its own base environmental policy, nor does it have any individual or group of individuals assigned to monitor its implementation of the “EMS”. Yet, there is an environmental coordinator/environmental manager and the RFIM assigned to this installation. This might, however, be the case because the implementation of EMS in the SANDF has collapsed. Furthermore, there is no procedure to evaluate the environmental impacts of existing activities. Surprisingly, the Guidebook on EIA in the Military was published in 2004 by the Joint United States – Republic of South Africa Environmental Security Working Group. This indicates that the document has not been translated into action. Ramos and de Melo (2005) indicate that performance evaluation is much better supported with the existence of EMS. Nonetheless, this can be attributed to understaffing and a lack of facilities and skill limitations which have been acknowledged in the SAACTC report, and in the two editions of the EIP for the defence. Individuals who are supposed to oversee environmental management are also expected to discharge other duties; this is one of the reasons why all these weaknesses still exist.

Designated environmental officers should only be responsible for the management of the environment and the development of environmental management tools. Ramos and de Melo (2005) argue that the incorporation of environmental issues in the activities of the military demands that designated environmental professionals are assigned to deal with these issues. Thus, the determination of annual environmental objectives and targets can be dealt with much easier.

The designated environmental professional will also be responsible for the environmental training of personnel, implementation of the EMS and environmental programmes (Ramos & de Melo, 2005). Thus, weak internal structures for appropriate environmental management can never yield the desired the results. Consequently, the SANDF still has a lot to do in order to improve its environmental management profile. According to Ramos and de Melo (2005), for a military sector to improve on its environmental management practices, it need environmental education and awareness, which would improve its environmental management profile.

Environmental Management Capacity at SAACTC

The capacity gaps and limitations outlined in both the 2001 and 2008 EIPs accurately captured the information obtained in the field. Clearly, the SANDF is facing serious challenges in its quest to fully comply with environmental legislation. As discussed in the GMI case study, there is an urgent need for the SANDF to develop and enhance the competence of its environmental management personnel across all of its EMF, if it is to succeed in honouring its environmental obligations. Nevertheless, the situation at SAACTC is not exactly the same as is the situation at GMI. The major constraint at SAACTC EMF is understaffing (aside from funding).

Again, the current state of affairs at SAACTC indicates partial commitment to the effective management and protection of the environment from military activities at this installation. Thus, the SANDF needs to ensure that its activities adequately integrate environmental management practices, as many other defence organisations are doing or have done (Ramos & de Melo, 2005). For example, the defence forces of countries such as Australia, Canada, Spain, Sweden, the United Kingdom and the United States of America have long understood the role of environmental management in peacetime activities (Ramos & de Melo, 2005 & 2006). Moreover, environmental management may prove critical in land used primarily to support field training requirements for combat readiness (Ramos & de Melo, 2005). This is vital because effective military training requires a natural landscape with the appropriate features in order to care for the training needs (Ramos & de Melo, 2005).

Degraded training ranges may adversely affect the potential for diversified military training. Lewis (2010) argues that access to high-quality training areas serves as a third factor, in addition to time and money, in terms of troops' combat readiness. With this in mind, the appropriate management of SANDF training areas is paramount to ensuring their sustainability.

Military Integrated Environmental Management

The broader environmental management programme for the SANDF is called military integrated environmental management (MIEM). This programme is based on six environmental management pillars, as shown in Figures 13 and 41. The incorporation of environmental planning as the building block of MIEM is highly commendable. Environmental planning refers to the process of facilitating decision making in carrying out an activity with due consideration for the natural environmental, its social aspects, hazardous material (handling, waste management and disposal) and many other relevant issues. It thus provides a holistic framework to achieve sustainable outcomes, such as minimizing the environmental impact (ESWG, 2006). It is expected that when these programmes are correctly applied, they can yield the desired outcomes, as elaborated upon by Godschalk (1996) and Smit (2011). However, due to the current limitations in the SANDF, with regard to the lack of internal environmental expertise, the programmes will fail to achieve the aims for which they were developed.

As it currently stands, it can be argued that MIEM is based on a weak foundation. The major challenges, as explained in some of the sections above, are not favourable for the adequate implementation of these environmental management programmes. This argument is based on the deficiencies evident in the results, which indicate that there are severe limitations to the adequate incorporation of environmental considerations into military activities. Neither of the two EIP documents indicates specific activities which constitute each of these programmes. However, Smit (2011) narrowly tried to expand on some of these programmes while comparing the new approach to the older SANDF conservation programme.

Since each of these programmes has been developed to improve the consideration of environmental issues in defence force activities, the specification of activities in each programme is paramount. In addition, the successful implementation of all these programmes within the SANDF requires good internal structural organisation, adequate coordination of processes and procedures, adequate capacity within the defence, and relevant external collaborations. Neither of the EIP documents explicitly outlines sub-programmes which constitute each of these major programmes, which form the building blocks of MIEM.

The current study proposes some of the activities should be undertaken in each programme (Figure 42). However, it should be noted that the activities indicated are not in any way exhaustive; instead, there are many other possible activities that can be carried out within each of these programmes.

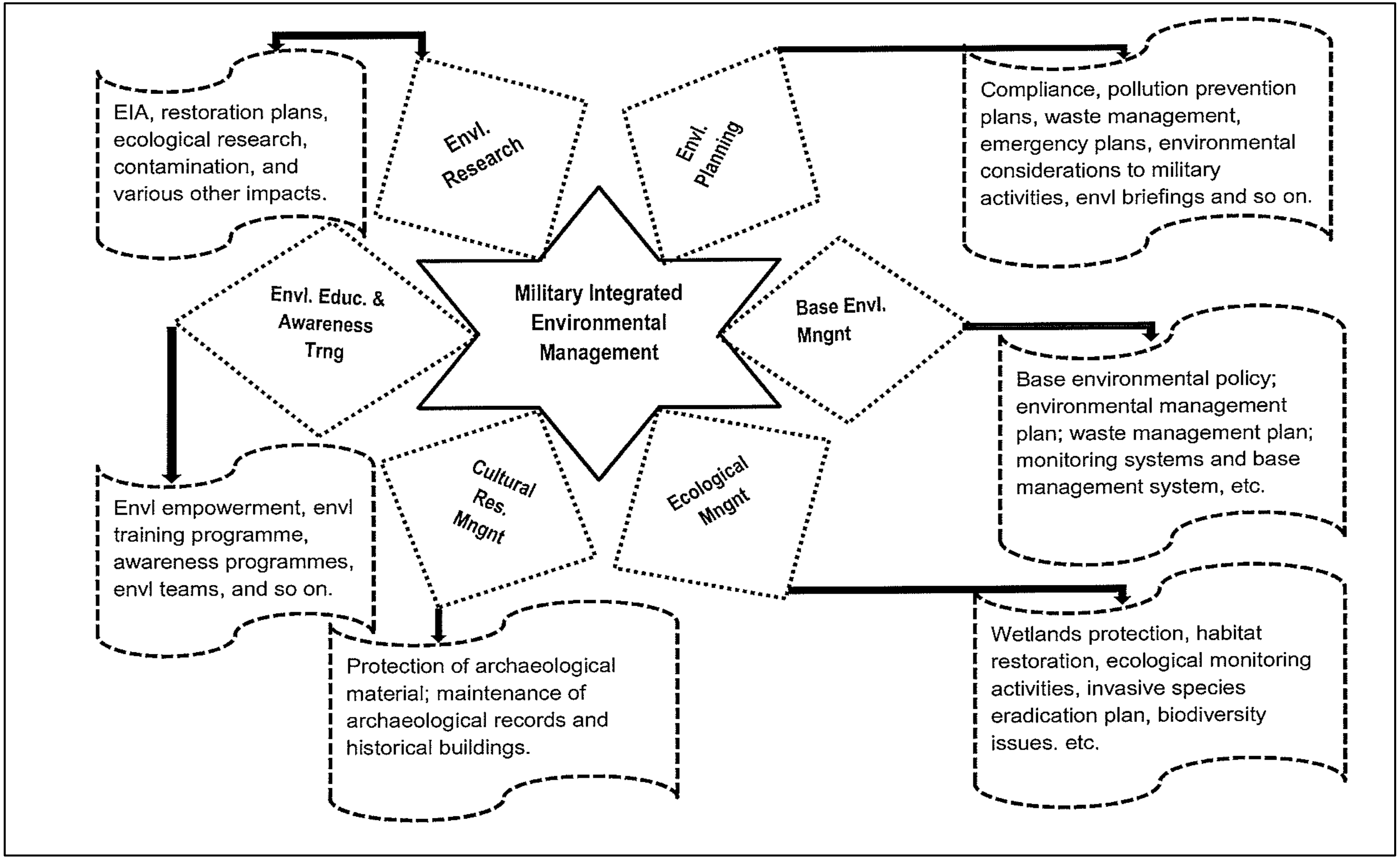

Figure 42. Proposed military integrated environmental management

Note: "Envl" stands for 'environmental', "Educ" stands for 'education', "Trng" stands for 'training', "Mngnt" stands for 'management', "Res" stands for 'research'

This study proposes that environmental planning becomes a programme that provides directions regarding the activities of the other programmes. Thus, environmental planning is a key element in MIEM because it directly influences all the other programmes. During environmental planning, issues that require scientific investigation will emerge, and inform the research programme. The outcomes of the study will, in turn, influence environmental planning. In addition, environmental planning will also identify issues that are important to ecological management. This may necessitate research to be carried out in relation to ecological management, which will then improve ecological management in the defence.

Furthermore, environmental planning can enhance ecological management. To this end, the environmental research programme will also play a significant role in determining what needs to be incorporated into the defence environmental education awareness and training programme. Military environmental education awareness and training ought to identify training needs at various levels, such as commanders, middle managers, supervisors and soldiers at the base or installation (ESWG, 2002). This will ensure the continued improvement in the overall performance of the SANDF, with regard to environmental management (ESWG, 2002). Similarly, ecological management can highlight the importance of ecological elements for realistic military training. The ecological issues should also be incorporated into environmental education awareness and training programmes and activities.

In turn, environmental research, ecological management, environmental planning as well as environmental education awareness and training have significant influence on cultural resources management (CRM). The assumption is that soldiers ought to know what constitutes a cultural resource and why it should be protected and preserved. The US DoD prides itself on the knowledge that all its installations are rich in both natural and cultural resources, partly due to the effectiveness of their previous conservation initiatives (US/FY, 2004). Furthermore, military lands are protected from other forms of development, thus harbouring a wide range of undisturbed natural habitats leading to a variety of diversity of species (CEMML, n.d.). The SANDF should also strive towards achieving a similar high standard of environmental protection, where it would become clear that its military installations are habitats for rare, endangered species and rare ecosystems.

Environmental research will also reveal other cultural resources that are yet to be identified. This is possible in a country as diverse as South Africa as any unusual object might be linked to a particular ethnic group. This can only be revealed through research. Thus, research is the only tool that can inform the cultural resources management plan. The ESWG (2006) argue that, for cultural resources to be maintained, a proper management plan is important. Cultural resources include but are not limited to cemeteries, religious sites, archaeological sites, historical structures (ESWG, 2006). It is also important to consider educational sites, such as meteorite impact craters, as cultural resources. The SANDF at SAACTC has already developed a database for all the cemeteries within the training area; these graves date as far back as 1894 to as recently as 1976. Therefore, the SANDF has tried to maintain the cultural history of the land.

Veld fires have proved to be a major challenge at SAACTC, thus indicating that effective fire management plans need to be developed. This signalled that the fire problem ought to be part of the environmental research of the SANDF as shown in Figure 42. The CEMML (n.d.) provide more details on what and how wildfires associated with military training activities can be studied and managed. This includes knowledge of fire history, fuel load distribution and mapping, fire danger rating systems, wildfire prevention analysis and mitigation strategies, as well as the determination of the kinds of munitions posing the greatest ignition risk (CEMML, n.d.). Thus, it is critically important for the SANDF to embark on this process to alleviate the ecological threat posed by wildfires which are ignited during training exercises. This can only be achieved through research which ought to be carried out within the environmental research programme of the SANDF.

Environmental planning, ecological management as well as the environmental awareness and training programme are vital to ensuring minimum harm to both natural and cultural resources within military installations. Degradation of the ecological integrity of the military training areas would mean no realistic military training activities could be carried out. These could be a major setback in troop's preparations for active combat.

It is noted with dismay that the EIPs do not indicate the involvement of institutions of higher learning in assisting the SANDF/DoDMV in carrying out any of their programmes, particularly the environmental research and ecological management programmes. Countries such as Australia and Portugal have requested that academics assist them with the management of the environment in their respective defence sectors (Ramos & de Melo, 2005; ADF, 2010). Experts from various sectors of society need to be involved by the SANDF/DoDMV to assist with the strengthening and improvement of environmental practice in the defence. As an example, the US DoD works very closely with an environmental expert (Schmidt, 2004). Hopefully the SANDF/DoDMV will eventually realise the importance of intensively involving other experts from relevant institutions in efforts to improve the defence force's environmental management profile.

Summary

The environmental performance at GMI is insignificant, and borders on being non-existence. Environmental issues are only taken into consideration for major military exercises. The significant lack of environmental protection at this military installation is attributed to the absence of environmentally qualified or competent personnel. As of July 2011, the military installation did not have a person who would provide leadership on environmental management issues. Numerous challenges regarding environmental considerations, both at GMI and SAACTC, are highlighted in this chapter. These include the lack of funding, lack of environmental management skills, lack of facilities, such as vehicles, and adequate training on environmental issues. These shortcomings have been acknowledged in both EIP documents. The removal of solid military wastes from training ranges is not adequately carried out. To this end, many military waste materials were found scattered on the ground surface in both military training areas. Attempts to reduce and prevent various kinds of pollution are well under way at SAACTC. Most of the preventative pollution measures adopted for training exercises make a significant difference to the pollution problem.

Annual environmental reports are also prepared at SAACTC, as prescribed in the EIP, as one of the environmental management tools. This is ascribed to the presence of a qualified and competent designated environmental officer. Furthermore, the SAACTC military installation has established several environmental management programmes that are linked to the broader SANDF environmental programme. In addition, the SAACTC has established healthy and invaluable external collaborations with various other government departments; in comparison, GMI has only one active collaboration which is functional at present.

Despite the existence of all the positive signs of effective environmental protection and sustainability at SAACTC, there are still many challenges and uncertainties regarding environmental management. Thus, the broader environmental management programme of the SANDF (i.e., MIEM), constituted by six major programmes, is based on a fragile foundation.

Some of the arguments raised in this chapter are consolidated in the next chapter (i.e., Chapter IX). Chapter IX discusses the results of the quantitative analysis that was presented in Chapter VII.

CHAPTER IX

ATTEMPTS AND CHALLENGES TO INCORPORATE ENVIRONMENTAL CONSIDERATIONS TO THE SANDF ACTIVITIES

Introduction

This Chapter discusses the results of the quantitative analysis of the data presented in Chapter VI. This chapter is therefore divided into two parts, the first of which discusses the attitudinal and perception-related results obtained in both case studies. The second part focuses on discussing the results of the comparative analysis of the data gathered from the two areas investigated. It should be noted that a significant proportion of the results and discussion in this chapter has been published in two journal articles. The discussion on attitudes was published in the *Fort Hare Papers Journal* which is a peer reviewed journal and the results related to concentrations of heavy metals were published in the *Polish Journal of Environmental Studies*.

CONTEXTUAL BACKGROUND

Environmental considerations in military activities, such as planning and operation, are imperative. However, this can only occur once there is recognition of the role of the environment in the sustainability of military territories. There are many factors, including attitudes and perceptions that can obscure or lead to disregard for this critical aspect. Kulatunga *et al.* (2006) define 'attitude' as a psychological tendency to evaluate a particular object or situation in a favourable or unfavourable way, which causes someone to behave in a certain way towards it. Pickens (2005) defines 'attitude' as a mind-set or a tendency to act in a particular way due to both an individual's experience and temperament. Attitudes are the individually attributed emotions, beliefs and behavioural tendencies that a person has towards a specific condition or situation, including an object. Clearly, attitude is not behaviour but a behavioural tendency (Narli, 2010). Accordingly, Pickens (2005) considers perception as a process by which an individual interprets and organises sensation in order to produce a meaningful experience of real world motivations. Pickens (2005) argues that perception is closely related to attitude. Pickens (2005) also puts forward that the perception process follows four stages: stimulation, registration, organisation and interpretation. Therefore, attitudes and perceptions are critical in performing a particular job function (Schlager, 2008).

Success and/or failure of a planned activity, such as the implementation of a policy or programme, depends on attitudes towards the prevailing situation and the value attached to the object. A positive attitude always leads to the successful accomplishment of the task at hand, provided that all other necessary resources are available. However, the same cannot be said about negative attitudes towards a specific task. Defence force members are always at the receiving end of directives from their superiors and, more often than not, the instructions are not contested (Firing *et al.*, 2009). This is the doctrine which is instilled in all recruits when they join the defence force; it also forms part of the defence culture. Therefore, in such cases, huge differences in attitudes and perceptions are likely to arise. The top-down approach towards the integration of environmental issues into military activities is not favoured by the respondents. Both EIPs for the defence (2001 & 2008) argue that a bottom-up approach on environmental considerations into military activities will never work in the defence forces. Supporting this argument in the EIPs, over 50% of the respondents at the SAACTC recognise that a bottom-up approach can never work in the defence force, particularly in regards to the considerations of environmental issues in the activities of the military. Furthermore, this is contrary to the defence culture of receiving directives and instructions without question and contestation (Firing *et al.*, 2009).

Some of the differences noted in the results are, in turn, likely to affect the commitment of individual defence force members to being pro-active or reactive towards environmental problems. In the past seven decades, military forces and society in general were not fully conscious of their impact on the environment. This emerged primarily from the perception that development must come first and environmental protection later, or 'pollute first then clean up later' (Liu, 2010). This legacy has left its footprint on the environment. To this end, military forces have also left their own legacy or footprints on the environment in many parts of world. In most cases, these environmental footprints were accidental, in that, the environment damage could not be avoided. However, in some instances, the damage was deliberately induced to achieve certain objectives. The Vietnam and Iraq wars are good examples of the latter. Other sectors of society have also caused their own environmental footprints, which are well documented in the literature. All these impacts portray certain attitudes towards and perceptions of the environment at that time. In the most recent four decades, significant changes in attitudes and perceptions towards the environment, in all sectors of society, have been noticed, but less so in the defence sector.

In recent decades, protection of the natural environment has become a major global debate. This has emerged from the increasing recognition of the increasing human and industrial impacts on the environment (Eltayeb & Zailani, 2009). From the 1970s onwards there has been an increase in environmental awareness. This awareness has intensified in recent decades, during which governments, industries and citizens across the world have become more sensitized to environmental issues and the need to manage the natural environment more systematically (NATO-CCMS, 2000). Thus, environmental issues have been increasingly integrated into various organisations' activities (Eltayeb & Zailani, 2009). This has led to the conception and development of an environmental management system (EMS).

The 1980s can be perceived as conspicuous in its adoption of a systematic approach to environmental management in dealing with environmental problems. It is during this period that the term 'sustainable development' was coined (Moldan *et al.*, 2012). It was defined (in 1987) to mean the ability to satisfy current needs without compromising the possibility of future generations satisfying their own needs (Caniato *et al.*, 2012). This concept has three major strands or pillars: economic, social and environmental sustainability. Accordingly, Moldan *et al.* (2012) describe environmental sustainability as seeking to improve human welfare by protecting the natural resources used for their needs, as well as providing and ensuring that the sinks capacity for human wastes are not exceeded (Moldan *et al.*, 2012). Nel *et al.* (2012) define environmental sustainability as the utilization of the earth's natural resources wisely in order to meet the necessities of and to save resources for future generations. Similarly, Hueting (2010) defines environmental sustainability as the situation in which vital environmental functions are safeguarded for future generations. Accordingly, environmental sustainability is an approach through which natural resources can be used and managed for long-term human benefit (Goodland & Daly, 1996).

Consequently, since the late 1980s, the concept of sustainability has been central to the natural environmental sciences, in order to understand the complex nature of environmental problems and to find mitigating measures or solutions to such problems (Uiterkamp & Vlek, 2007). Since then, the concept of sustainability has posed serious challenges to many organisations in terms of carrying out their activities within the principles of sustainability. Furthermore, environmental protection refers to practices aimed at safeguarding the environment, together with all its components, against abuse by human activities (Lẽvệque & Mounolou, 2003). Environmental protection is viewed as a means towards achieving environmental sustainability (Padoch & Sears, 2005). In other words, environmental sustainability cannot be achieved without implementing environmental protection practices.

Managers of military ranges face conflicting demands of balancing the primary military mission with the legal requirements of protecting military land assets from degradation (Quist *et al.*, 2003). Currently, there is still considerable resistance within defence force organisations against adopting and implementing environmental management tools. This exists even though environmental issues are critical in, and should be central to, modern day military planning and practice (Smit, 2011). The majority of military organisations have not realized this critical aspect. This attitude is believed to be embedded in the debate on whether or not military activities are compatible with environmental protection and sustainability (Truba, 2004).

It is against this backdrop that even military activities must be carried out within the ambit of environmental protection and sustainability. The sustainability of military training ranges depends on their ability to provide the conditions for realistic military training (Nyakatawa *et al.*, 2011). Once military training ranges become degraded, the proficiency of troops will be affected. However, the majority of military practitioners still believe that the impact of military activities cannot be minimised. In other words, environmental protection and sustainability are impossible in the territories of the armed forces. The incompatibility of environmental issues and defence activities is further exacerbated by the challenges associated with the lack of capacity to effectively deal with environmental concerns and the insufficiency of the financial resources that defence organisations have been granted in the past few decades.

Above all, the most serious challenge is to change the mind-set of thousands of soldiers and military practitioners who went through military training that did not incorporate training related to environmental concerns. Thus, these people may not value the environment, and their behaviour towards it is largely influenced by what they learnt during their training and briefing sessions. The emerging attitudes and perceptions will determine the success or failure of programmes aimed at achieving environmental protection and promoting sustainability. The current study intended to contextualize the perceptions of members of the 6SAI Bn concerning environmental issues and its management.

More recently, there has been a significant change towards integrating environmental concerns into military activities (NATO-CCMS, 2000). Although this process has been very slow, efforts are being made by some governments, in their respective countries, to enforce environmental consciousness in their defence forces. For example, the literature indicates that the United States of America, Australia, Canada, Sweden, the United Kingdom and Portugal have made significant inroads towards the incorporation of environmental considerations into their military activities (NATO-CCMS, 2000; Ramos & de Melo, 2005 & 2006; Wu, 2013). Nevertheless, in comparison to the private sector and some public entities, attitudinal change towards environmental issues appears to be lagging behind in the military forces (Smit, 2009). Smit (2009) further attests that knowledge about the environment is not the only factor that can change the behaviour of military personnel, but attitudes towards and perceptions of the environment are also imperative. Thus, growing environmental awareness has posed a considerable challenge to modern-day defence forces in regard to environmental responsibility (Smit, 2009).

Generally, there is a paucity of published research on the attitudes and perceptions of military personnel regarding the incorporation of environmental concerns into military activities. However, literature is available on attitudes and perceptions related to many other aspects such as social and educational issues. Only a few studies have assessed military attitudes towards environmental issues. Some of these studies include research conducted by Ballantyne (1999) on teaching environmental concepts, attitudes and behaviour through Geography. This study established that educators are committed to teaching and promoting environmental knowledge, responsible environmental behaviour as well as positive attitudes and values. DeChano (2006) considered the relationship between environmental knowledge and attitude; he concluded that environmental knowledge does not translate directly into a positive attitude towards the environment. A study by Barr and Gilg (2007) concluded that substantial behavioural changes are unlikely to result from policies and campaigns that continue to present behavioural change as a consequence of increased awareness of ecological problems. They emphasize the need to critically examine other underlying features of a range of environmental practices, accepting that changes in attitudes and values may be required in many cases in order to fundamentally change behavioural commitment towards the environment (Barr & Gilg, 2007).

Carvalho and Fidélis (2009) concluded that environmental perceptions provide a useful indicator and a credible instrument for local environmental planning and management. They further explain that attitudes and perceptions are instruments that can present better opportunities for understanding the condition of the local environment, thereby providing a tool for the development of area specific environmental policies (Carvallo & Fidélis, 2009). Ugulu *et al.* (n.d.) established that the teaching of environmental concepts, such as endemism, to secondary learners can positively change their attitudes towards the environment. Smit (2009) explored whether there is a difference in attitude, towards environmental issues, between military geography and non-military geography students, and whether military geography teaching changes the students' attitudes towards environmental issues. Smit (2009) revealed that general military geography students acquired a positive attitude towards environmental issues in comparison to their non-military geography counterparts.

PART I: GENERAL ATTITUDES AND PERCEPTIONS IN THE SANDF

The analysis of the responses, generally, indicates positive attitudes towards and perceptions of environmental considerations in military activities at both installations (i.e., GMI & SAACTC). This is a good indicator of the protection of the environment and promotion of sustainability of military training areas. The multiple analyses of the data intended to reveal whether there were any significant differences in the perceptions of defence force members regarding environmental issues and military activities. Generally, no significant differences were noted in the results, especially when compared to each other. It also proved difficult to discuss each case study in isolation from the other, because of the similarity in the results. The discussion is thus carried out under five themes, or categories, as explained in Chapter VIII.

Environmental Education Awareness and Training in the SANDF

In the current study, there is significant divergence or disagreement between what the respondents indicated and what official documents articulates. Respondents claim to have received adequate environmental education and training to deal with environmental issues in their daily military activities. However, this claim contradicts the articulations in the EIP documents, which state that formal SANDF training programmes have not yet incorporated environmental training. Environmental education and training is viewed as a starting point towards ensuring that environmental awareness is increased within the defence force. Moreover, environmental education, awareness and training also cultivates a culture of environmental responsibility, thereby promoting environmental protection and sustainability.

These contradictions indicate that the respondents wanted to project a positive image of the SANDF. However, few of them were honest when stating that they never received adequate environmental training. This also indicates that SANDF training programmes have not evolved fast enough over the 16 years since the formation of the Environmental Security Working Group (ESWG) in 1997. The ESWG was established to address environmental considerations related to the activities of the defence force.

The questionnaire, unfortunately, could not elicit information regarding the form of environmental education that the members received. Ogunbiyi and Ajiboye (2009) established that the action learning education strategy can improve knowledge of and attitudes towards the environment. Therefore, this approach can be adopted as an environmental education strategy to promote the value and benefits of environmental protection to the SANDF. The concept of action learning refers to learning while carrying out a task. Thus, action learning can bridge the gap created by the lack of formal environmental education awareness and training. Therefore, the adoption of this approach will also mean that environmental issues are not addressed in an *ad hoc* manner, but on a continuous basis. The RAC (2008) denounced the tendency of environmental considerations being addressed on an *ad hoc* basis in the military forces. This approach is criticised because it tends to focus on short-term solutions rather than both short- and long-term solution planning.

In order to improve environmental training and awareness, it is critical that commanders incorporate lessons based on field experience rather than lessons based on abstract situations (RAC, 2008). Lessons based on field experience will consolidate the positive attitudes shown by the respondents, thereby benefiting environmental protection and sustainability. Furthermore, benefits associated with this approach include maintaining positive attitudes towards the environment, and improving the incorporation of environmental issues into defence training activities as well as avoiding deliberate pollution of the environment.

Environmental training creates awareness amongst employees (defence members in this case), regarding control requirements, and fosters a proactive attitude towards the natural environment (Massoud *et al*., 2011). Environmental training is regarded as a key component in effective environmental management (Massoud *et al.*, 2011). With adequate environmental training, a designated environmental officer of the SANDF would be able to carry out environmental considerations and planning into military activities with ease. As of July 2011, the EMF personnel at GMI needed significant environmental empowerment in order to execute their responsibilities effectively. The situation was significantly different at the SAACTC where the DEO is competent in environmental issues. Massoud *et al*. (2011) defined environmental empowerment as a process through which employees are trained to address and embrace environmental issues in their daily activities.

Enforcement and Compliance with Environmental Laws in the SANDF

The results indicate that enforcement and compliance with environmental legislation and regulations are largely regarded as a waste of time and other resources (Figures 22 & 23). This clearly contradicts the view that defence force members at both installations have received adequate environmental education (Figures 21 & 28). With adequate environmental education and training, this perception would not exist amongst defence force members. Moreover, the existence of perceptions that the SANDF must be given total exemption from all environmental management requirements is not in line with adequate environmental training. Worse still, it goes against environmental protection and sustainability principles. This is linked to the perception that the consideration of environmental issues in military activities has profound effects on military proficiency. This perception underscores the importance of environmental education awareness and training in the SANDF, which is lagging behind.

However, this is not unique to SANDF members. For example, in 2003, the Pentagon in the US sought further exemptions from environmental agency regulations in order to, as it was argued, benefit national security. This request was reportedly justified on the basis of the increasing numbers of US soldiers killed during military missions outside the borders of America (Truban, 2004). The implication of this is that environmental considerations impede military combat preparedness or readiness.

Another supporting argument, put forward by the Pentagon, was that commanders could not expect that, during a war, soldiers would learn war tactics which ought to have been taught during training exercises (D'Agostino, 2002). This perception shows that military personnel view environmental considerations in the military as a constraint on achieving the objectives of planned military exercises. It is clear that the negative attitudes towards and perceptions of environmental consideration in military activities is not unique to members of SANDF. However, Ramos and de Melo (2006) argue that environmental standards set for industrial processes can be applied to the defence forces without adversely affecting military performance. Clearly, Ramos and de Melo (2006) refute any argument that uses military proficiency to justify partial integration of environmental considerations into military activities.

Undoubtedly, adequate integration of environmental issues into defence activities lies at the core of the cognitive dissonance of military practitioners. At both installations, however, there are some respondents who realise the necessity and benefits of enforcing compliance with environmental laws. Thus, environmental education awareness and training will consolidate some of the positive perceptions of environmental protection.

Availability of Resources for the Management of the Environment in the SANDF

The provision of adequate resources of all forms is critical to adequate integration of environmental issues into military activities. The lack of sufficient resources appears to be one of the major challenges of the SANDF, especially in regard to environmental management (Figures 18 & 24). Without the required resources, no progress can be made in improving environmental protection in military training areas. The adequate integration of environmental issues is intended to protect the environment during peacetime training activities. The protection of the environment in military training areas hinges on the recognition that environmental issues play a key role in the success of military training and, more importantly, in the execution of military operations (RAC, 2008). Amongst the basic resources required for this is a vehicle that makes it easier for personnel to do field inspections before and after a training exercise. Unfortunately, the EMF at GMI and SAACTC do not have a vehicle attached to them, for effective and frequent training area inspections and management. This lack of a simple provision is one of the major drawbacks with regard to effective environmental management at these military installations.

Military practitioners must develop environmentally friendly training programmes. There are many principles currently available to direct societies on how to best connect with the environment, without harmful consequences (Whitford & Wong, 2009). The SANDF must adopt an appropriate principle from which to craft its own environmental management programme, which should be unique to each military installation. However, its implementation and success will depend firmly on the availability of appropriately skilled human resources, adequate funding and positive environmental attitudes. According to Wang (2011), the availability of financial resources is a major cause of effective environmental management. Without financial support, efforts towards environmental protection and sustainability will not materialise.

The importance of recruiting adequate environmentally qualified and competent individuals to lead environmental management and its incorporation into military activities has been recognised by the majority (86%) of the respondents at the SAACTC. The lack of qualified personnel is clearly noted by the respondents as negatively affecting the implementation of environmental tools in their respective installations. Therefore, the availability of qualified persons to lead considerations of environmental issues into military activities can never be overemphasised.

Obviously, the respondents' reflections are drawn from their experiences, as they might have encountered problems in the implementation of environmental management tools. Thus, the lack of essential resources to address environmental problems and issues in the military compromises the commitment of the SANDF to comply with the relevant legislation. Furthermore, they have realised that the implementation of the EMS in the SANDF has encountered major challenges.

Processes, Procedures and Practices in the Management of the Environment in the SANDF

Knowledge of environmental management processes, procedures and practices by members of the SANDF is imperative to achieving the desired outcome. The environmental management processes, procedures and practices of the SANDF, at both military installations, must be known and fully understood by all defence personnel. This will assist them in carrying out their duties, by knowing exactly what to do to protect the environment. Defence members must know how and where to report environmental accidents, such as the spillage of gasoline, and this practice must be encouraged. Action must be taken to deal with reported incidents and records of such reports must be kept. However, almost half (48%) of the respondents at GMI seem not to know of the processes, procedures and practices related to environmental management and military environmental impact evaluation (Figure 19). In contrast, 69% of the respondents at SAACTC appear to be aware of environmental management tools at the installation (Figure 25). This is not surprising because environmental reports are prepared, but the extent to which these reports are made available to anyone cannot be confirmed. This further indicates that every defence force member is, to a certain extent, involved in the environmental management process.

Each person within the military installation must be able to comment on the effectiveness of the environmental audit programme in measuring its environmental performance and compliance with legislation and regulations. In cases where individuals hold back their views about any environmental management processes, procedures and practices of the SANDF, it may imply that they are neither aware of the existence of these, nor of the defence environmental management monitoring plan. It is therefore important that environmental management processes, procedures and practices are effectively and adequately communicated to everyone within the unit, so as to ensure the active participation of all members in environmental protection and sustainability. Accordingly, if only a few are aware of the processes, procedures and practices, rather than the majority, it will be difficult to achieve environmental protection. In the long-term, this may have a significant impact on the sustainability of the military training areas in both GMI and

SAACTC. Moreover, it is important that processes, planning and operating procedures for military activities evolve, with time, to provide for new developments in the military (ADF, 2010). Flexibility to change could also create opportunities for the incorporation of environmental issues into military activities in order to comply with various legislations. Smit (2009) attests that more is expected from the military, in terms of environmental stewardship, in the present day. Accordingly, military training programmes need to incorporate environmental issues in order to ensure the sustainability of military training areas.

The Government of India, for example, has worked very hard towards adopting an environmental policy and strategy that would promote military preparedness and compliance with environmental laws (Rao, 2005). This demonstrates how committed other countries are to ensuring environmental protection in and the sustainability of their military training ranges. The Portuguese Ministry of Defence has also made major strides in enforcing a culture of environmental protection in the defence (Ramos & de Melo, 2006).

Environmental Protection Compatibility with Military Activities

There is a popular perception that environmental protection is not compatible with military activities (Figures 20 & 26). These perceptions can be attributed to factors such as poor planning, lack of skilled personnel to lead the environmental considerations of military activities, especially at the GMI, and so forth. It can be argued that, at the GMI, environmental issues are not adequately integrated into the entire management process of the defence force, but are dealt with in isolation; this is contrary to what Ramos and de Melo (2005) argue for. Ramos and de Melo (2005 & 2006) argue that there is a growing need to integrate environmental management into the administrative practices of the army. Furthermore, they posit that environmental management practices must be integrated into the overall defence management chain, in order to support military personnel tasked with overseeing environmental management issues in their respective installations.

Overall, the results of the current study show that the respondents do not view environmental protection as compatible with military activities. Accordingly, the SANDF needs to review its *modus operandi* in line with the global defence environmental management trend. The integration of environmental practices at all levels may assist defence force members in realizing that these two can be well integrated if proper planning is done. Military activities are naturally aggressive; hence, environmental impacts cannot be totally avoided but could be minimised (ESWG, 2006; Ramos &de Melo, 2006). Military activities are destructive to vegetation, soil and water, but some of these impacts cannot be mitigated (Sample *et al.*, 1998; Garten *et al.*, 2003; Haugen *et al.*, 2003; van Donk *et al.*, 2003; Silveira *et al.*, 2010; Marlaer & Moore, 2011; Nyakatawa *et al.*, 2011). It is therefore important that military planners and commanders take the necessary steps, during training exercises, to promote environmental protection practices and mitigate applicable impacts (RAC, 2008). This is not only for the benefit of the environment but also for the military. Realistic military training depends, significantly, on the viability and sustainability of the military training landscape (Nyakatawa *et al.*, 2011).

Social Influences in the SANDF

All these results appear to point towards what Firing *et al*. (2009), King (2007), Kirke (2009) and Siebold (2007) call group cohesion in the defence organisation. King (2007) and Siebold (2007) have extensively interrogated the concept of group cohesion in the military setup. This concept has been adopted to assist in interpreting of some of the results of the current study. For example, there is little difference in the responses provided by the Riflemen, Privates, Corporals, Lance Corporals and Sergeants regarding environmental issues within the defence force (Tables 5 – 10). Moreover, Nel *et al.* (2012) argue that human attitudes, perceptions and behaviour towards the environment involve a complex socio-cultural element. Furthermore, Siebold (2007) states that group cohesion has four critical elements: peers, leaders, organisation and institutional bonding. These elements seem to emerge in the current study.

It can, therefore, be argued that the results of the study are inclined towards these socio-cultural influences, which characterise the defence force. For example, non-disclosure of information, especially if it would tarnish the image of the defence (i.e., organisation), is practiced diligently. This might be the reason why some of the respondents chose to hold back their perceptions of certain issues. It is assumed that the respondents were caught in conflicting situations, where their individual perceptions conflicted with perceived group perceptions. The only option to circumvent the conflict arising from the individual self and social influence was to remain neutral. Firing *et al.* (2009) argue that the individual self and social influence come into play in doubtful situations. This possibility explains why some of the respondents could not open up and speak their minds truthfully. The uncertainty in their minds exists because they belong to units and military “companies” within an institution (i.e., the army) that changes one's identity through interpersonal interactions within the institutional social structure (Firing *et al.*, 2009). All these structural relationships play a role in an individual's attitudes and perceptions. What is valued by the institution will also be valued by the members associated with it. Therefore, if the DoDMV can appropriately invest in the protection of the environment, the environmental management of the SANDF can improve drastically.

Therefore, the way in which the institution prioritizes the environment, and how leaders within units communicate environmental issues, influences soldiers' attitudes towards it. If commanders (leaders) emphasize the importance of protecting the environment and adequately incorporate environmental issues into training activities and other military practices, a positive attitude towards environmental protection and sustainability can also be enhanced amongst the soldiers. It is imperative, therefore, that the army, as an institution, shows total commitment to the protection of the environment and the sustainability of military ranges through the provision of the requisite resources, so as to positively influence the attitudes and perceptions of all involved. As Kirke (2009) emphasizes, organisational and military culture plays a significant role in social cohesion within the army. Thus, defence force members may provide misleading information in order to protect the integrity and image of their organisation and the institution, should the need arise.

Environmental Considerations into Military Activities

Generally, the ANOVA results in Table 5 revealed no significant variation in the responses to the questionnaire statements. This means that the respondents have the same views/perceptions of all the issues that the questionnaire addressed. However, the GMI results show variation in the responses between military service period and the mean responses (Table 6). This is expected because environmental regulations have recently been enforced in defence activities. Therefore, the views of defence members who have served for a relatively longer period would be different from those who recently joined the defence. This is clearly shown in Table 7, which indicates that those who have served for more than twenty years had different views to those who have served for a shorter period. This may indicate that the longer the period that one has served in the defence force, the more resistant one would be to embracing change.

Those who have been in the army for a longer period are more aware of the numerous challenges encountered in the attempt to incorporate environmental issues into military activities, than those who have served shorter periods. Similarly, those with relatively short service periods may not be aware of the extent to which the SANDF complies with environmental legislation. Moreover, defence force members with short service periods, for example 1-10 years, may have gone through military training that incorporated some environmental issues as opposed to those with 16-25 years of military service. This is because environmental considerations in defence activities are a recent development that gained momentum at the turn of the century (i.e., the year 2000).

However, the results from SAACTC show a different scenario (see Tables 8; 9 & 10). None of the statistical analyses show any variation in the responses between all categories of periods of service. This is striking because, even in a well implemented project, variations in people's perceptions will always exist. Remarkably, there are no variations in the responses, whilst the programme encounters countless problems. The variations shown in Tables 11 and 12 are the only indicators that the state of environmental management in the two military installations is not the same. Furthermore, their environmental management processes and practices are also not similar.

Consequently, an awareness of environmental programmes must be implemented to accommodate most of the shortfalls identified by the results. As Ramos and de Melo (2006) explain, environmental responsibility is a recent and complex issue confronting defence forces. However, the consequences of not caring for the environment are catastrophic in the short- to long-term. The short-term effects include a lack of usable training areas and failure to achieve military tactical objectives (RAC, 2008). While Lewis (2010) believes that the short-term effects relate to the absence of a guarantee that troops can train effectively on realistic terrain. The long-term effects relate to the ambiguity of military readiness for combat due to the loss of pragmatic training areas (Lewis, 2010). It is therefore imperative for the attitudes of military practitioners in the SANDF, towards the environment, to become more positive in order to avert the long-term adverse effects of "destructive training practices". Clearly, environmentally unfriendly training may damage or destroy land features in training areas, thus causing ecological detriment to the environment (Komar *et al.*, 2009).

The way in which defence activities are carried out in modern times needs to change in order to accommodate environmental concerns (Smit, 2009). Pun *et al.* (2002) point out that environmental issues are forcing organisations to change their approach towards performing their daily activities in compliance with environmental regulations. Therefore, the SANDF is also expected to alter its practices so as to incorporate environmental issues in all its military training exercises. These changes, however, are heavily embedded in the attitudes and perceptions of senior military officials in ensuring that environmental issues become an integral part of military planning and training.

Another critical element, in this regard, is the political will to make resources (both human and financial) available for the incorporation of environmental issues into defence activities. Furthermore, there are fewer chances to acquire land for military activities in many countries around the world. Daniels (2007) correctly noted that the chances of acquiring alternative land for military training in South Africa are non-existent, and that the impact of military activities on the environment is a major challenge to the future of realistic military training. Similarly, Rao (2005) pointed out that future realistic military training and preparedness is threatened by the inadequate management of training areas. Clearly, there is a great need to protect the environment from aggressive military activities. Despite the growing need for environmental protection and sustainability, there is always a shortage of available resources to meet this need (Wang, 2011). This situation is worse in developing countries, such as South Africa, given all the other pressing social challenges which require government attention in these countries (these challenges are, however, beyond the scope of this study).

PART II: CONCENTRATIONS OF HEAVY METALS IN WATER AND SOIL SAMPLES

Concentration of Heavy Metals in Water Samples

Heavy metals were detected in all water samples collected from the two military training areas (GMI & SAACTC). However, the concentrations of most of the elements ranged from ≤0.01 – ≥0.05mg/l. The concentration of heavy metals in water samples was found to be decreasing in the order of Pb<Cd<Cu<Sr, whilst other metals show similar concentration (Figure 31). The remarkable similarities in the concentration of these elements is unusual and unexpected because the samples were collected from different areas. These sites are different in various aspects, including geographic location, aggression of military training exercises, climatic conditions and the frequency of military activities (i.e., frequency of use).

The GMI training range is characterised by a relatively humid climate. Thus, heavy metals can be easily mobilised from the ground surface to lower layers of the soil and to the nearest water body. Contrary to this, the SAACTC training range is situated in a relatively dry climate. Therefore, under such conditions, the mobilisation of heavy metals into water bodies and deeper into the soil profile could be very slow. Consequently, the constant concentration of heavy metals detected in the water samples was not expected.

A low concentration of heavy metals was only expected from the infantry battalion training area (i.e., GMI) but not in water samples collected from the heavy military training area (SAACTC). Nonetheless, it is worth noting that all the water sources within these military training areas are not flowing, but stagnant. Thus, a greater proportion of heavy metals might be entrapped in the sediment at the bottom of the water bodies. Tabari *et al.* (2010) argue that sediments are the most common depositories of heavy metals and can hold more than 99% of the concentration of metals present in water at one particular time. Furthermore, it can also be argued that the pH of the water (not determined in the present study) played a role in reducing the concentration of these chemical elements.

For instance, Igwe *et al.* (2005) established that asenic (As), lead (Pb) and mercury (Hg) concentration decreases drastically at pH values of 2 and 12. Meena *et al.* (2010) also report that 99.9% of Hg, 98.5% of Mn and 99.9% of Cd are removed from aqueous solution at pH 4. Furthermore, they noted that, at pH 8, the removal of 99.9% of Pb, 80% of Ni and 93.3% of Zn occurs. Meanwhile, Cu was observed to decrease by 89% at pH 4.5-6 and, similarly, Zn decreased by 85% at pH 5.5-7, in a study conducted by Balintova *et al.* (2012). This evidence strongly suggests that pH influenced the concentrations of the heavy metals determined in the water samples of the current study.

Nonetheless, the results of the water samples for the present study are not unique. Similar findings were obtained by Matias *et al.* (2009) in a study conducted in Santa Margarida military camp, in Portugal. The Santa Margarida study reported low concentrations of Cd, Pb, Cu, Cr, Ni and Zn in water samples collected in a dam, spring, borehole and wells.

The concentrations of these heavy metals varied from <1.00 - <5.00µg/l. In addition, a study by Davies *et al*. (2006) also obtained constant concentrations of heavy metals in water samples from four stations. The only highest concentration of <0.002mg/l for Cr was observed in station 1, while all the other elements were <0.001mg/l (Davies *et al.*, 2006).

The results of the current study, as presented in Figure 31, may also indicate that, if these metallic elements did not react with other chemical elements in water to form compounds, they were deposited at the bottom of the water source. Therefore, they can only be detected from sediments collected from the bottom of the water source (be it a well, dam or lake). Benomar *et al.* (2012) also argue that aquatic sediments are essential in trapping heavy metals entering the water body. Moreover, heavy metals do not degrade over time, but become mobile through the soil matrix as environmental conditions change from time to time (Qishlaqi & Moore, 2007; Ogoyi *et al.*, 2011). The contaminated sediment can be re-suspended by any force that may cause turbulent currents in the water. Therefore, the results of the present study show that it is imperative to disturb a stagnant water body before collecting samples for the purpose of determining heavy metal concentration in non-flowing water source. Even in relatively stagnant water, or slow moving water, heavy metals can be deposited and trapped at the bottom of the river channel through sedimentation. For example, Abdullah *et al.* (2007) establish that *Anadasa granosa* (mollusk species) collected from estuaries had great bioaccumulation of heavy metals in their tissues simply because they are infaunal deposit feeders. Thus, they are overly exposed to heavy metals accumulated in the sediments.

Concentration of Heavy Metals in Sediment Samples

Considerable concentrations of heavy metals were obtained from sediment samples collected from the two military training ranges. Baltrėnas *et al.* (2001) argue that heavy metals pollution is one of the major environmental challenges in military training areas. Studies such as those conducted by Diaz and Massol-Deya (2003), Greičiūtė *et al*. (2007), Robinson *et al*. (2008), Matias *et al.* (2009) and Ahmad *et al.* (2012) have also shown that military training areas are among the earth surfaces contaminated with heavy metals.

The two studied military training areas have also proved to be contaminated with heavy metals. The mean concentrations of heavy metals in the two military training areas were found to be decreasing in the order of Pb>Cu>Zn>Cr>Sr>Ni>Co>Cd as shown in Figure 31. The major pollutants at GMI and SAACTC appear to be heavily contaminated with Pb, Cu, Zn, Cr and Sr. Greičiūtė *et al*. (2007) rightly point out that the various kinds of ammunitions and explosives used in military training areas tend to pollute the soil with heavy metals. Thus, it was determined, from the surface samples from GMI and SAACTC, that all these heavy metals have been introduced to the environment in various ways. For example, Pb and Cu are known to be components of fuel and cartridges of ammunitions contain these elements (Greičiūtė *et al*., 2007). Accordingly, fuel spillages during training activities account for these elements in the soil. Similarly, explosions often carried out in military training areas also introduce compounds like Pb, Zn and Cu into the soil (Greičiūtė *et al*., 2007). Military shooting ranges have been established to be the most Pb-polluted sites in many different countries (Ahmad *et al.*, 2012).

Another significant contamination source of these heavy metals in military training areas is the accumulation of ammunition cartridges and fragments of various mortars on the ground. Greičiūtė *et al.* (2007) explain that ammunition cartridges are coated with copper and the core of bullets are leaded (contains Pb). Robinson *et al.* (2007) state that tracer and incendiary bullets contain Sr and Ba (barium) as well as Zn. Furthermore, the presence and accumulation of Zn and Cd can be attributed to the wear and tear of the tyres of military vehicles. According to Leitão (2005), Cd is introduced on ground surfaces by oil and vehicle tyres. Thus, Cd in military training areas originates from the brake pads/linings of military vehicles. A study conducted by Nazzal *et al.* (2014) reported an increased concentration of heavy metals, including Cd, in roadside dust, especially near traffic lights. This indicates that Cd can be introduced to the soil by the wearing of the brake linings of automobiles.

Moreover, Wheeler *et al.* (2005) found that Zn, Fe (iron), Pb, Cd, Ni and Cu accumulate in dust along roadsides. This indicates that vehicle tyres and lubricant oils are significant sources of Zn on the road surface (Sadar *et al.*, 2013), while Cu is introduced to the environment by the wearing of vehicle brake pads (Wheeler *et al.,* 2005). Similarly, Pb is continuously added to the environment through the leaking of leaded fuel (Wheeler *et al.,* 2005). Therefore, without doubt, the presence and accumulation of Zn and Cd in military training areas can be attributed to the wear and tear of tyres of military vehicles. According to Westerlund (2001), Cd, Cr, Cu, Ni, Pb and Zn are used in brake linings, thus, the wearing down of brake linings in military vehicles introduces these heavy metals to the environment. Khan *et al.* (2008) identified metal plating as another source of Cd, paints as a source of Cr, while Pb was linked to automobile exhausts and paints, and Ni was associated with diesel oil and metal plating.

The concentration of Zn can also be attributed to fragments of ammunition shells, as Matias *et al.* (2009) prove that bullet shells and ammunition fragments contain this element. It is therefore important that ammunition fragments and bullet shells are collected after a training exercise to try to control the levels of Zn, Cu, and even the introduction of aluminium (Al) to the soil. Greičiūtė *et al*. (2007) warn that sampling from the surface layer of the soil is not sufficient to determine the concentration of heavy metals. The determination of heavy metals pollution in active military training areas such as SAACTC is a challenge. This challenge relates to limited access to certain target sites where there are unexploded ordinances (UXO) within the military areas. This affects the collection of sediment samples which, in turn, affects the true reflection of the level of soil contamination by heavy metals in the military training areas.

All the fuel spillages that have ever occurred in the two military installations account for the concentrations of Cu, Zn and Pb. Greičiūtė *et al.*'s (2007) study established that the motor-field of the Kairial military range and Gaižiūnai military ground airfield in Lithuania are mostly polluted by Cu, Zn, and Pb. According to Leitão (2005), the major sources of heavy metals such as Pb, Zn and Cu are fuel, the wearing of tyres and brake pads as well as lubricating oils.

Furthermore, Cu and Zn are also linked to live-firing and explosions that are normally carried out in military training areas. Nevertheless, Ni and Cr are attributed to the wearing of metallic automobile parts (Naser *et al.*, 2012) of military vehicles. Therefore, the strong correlation between Ni and Cr confirms that they share the same source. Further, Cr is also linked to the wearing of automobile bearings, tyres and brake pads (Leitão, 2005). In other cases, the local geology also contributes to the concentration of other heavy metals. For example, Hu *et al.* (2013) argue that Mn (manganese), Co and Fe are normally of lithogenic origin rather than a result of human activities.

Potential Contamination Sources at GMI

The results from GMI, as presented in Table 13, show that Cd/Ni, Cd/Cu, Cd/Pb, Cd/Sr Cd/Zn, Co/Cu and Co/Pb have different environmental pollution sources, as they show negative correlations. This indicates that the source of Cd and Co is different from the source of the other heavy metals. Therefore, it can be argued that Cd might originates from the wear of brake pads/linings and tear of tyres (Leitão, 2005). The presence of Cd in soil could also be associated with motor oil leakages (Nazzal *et al.*, 2014). It is clear from the results that Zn does not share the same source as Cd at GMTA, whereas Leitão (2005), Greičiūtė *et al.* (2007) and Nazzal *et al.* (2014) attribute this heavy metal (Zn) to lubricating oil. Thus, in the current study, the primary source of Zn is bullet fragments (Matias *et al.*, 2009).

The correlation between Co, Ni is strong with Cr signifies that these elements originate from the same source. However, Co is known to be widely distributed in the earth's crust (Hu *et al.*, 2013), thus, the strong correlation of Co and Cr suggests that the local geological structure is also the source of these metals. Sekabira *et al.* (2010) refer to the local geology as a terrigenous source. Ni and Cr are assumed to originate from the wearing off of metallic automobile parts (Naser *et al.*, 2012) of military vehicles, thus the strong association with between the elemental pair. The relationship shown by Ni and Co could indicate that the source of origin for these two elements relates to the wear of motor vehicle engine parts as well as dust mobilisation from other sources elsewhere (Mmolawa *et al.*, 2011).

The association of Cr with Sr cannot be adequately explained in terms of origin. However, both Zn and Cr could be deposited into the environment through the wearing of automobile bearings, tyres and brake pads or brake linings (Leitão, 2005). In contrast, Sr is used in tracer and incendiary bullets (Robinson *et al.,* 2007), thus, the strong and positive correlation between Sr and Ni (r = 0.848), obviously shows that Ni is also used in the manufacturing of certain bullets. For example, Robinson *et al.* (2008) indicate that bullets manufactured in recent times contain less than 0.5% Ni. This also explains the association of Sr with Cu, Pb and Zn as well as that of Zn with Ni, Cu and Pb (Table 13). Heavy metals such as Cu, Pb and Zn are the main compounds of ammunitions (Greičiūtė *et al.,* 2007; Matias *et al.*, 2009; Ahmad *et al*., 2012; Siebielec & Chaney, 2012). Thus, military training areas which have been used for a long time are likely to be heavily contaminated with these pollutants, as is the case at GMTA.

Potential Contamination Sources at SAACTC

The SAACTC results, in Table 14, show a relatively different combination of heavy metal associations. This obviously indicates that the sources of environmental pollution in these military training areas are somehow different. A very strong correlation (r = 0.988) is noted between Ni and Co, thus indicating that this pair of heavy metals originates from the wear of motor vehicle engine parts (Mmolawa *et al.,* 2011). Similarly, a strong and positive correlation (r = 0.899) is also observed between Ni and Sr, further indicating that these elemental pairs are compounds from the bullets used in this military training area. Ni and Cr are also assumed to originate from the wearing of metallic automobile parts (Naser *et al.*, 2012), as explained in the section above. A moderate correlation (r = 0.492) has been found between Ni and Pb, as these are compounds for ammunitions.

Another strong relationship (r = 0.838) was found between Cd and Zn, thus, the presence of these two elements is attributed to the wearing down of tyres and brake pads/linings of military vehicles (Westerlund, 2001; Leitão, 2005). It is also noted that Co is strongly correlated (r = 0.911) with Sr and weakly to moderately correlated with Cr, Cu and Pb. The latter three elements are known to originate from fuel as well as the wearing down of machinery bearings, tyres and brake pads/linings (Westerlund, 2001; Leitão, 2005). This, therefore, means that Co could also be linked to the wearing down of metallic vehicle parts (Mmolawa *et al.*, 2011; Naser *et al.*, 2012).

The correlation of Cr with Sr is also noted in the results from SAACTC. This seems to suggest that the tracer and incendiary bullets contain Sr and Ni, which is why Cr is always moderately correlated with these two heavy metals. Thus, Cr, Ni and Sr originate from bullet fragments, especially tracer and incendiary bullets (Robinson *et al.,* 2007) or propellant boosters. Furthermore, environmental pollution by Pb increases as a result of the use of leaded petrol (Onder *et al.*, 2007; Sadar *et al.*, 2013). The very strong correlation (r = 0.902) of Cu with Pb and Zn (moderately weak correlation coefficient of 0.457), therefore, implies that the source of these elemental pairs is the wearing down of tyres and brake pads/linings.

Overall, the pollutants at SAACTC strongly suggest that the sources of heavy metals are bullet fragments, motor vehicle exhaust emissions, wearing down of vehicle parts (i.e., tyres and brake pads/linings) as well as lubricating oil and fuel. In most cases, when this training area is used, there is considerable traffic from military vehicles and manoeuvres within the area.

Comparative Analysis of Potential Sources of Contaminants

It was imperative to try to compare potential contamination sources between the two military training areas. Consequently, Table 15 presents a comparative analysis of the heavy metal concentrations determined from the soil samples collected from the two military training areas. The purpose of this analysis was to establish whether the sources of heavy metals in both training areas are similar or different. Thus, it was noted that Ni, Co, Cr, Sr and Zn share the environmental pollution source. The common pollution sources for these heavy metals could be ammunition fragments.

As previously mentioned, Ni shows a strong correlation with Cr and very strong association with Sr; this indicates special bullets and propellant boosters as the sources of origin for these three heavy metals. The strong association exhibited by Co and Cr suggest that these elements have originated from a terrigenous source (Sekabira *et al.,* 2010) as well as bullet fragments (thus indicating mixed sources). Whereas the correlation of Cr with Sr (moderately, r = 0.604) and Zn (r = 0.407) shows that tracer bullets and propellant boosters are the main environmental pollution sources for these elements.

Fuel spillages have also emerged as a common pollutant source, as shown by the correlation between Cu, Pb and Zn; these heavy metals are compounds which were found by Greičiūtė *et al.* (2007) to have polluted the motor-field of Kairiai Military grounds. Therefore, their correlations show that their source is fuel spillages. The results further show that Cd, in this analysis, is not correlated with any one of the heavy metals analysed. Most of the correlation coefficients of Cd with other elements are insignificant and negative as well as weak (Cd/Zn, r = -0.167) to very weak (Cd/Ni, r = -0.090). This shows that Cd, as a pollutant in the two military training areas, does not have a common environmental pollution source, despite the fact that Cd could be associated with the wearing off of tyres and brake pads/linings in both individual military training areas. However, when combined, Cd seems to indicate that it might be originating from mixed sources. Another possible source of Cd, as identified by Khan *et al.* (2008), is metal plating. This could explain the lack of correlation of Cd with any of the heavy metals when the two samples are compared. However, Co appears to have mixed sources as it correlates with some elements and negatively correlates with others.

Heavy Metals' Relationships and Potential Sources

PCA was carried out in attempting to improve the description of the relationship amongst the variables (Al-Tawash *et al.*, 2013). Al-Tawash *et al.* (2013) state that PCA further assists in identifying the possible sources of heavy metal pollutants. Table 14 simply shows the basic statistical characteristics of the results. Variations are noted in the means, by order of increase in variability in Pb, Cu, Zn and Cr. The standard deviation shows a greater variability in the heavy metal concentrations from the two military sites. Thus, the application of PCA was appropriate to expose or reveal these variations. Table 15 revealed the variations detected from the heavy metal concentrations.

The correlations shown in this table are totally different to the correlations shown in Table 13. Table 15 shows a very strong correlation between Ni and Co (r = 0.925) and a strong correlation with Sr (r = 0.884). Nonetheless, these correlations confirm that the elemental pairs have a similar source. The information presented in Table 15 further reveals that Cd is moderately correlated with Zn; Co is associated with Cr and strongly correlated with Sr (r = 0.885) thus, once again, confirming the source of origin for these heavy metals, as stated above. Another strong correlation (r = 0.769) is observed between Cu and Pb, confirming that these heavy metals come from the same pollution source.

The variations shown in Tables 14 and 15 four components were extracted in an attempt to explain the variability in the observed variables. The fourth variable, however, had an eigenvalue less than 1 but greater than 0.32 which is regarded as very poor (Hu *et al.*, 2013). This component was included in the analysis because it contributes over 8% of the variance, which is a significant contribution. Furthermore, there is no theoretical justification to only consider eigenvalues greater than 1 (Mazlum *et al.*, 1999). Moreover, the fourth component's eigenvalue of 0.658 falls into the moderate factor loading category of 0.75 – 0.5 (Al-Tawash *et al.*, 2013).

In this regard, there are some studies which have used eigenvalues where all the components had factor loading of less than 1. For example, in Al-Tawash *et al*.'s (2013) study, all four components had eigenvalues ranging from 0.975 – 0.239. Mohiuddin *et al.* (2011) also used principal components with values less than 1 (values ranged from 0.99 – 0.05). A study of heavy metals from the northern Moroccan coast, conducted by Benomar *et al.* (2012), also had principal components with eigenvalues of less than 1, ranging from 0.927-0.043. In a study conducted by Chen *et al.* (2007), the principal components when trace elements in groundwater were analysed, had eigenvalues ranging from 0.92 – 0.02. All these studies demonstrate that eigenvalues less than 1 can still be used to achieve the objective(s) of the investigation.

In all the highlighted studies, only the components with eigenvalues within the strong (eigenvalues >0.75) and moderate (eigenvalues between 0.75 – 0.5) categories were used. This is a scale suggested and used by Nair *et al.* (2010) when studying trace metals in the Meenachil River in India. Consequently, all four components in the current study explained over 90% of the variability in the observed variables. Accordingly, the variables (i.e., heavy metals) were well distributed and accounted for by each of the extracted components (Table 17). The percentage of variance ranged from 96% to 88%; this is important because the variability in the heavy metals (observed variables) is not explained by a single component. According to Mazlum (1999), communalities that are greater than 0.7 (i.e., 70% of the variance) indicate that the variables were described to an acceptable level in the analysis.

All eight variables contributed to explaining the variance between the heavy metals determined from soil samples for the current study. This indicates that there are various sources of environmental pollution which contribute to these heavy metals, as determined from samples collected in the two military training areas. If there was only one source of environmental pollutants in both training areas, the variance would have been loaded in one component (Mmolawa *et al.*, 2011). Figure 31 displays plots for the rotated components. The plots have organized the variables (heavy metals) on the basis of sources of origin. Clearly, all the loadings of PC1 (i.e., Sr, Co, Ni and Cr) originate, primarily, from bullet fragments and bullet shells, as explained in the sections above. Heavy metals originating from fuel related pollution constitute PC2, and these metals are Cu and Pb. The third component (PC3) is loaded with Cd and Zn which are heavy metals associated with automobile pollution such as the wearing of tyres and brake pads/linings. PC4 was loaded only with Cr, but plotted with the PC1 variables. This indicates that Cr originates from bullet fragments and shells.

Association of Heavy Metals by Potential Source(s)

The results of the cluster analysis, as shown in Figure 32 (dendrogram), reveal three clusters. The first cluster is formed by the heavy metals which are assumed to originate from bullets fragment and/or compounds of tracer and incendiary bullets (Robinson *et al.,* 2007) because of the presence of and strong correlations with Sr. Thus, all the heavy metals which make up the first cluster have been associated with tracer and incendiary bullets. Moreover, Robinson *et al.* (2008) state that bullets manufactured in recent times contain less than 0.5% Ni, which validates the origin of the heavy metals in the first cluster. The second cluster includes Cd and Zn which have been associated with lubricating oils, the wear of tyres and vehicle brake pads/linings (Leitão, 2005). However, Zovko and Romić (2011) argue that Cd is highly mobile, and therefore has the potential to contaminate areas far from the source. The last cluster is formed by Cu and Pb; these heavy metals have been associated with fuel spillage and lubricating oil pollution incidents.

Of all these pollution sources, only one can be completely avoided: fuel spillages, inappropriate disposal of used lubricating oils or preventing the usage of military vehicles which leak lubricating oils. The other group of pollution sources can be minimised by adequately removing all bullet cartridges and mortar fragments after each training exercise.

Variability of Heavy Metals in Military Training Areas

The variations between the concentrations of heavy metals from the two military training areas are shown in Tables 20 and 21. The 'heavy military' is distinguished by Zn, Sr and Cr, while the 'light military' is distinguished by Pb, Cu, Zn and Cr. There are only two variables (Zn and Cr) that cause an overlap in the signature of the chemicals. This is further confirmed by Table 22 which indicates that there is not much multicollinearity in the results; thus, group members (heavy metals) can be classified into either 'heavy' or 'light military' group appropriately and correctly. This is further affirmed by Table 23. In other words, the classification of most of the heavy metals was carried out correctly. However, a smaller proportion, just over 40%, of the variability between the groups is explained (Table 24a). Although, the model appears not to be excellent in accounting for the variability between heavy metals constituting both groups, it is reasonable (Table 24b). In other words, there were no greater variations in the concentrations of the heavy metals from the two military training areas.

Nonetheless, the existing variations were significant enough to discriminate between the variables ($\chi^2 = 27.714$ with $p<0.001$) as shown in Table 24b. Subsequently, heavy metals such as Cr, Cd and Cu were identified from the structure matrix as important variables to discriminants between the two groups (Table 25). Of the eight variables, these three were the only heavy metals that were significant enough to serve as predictor variables. The fourth most important predictor variable was Cu. Thus, on the basis of the concentrations of these variables, all the others were then classified or discriminated between the two groups. Cadmium (Cd) was identified as the most powerful discriminating variable in the two samples (Table 25). This is the heavy metal that did not correlate with all the other variables, as shown in Table 13.

Other variables noted as powerful in classifying heavy metals into the two military training areas, in the descending order, are Cr, Cu and Pb. Therefore, samples were grouped on the basis of these heavy metal predictors/discriminators. To this end, Figures 34 and 35 were generated to reflect the distribution of the variables in the two groups. Clearly, there is a minor overlap between the discriminant scores of the two groups. Statistically, heavy metals were better classified into the heavy military group, compared to those in the light military group, as indicated by their respective standard deviations.

Table 28 indicates that heavy metals were classified into the 'heavy military' group with an accuracy of 83%. Thus, only 17% of the heavy metals were misclassified in this category. Furthermore, approximately 77% of heavy metals were accurately classified into the 'light military' category. Accordingly, 23% of heavy metals were erroneously classified in this category. Overall, this proved to be a better classification as the cross-validated classification show that 80% of group cases were correctly classified. This is also reflected in Figure 34 and 35, as both groups show a normal distribution curves of the respective discriminant scores.

Unfortunately, the contamination of soil by heavy metals is permanent, although they can form compounds but do not decay in the soil or aquatic environment (Purushotham *et al*., 2012). This suggests that attempts need to be made to reduce the level of heavy metal contamination of the soil in the two military training areas. The introduction of plant species that utilises these chemical elements would be a vital undertaking. This practice is called phyto-remediation, as suggested by Riefler and Medina (2006), Pal *et al*. (2010) and Nwaedozie *et al.* (2013). Pal *et al.* (2010) state that bioremediation has become the most effective, practicable and environmentally friendly strategy to treat polluted soil, especially on a large scale.

Change in Vegetation Cover at 6SAI Military Training Area

Over the period of 28 years (from 1986 to 2014), change in vegetation cover at the Grahamstown military training area (GMTA) has been noted. There have been changes in all types of ground cover (Figure 35). The dense forest appeared to have decreased by 3.24% over the period. Over the same period, bare land surfaces and shrub lands have also increase by 1.85% and 1.91%, respectively (Figure 36). The change in dense forest can be attributed to efforts in trying to eradicate the invasive *Opuntia Indica* plant species. This plant species forms clustered colonies wherever it grows, thus increasing the surface area covered and creating a dense forest. *Opuntia Indica* has an average height of 3.5m.

The eradication of the *Opuntia Indica* plant species, in some instances, leaves behind bare surfaces. Accordingly, this in part accounts for the increase in bareland surfaces. In addition, the increase in bareland surfaces can also be attributed to an increase either in the frequency of military training activities or an increase in the aggressiveness of military activities. Haugen *et al.* (2003) indicate that frequently used training areas tend to show more signs of the degradation of flora, fauna and soil in comparison to seldom used areas. The grassland within the training area has also decreased between 1986 and 2014. This is also attributed to either an increase in the frequency or aggression of military activities.

It has been noted that military activities often result from the direct removal of vegetation through various activities (Silveira *et al.*, 2010). Significant damage to vegetation and soil is observed where armoured vehicles turn and where off-road military vehicles have travelled during training exercises (Haugen *et al.,* 2003). With the continuous disturbance of the top soil, in military training areas, vegetation tends to be very scarce (Sample *et al.,* 1998; Greičiūtė *et al.,* 2007). Thus, the mechanical disturbances induced in military training areas create conditions conducive for soil erosion (Haugen *et al.,* 2003; Johnson *et al.*, 2011; Nyakatawa *et al.*, 2011). Military training exercises that involve vehicular manoeuvres cause significant loss and destruction of vegetation (Haugen *et al.*, 2003).

Not only military vehicles have a significant impact on vegetation, but high foot traffic can also significantly affect vegetation cover (Whitecotton *et al.*, 2000, Garten *et al.*, 2003). The impact on the physical environment does not only occur in places where tracked and wheeled military vehicles drive over, but high levels of surface disturbances are also observed on targets points which, over time, would be devoid of vegetation cover (Quist *et al*., 2003; Tikhomirov, 2006). Therefore, the increase in bare surfaces and decrease in dense forest vegetation cover at GMTA is ascribed to military activities. The increase in shrublands can only be attributed to the re-colonisation of the bare surfaces left behind by the felling of the *Opuntia Indica* by native vegetation.

Summary

This study has established that there is little variation in the attitudes and perceptions of members of the SANDF at both military installations. Generally, positive attitudes and perceptions are projected about environment management at these installations; whether or not these attitudes and perceptions actually translate into real action in the training fields cannot be confirmed. Negative perceptions about the compatibility of environmental issues and military activities have also emerged. Such perceptions are not good indicators for the environmental protection and sustainability of military training areas. Moreover, they indicate that environmental concerns are not adequately integrated with military planning and the execution of all activities.

The adequate integration of these two aspects would provide ample opportunity for defence force members to learn and realize that these aspects are actually attuned when well planned. It is also evident that adequate environmental leadership is lacking, especially at the GMI; this, in turn, reflects negatively on the commitment of the DoDMV towards honouring its environmental management obligations. To meet this obligation, the SANDF/DoDMV at the GMI still needs to deal with major challenges related to financial and skilled human resources. Skilled human resources would take the lead in adequate integration of environmental issues into military practices. The process and procedures are reported to be open for input and suggestions from all members. However, these processes, procedures and practices appear to be somewhat flawed.

It appears that the major causes of this deficiency include, but are not limited to, the communication and dissemination of information as well as the lack of environmental leadership on-site at all times. This study has shown that defence force members with a lengthy military service (only at GMI) have different perceptions of certain issues related to the management and integration of environmental issues into military activities. The existence of social, organisational and institutional bonding was also noted in this study, particularly in cases where respondents chose to remain neutral on certain issues in order to avoid taking a stand. This is assumed to have happened because taking a stand as an individual may tarnish the integrity and image of the organisation and, possibly, the institution.

Water samples from both military training areas did not show considerable concentrations of heavy metals. This might indicate that heavy metals change from one form to another when getting to water bodies (Purushotham *et al*., 2012), this, however, also depends on other water parameters such as pH. This water parameter was noted by Igwe *et al.* (2005), Meena *et al.* (2010), Sekabira *et al.* (2010), and Balintova *et al.* (2012) to significantly influence the concentration of heavy metals in water. In addition, heavy metals may also settle at the bottom of a water source through sedimentation (Abdullah *et al.*, 2007; Duruibe *et al.*, 2007; Tabari *et al.*, 2010; Benomar *et al.*, 2012; Naser, 2013). Thus, the bottom sediments pose the threat of a secondary water pollution source (Linnik

& Zubenko, 2000). Therefore, the detection of low concentrations of heavy metals in a still water body was not mistaken for non-pollution by military activities.

The surface sediments collected from the military training areas have indicated a notable contamination of the physical environment by heavy metals, through military activities. The study has established that the concentration of heavy metals at GMI and SAACTC is decreasing in the order of Pb>Cu>Zn>Cr>Sr>Ni>Co>Cd. The presence of these elements is attributed to various sources. These sources include fuel spillages, oil leakages from military vehicles, bullet shells and the wearing down of vehicular brake pads/linings during training exercises.

The PCA extracted four major components, which differentiated between the concentrations of heavy metals at the two investigated military land areas. Both the PCA and HCA have shown that the heavy metals determined to be present in these military training areas have different sources, as indicated above. Overall, both of these military training areas are heavily polluted by Pb, Cu, Zn and Cr. Therefore, this study has shown that it is important that bullet shells and other metallic fragments are removed from the training areas after every training exercise. This will reduce the introduction of heavy metals into the soil system and thereby prevent their mobilisation to water bodies. This study has, to a certain extent, revealed the level of heavy metal pollution in two South African military installations.

The change in vegetation cover at GMTA, noted from the analysis of the January 2014 satellite imagery, has been associated with an increase in the frequency of military training and the aggression of the training activities. Project Vuselala was linked to the decrease in dense forest vegetation cover as it eradicated alien invasive species, especially *Opuntia Indica,* within the military training area.

CHAPTER X

CONCLUSION AND RECOMMENDATIONS

Introduction

This chapter draws from all the other chapters of this thesis in an attempt to show the extent to which the specific objectives and aims of the study have been achieved. This study was set out to investigate the following: the extent to which the SANDF complies with environmental legislation; the extent to which the SANDF integrates environmental protection practices and conservation in its training and operational activities; major challenges encountered in the implementation of effective EMS; how the implementation of EMS has affected troop training and weapon testing; to assess the level of degradation of the selected South African military training ranges; and to ascertain best management practices within active firing/ammunition training ranges.

The study aimed to explore the extent of environmental protection and conservation practices in the SANDF and to assess the challenges and capacity of the SANDF to effectively implement environmental protection and conservation without jeopardizing the preparedness of its military forces. Furthermore, the study sought to explore the ecological footprints of the South African military force.

Thus, this chapter provides concluding remarks on most of the issues under investigation in this study. It also highlights areas for future research within the field of environmental management and military activities. In addition, recommendations are made based on the findings of the study. Finally, the last part of this chapter presents a description of the challenges encountered during the data collection process.

Concluding Remarks

This study has indicated the actual and potential environmental impacts of military activities during war and peacetime. In fact, the study has been more concerned with peacetime military environmental impacts. Thus, environmental management practices in military sectors around the world have been reviewed. It has been noted that environmental concerns in the military, on a global scale, began almost three decades after environmental issues became a topical issue in the public domain. Thus, the turn of the 21st century has seen environmental management issues enforced in defence activities. This paradigm shift was started by NATO-CCMS, in 1996. By the year 2000, a final report on the integration of environmental considerations in military activities was published.

The publication of this report has had positive effect on environmental considerations in military activities. Many countries responded positively to the challenge to integrate environmental concerns into military operations. Consequently, the United Kingdom, the Netherland, the United States of America, Canada, Portugal, South Africa, Slovak Republic and India are countries that have developed and implemented EMS in their respective defence sectors (Wang & Wu, 2013). The Australian Defence Force is reported to have adopted its EMS in 2001 (Wang & Wu, 2013). The USA is reported to have started piloting the implementation of EMS in 1997 (Ramos & de Melo, 2005), and the Portuguese military implemented its EMS in 2001 (Ramos & de Melo, 2005). The current study has noted that the implementation of EMS in the SANDF collapsed in 2007, due to a lack of significant progress; similar results were found by Smit (2011), who indicates that since then, no significant efforts have been made to resuscitate its implementation. Some of the challenges that led to the collapse of the implementation of EMS in the SANDF are discussed by Smit (2011) and Magagula (2014). Currently, therefore, environmental management issues in the SANDF are addressed on an *ad hoc* basis. Thus, the SANDF has, as of 2013, forgone the benefits associated with the implementation of EMS in the military, as discussed by Godschalk (1998).

The methodology adopted in the current study proved to be appropriate and effective in eliciting the data required to achieve the aims and objectives of the study. For instance, the analysis of official documents led to the discovery of current environmental practices in the two SANDF military installations under discussion in this study. In addition, the analysis of official documents prove some of the data, provided by some respondents, otherwise. Furthermore, field observations found results that conflicted with what some of the respondents have indicated. The analysis of heavy metal pollutants from soil samples made it possible to identify environmental pollution sources.

The findings from GMI indicate a poor environmental management profile by the SANDF at 6SAI Bn. This poor performance in terms of environmental management is attributed to the absence of competent environmental personnel. At this installation, environmental assessment is only carried out for major military training activities. This was noted when Exercise Shared Accord was about to be carried out at GMI (in July 2011). Thus, it can be argued that, at this installation, only major training exercises draw the attention of senior environmental officers/managers towards enforcing environmental management practices. This is related to the absence of a competent environmental officer. Moreover, evidence suggests that military waste is inappropriately disposed of at GMI. Consequently, the issuing of clearance certificates, to withdrawing troops, from training exercises seems to be flawed. Similarly, no annual environmental reports have been prepared, as required by the EIP for the defence. In addition, the 6SAI does not even attempt to comply with national environmental management laws. Based on this information, it can be reasonably concluded that the potential environmental impacts of other military training exercises are disregarded. This has the potential to jeopardise the protection and sustainability of the environment.

It appears, from all the environmental reports of SAACTC that were analysed in this study that the coordination of environmental management and reporting is still in a state of disarray. In other words, this responsibility is not properly carried out. In some instances, the environmental representatives appointed in each Unit will report directly to the commanding officer of the Unit. Yet, all environmental reports should be directed to the environmental officer (designated environmental officer - DEO) in the EMF. It should be this person who reports to the commanding officer. The head of the EMF and other individuals must be solely responsible for ensuring adequate environmental planning, environmental reporting, identification of environmental education awareness and training needs, as well as compliance and protection of the environment during military training exercises (development of EMPs). This individual should also be responsible for identifying and establishing external collaborations with other stakeholders.

This ideal situation will enable the DEO to develop a proper information management system, and to report environmental framework and performance indicators. The DEO with the environmental team would also have enough time to develop EMPs for the Unit, draw up a policy statement, and set annual environmental objectives and targets. In addition, the DEO will monitor the implementation of plans and programmes, develop environmental awareness activities and effectively communicate and disseminate the results of environmental audits and review processes. The lack of an internal audit process is one of the major weaknesses in the adequate implementation and monitoring of environmental management practices in the SANDF. Thus, this installation is only partially compliant with environmental management legislation and regulations.

This study has established that there are major challenges faced by the SANDF in implementing and integrating environmental considerations in military activities and training programmes. These challenges include a lack of adequate funding, a lack of capacity, and the inadequate coordination of environmental management.

The study has also revealed that the SANDF is lagging behind in terms of it integration or incorporation of environmental protection practices in its training activities, when compared to countries such as Portugal, Canada, Spain, the United Kingdom and the Unites States of America. However, these countries are First World countries, whereas South Africa is a developing country. South Africa is still held back by pressing social issues that are yet to be addressed. Conversely, this study has proposed a model towards the effective implementation of EMS in the SANDF. This model is presented in Figure 40.

Nevertheless, the results obtained from SAACTC show that the SANDF at this installation partially complies with environmental legislation and the EIP for the defence. This is based on the fact that annual environmental reports are prepared. However, environmental closure reports are not often prepared as explained in the guidebook on environmental considerations during military operations drafted for use by the SANDF (ESWG, 2006). This can be viewed as compromising adequate environmental protection and the sustainability of military training ranges. Without the environmental closure report, it is difficult to evaluate the environmental impact of the military exercise as well as the relevance and adequacy of the EMP developed for that specific military training exercise. Thus, this is not in keeping with environmental protection and the sustainability of the military training area.

The study has also established that the SAACTC has implemented the cultural resources management programme and, in this regard, a cultural database has been developed. In addition, the restoration programme has also been developed and implemented. This programme mainly includes the rehabilitation of severely degraded sites within the training area. As such, one training range has been suspended from any military activities in an attempt to allow it to recuperate. In some instances, the replanting of indigenous vegetation (Acacia trees) has been implemented, although the climatic conditions do not favourably support this programme.

The study has further exposed some of the challenges that led to the failure of the implementation of EMS in the SANDF. The collapse of EMS for the SANDF disrupted the systematic environmental management approach. Thus, the environmental management initiatives that are currently applied are carried out unsystematically. However, the SANDF (especially at SAACTC) is trying very hard to integrate environmental issues into their activities. Most of the respondents who were interviewed and who responded to the questionnaires stated that environmental considerations in military activities do not affect troops' proficiency for combat.

Contrary to this, they also advocate for the granting of total immunity/exemption of the SANDF from all environmental management legislations and regulations. This is contrary to the threshold set by the EIP documents (2001 & 2008 editions) that the SANDF must comply with international, national and provincial environmental legislation as well as any relevant norms and standards (EIP, 2001 & 2008). In some cases, the respondents provided biased information in an effort to project a positive image of the environmental management practices of the SANDF. For example, the assertion that the DoDMV has provided sufficient resources for efficient environmental management practices in the defence is contrary to the information contained in the 2008 EIP. Furthermore, some respondents contended that they received adequate environmental training to deal with environmental issues in their day-to-day military activities. However, the EIPs (2001 & 2008) indicate that environmental education and training awareness has not been formalised into the military training of the SANDF.

Overall, the SANDF is yet to formalise environmental training, education and awareness. Ramos and de Melo (2006) regard this as the first step towards improving poor environmental performance. Otherwise, the goals of adequately incorporating environmental issues into its activities and promoting the sustainability of all military training areas will remain elusive. It has been noted that there are six pillar programmes of the military integrated environmental management for the SANDF. However, these programmes are not adequately explained in terms of the activities that each contains or constitutes. Thus, this study has highlighted some of the activities likely to, or which should, constitute each of the programmes (Figure 41). Based on the challenges of environmental management in the SANDF, it can be concluded that the MIEM is centred on a very weak foundation.

Evidence of various forms of pollution and contamination by solid waste and heavy metals has been discovered at both the training areas. Potential sources of the heavy metal contaminants were identified as fuel spillages, oil leakages (lubricating oils) from military vehicles, bullet shells and the wearing of vehicular brake pads/linings during training exercises. The origin of heavy metals such as Co and Cr has been identified as a mixed source, including terrigenous and bullet fragments. Solid waste included bullet cartridges, UXO and fragments of mortars, the sources of which are live-firing military training. Certain sections of the SAACTC training area have been described as heavily contaminated with spent shells and UXO from airstrike munitions, as well as heavy and light artillery and infantry support munitions (Mckenzie, 1998b). All these become sources of heavy metal contamination in the training area.

The change in vegetation cover at GMTA has been associated with two major activities. Firstly, the increase in bare land surfaces was linked to an increase in the frequency of military training exercises and the aggression of these training activities. Secondly, the decrease in dense forest vegetation cover has been related to Project Vuselala, which is trying to eradicate alien invasive species, especially *Opuntia Indica,* within the military training area (Figure 13). Veld fires which ignite, especially during live-firing military training exercises at SAACTC, have caused significant ecological damage. Thus, endangered plant species such as the camel thorn tree (*Acacia erioloba)*, shepard's tree (*Boscia albitrunca*) and grey camel thorn tree (*Acacia haematoxylon*) are likely to be locally extinct. The affected areas are estimated to fully recover from the fire damage in 200 years. This is one of the ecological footprints of the SANDF that have been noted in this study.

Propositions for Future Research

There are multitudes of research activities that still need to be undertaken in this field of study. In particular, this study has identified the following gap: environmental performance indicators for the SANDF, effective environmental reporting in the SANDF, level and challenges of environmental clean-up after military base closure (or demilitarisation of the landscape), and the identification of phytoremediation in the SANDF military training areas. Furthermore, studies can also be carried out to assess the bio-accumulation of heavy metals in the different plant species found in the SANDF military training areas. A gap also exists in research on the impacts of military activities on the breeding of wildlife as well as the role of military vehicles as vectors for the spread of exotic plant species. A study can be conducted to assess the level of biodiversity within military training areas.

Recommendations

This study puts forward the following recommendations:

- The DoDMV should recruit environmental professionals to lead the environmental management programme of the SANDF. These individuals should take full responsibility of environmental management issues within the defence force, as suggested by NATO-CCMS (2000) and Ramos and de Melo (2005).
- Environmental education awareness and training must be incorporated into the formal training of the SANDF. This will improve the environmental management practice and profile of the SANDF, as suggested by Ramos and de Melo (2005).

- The SANDF, through the DoDMV, must invest in the environmental management facility of the defence, as suggested in the model proposed by Magagula (2014).
- The environmental research unit of the SANDF environmental programme must be restructured and well-resourced to carry out all the necessary environmental management research required within the defence territories.
- Phyto-remediation or bioremediation, as suggested by Riefler and Medina (2006), Pal *et al*. (2010) and Nwaedozie *et al.* (2013), needs to be implemented in SANDF training areas, in order to reduce environmental pollution by heavy metals. Pal *et al.* (2010) state that this practice has become the most effective, practicable and environmentally friendly strategy to treat polluted soil, especially on a large scale. *In situ* bioremediation is regarded as the most cost effective strategy (Pal *et al.*, 2010) to reduce environmental pollution in large areas, such as military training areas. This, therefore, suggests that the DoDMV must adequately invest in the research unit of the SANDF, so that it is able to identify the most appropriate plants to be used for this strategy.

Challenges Encountered during Data Collection

Data collection by non-military personnel has its own challenges especially in a Military environment; these challenges manifest in various forms and magnitude. The data collection process of this study encountered certain challenges. These challenges included following:

- Obtaining authorisation from the DoDMV to carry out this investigation within the defence territories.
- The non-response to some of the request made to carry out the study and also declining to participate in the interviews and responding to questionnaires.
- High ranking carrying officials refused to participate in the study. Thus, the non-participation of senior defence force members excluded possible variability in the data. The junior soldiers were also not keen to divulge information without a directive from their superiors.
- The collection of samples and field observations also posed serious challenges. For example, at SAACTC, the major problem was the existence of unexploded ordinances (UXO). There were sites where access was not allowed, in order to collect soil samples.
- At the Grahamstown military installation, none of the requested official environmental management documents were made available to the researcher. The requested documents included environmental audit reports, the environmental management system, environmental funding, and environmental management programme(s) for the unit and others.
- Not a single open-ended questionnaire was received from the commanders, soldiers or the Regional Facility Interface Managers (RFIM). The non-response from RFIMs was surprising because these individuals lead environmental management in their respective military installations.

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