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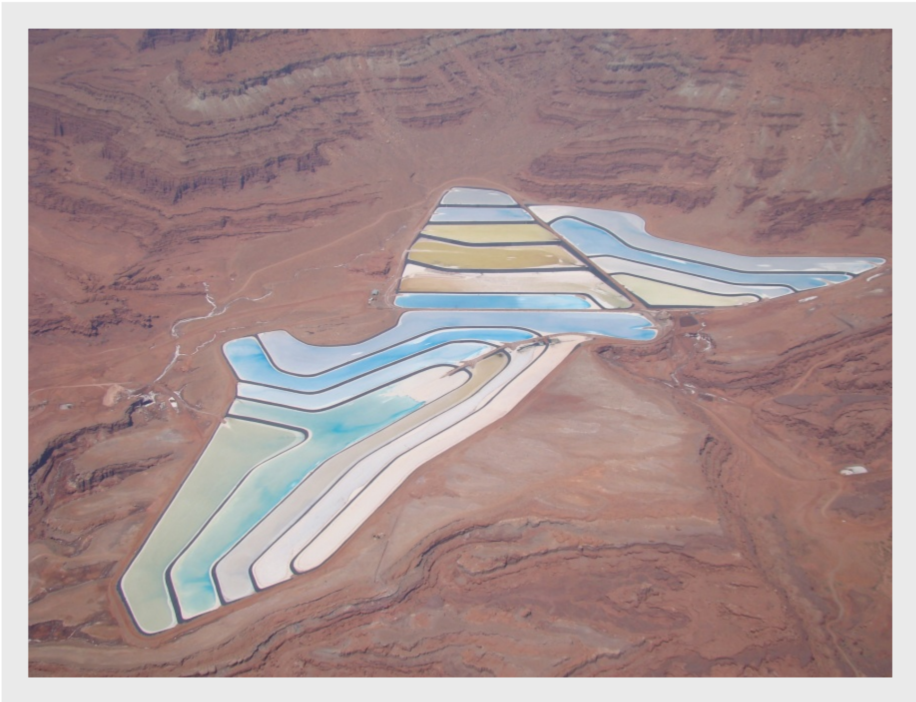


B. J. Merkel & M. Schipek (Eds.)

Mining and Water

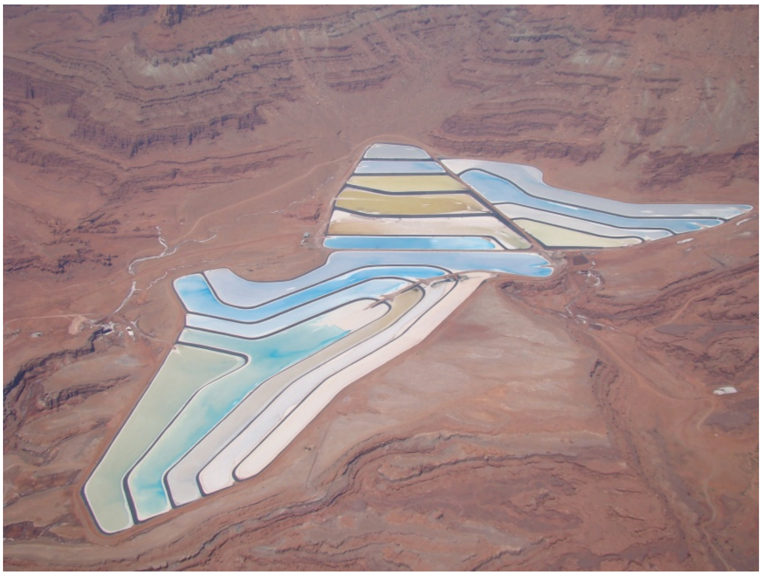
DAAD Alumni Expert Seminar - Proceedings

14 abstracts, 70 pages, 24 figures, 6 tables

DAADAlumni expert seminar

"Mining and Water"

October 5 – 9, 2009



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in cooperation with

DAAD Deutscher Akademischer Austausch Dienst
German Academic Exchange Service

German Alumni Water Network

BERGAKADEMIE · FREIBERG ·
TECHNISCHE UNIVERSITÄT

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TECHNISCHE UNIVERSITÄT BERGAKADEMIE FREIBERG

Preface

GAWN (German Alumni Water Network) was founded in 2005 with the goal to coordinate activities of former international students in Germany with respect to water related subjects such as groundwater, surface water, water supply, water treatment of both drinking water and waste water. GAWN is supported by the DAAD (Deutscher Akademischer Austauschdienst) and is managed by the University Siegen and a consortium of nine German Universities. GAWN provides water related contact information from and for DAAD Alumni on the one hand and offers summer schools and expert seminars in different countries on the other side. Registered users may search the GAWN database to identify potential collaborators, to locate former colleagues, and to establish new links. For non registered users access to information is limited. Members of the GAWN consortium offer summer schools and expert seminars for the members of GAWN and Alumni.

The expert seminar in October 2009 in Namibia is focusing on the topic mining and water. Mining and water is closely linked for certain reasons: in many countries groundwater has to be pumped from the subsurface in order to run a mine. This is true for both open pit mines and deep mines. Often the huge amount of water pumped from the underground can not be used and is spilled into rivers. However, at the end of the mining activities there is a deficit of groundwater which might take years and decades until pre mining groundwater conditions are reached. In many cases pre mining conditions even do not occur at all due to severe alteration of the hydraulic conditions. In semiarid and arid regions with very deep groundwater levels there is no need to lower the groundwater level, however, water is needed for dust control, milling and ore processing and thus fighting for water may occur between mining, irrigation and drinking water needs. On the other side acid mine drainage (AMD) is a common problem in mining areas with sulphide minerals and probably the biggest mining related problem worldwide since AMD causes not only low pH and high sulphate concentrations but as well increased concentrations of toxic trace elements like arsenic, cadmium, mercury and others. But AMD is not the only chemical problem related to mining and water: most of the world's gold is recovered with cyanide and due to sometimes poor techniques cyanide is released to the environment. Roughly 12 million artisanal miners worldwide constitute one of the largest sectors of the mining industry and huge environmental problems, since more than 250 tons of mercury are emitted annually from artisanal gold mines contaminating humans, soils, and water bodies.

The expert seminar "Mining and Water" in Namibia was jointly organized by the Technische Universität Bergakademie Freiberg (TUBAF) and the University of Namibia (UNAM). We wish all participants a pleasant stay at Windhoek and fruitful discussions.

Freiberg/Saxony, 27.09.2009

Prof. Broder J. Merkel

Technische Universität Bergakademie Freiberg

The German Alumni Water Network has been established to better coordinate activities for former students of German Universities and development associations in Germany. It is the outcome of a joint effort of DAAD and six universities who offered alumni summer schools in 2005 in coordination with IFAT 2005. It provides contact information from and for DAAD Alumni and Alumnae active in the water sector online.

Registered users of the database have the opportunity for using detailed search functions within the database to identify potential collaborators, to locate former colleagues, and to establish new links.

For non registered users access to personal information must be kept limited, therefore, only a few search functions are available. However, requests for more detailed information may be send to the project coordinator or webmaster and the contact person already registered.

The database is managed and organised at present by the Universität Siegen on behalf of DAAD. Furthermore, a consortium of nine German Universities co-operate for strengthening the German Alumni Water Network GAWN by offering access to their existing alumni networks and by organising summer schools and expert seminars in different continents:

- Ruhr-University Bochum - Prof. Orth
- Universität Karlsruhe - Prof. Winter
- Cologne University of Applied Sciences - Prof. Roehrig
- Hochschule Ostwestfalen Lippe - University of Applied Sciences - Prof. Austermann-Haun
- University Rostock - Prof. Eckstaedt
- Universität Siegen - Prof. Foerch
- Technische Universität Dresden - Prof. Horlacher
- Technische Universität Carolo-Wilhelmina zu Braunschweig - Prof. Schöniger
- Technische Universität Bergakademie Freiberg - Prof. Merkel

Further information about GAWN is available under: http://www.gawn.de/

Change by Exchange – the German Academic Exchange Service

The German Academic Exchange Service (DAAD) is the largest funding organisation in the world supporting the international exchange of students and scholars. Since it was founded in 1925, more than 1.5 million scholars in Germany and abroad have received DAAD funding. It is a registered association and its members are German institutions of higher education and student bodies. Its activities go far beyond simply awarding grants and scholarships. The DAAD supports the internationalisation of German universities, promotes German studies and the German language abroad, assists developing countries in establishing effective universities and advises decision makers on matters of cultural, education and development policy.

Its budget is derived mainly from the federal funding for various ministries, primarily the German Federal Foreign Office, but also from the European Union and a number of enterprises, organisations and foreign governments. Its head office is in Bonn, but the DAAD also has an office in the German capital, Berlin, to which the famous Berlin Artists-in-Residence Programme (Berliner Künstlerprogramm) is closely affiliated. It maintains contact with and provides advice to its main partner countries on every continent via a network of 14 regional offices and 49 information centres.

The DAAD runs over 250 programmes, through which it funds more than 57,000 German and foreign scholars worldwide per annum. These programmes range from semesters abroad for undergraduates to doctoral programmes, from internships to visiting lectureships, and from information-gathering visits to assisting with the establishment of new universities abroad. It supports the international activities of German institutions of higher education through marketing services, publications, the staging of events and training courses.

The DAAD's programmes have the following five strategic goals:

- to encourage outstanding young students and academics from abroad to come to Germany for study and research visits and, if possible, to maintain contact with them as partners life-long;
- to qualify young German researchers and professionals at the very best institutions around the world in a spirit of tolerance and openness;
- to promote the internationality and appeal of Germany's institutions of higher education;
- to support German language, literature and cultural studies at foreign universities;
- to assist developing countries in the southern hemisphere and reforming countries in the former Eastern Bloc in the establishment of effective higher education systems.

Further information is available under www.daad.de

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Past and future tasks of the Geological Survey of Namibia

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The Geological Survey of Namibia is the National Institute for Earth Science and Mineral Resources. It is entrusted with management and research of one of our most important assets – the earth in which our life support system is rooted. Its mission is to enhance the knowledge and awareness of Namibia's geological resources. Through scientific investigation as well as application and dissemination of quality research data, the Geological Survey of Namibia is facilitating the search for and the assessment of mineral resources, geological engineering, land use planning and sustainable development with due regard to the environment. The Geological Survey of Namibia is therefore the central geo-science institution in Namibia dealing with information and research to promote the sustainable management and utilisation of the land surface and subsurface and its natural resources.

The Geological Survey main objectives are: promoting sustainable development and investment for the optimum utilization of Namibia's geological resources; increasing the contribution of the minerals sector to the Namibian economy; enhancing the understanding of the geo-environment for the future welfare of our society; minimizing negative impacts of the utilization of Namibia's geological resources; contributing to multi-disciplinary land-use planning and providing quality scientific data to address issues related to geological resources and the geo-environment. To this end the Geological Survey of Namibia advises the Namibian Government and participates in regional and international cooperation in the field of the earth sciences.

The Geological Survey of Namibia provides government and policy-makers, industry and the public at large with information and data pertaining to such issues as exploration, mining, building and construction, environmental engineering, land use planning, coastal zone management and natural hazards. Scientific knowledge is the pillar on which sustainable societies are built. Our knowledge of the resources in the world around us, and our ability to find and utilize them, forms the basis for a good standard of living for all. Geological knowledge should therefore be a readily available and applicable component in the infrastructure of every society. It is a precondition for taking informed decisions on a range of important issues which may have broad economic and social implications.

While the first, albeit short-lived Mining Commissioner's Office was opened in Otjimbingwe as early as 1889, the roots of the Geological Survey of Namibia go back to 1903 when the first Government Geologist, Dr FW Voit, took up his duties in Windhoek. In the past, the principal role of Geological Surveys worldwide has remained virtually unchanged for a century. Until recently, it was dominated by mapping the country at increasingly smaller scales, studying mineral and fossil fuel deposits to establish future potential and delineating areas prone to natural disasters. While these tasks remain of vital importance, more recently the concept of human destruction of the environment has made environmental geology an issue of growing importance

In today's global world with its increasing population and strong demand for better quality of life for all people, the strain on the limited resources has never been as dramatic as now. To ensure any prospect for future generations, sustainable development has become a first and foremost task. The application of earth sciences in supporting wealth creation, quality of life, and laying the foundations for a sustainable future is of ever-increasing importance for civil society. The Geological Survey of Namibia is positioned to play a pivotal role in both geo-scientific research and its application. The Namibian geology will continue to pose challenges at grass roots level. The Geological Survey of

Namibia has been instrumental in supplying information regarding the minerals base of the country, as well as the use of Namibia's subsurface for various developments, and will continue to do so.

Also, global changes in ecosystems are evident today, and Namibia is no exception. Global warming and the anticipated associated sea level changes are believed to be amongst the reasons for the dramatic changes seen along the Namibian coastline and for the extended periods of draught experienced recently. In contrast to historical times, when changes in ecosystems were dominated by Earth's own dynamics, today's changes are induced to an unprecedented extent by human activities. In Namibia, with its extremely fragile arid ecosystem, the pressure exerted by a rapidly growing population necessitates innovative ideas for sustainable development.

Worldwide, the overall economy has shifted from one that was driven by the primary and natural-resources-based sector to the tertiary sector. This development is also evident in Namibia, where value-adding is encouraged to enhance the creation of wealth. This has also caused a change in the demand of Geological Survey products, with thematic geological information including added intelligence in the form of interpretation gaining increasing importance. The Geological Survey of Namibia has taken up the challenge to respond to that need.

Looking at the greater picture, Namibia's economy rests on four pillars, namely mining, agriculture, fishing and tourism. Co-existence of these four sectors is not always without conflict. Nevertheless, the development of all of Namibia's economic sectors is a political priority to ensure quality of life for all Namibians. Coupled with the growing population this leads to ever increasing demands in terms of electricity, consumption of disposable goods, and grazing and arable land. The Geological Survey of Namibia has fully recognised this situation, and consequently tasks such as land use planning, waste disposal siting, engineering geology for town and other developments, geochemical mapping and mineralogy for purposes other than exploration (e.g. health), coastal zone management and environmental impact management have gained increasing importance.

At the beginning of the 21st century, Geological Surveys world-wide face the challenge of serving the needs of society by utilizing geological resources and geo-scientific knowledge effectively. This includes scientific challenges as well as data management using new technologies for information and communication. Networking plays an important role for interdisciplinary research, incorporating the social sciences, and integration of information at local and global levels. Products must be relevant to the problems with which the general public is concerned. The focal point for the Geological Survey of Namibia is therefore to synthesize the available and new geo-scientific information into thematic products, which directly meet the changing needs of society.

The importance of geo-scientific data to assist in decision-making processes cannot be over-emphasized. The Geological Survey of Namibia has extensive geological databases, containing data both in conventional and electronic formats. These databases are continuously updated with the needs of the customers being taken into consideration. The increase in digital geo-information opens new possibilities for applications in various fields. Different kinds of thematic maps and products can be made by modifying and re-classifying geological data. Geoscientists therefore develop key components of decision-making tools and methods to exploit geological data and facilitate their use in modern society. Such data is presented in a relevant and understandable format in order to draw maximum advantage.

With its motivated staff, excellent facilities and a wealth of data gathered over the last 100 years, the Geological Survey of Namibia is well geared and committed to serve the country for the benefit of all Namibians.

Oil and gas extraction in the Niger Delta Region of Nigeria: The social and environmental challenges

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Abstract. The large-scale exploitation of petroleum resources from the Niger Delta region of Nigeria has adversely affected the ecological balance of the area and created serious social and environmental problems for the local inhabitants. Decades of oil and gas extraction by oil companies operating in the region has not only resulted in the destruction of farmlands, forests, fishponds and other sources of livelihoods, it has also led to the pollution of local sources of drinking water such rivers and streams.

Between 1976 and 2000 a total of 6,141 environmental accidents recorded from the oil industry in the region resulted in the spillage of approximately 3,019,465.90 barrels of crude oil into the surrounding environment, rivers and stream, thus polluting the people's sources of water. A comparative environmental performance study of three multinational oil companies operating in the Niger Delta also indicated that between 1991 and 2002, 3,544 cases of environmental pollution were reported, resulting in the spillage of 355,809 barrels of crude oil into the Niger Delta environment. Out of these incidents, production factors were responsible for 41.6%, sabotage/theft accounted for 35% followed by corrosion 19.9%. Other operational factors accounted for 1.7%, engineering related factors accounted for 0.4% and drilling contributed 0.4% of the oil spillages. Sadly, most of theses environmental accidents emanating from the Nigerian oil industry end up spewing crude oil and other industrial effluents into the surrounding rivers and streams, which the local people depend on for drinking, cooking and other domestic uses.

This paper examines the social and environmental problems associated with oil and gas extraction in Nigeria, especially the incessant pollution of local sources of water by oil and gas companies operating in the Niger Delta Region of Nigeria and makes some recommends on how to tackle the menace through adequate monitoring and appropriate legal frameworks.

1 Background

The Niger Delta is located in the South-South region of Nigeria. The bulk of the inhabitants in the region live in three states of the present day Nigeria (Rivers, Delta and Bayelsa). The rest are scattered in other states such as Cross River, Akwa Ibom, Imo, Ondo and Edo. The major ethnic groups in the region are the Ijaws, Urhobos, itsekiris, Ogoni, Ibibio, Edos and other minority tribes.

The Niger Delta has substantial oil and gas reserves and is host to many multinational oil corporations from Europe, Asia and North America. Crude oil extracted from the area accounts for 95% of Nigeria's foreign exchange earnings and about 25% of Gross Domestic Product. The bulk of Nigeria's proven oil reserves, currently estimated at 20 billion barrels, are located in the region. Beside its great mineral wealth, the Niger Delta also has fertile agricultural land, forests, rivers, creeks and coastal waters teeming with fish and sundry water creatures. Clearly, the Niger Delta, at least for the moment, is the goose that lays Nigeria's golden egg (Okonta and Douglas, 2001).

The large-scale exploitation of petroleum resources from the Niger Delta region of Nigeria has completely disrupted the ecological balance of the area and created serious social and economic problems for the local inhabitants. The World Bank (1995a: 81-82, 86) has attributed the social and environmental problems confronting the Niger Delta to three major factors. They include the arrival of the oil industry, population growth and the failure of government policies. The World Bank report argues that these three developments, in combination with other secondary developments they have stimulated, are together largely responsible for the present socio-economic and ecological situation in the Niger Delta. This paper presents the social and environmental challenges of oil and gas exploration and exploitation in the Niger Delta through documented cases.

1.1 Structure of the Paper

The paper has been organized into chapters to reflect the key elements and problems associated with the oil and gas industry in the Niger Delta. The first chapter introduces the Niger Delta and its people while the second chapter focuses on the policies and practices within the oil industry and how the relevant authorities have failed to ensure the implementation of these policies. Chapter three examines the impact of oil and gas extraction on the people and environment of the Niger Delta. Chapter four outlines the various dimensions of oil related conflicts in the Niger Delta region while chapter five gives a broad overview of the gender dimension, taking into consideration the role women have played in the areas of activism and the struggle to change the appalling situation in the region. Chapter five wraps up the paper with some conclusions and recommendations.

2 Policies and Practices within the Nigerian Oil Industry

2.1 The History of Oil in Nigeria

In the colonial era, the development of Nigerian oil was driven by the interest of the colonial economy and her strategic contestation for the supply of the resources to the world market. To promote these interests, the British colonial government provided subsidies, in the form of interest-free loans, to the Nigerian Bitumen Corporation, a pioneer company in the business of oil exploration in Nigeria. The corporation, however, stopped exploration following the outbreak of the First World War. In 1937, Shell D'Arcy, which later became Shell-BP Petroleum Development Company of Nigeria Limited, commenced another round of crude oil exploration in the country. In 1956, it discovered oil in commercial quantities at Oloibiri and Afam in the Niger Delta region of the country. In the mid-fifties, other multinational corporations such as Mobil, Gulf, Agip, Safrap (now Elf) and Tenneco (now Texaco) joined the race for oil prospecting in Nigeria.

Following its membership of OPEC, Nigeria created a Nigerian Oil Corporation (NNOC) in 1971. The corporation, which was later renamed the Nigerian National Petroleum Corporation (NNPC) in 1977, was created with a view to establishing partnership with oil companies operating in the country. NNPC soon acquired interests in the oil companies, which reached 60 percent in 1979. These partnerships conferred on the NNPC access to over 1.7 million barrels of crude oil per day by the end of 1979, thus making the corporation a major player in the market place for crude. Subsequent development has taken the form of joint ventures between NNPC and the oil companies. As of today, six joint ventures exist with foreign multinational companies (Human Rights Watch, 1995: 28-29).

The review of the history of the Nigerian oil industry has a bearing on the manner of policy formulation and implementation in the sector. The next section therefore attempts to review the policies and practices within the oil extraction industry in Nigeria and how the authorities have failed to monitor the implementation of these policies.

2.1 National Policy, Laws and Regulations and Institutional Arrangements

The Federal Government of Nigeria is, by law, responsible for the formulation of policies concerning the country's oil industry. For the purpose of gaining an in-depth understanding of what prevails within the sector, the policy and regulatory framework governing the Nigerian oil and gas industry are examined in this section. How these are implemented in practice is also discussed.

2.1.1 Policy Direction

The focus of government's direction within the oil in industry in Nigeria is outlined as follows:

1. Intensification of exploratory activities, both onshore and offshore, including the Lake Chad Basin
2. Increased oil production

3 Encouragement of gas gathering and utilization
4 Reduction of gas flaring and eventual abolition by 2008
5 Promotion of private sector participation, particularly by indigenous companies

To achieve these policy directions, the Nigerian National Petroleum Corporation (NNPC) has called for collaborative efforts between the public and private sectors of the economy. The Chief Executive Officer has been quoted as saying: "the proper collaborative efforts between the public and private sectors of the economy would ginger up oil and gas exploration in the country, if all hands are on deck" (South-South Express Newspaper, July 30, 2002:5). The areas identified for investment by the NNPC include domestic pipeline network expansion and the construction of another Liquefied Natural Gas plant. To encourage private sector participation, the Nigerian government has offered several incentives to investors. The incentives include tax holidays granted to oil companies under the Petroleum Profit Tax Act (PPTA).

The Nigerian Presidential Adviser on Petroleum and Energy Matters has also stated that the objective of government regarding natural gas in the country is to end gas flaring by 2008, capture the economic value of gas, develop domestic markets for the product and address environmental issues associated with it (ibid: 5). The areas identified for gas utilization as part of the process of attaining these objectives are electricity generation, fertilizer blending, cement manufacturing and iron and steel production.

2.1.2 Legal Framework of the Oil Sector

Various legal instruments have been enacted to regulate the oil and gas sector activities in Nigeria and their effects on the environment. Some of these laws have been in existence since the colonial era. Prominent among these was the Water Works Act of 1915 and the Public Health Act of 1917. The state government at the time also passed the Forest Law in 1956. With the attainment of independence in 1960, most of these laws ceased to have effect, since they were tied to the British Legal System (Okonta and Douglas, 2001:214). Since independence, some laws enacted that directly or indirectly influence operations within the oil industry are:

5 Oil in Navigable Waters Decree
6 Sea Fisheries Act
7 Criminal Codes
8 Harmful Waste (special criminal provision etc) Decree
9 River Basin Development Authority Act
10 Petroleum Act of 1969 (amended in 1990)
11 Petroleum (drilling and production) Regulation Decree
12 Land Use Act of 1978
13 Oil Pipeline Act and Land Decree of 1993
14 Federal Environmental Protection Act (now defunct)
15 Associated Gas Re-injection Regulation of 1985
16 Nigerian Liquified Natural Gas Decree of 1990
17 Natural Gas policy of 1995
18 National Guidelines and Standards for environmental Pollution Control in Nigeria
19 National Affluent Limitation Regulation
20 Pollution Abatement in Industries and Facilities Generating Wastes Regulations
21 Waste Management Regulations
22 Environmental Impact Assessment Decree
23 Natural Resources Conservation Action Plan
(Obadan and Egbon, 1995: 70)

These laws define the basis for obtaining approval to operate in the oil sector, set the standards within which the oil companies are to operate and the penalty and sanction that can be imposed for violating them. The National Effluent Limitation Regulation (1991), for instance, specifies the need to install anti-pollution equipment in factories, treat effluence before disposal and limit the level of effluence disposal into the environment. Cumulatively, it is observed that there are some 46 instruments regulating the petroleum industry in Nigeria (Civil Liberties Organization, 2001:5)

2.3 Institutional Arrangement

The key government institutions involved with the issues of oil exploration, production, marketing and social developments are the Federal Ministry of Petroleum resources (Department of Petroleum Resources) and the Nigerian National Petroleum Corporation (NNPC).

The Department for Petroleum Resources is responsible for policy formulation within the industry and has an overall supervisory and monitoring role. The NNPC is not involved with oil exploration and production (although it is currently venturing into this area), but it is the institution that manages the government's interest in the oil industry. NNPC owns between 55% and 60% of the shares in all joint venture partnerships with oil producing companies in the country. NNPC also owns and manages the country's oil resources and joint venture partnerships with various indigenous marketers. NNPC has regulatory functions concerning the distribution and sale of petrol and allied products by issuing licenses, franchises and permits to dealer (Okonta and Douglas, 2001: 60).

The Federal Ministry of environment and the Niger Delta Development Commission (NDDC) are indirectly related to the industry. The Federal Ministry of Environment is concerned with ensuring the effective management of the environment through the formulation of appropriate policies. The protection of the environment and other related issues have been clearly defined in various Acts, including the Environmental Impact Assessment Act of 1992. The NDDC is charged with the responsibility of policy formulation, project planning and implementation, identification of factors inhibiting development in the Niger Delta and tackling ecological problems resulting from the exploration of minerals in the region (part 2 of NDDC Act). For purposes of understanding the effectiveness of policy implementation, it is important to identify other key stakeholders in the Nigerian oil sector.

2.3.1 Other Major Stakeholders operating in the Oil Sector

The other major stakeholders are the oil companies themselves. The major companies are Shell Petroleum Development Company (SPDC), AGIP, Gulf Oil, Texaco, Chevron, Exxon-Mobil, Total-Final-Elf and Stat-Oil. In total, all these companies operate 159 oil fields (Civil Liberties Organization, 2001: 2) in the coastal areas of the Niger Delta, with SPDC as the largest transnational operator in the sector. The ultimate interest of these companies is profit maximization and this objective clearly overrides any consideration concerning the environmental effects of their activities. Recently, they have started to recognize the importance of maintaining cordial relationship with their host communities through corporate social responsibilities.

The third layer of stakeholders is made up of the communities from where the oil is extracted. Historically, the host communities have depended on farming and fishing activities as their sources of livelihoods. Their interests have been access to land and other natural resources, which provide them with food and income. As far as oil is concerned, their interest is to gain employment in the oil sector and the provision of basic amenities in their communities. It is the continuous neglect of these communities and the negative impact of the oil industry on their environment that are responsible for the conflicts we now see in the Niger Delta today (Human Rights Watch, 1995).

2.4.1 Monitoring of Oil Sector Activities

In assessing the level of implementation of the rules and regulations, it has been observed that the laws and regulations are not enforced and the oil companies hardly prepare Environmental Impact Assessment (EIA). One source has observed that the laws and regulations "are rarely applied" (Civil Liberties Organization, 2001: 5). In an attempt to determine the causes of non-enforcement, some of the explanations given are the failure to adequately fund environmental institutions and the lack of power of enforcement (Elliot, no date: 96). Others have attributed it to lack of skills. But, environmental activists have identified corruption and manipulation of enforcement agencies by the oil companies (Okonta and Douglas, 2001: 22) as the major problem.

Obadan and Egbon (1995) have also stated that intervention policies and regulations are principally regulatory and that these regulatory approaches rely heavily on monitoring and enforcement, which could be costly. Some other sources point out that there are no stringent environmental standards in the Nigerian oil and gas industry.

2.4.2 Compliance with Policies and Regulations

As observed earlier, the rules governing the operations within the oil sector are based on provisions contained in various legal instruments, regulations and the Nigerian constitution (Okonta and Douglas, 2001). The reality is that most of these laws and regulations have not been adequately enforced. Ross (1999: 110) has observed that “companies and industries have a tendency of growing too large and powerful to the extent that they end up making the rules that they are supposed to obey and government agencies become captives of the very corporations they are supposed to regulate”.

However, the oil companies have always maintained that they conform to national laws and policies and that the country benefits greatly from their operations. They also claim to be performing their corporate social responsibilities in the communities where they operate. A message in one of the companies’ website reads: “Nigeria is benefiting from Shell’s approach to business. Operationally, it is gaining the latest technology. New techniques such as horizontal drilling, piloted in Oman and the North Sea, are increasing efficiency and decreasing the environmental impact of operations. Investment plans pay particular attention to environmental issues, an area we are committed to continuous improvement. Shell’s contribution to sustainable development also includes being open about its performance and having its claims independently verified. The company believes it can play a part in building a better future” (culled from Shell’s website).

Contrary to the views expressed by Shell, the Group Managing Director of NNPC has revealed that “the lack of break-through in the nation’s effort to transfer technology is partly due to the absence of cooperation from the multinational oil companies. The multinational companies domesticate technological know-how within the boundaries of their companies at the expense of the nation” (The Guardian, August 7, 2002: 7). This statement is a reflection of the real situation, which is why some civil society actors have always described the claims by the oil companies as mere public relations gimmicks.

Having examined the policies and practices within the Nigerian oil industry, the next chapter will deal with the impact of oil and gas extraction on the people and environment of the Niger Delta.

3 The impact of oil and gas extraction on the people and environment of the Niger Delta

Since the 1960s, the ecological balance in the Niger Delta has been drastically disrupted by the impact of oil and gas extraction. The World Bank, in one of its reports (1995a: 81-82, 86), has identified three major causes of this situation: the arrival of the oil industry, population growth and the failure of government policies. The World Bank report argues very plausibly that these three developments, in combination with other secondary developments they have stimulated, are together largely responsible for the present socio-economic and ecological problems in the Nigeria Delta.

3.1 Socio-economic Problems

In particular, the rapid population growth in the Niger Delta since the 1960s is clearly related to the emergence of the oil industry in the same period. “Since oil development began in the 1960s, immigration into the region has greatly increased. The oil companies attracted workers from all over Nigeria, but only employed a relatively small number of locals” (World Bank, 1995a: 67). Between 1963 and 1991, the population of River State, where one of the biggest cities in the Niger Delta is located, grew at a rate of 2.7 percent. As a result, the population more than doubled in this period. The population of the Niger Delta is currently growing at a rate of 3% per annum and this will lead to a doubling in twenty years (Federal Office of Statistics, 1996). Delta state and River State, which together contain some 80% of the Niger Delta, have a combined population of about 6.7 million (ibid). Considering that only a fraction of the region is habitable (the low lying areas are regularly flooded), this has resulted in population densities in most communities of the Niger Delta. Housing is in short supply in most cities of the Niger Delta and the occupancy average is four to six people in a room measuring less than 10 square metres. More than 20 persons may share a toilet in a multi-family compound (Ashton-Jones, 1998)

To supply this growing population with food, housing and other daily necessities of life, has intensified the exploitation of the natural environment. The existing ecological balance has been greatly disturbed. The effects have been manifesting in the form of deforestation, over-fishing, erosion of farmlands, rapid urbanization and a certain degree of industrialization (World Bank, 1995a: 1-7).

For the rural population of the Niger Delta, who depend on the region's delicate ecological balance, these developments set off a distinct process of impoverishment. The Gross Domestic Product per head in the Niger Delta is significantly lower than the average for Nigeria as a whole ($280). Unemployment is estimated at 30%, while the cost of living in the urban areas of the Niger Delta is the highest in all of Nigeria.

The level of education is also below the national average. Whereas 76% of Nigerian children attend primary school, attendance rate in some parts of the Niger Delta are only 30% to 40%. Only one in five of the region's houses is in a reasonable state, and the provision of electricity, drinking water and sewerage is clearly behind the rest of Nigeria. Water-related infectious diseases are very prevalent and the most important causessss of death in the region are malaria, dysentery, typhoid and cholera (Ambio, 1995: 534-535). Some of these ailments have been traced to the pollution of the communities' sources of drinking water by the oil industry.

2.5.2 Government's Inefficiency and Policy Failure

Besides being guilty of failing to counteract these negative developments through adequate policies, the Nigerian authorities have also directly contributed to the disruption of the ecological balance in the Niger Delta. In the Niger Delta, there has been virtually no government planning of the oil industry and the infrastructure, neither had there been effective enforcement of environmental regulations or efficient administration of natural resources. Oil production has generated a tremendous flow of revenue for the Nigerian government, but only a very small fraction of this has been allocated to sustainable socio-economic development of the Niger Delta (World Bank, 1995a: 53). The Nigerian government has invested in the construction of a large number of dams in the region. However, the electricity these generate is largely used outside the region and the dams themselves have caused serious disruptions of the ecological balance in the Niger Delta.

For these reasons, the World Bank has cited policy failures as one of the three primary causes of social and environmental problems in the Niger Delta. The shortcomings of the government, however, cannot be separated from oil and gas production. Firstly, the government has a definite economic interest in smoothening the way for oil production as much as possible. And secondly, important environmental laws enacted by the government are simply ignored by the oil companies. An important example is the Associated Gas Re-injection Decree of 1979, which obliged the oil companies to end gas flaring by 1984 at the latest. From that date, all non-saleable associated gas was to be pumped backed to the oil fields concerned. Because the oil companies refused to comply with this law, it was soon replaced by a paltry levy on each cubic metre of gas flared (Gelder and Moerkamp, 1996).

2.6.2 Environment and Livelihoods Problems

The environment of the oil producing communities of the Niger Delta has been severely degraded as a result of the activities of the oil companies and the neglect of the government. This degradation results from the contamination of lands and waters in the communities by oil emanating from spillages and burst pipelines. It is also associated with the scotching effects of sustained gas flares and the resulting acid rain as well as the non-enforcement of rules and regulations. The nature of the Niger Delta Environment makes the situation more acute. The soil in the rain forests easily absorbs and retains spilled oil, which then seeps back to the surface every raining season. Agricultural lands and fishing waters are consequently degraded and rendered unusable.

Oil pipelines explosions are essentially a Nigerian type of disaster, affecting this country more than any other in the world (UNICEF/FGN, 2000: 218). The explosions over the years have resulted in horrific injuries and fatalities, predominantly among women and children. Many of the oil pipelines are overland and have not been maintained or replaced by oil companies since they were laid several decades ago. Some explosions are said to result from accidental igniting of fuel from leaking or antiquated pipelines. Other explosions have been linked to sabotage perpetuated by impoverished communities and organized criminal gangs seeking to make profit from oil on the 'black' market. Women and children are often the victims of pipeline explosion, because they are the ones usually sent by the perpetuators to scoop oil from broken pipelines. A major pipeline explosion occurred at Okpe Local Government Area of Delta State in 2000. The explosion resulted in the death of 250 people of whom 65% was reported to be women (ibid). According to the National Association of Niger Delta Professionals (NANDP), in 2000 alone there were 82 cases of oil pipeline explosions, resulting in the death of around 5000 people.The consequences of the environmental damage from oil spills and gas flaring on the sources of livelihood of the local people of the Niger Delta are far reaching. Traditional livelihoods like farming and fishing can no longer sustain the inhabitants of theses communities, resulting in the intensification of poverty. Among the people themselves, the link between activities of oil companies and the declining role of traditional livelihoods and poverty is very well recognized. A recent study of some oil producing communities noted that both men and women, interviewed in a focus group discussion, emphasized the gradual disappearance of traditional livelihood systems in their communities as a major cause of increasing poverty in the Niger Delta (Ozo-Eson and Ukiwo, 2002)

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Environmental Protection and Participation of women in Mining activities in Tanzania

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Abstract. Mining can result in significant environmental damage with consequential impacts on adjacent local communities. Women usually consist of more than 50% of a community and form an integral element of society often owning the land. Negotiations about mining developments are too often on a man to man basis, ignoring the interests and welfare of women. As a result, women can be more susceptible to the environmental impacts of mining which result in destruction of traditional lands and the use of chemicals for processing. Removal of forests can prevent women from accessing traditional medicines, foods and cultural materials. The pollution of water by mining discharge can contaminate drinking and bathing water; and result in toxic levels of metals in local fish. The use of dangerous substances such as mercury by women can lead to birth deformities.

Women need to be better informed about these impacts and greater involvement and influence at both the planning and closure stages of mine developments. Consultation about the environmental impacts of mining needs to be gender specific to encourage women to discuss issues which pertain to women's roles in the provision of health, education, food security and cultural activities (ceremony). This paper discusses a number of case studies from South Africa and northern Australia and provides examples of how women's knowledge can be incorporated into the various stages of mining projects.

1 Introduction

Mining projects developed by large companies are generally undertaken in a number of distinctive and successional stages as follows:

- Exploration – determination of an economic resource requiring the collection of samples and some disturbance to land
- Approvals – the mining company is usually required to undertake a number of studies and suggest strategies to mitigate or control impacts prior to obtaining approval for the development
- Construction – building the mine infrastructure such as camp, tailings dam, processing facilities requires that necessary land is acquired, communities relocated and land cleared.
- Operational – involving the production of wastes, discharges (water and air) and Ongoing disturbances to land as the mine expands.
- Mine Closure - after exhaustion of the ore reserves, the pit/s will be closed, Infrastructure sold or removed, the site rehabilitated and post-closure management systems implemented.

During the various stages of the mine, the community is impacted in different ways. Women's knowledge and view of the environment needs to be included during the various stages using mechanisms that are culturally and gender appropriate.
The earlier that consultation commences the more easy it is to incorporate relevant information into mitigation measures that can be implemented throughout construction and mining; and remain sustainable after the mine closes, see Table 1.

Table 1. Inputs and Outcomes from the involvement of Women in Mining

Inputs	Mining Stage	Outcomes
Knowledge and women's culture	Exploration	Protection of important Women's sites and activities
Knowledge of women's Land ownership, decision mechanisms and environmental requirements	Approvals	Land compensation Mechanisms and environmental mitigation Plans appropriate for women
Ongoing consultation including women representatives	Construction	Employment for women, design and implementation of mitigation measures appropriate for women
Ongoing consultation including women representatives Mechanisms for dispute resolution	Operational	Women with increased knowledge; senior women emplyed; mechanisms for dispute resolution
Ongoing colsultation including women representatives	Mine closure	Gender appropriate rehabilitation and final land uses; enhanced livelihoods that are sustainable

Knowledge of women's culture Protection of important women's sites and activities Knowledge of women's land ownership decision mechanisms and environmental requirements Land compensation mechanisms and environmental mitigation plans appropriate for women Ongoing consultation including women representatives Employment for women, design and implementation of mitigation measures appropriate for women consultation including women representatives Women with increased knowledge; senior women employed; mechanisms for dispute resolution Ongoing consultation including women representatives Gender appropriate rehabilitation and final land uses; enhanced livelihoods that are sustainable

2 Involvement of Women in Mining Stages

2.1 Exploration Stage

Exploration involves the collection of samples from stream sediments and drill holes to determine if an economic resource is available. This is undertaken by exploration geologists. Due to the remoteness and harsh conditions, men rather than women are usually attracted to this profession. Often local men are employed by these geologists to assist them with exploration work. Consequently, any negotiations regarding access to land or destruction of the environment for exploration sampling has usually been conducted by male representatives of the company. This is the first stage where women need to be consulted to ensure that areas important to them will not be destroyed or disturbed. In many cultures, it is not appropriate for indigenous women to discuss their culturally important areas and issues with men. An example of this is at Argyle Diamond Mines in north-western Australia. The site of diamond exploration and later mining is a significant women's creation site with associated cultural stories and ceremonies. Some regions in Australia now recognize this issue and routinely send both male and female anthropologists into the field with the exploration geologists to negotiate land access for exploration with Aboriginal communities.

3.2 Approvals Stage

The collection of baseline data is usually the first step in the approval stage. This should involve a detailed collection of both social and environmental site information. The data is then assessed against mine plans and appropriate mitigation measures developed. In some mines, such as the Mara project in Tanzania, the initial social data collected for the Environmental Impact Assessment (EIA) was very limited and only recorded the economic status of the surrounding communities. No data on the ethnic diversity of the communities or the traditional relationship of the communitie s to the land was determined until after the mine commenced production (Kunanayagam, 1995). Consequently, the feasibility team (which did not include any social or environmental experts; or any women) was not aware of the local communities' relationship to land and as a result land compensation issues have besieged the mine since construction and throughout the operation stage. Land ownership in the dominant ethnic group surrounding the mine, the Mara, can be inherited by both men and women.

Traditionally, after marriage, the husband will move to the wife's family village (Hopes, 1997). The Tanzania government requires land to be registered in the husband's name which complicates legal and traditional ownership of land. Further complexities arise when migrant and trans migrant groups move into the area and use traditional Mara land (Green, 2002). If social data is collected it is often collected only by men and from men; and similar to the exploration stage, the knowledge of women's interests and concerns are overlooked. The example of Mwadui Diamonds fits this mode. Although, the current location of mining pit and alluvial operations was an important women's cultural site, this is not mentioned in the Environmental Impact Statement (EIS) which provided the basis for government approval

Only recently, almost 20 years after the commencement of mining are women being formally consulted and represented on a Steering Committee which will negotiate issues relevant to the remainder of the mine life and closure. Environmental data which is collected during baseline studies usually only records scientific information such as geology, water quality, animal species and plant species. Traditional knowledge on the importance or use of certain land area, water bodies or species in not recorded or required by government for the approval processes. However, if this information is not collected, the decision to disturb an area will be based on by on scientific reasons rather than traditional knowledge. Fore example certain areas may be excellent areas to use as quarries during the construction phase but not information is available on their cultural importance. Recently, approval was provided by a community advisory group at Mara (which included senior traditional law women) about using rock from a mountain that was required for upgrading a dam. The community advised the mine that they could use the rock from one side of the mountain on the condition that they didn't alter the height of the mountain as it was an important location in their traditional mythology and creation stories.

3.3 Construction Stage

The construction stage of the mine usually involves the disturbance and compensation of land; and building of mining infrastructure. This should be based on approved plans which are the result of wide consultation with community members. Not always is this the case due to a lack of knowledge of the community and the community decision making processes. Therefore, the decision making mechanisms of the society need to be determined at an early phase in mine development, preferably prior to construction. The example of the complexities of Mara land inheritance indicated that resolution of land compensation requires ongoing consultation with both male and female community representatives throughout the construction stage. The issues of community health often surface during the construction stage as community members become aware of the extent of disturbance. The enormity of many mining ventures is often outside the realm of experience of many individuals in remote communities. Therefore even if consultation about impacts has been undertaken, it is extremely difficult to visualize the impacts. In high rainfall locations, such as Tanzania, construction is usually associated with high levels of erosion, resulting in sedimentation of river systems. These rivers are often important sources of food and necessary for the demands of daily living such as washing, bathing and cooking. In many societies, it is these tasks undertaken by women during the care of their families which are impacted by these polluted river systems. If women have not been consulted, impacts are amplified as they have not been expected and alternative arrangements, such as clean water supplies, have not been constructed. Downstream of the Mara mine in Tanzania, live approximately 3000 people who are associated with artisanal mining activities and depend of the river for their livelihoods. The relationship with these people and the mine has on occasions been extremely hostile with numerous incursions into the mine area.

In addition there are ongoing complaints of "itchy skin" disease attributed by the community to the mine, although there is no evidence to support these accusations. In recent months, through the community advisory group, senior women in these down stream communities have been involved in health surveys with the local doctors to determine the cause and hopefully develop a cure for this chronic affliction.

3.4 Operational Stage

The aim of this stage is to extract, process and sell the commodities of the mine, such as gold, diamonds, copper etc. Mining and processing are the major activities taking place in the operation which can have environmental impacts. Usually these activities result in ongoing disturbances to land and require the use of fuels, oils and chemicals. Mitigation measure such as rehabilitation and water treatment processes need to have input from women to ensure that they include women's concerns. Unless women are included in appropriate consultation processes their knowledge will not be incorporated in the mitigation measures. For example, a rehabilitation plan using local plant species at an Aboriginal community in northern Australia, only included the plants which were significant to Aboriginal men. These were plants that upon flowering indicated that it was time to hunt turtle or fish on the adjacent re ef. The reason for this oversight was because the rehabilitation plan was designed by a man in consultation with the men of the community. After a woman became involved in the project, the Aboriginal women told her the plant species that they also wanted in the project. These were species of important medicine plants and others that had seeds which could be used to make necklaces. The management of contaminants in water discharges is a critical activity during the operational stage of the mine. This activity can impact more severely on women, depending on the types of chemicals used. Most artisanal gold mining operations in Indonesia use mercury to separate the gold from other impurities. The mercury, which has been mixed with the gold is then "burnt off" or vaporized over a hot flame. Mercury can be absorbed through the skin during handling, and the vapors from the burning procedure can be inhaled. Often it is women who undertaken the processing of alluvial gold because he men are occupied in the more manual mining activities. If women are pregnant or breast-feeding they and the off-spring are most susceptible to mercury toxicity. Deformed babies have been born in North Sulawesi In Indonesia after their mothers have been exposed to mercury vapors and high levels of mercury have been found in the breast milk of artisanal mining women in Java in Indonesia. Provision of health information to women prior to and during the construction stages of the mine can assist with the development of alternative methods to reduce risks. There is a husband and wife team of mining engineers in Java, who have developed a simple piece of equipment which allows the safe vaporization of mercury. They have trained local people, including women, in the use of this equipment which also enables mercury to be captured and reused.

3.5 Closure Stage

A key focus at the closure stage is the selection of sustainable post-closure land uses. This is another avenue to involve women in consultation with the mine. However, unless women have participated in discussions during the operation of the mine and have an understanding of the technical issues, it is extremely difficult for them to contribute at this stage. In the Mara project, the Mine Closure Steering Committee requested the contributions of local women at the mine closure planning meetings. A local Mara health worker from the nearby Community Foundation agreed to attend the meetings. She required a lot of background information and needed to attend several meetings before being able to effectively contribute. However, it was due to her contributions that a village level mine closure communications program for 28 critical villages was designed and implemented. In one meeting she stated, 'the mine closure plans that you are talking about in this meeting are not the same discussions on mine closure that women are having at the washing holes on the river – they need to be the same'. Other women who were involved in the mine closure process ensured that agreed criteria were used to select post-closure land uses which would be sustainable and have wide community support. The option chosen for the site was relocation of buildings to a nearby population centre for use by the community as education or cultural facilities; and rehabilitation of the site. In contrast the local Mayor (also a member of the Steering Committee) wanted the buildings to remain on the site for use as gambling center.

4 Conclusions and Recommendations

Involvement of and consultation with women should be an integral component of mine planning; not just an add-on or after thought. If the following steps are included early in the mine development, impacts on women will be reduced and more women will be able to contribute to development of inclusive mitigation measures and sustainable mine closure options. If the mine is already in operation, be proactive, obtain the information that is required and start to involve women in consultation forums.

- Include women's cultural and environmental knowledge as early as possible in mine development
- Allow local women access to professional women who can appropriately record their Knowledge
- develop an understanding of traditional land ownership by consulting with both men and women
- Include decision making mechanisms which include women into planning processes
- Involve women and their knowledge in discussions about mitigation measures
- Include women in steering committees on mine planning and closure options

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Mine Water Management in South Africa

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1 Introduction

1.1 Mining and the environment in South Africa

Since the late 19th Century mining has played an important role in the economy of South Africa, with much of the current economic activity tracing its origins back to the discoveries of diamonds and gold in the 1880s. While this has provided the impetus to become a commercial and financial hub in Africa, it has not been without its negative impacts on the environment. The specific characteristics of the environment which hosts the major mineral deposits in South Africa, in particular relatively low and erratic seasonal rainfall, high evaporation rates and a low ratio of runoff to precipitation (Ashton et al. 2008).

The distribution of mineral deposits is also unfavourable from the point of view of water management, with many of the major gold, coal, base-metal and platinum group element deposits being located in the on or close to watersheds can lead to large-scale contamination of major water resources if pollution is not well managed at mining sites (Hodgson et al. 2001).

South Africa's mining history can be traced back to pre-colonial times but large-scale mining started in the second half of the 19th Century with the discoveries of diamonds and gold in the then-independent Transvaal and Orange Free State Republics. As far as current water management problems are concerned, the mining of gold and uranium in the Witwatersrand and associated goldfields and coal from rocks of the Karoo Supergroup have had the most profound impacts. Other mining areas, such as the copper mines of Namaqualand and the polymetallic carbonatite mine at Phalaborwa also have associated water management problems.

In a number of cases, most notably the Witwatersrand Goldfields and some of the larger coal mining areas, a number of different mines have existed on a single contiguous deposit, with the resultant interconnection of the underground voids. This leads to a situation where groups of mines have an integrated impact on the surrounding environment (Pulles et al. 2005; van Tonder et al. 2008). In several cases this also leads to large volumes of water being managed at a site which is geographically remote from the area where it first entered the mine void. Furthermore, as groups of interconnected mines flood after the cessation of operations, water may be discharged to the surface in low lying areas within a large group of mines. This occurred in 2002 in the West Rand Goldfield, after the cessation of underground mining and pumping in 1998 (Coetzee et al. 2002). In most cases in the gold and coal mining areas of South Africa, high salt loads and low pH waters are expected to discharge from these operations (Hodgson et al. 2001).

1.2 Active and abandoned mines

A further challenge faced by the South African mining sector relates to abandoned mines. Approximately six thousand abandoned mine sites have been identified in South Africa (Coetzee et al. 2008). Of these, many may not have traceable owners who can be held responsible for rehabilitation and, even where owners can be traced, where mines closed before the requirement to provide financially for post closure environmental management existed, they may well not be in a position to rehabilitate these sites.

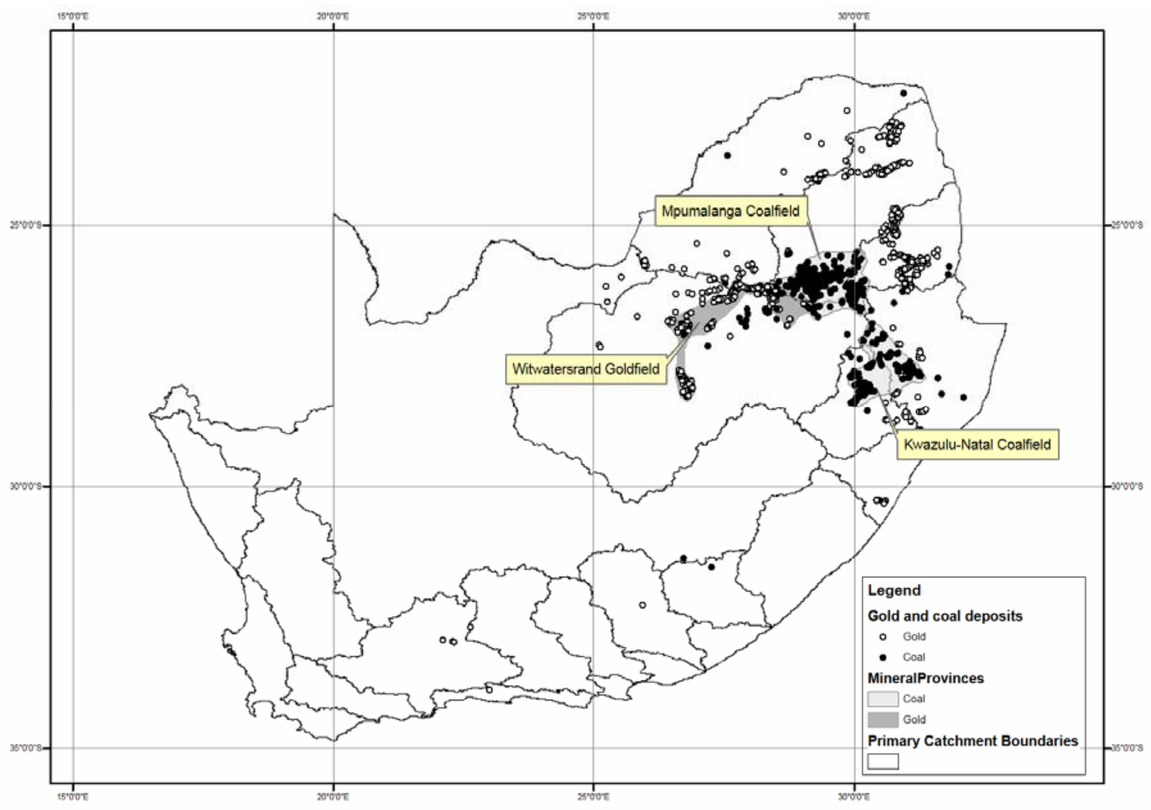

Fig 1. South African gold and coal deposits and primary surface water catchment areas. Note the large number of mines located on or close to primary catchment boundaries.

2 Mine water issues in South Africa

2.1 Gold and uranium in the Witwatersrand

The Witwatersrand goldfields have historically been the world's largest source of gold and, during the uranium boom years of the 1950s to the 1980s were the world's fourth largest producer of uranium. The pyritic nature of the ores has leads to the acidification of water within the mine voids as well as seepage from tailings, waste rock and other surface features (Funke 1990). In addition to low pH and high salinity, a number of radionuclides and heavy metals including uranium have been identified as key pollution threats related to these mining areas, with both water resources and downstream sediments negatively affected by mining discharges (Coetzee et al. 2006; Wade et al. 2002).

Gold mining has been in decline in the Witwatersrand since the 1970s, with a growing number of mines closing. The mines in this region have developed in a number of goldfields defined by geological structures, each containing a group of interconnected mines (Pulles et al. 2005). As a result, as each mine ceases underground operations, stops pumping and starts to flood, water will flow to those mines which are still operational, placing additional pumping load and increased costs onto the remaining mines. As these mines cease underground operations and stop pumping the large interconnected voids flood and will eventually discharge to the surface and near-surface groundwater in low-lying areas. This has already happened in the West Rand Goldfield (Coetzee et al. 2002) and is predicted to occur in the Central Rand within two to three years after the cessation of pumping at East Rand Proprietary Mines in September 2008.

2.2 Coal mining

South Africa's economy is, to a large extent, dependent on abundant coal reserves for energy (See Figure 1 for the location of coal deposits). In recent years public attention has been focussed on acid mine drainage impacts due to coal mining, particularly in the Olifants and Vaal River catchments of

Mpumalanga Province in the north-east of South Africa (Hodgson et al. 2001). Repeated fish kills in the Olifants River and recent reports of the deaths of other large animals including crocodiles have raised the profile of these mining areas. Large-scale remedial efforts have, however been relatively limited with the exception of the construction of the Emalahleni Water Treatment Plant (See Section 3.1).

2.3 Water issues in other mineral provinces

In addition to the large scale coal and gold mining, South Africa has a large number of other mines and mining districts. The smaller scale of mining in these areas results in their impacts on the local water systems generally being localised and easier to manage. Some notable impacts have, however been identified related to smaller-scale mining.

3 Responses to mine water issues in South Africa

3.1 Responses from the mining industry

The mining industry has responded to a number of the recently highlighted challenges with respect to the management of the large volumes of poor-quality water which they generate. Two notable initiatives taken by the industry have been the construction of the Emalahleni Water Treatment plant in the Mpumalanga Coalfields and the creation of the Western Utilities Corporation, which aims to treat and sell water pumped from the mine voids of the Witwatersrand.

The Emalahleni Water Treatment Plant was established by two local coal mining companies and receives approximately 20 Ml of acid mine drainage from their mines and a number of adjacent abandoned mines. This water is treated using reverse osmosis to potable quality and sold to the local municipal water supplier.

In the gold mining areas surrounding Johannesburg, a consortium of mining companies has proposed the pumping of water from flooded mine voids, the transfer of water over a distance of several tens of kilometres to a single large treatment plant and the treatment of this water to a quality suitable for sale as both industrial and potable water. The proposers of this scheme, the Western Utilities Corporation are currently seeking regulatory approval, offtake agreements for the water produced and investment to fund the construction and operation of the plant and transfer schemes. While this has been linked to mine closure, environmental and financial sustainability will have to be demonstrated if approval is given for the construction of the scheme.

3.2 Government initiatives

In general, South African environmental legislation is non-prescriptive with respect to technology and focuses on the licensing and regulation of industries provided that correct procedures are followed for impact assessment and compliance with legislation. Regarding mine water management, three major government initiatives are described below:

In the 1950s, the mining industry in the Far West Rand Goldfield was faced with serious water management challenges. The goldfield's key characteristic is the presence of rich gold deposits which sub-outcrop below an extensive karst aquifer system. During the late 1950s, a large amount of scientific research was performed by both the industry and the government, culminating in the report of the Jordaan Commission (van Eeden et al. 2008) which authorised dewatering of the dolomitic aquifers. Following this, the State Coordinating Technical Committee was established to assess and adjudicate claims for compensation due to subsidence and sinkhole formation which occurred in response to the dewatering.

More recently, the Department of Mineral Resources has pioneered the regional closure strategy concept (van Tonder et al. 2008) which acknowledges the interconnection of underground gold mines and aims to achieve coordinated closure of all mines which impact on one another and which have an integrated impact on the surrounding environment. This concept is also applicable to a number of other mining areas in South Africa, most notably coal mining areas. A further key action being undertaken by the South African government is the reduction of water ingress into gold mines with the aim of reducing the volumes to be pumped and the volumes which will eventually decant. The first major engineering project in this regard is the construction of a canal to prevent the recharge of shallow groundwater from the Klipspruit – a river crossing areas of shallow undermining in the Central Rand Basin (Krige 2001) – which commenced in 2009.

Until recently, the South African government's regulatory actions were relatively fragmented, with a number of government departments and agencies, including the Departments of Mineral Resources, Water Affairs, Environmental Affairs and Agriculture and the National Nuclear Regulator playing a role in the regulation of the Industry. In response to this fragmentation, the Government Task Team on Mine Water Management and Mine Closure was convened. This aims to coordinate and streamline government's regulatory actions with respect to the mining industry, specifically focusing on the water management challenges mentioned above.

4 Concerns for the future

In the immediate future, the closure of mines in the Witwatersrand Goldfields will pose great challenges. The mines of the Central Rand Goldfield, which underlie central Johannesburg are currently flooding (Naidoo 2009; Creamer 2008; Cameron 2009). The lessons already learned in the West Rand Goldfield make it clear that solutions need to be found and implemented before water levels rise to the level where serious environmental consequences will be felt.

In the coalfields, serious environmental consequences are already being felt due to past and present mining activities. Following energy shortages felt in South Africa in 2007 and 2008, coal mining has been expanding with many new applications for prospecting and mining licenses having been submitted. This expansion underlines the need for comprehensive monitoring and better environmental management at existing and new coal mines.

5 Conclusion

Over more than a century of large-scale mining, South Africa has experienced great challenges related to water management in its mining industry. These are seriously exacerbated by the erratic and relatively low rainfall in many of the major mining areas and the low ratio of run-off to precipitation. In recent years, legislation has developed to the point where principles such as the polluter-pays principle and sustainability are entrenched in legislation. Mine water management has received significant public attention in recent years and the mining industry and the government departments who regulate it are actively seeking solutions to key water management challenges.

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Hydrochemistry of waters near some abandoned Barite Mining Areas, Cross River State, Nigeria

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Abstract. The present study was designed to assess the effect (if any) of abandoned barite mines on water quality in some rural communities in Cross River State (Nigeria). Results indicate elevated concentrations of parameters in the abandoned mine areas compared to the surrounding areas. The data also show that the water is suitable for drinking and irrigation purposes.

1 Introduction

The Government of Nigeria has in the last few years, emphasised and encouraged the sourcing and utilization of local raw material especially, as related to the oil and gas industry. This led to the increase in the mining of barite mineral. This activity may alter the water quality by polluting the environment. The quality of water plays a prominent role in affecting both agricultural production and human health (Banks et al, 1997, Nagaraju et al, 2006). Open cast mining as used in the present study area inevitably produces major environmental degradation since vegetation, topsoil and underlying soil have to be removed to gain access to the to the mineral beneath (Nagaraju et al 2006). The problem can be compounded as natural surface and groundwater courses and circulation may be disrupted.

Generally mining affects water resources at various stages of the life cycle of the mine and even after abandonment (Fig. 1). Younger et al (2002) noted that the mining process itself, mineral processing operations, mine dewatering, seepage of contaminated leachates, the flooding of mine workings, and discharge of untreated water are some important process with related mine water problems.

The present work examines the quality of water of abandoned barite mining areas and nearby virgin areas in Cross River State (Nigeria). The study also assesses the impact (if any) of barite mining on water quality with respect to drinking and agricultural purposes.

2 The Abandoned Barite Mining Areas

The study area comprises abandoned barite mines at Iyametet, Okumuretet, Ibogo and Akpet No 1 which are major settlements in Obubra and Biase Local Government Areas (LGAs) of Cross River State, Nigeria. The LGA extends approximately between latitudes 5° 37.713' and 5° 57.543' N and longitudes 8° 05.053' and 8° 25.294' E (Fig 2).

A tropical climate prevails in the project area, characterised by distinct wet and dry seasons. The months of April to October mark the wet season while the dry season lasts from November to March. Other characteristics of this climate include high temperature (22.4–30.1°C), high relative humidity (> 80%), and high precipitation (1800 – 2018mm.)

The project area belongs partly to the Cross River Plain (Iyametet, Okumuretet) with elevations of the order of 80 to 90m above sea level and partly to the Oban Plateau (Ibogo and Akpet No 1) over which the elevations reach up to 500m. The major occupation of the people is farming.

Fig. 1 A typical abandoned barite mine

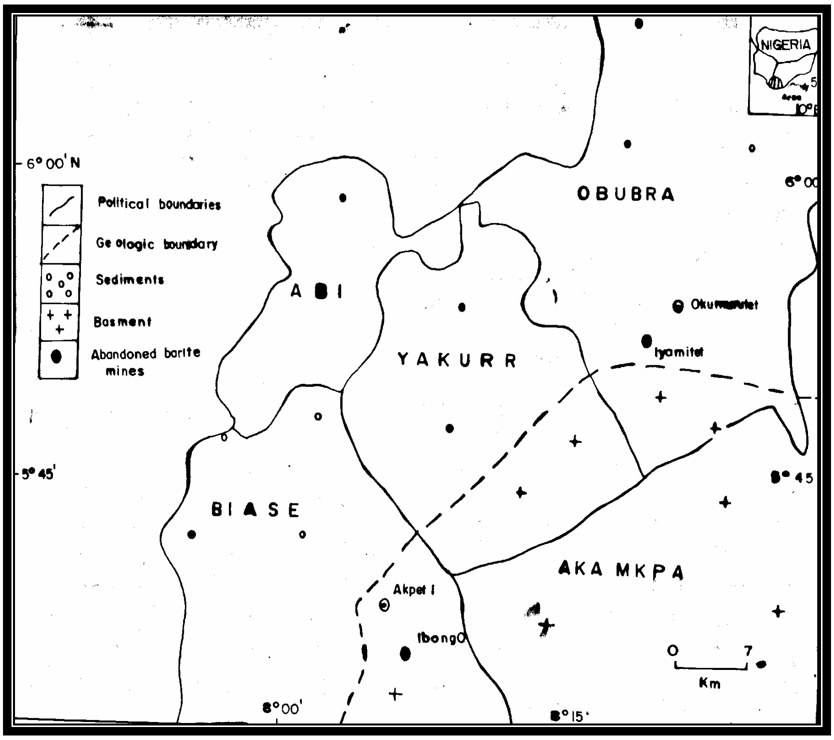

Fig. 2 Map of parts of Cross River State (Nigeria) showing the sample locations

Geologically, the areas of interest belong to the Precambrian Oban massif and Cretaceous Mamfe Embayment. A simplified geologic sequence is presented in table 1.

Table 1 Simplified geologic sequence at the study area

Age	Formation	Lithology	Sample Location
Cenomanian	Amaseri	Fractured & baked Shales, Sandstones, Intrusives	Okumuretet
Turonian	Ezillo	Fractured & baked Shales, Sandstones, Intrusives	Iyamitet
Cenomanian	Mamfe/Ezillo		
Albian	Mamfe	Sandstone	
Precambrian	Oban massif	Gneiss, Schist, Granodiorite	Ibogo, Akpet 1

3 Materials and Methods

Representative surface and groundwater samples were collected from the abandoned mine and the surrounding virgin area. The physical parameters were measured in the field using standard equipment. The chemical analyses were based on the standard methods presented in (APHA 1981). The heavy metals concentrations were determined by means of Atomic Absorption Spectrophotometer (AAS) Perkin Elmer model 2380.

4 Results and Discussion

The result of the analysis and calculated parameters are presented in tables 2 and 3.

4.1 Electrical Conductivity (EC) and Total Dissolved Solids (TDS)

A high concentration of salts in irrigation water renders the soil saline. This also affects the salt intake capacity of the plants through the roots. Electrical conductivity (EC) of water samples ranges from 17.64-499.0µS/cm in samples obtained from the abandoned mining area and for samples from the non mining areas, EC varied between 39.60 and 88.50µS/cm.

Based on the total dissolved solids the water samples in the present area belong to the "Fresh water" category (TDS < 1000mg/l, Freeze & Cherry, 1979), having a range of 8.86-250mg/l in the abandoned mining area, and 19.80-44.30mg/1 in the virgin area samples.

Waters can also be classified based on the concentration of TDS (Wilcox, 1955; ICMR, 1975) given as: < 500 mg/1-Desirable for drinking; 500-1000 mg/1-Permissible for drinking; 1000-3000 mg/1-Useful for irrigation; >3000 mg/1-Useful for drinking and irrigation

Based on the above classification, all samples in both mining and virgin areas will come under desirable for drinking.

4.2 Hardness (H)

In the present study, the hardness of water samples in the abandoned mine area from 1.56-93.2 mg/l and from 5.80-13.79 mg/l in the virgin area samples. All the samples collected in the study area fall into the soft (< 60mg/l as $CaCO_3$) and moderately hard (61-120mg/l as $CaCO_3$) categories (Freeze & Cherry, 1979).

4.3 Ion Concentration

The data for Na, K, Ca, and Mg for the water samples show higher values for samples obtained from the abandoned mine areas compared to the virgin area. The mean values were 32.35, 1.20, 9.76, 0.95 mg/l (abandoned mine area) and 9.60, 0.34, 2.74, 0.26 mg/l (Virgin area) respectively for Na, K, Ca and Mg. The mean values for the anions were 57.25 and 42.05mg/l (abandoned mine area) and 16.60 and 11.81mg/l (virgin area) for Cl and HCO_3 respectively.

4.4 Barium and Sulphate

The difference between the concentration of Ba and $SO_{4\ for}$ the abandoned mine area and non mine area is due to the presence of barite. The mean concentrations of Ba were 0.14 and 0.04mg/l for the abandoned mine area and virgin area respectively. The mean concentrations of SO_4 were 8.14 and 2.21mg/l respectively for the abandoned mine area and virgin area.

Table 2 Summary of water physicochemical characteristics from the study area

Parameter	Units	Abandoned mine Area Surface water					Virgin Area Surface water					Ground water	Standard	
Statistics		Mean	Med	Min	Max	SD	Mean	Med	Min	Max	SD		(WHO, 1993)	(EU, 1975)
Temp	^oC	26.00	26.00	25.50	26.50	0.41	26.10	26.00	25.00	27.00	0.74			
EC	µS/cm	158.04	57.75	17.64	499.00	230.31	53.46	43.60	39.60	88.50	20.58	31.10	1400	1250
TDS	ppm	79.16	28.89	8.86	250.00	115.39	26.72	21.80	19.80	44.30	10.32	15.50	600	1500
pH		6.69	6.71	6.53	6.82	0.12	6.75	6.75	6.70	6.82	0.04	6.76	6.5-8.5	10
Eh	mV	85.75	85.00	82.00	91.00	3.86	83.20	83.00	81.00	85.00	1.48	83.00		
DO	mg/l	3.80	3.55	3.50	4.60	0.54	3.40	3.20	2.70	4.60	0.75	3.10	5min	5
Turbidity	FTU	206.75	19.00	9.00	780.00	382.24	53.40	23.00	13.00	192.00	77.66	9.00	5	
TSS	mg/l	208.25	9.00	5.00	810.00	401.17	23.80	11.00	6.00	82.00	32.71	3.00		
Na^+	mg/l	32.35	10.10	1.80	107.40	50.42	9.60	7.80	6.60	18.00	4.74	4.60	200	100
K^+	mg/l	1.20	0.37	0.07	3.98	1.87	0.34	0.27	0.24	0.62	0.16	0.17	12	12
Ca^{2+}	mg/l	9.76	3.05	0.54	32.40	15.21	2.74	2.23	2.01	4.76	1.14	1.39	75	100
Mg^{2+}	mg/l	0.95	0.30	0.05	3.15	1.48	0.26	0.22	0.19	0.46	0.11	0.13	200	50
Ba^+	mg/l	0.14	0.04	0.01	0.48	0.23	0.04	0.03	0.03	0.06	0.01	0.02	0.7	0.100
Cl^-	mg/l	57.25	18.00	3.00	190.00	89.16	16.60	13.00	12.00	30.00	7.67	8.00	250	200
HCO_3^-	mg/l	42.05	13.13	2.34	139.60	65.53	11.81	9.62	8.58	20.60	4.98	5.98		30
SO_4^{2-}	mg/l	8.14	2.54	0.45	27.02	12.68	2.21	1.81	1.63	4.10	1.06	1.22	250	250
NO_3^-	mg/l	0.86	0.88	0.51	1.19	0.32	0.65	0.77	0.31	0.84	0.22	0.75	50	50
NO_2^-	mg/l	0.0008	0	0	0.003	0.0015	0	0	0	0	0	0	3	
NH_4^+	mg/l	0.212	0.157	0.044	0.492	0.195	0.141	0.117	0.026	0.313	0.114	0.081	1.5	
Fe	ppm	0.402	0.396	0.048	0.769	0.345	0.757	0.791	0.373	0.987	0.233	0.665	0.3	0.300
Mn	ppm	0.026	0.025	0.003	0.050	0.023	0.052	0.050	0.030	0.090	0.025	0.020	0.4	0.050
Cu	ppm	0.012	0.010	0.006	0.023	0.008	0.006	0.006	0.004	0.010	0.002	0.010	1	0.050
Zn	ppm	0.073	0.066	0.026	0.133	0.049	0.025	0.024	0.020	0.033	0.006	0.023	5	0.100
Pb	ppm	0.002	0.002	0.000	0.005	0.003	0.005	0.006	0.002	0.007	0.002	0.005	0.05	0.050

Table 3 Summary of calculated parameters for irrigation purposes

Area	Type	Statistics	SAR	RSC	Na %	PS	PI %	MR	Alk mg/l	H mg/l $CaCO_3$
Abandoned Mine Area	Surface water	Mean	2.06	0.12	71.77	0.57	166.01	15.90	46.83	28.28
		Min	0.63	0.01	71.68	0.03	94.36	15.43	2.61	1.56
		Max	4.81	0.41	71.97	1.90	250.50	16.22	155.46	93.92
		SD	1.91	0.19	0.14	0.89	68.27	0.38	72.98	44.09
Virgin Area	Surface water	Mean	1.44	0.03	72.40	0.16	152.86	16.04	13.15	7.94
		Min	1.19	0.02	71.58	0.12	128.78	15.75	9.55	5.80
		Max	2.11	0.06	74.28	0.28	164.15	16.44	22.94	13.79
		SD	0.38	0.02	1.14	0.07	14.00	0.29	5.55	3.32
	Groundwater		1.00	0.02	71.77	0.08	183.03	15.59	6.66	4.01

SAR-Sodium Adsorption Ratio; RSC-Residual Sodium Carbonate; Na-Percent Sodium; PS-Potential Salinity; MR-Magnessium Ratio; Alk-Alkalinity; H-Hardness

4.5 Heavy metals

Of all the heavy metals considered (Fe, Mn, Cu, Zn, Pb) in the present work, only Cu and Zn were higher in the abandoned mine area relative to the virgin area.

4.6 Sodium adsorption ratio (SAR)

Excess sodium in waters produces the undesirable effect of the changing soil properties and reducing soil permeability (Kelly, 1951). Hence, the assessment of sodium concentration is necessary while considering the suitability for irrigation. The degree to which irrigation water tends to enter into cation-exchange reactions in soil can be indicated by the sodium adsorption ratio (US Salinity Laboratory, 1954). Sodium replacing adsorbed calcium and magnesium is a hazard as it causes damage to the soil structure. It becomes compact and impervious.

SAR values of the water samples in the virgin area vary from 1.19 to 2.11 in the abandoned mine area from 0.63 to 4.81 in the non mining areas. According to Richard's (1954) classification all the samples of the study area have been classified as excellent for irrigation.

4.7 Percent Sodium

Sodium concentration is important in classifying irrigation water because sodium reacts with soil to reduce its permeability. Soils containing a large proportion of sodium with carbonate as the predominant anion are termed alkali soils; those with chloride or sulphate as the predominant anion are saline soils. The role of sodium in the classification of groundwater for irrigation was emphasized because of the fact that sodium reacts with soil and as a result clogging of particles takes place, thereby reducing the permeability (Domenico and Schwartz, 1990). Percent sodium in water as a parameter computed to evaluate the suitability for irrigation (Wilcox, 1948). The percent sodium values of the abandoned mine area samples vary from 71.68 to 71.97 and in the virgin area it ranges from 71.58 to 74.28. This indicates 'Excellent to good' water for irrigation purposes on the Wilcox (1948) diagram.

4.8 Potential salinity

This is defined as the chloride concentration plus half of the sulphate concentration. Doneen (1954) pointed out that the suitability of water for irrigation is not dependent on the concentration of soluble salts. Doneen (1962) is of the opinion that the low solubility salts precipitate in the soil and accumulate with each successive irrigation, whereas the concentration of highly soluble salts increases salinity of the soil. The potential salinity of the water samples ranges from 0.03-1.90 in the abandoned mine area and in the adjacent area it varies from 0.12-0.28.

4.9 Residual sodium carbonate (RSC)

In addition to total dissolved solids, the relative abundance of sodium with respect to alkaline earths and boron, and the quantity of bicarbonate and carbonate in excess of alkaline earths also influence the suitability of water for irrigation. This excess is denoted by 'Residual sodium carbonate' (RSC) and is determined as suggested by Richards (1954).

According to the U. S. Salinity Laboratory (1954), an RSC value less than 1.25 meq/1 is safe for irrigation, a value between 1.25 and 2.5 meg/1 is of marginal quality and a value more than 2.5 meq/1 is unsuitable for irrigation. In the present study, the waters in both virgin (0.02-0.06meq/l) and the abandoned mine (0.01-0.41meq/l) areas indicate that the waters are safe for irrigation.

4.10 Permeability Index (PI)

The soil permeability is affected by long-term use of irrigation water. Sodium, calcium, magnesium and bicarbonate content of the soil influence it. Doneen (1964) evolved a criterion for assessing the suitability of water for irrigation based on a permeability index (PI) where.

Accordingly, waters can be classified as Class I, Class II, and Class III orders. Class I and Class II waters are categorized as good for irrigation with 75% or more of maximum permeability. Class III waters are unsuitable with 25% of maximum permeability. In the present study, P.I. values vary from 94.36 to 250.50 in the abandoned mining area samples and from 128.78 to 164.15 in the virgin area samples. The present study samples fall into the Class I category of Doneen's chart.

4. 11 Magnesium ratio

Generally, calcium and magnesium maintain a state of equilibrium in most waters. In equilibrium more Mg in waters will adversely affect crop yields. In the present study, the 'Magnesium ratio' values vary from 15.43 to 16.22 in the abandoned mining area samples and from 15.75 to 16.44 in the virgin area samples. This indicates Mg ratio less than 50%. This would not adversely affect the crop yield.

5 Conclusions

1. The water samples in the abandoned barite mining area show higher concentrations of physical parameters, cations and anions compared to the surrounding areas.

2. Barium and Sulphate are higher in the abandoned barite mining area compared to the virgin area. The mean concentration of Ba (0.14mg/l) in the abandoned barite mining area is higher than the maximum permissible limits of EU (1975) of 0.10mg/l but lower than that of WHO (1993) which is 0.70mg/l.

3. The waters in both the abandoned barite mining area and the surrounding area are suitable for agricultural (irrigation) purposes .

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Mine water treatment – Results using CO2 and dumped fly ash in AMD affected lakes

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Abstract. The aim of the study was to demonstrate both sequestration of carbon dioxide and improvement of water quality in areas seriously affected by lignite mining by means of direct carbon dioxide injection in combination with industrial by-products, e.g. fly ash, and subsequent precipitation of calcite.

Using gaseous CO_2 in combination with industrial by-products can be accounted as a sustainable method for CO_2 sequestration and for treatment of AMD. Nevertheless this method presents only a niche solution due to the dependence on the alkaline fly ash.

1 Introduction

Acidification of surface waters is a worldwide problem; major impact areas are rivers, lakes, estuaries, and coastal waters (Gray, 1997). Atmospheric deposition is one contributor to the acidification of surface waters; especially in catchment areas with low acid buffer capacities (Dickson et al., 1995; Svenson et al., 1995). Mining of lignite and/or metals is also responsible for acid mine drainage. Diverse concepts exist for the remediation of acidified waters; each depending on the geochemical parameters and boundaries as well as on water type. A number of publications deal with pump and treat, or in-situ-remediation methods like liming or alkalinity production by sulphate reducing organisms.

However, the remediation of acidified lakes does not affect the source (Merkel, 2005). In mining areas, remediation strategies can also be addressed to dump material, but this is often cost and work intensive (Merkel, 2005).

Different studies deal with remediation concepts in bench-scale such as batch experiments (e.g. (Fauville et al., 2004)), in microcosm and mesocosm studies (e.g. (Becerra et al., 2009).

Important disadvantages of the chemical treatment of AMD with various liming agents are high costs, which have produced a search for cheap and more effective liming agents. The alkaline industrial by-products that are gaining importance in the treatment of AMD include: cement kiln dust, red mud bauxite and the highly alkaline steel slag.

Several authors have investigated the capacity of fly ash to improve the quality of leachates generated by coal refuse (Daniels et al., 1993; Stewart et al., 1997; Wilson et al., 2001), by oxidation of sulphide-rich mining waste (Perez-Lopez et al., 2007a; Perez-Lopez et al., 2007b; Perez-Lopez et al., 2007c) and passive treatment of AMD (Gitari et al., 2008a). The prevention of acidic leachate generation and a significant reduction of inorganic contaminants were observed (Gitari et al., 2006; Gitari et al., 2008b; Perez-Lopez et al., 2007c; Vadapalli et al., 2008).

The aim of the study was to demonstrate both sequestration of carbon dioxide and improvement of water quality in areas seriously affected by lignite mining by means of direct carbon dioxide injection in combination with industrial by-products, e.g. fly ash, and subsequent precipitation of calcite.

2 Investigation Area

The post mining lake Burghammer is part of the storage chain Dreiweibern, Lohsa II and Burghammer. It received 26 million m^3 of fly ash deposition over a period greater than 24 years. The pit has since been flooded with groundwater and the ash deposited forms the basin of the lake; which shows no signs of reaction with the lake water. The lake water was characterized by a low pH value (2.9) and a high electrical conductivity resulting from a high content of an- and cations: calcium (341 mg/L), magnesium (48 mg/L), Potassium (9 mg/L), sodium (54 mg/L), iron (25 mg/L), sulphate (1250 mg/L) and chloride (81 mg/L).

3 Laboratory investigations

First, geochemical and mineralogical investigations of the settled ash body were conducted followed by different laboratory experiments. Theoretical conclusions (modeling with PhreeqC) and experimental results showed that settled fly ashes can be used to trap carbon dioxide in form of carbonates (e.g. calcite).

It was shown in laboratory experiments that carbon dioxide can drastically enhance acidic lake water treatment. Settled fly ash in combination with CO_2 can be used to increase the pH of the water quality of open pit lakes to 8.39 ± 0.55. Results from batch experiments showed a general decrease of trace metal concentrations with CO_2 treatment. The elements iron, manganese, cobalt, chromium, copper and zinc decreased significantly during treatment of the ash-water suspensions with CO_2. The proposed treatment technology has no influence on the concentrations of mercury, wolfram, cerium, lead, lanthan, cesium, tin, cadmium, nickel and selenium. Concentrations of these elements were determined to be below the detection limit. Some trace elements (arsenic, chromium, molybdenum, and antimony) contained in the fly ash were slightly mobilized this way.

In all batch experiments an increase of the $K_{s4.3}$ could be affected. In general, for fly ash sediment, an increase of the buffering capacity to 4.18 ± 2.51 mmol/L was observed.

In batch experiments it was shown that settled fly ash sediments are less reactive than fresh fly ash; in average they provide a sequestration rate of 17 g CO_2 per kilogram settled ash sediment whereas 33 g CO_2 / kg fresh fly ash could be mineralized.

4 Field experiment

To field test the sequestration capacity of the settled fly ash gas injection lances were installed to a sediment depth of 12 m by means of a hydraulic hammer mounted on a floating platform. A liquid CO_2 tank, situated on the lake shore, supplied CO_2 via a floating pressure hose (8 bar) connected with the floating platform; from the platform the CO_2 was injected into the ash body. CO_2 was applied with a pressure of 2.2 bar and 2.2 m³/h for a period of 3 months.

Fig. 1: Base of the pilot experiment in lake Burghammer: Floating platform, CO_2 injection technology.

Fig. 2: Tank of liquid CO_2 (provided by company Linde), Heat exchanger. The gas has been transported gaseous from the shore to the platform (pressure 8 – 9 bar).

The lake was continuously monitored over the period of gas injection. Drilling cores from the vicinity of the injection were used for mineralogical and geochemical investigations (TIC analysis, XRD, SEM-EDX, CL) before and after gas injection.

Considering the fact that no initial neutralisation of the lake water had been done before CO_2 injection, no effect on pH was determined during the course of the pilot experiment, only within the direct periphery of the injection lances was an influence on the total inorganic carbon content witnessed. Concentrations of main cations (K^+, Na^+, Ca^{2+}, Mg^{2+}), as well as main anions (Cl^-, SO_4^{2-}, NO_2^-, PO_4^{3-}, F^-, Br^-), did not change significantly.

The predominant part of the ash sediment is composed of amorphous, presumably alumina silicate glass (spheres). Calcium seems to be associated with iron rich particles and alumina silicate glass.

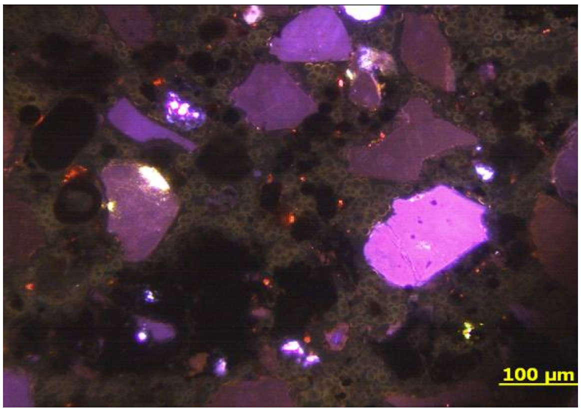

Fig. 3: Isolated carbonate grains (before CO_2 injection)

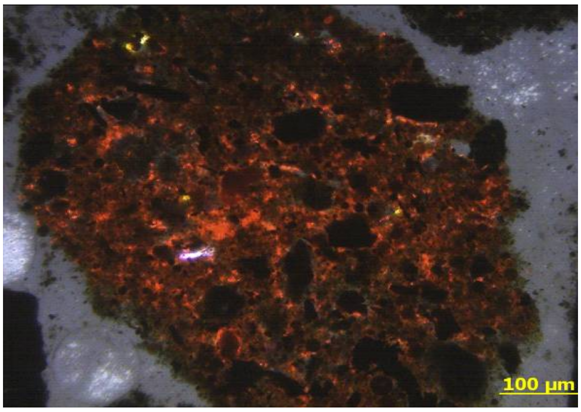

Fig. 4: Formation of orange to reddish luminescent carbonates as large and massive structures within opaque (partially amorphous) ash agglomerates (after CO_2 injection)

Results indicate that calcite precipitation was on average 0.5 wt.-% with maximum precipitation reaching 7.4 wt.-%, while in some areas as well calcite dissolution occurred. Saturation indices of the pore water calculated with PhreeqC were confirmed by TIC measurements. Hence, a sequestration potential of 2.2 g CO_2 per kilogram settled ash sediment was calculated.

5 Conclusion

Using gaseous CO_2 in combination with industrial by-products can be accounted as a sustainable method for CO_2 sequestration and for treatment of AMD. The advantage for mining operations can be seen in the use of an operational by-product (CO_2) in the treatment of acid mine lakes.

Nevertheless, this method presents only a niche solution due to its dependence on alkaline materials, e.g. fly ash. The treatment strategy proposed within CDEAL is an effective method of sustainable carbon dioxide storage, within appropriate boundaries.

A general advantage appears in regarding the costs of reducing carbon dioxide emissions when carbon dioxide is used for acidic lake water treatment and the protection of resources involved in alternative lake neutralisation measures. The following facts stress CDEALs potential:

- Avoidance of the construction of mine water treatment systems (end of pipe strategy); therefore: carbon dioxide emission during construction work is reduced and reduced green land area required for treatment plant installation , saving on resources,

- usage of alkaline substances from existing deposits / sediments possibly reduce chemical consumption, as a result of enhanced efficiency of treatment process; therefore, reducing carbon dioxide emissions with chemical production (CaO, $Ca(OH)_2$). – saves chemicals and reduces carbon dioxide emission,

- the combination of active and passive treatments can provide a sustainable alternative for remediation of acid mine lakes and for CO_2 sequestration

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The impact of Artisanal Mining in Water Pollution in Mozambique

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Abstract. Mozambique is one of the countries with the lowest income in the region of Southern Africa. Subsistence agriculture is the most important traditional economic acitivity to sustain life in the country side. However, over the last years, the productivity of this activity has been declining as a result of decrease of precipitation rates in association with the effects of global warming and thusm increasing aridity of the climates. Under this circumstances, the rural communities are forced to look for other soruces of income, with the artisinal mining beeing one of the most immediate acitivity because it does not need intensive investments and man power. In the central and northern parts of Mozambique there are large occurrences of economoc mineralisations such as gold and pegmatites. However the exploration and processing of such mineral need lots of water which can be polluted during the use. Morover, in the exploration of gold mercurium, which is highly toxic, is used in the processing phase and disposed in the water. Therefore, if this acitivity is nit regulated and controlled, there is a risk of large scale pollution of water resoureces inthe downstream aresa where surface water is used for domestic consumption.

Environmental Impact of Artisanal Gold Mining in the Pungwe River Basin.

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Abstract. Environmental sustainability is fundamental to sustainable development. Today, in the Pungwe River Basin which is shared by Mozambique and Zimbabwe, informal gold mining activities have spread through out the whole basin. The gold mining activities are mainly poverty driven and the majority of the miners are rural people, lacking sufficient knowledge in mining techniques and safety measures. The mining activities cause erosion with large amount of sediment feeding the Pungwe river system. The suspended sediment makes the water unfit for domestic use and irrigation. Miners use mercury in the gold mining process, causing concentrations of mercury in suspended sediment and water Mercury is potentially a hazard to the flora and fauna of the aquatic ecosystem, to human health. Heavy metals exist naturally in the soil of the basin and are thus transported to the river system through the gold mining. The costs for tratment of domestic water become higher and furthermore several stakeholders refuse to pay for the water they use because the quality is not good according to their standards.

1 Negative Environmental Impact

In Mozambique, particularly on the Pungwe river basin, the environmental impacts of artisanal & small scale gold mining are quite visible.Most result from deteriorated soils(siltation and water quality), deforestation, and the use of mercury(Mondlane and Shoko, 2003).

In more than 50 developing countries, an estimated 15 million people are involved in artisanal and small scale gold mining (ASM). This activity usually involves the use of substantial amounts of mercury in mineral processing, often in highly unsafe and environmentally hazardous conditions. As many as 100 million people may be exposed to mercury emitted from ASM. Mercury misuse in ASM is responsible for an estimated 1000 tones of mercury polluted annually into the environment, with negative impacts in diverse ecosystems including international waters. Globally, many of the hazards are similar extensive emissions in tailings, contamination of water bodies, vapor inhalation (Spiegel & Viega, 2007).

The main water quality problem arising from artisanal &small scale gold mining is the high sediment concentrations in the Pungwe river basin(Fig. 1). Other challenges faced in the management of the water resources of the basin are inappropriate land use practices and pressure on natural resources. The majority of the rural community is not connected to electricity and relies on wood fuel for domestic energy. Deforestation and the associated risk of soil erosion are therefore a serious threat to the natural environment and associated wildlife habitats. Poverty thus continues to be a major setback to sustainable development, despite abundant water and other natural resources.

2 Health and Safety Risks

Mercury is a potent neurological toxicant that interferes with brain functions and nervous system. It is particularly harmful to babies and young children. Low-level exposure to infants during gestation is associated with attention span, fine-motor function, language, visual-spatial abilities (such as drawing verbal memory. In adults, mercury can cause numbness and tingling, vision abnormalities, and memory problems (Counter et al. 2006). Miners do share in the related health and safety risks associated with mining and minerals processing. Miners frequently crush the ore and, in the case of gold, make the mercury amalgam used to recover the gold with significant health risks from handling the mercury and from mercury vapors when it is burned off to recover the gold (Fig 2). These chemicals can have harmful effects on women and reproductive health, and as women often conduct a significant portion of this work at home, entire families are often at risk.

Non-gold mining communities, particularly those situated downstream, are at major risk of exposure to methyl mercury though consumption of mercury – contaminated fish (Mondlane & Shokho, 2002).

Figure 1. Negative impacts on environment around of Pungwe river basin

Figure 2. Miner processing gold using mercury in the tributary of the Pungwe River

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Hydro-geological aspects in the Kilimanjaro region for water development and management

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Abstract. Kilimanjaro region is situated in the north-eastern part of Tanzania. Its bedrock is composed of intermediate to basic volcanics of Neogene age to the north and Precambrian metamorphic rocks of Usagaran system in the south. The overburden consists of transported and in-situ materials. For economical exploration and development of boreholes, drilling up to <10-25m, 50-60m.b.g.l., 65-85 m.b.g.l in alluvial, volcanic and metamorphic aquifers respectively is recommended.

Three types of waters, sodium bicarbonate, magnesium bicarbonate, and non-dominant characterise the waters. Bicarbonate, chloride sulphate, sodium-calcium and calcium-sodium hydrochemical facies have been identified.

Within middle slopes of the mountains (Zone II, 1500 – 3000 m.a.s.l.), the construction of dams and gravity canals is appropriate. Within the lower slopes of mountains and plains (Zone II, discharge zone), a combination of spring tapping and borehole construction is economical. Zone III (below 1500 m.a.s.l) needs a detailed exploration, development and management of its ground and surface water resources.

1 Introduction

The study area is situated in the north-eastern part of Tanzania. A unique feature within the region is the occurrence of various ranges of groundwater conditions ranging from alluvial, volcanic and metamorphic formations. However, no attempts have been made to gather information on the nature, occurrence, distribution, exploitation and economical zoning of groundwater as well as spring and stream waters for economic development of community (MAJI, 2009).

2 Study Objective

This study attempts to evaluate and review hydrogeological aspects of Kilimanjaro region based on desk studies and supplemented by limited field mapping, sampling and testing of waters, soils and rocks. Attempts have also been made to zone the Kilimanjaro region with respect to groundwater occurrence which may assist in community planning and management of water supply.

3 Methods

Desk studies comprised terrain evaluation, photo and imagery interpretation as well as updating borehole catalogue from MAJI –Dodoma and other published and unpublished reports were used. Between 1999 and 2000, the author with a Japanese team of geologists carried out field traverses to evaluate groundwater potential which was part of the Mkomazi Irrigation Feasibility study. Electrical surveys using Werner Electrode configuration necessitated the mapping of the southern part of the region and further confirmed that it is mainly dominated by gneisses and granulites.

3.1 Sampling and in-situ tests

The sixty representative water samples, thirty four disturbed soil samples were taken in the field between September, 2008 and May, 2009 were analysed for both cations and anions.

3.2 Water analysis

Cation and Anion laboratory investigations of samples collected were performed at analytical laboratory, Geology, Department, and University of Dar es Salaam using Standard Laboratory Techniques (Greenberg et al. 1985). Four major elements; Na, K, Mg Ca and three trace elements Zn Fe and Mn were analyzed using a Per kin-Elmer 2380 Atomic Absorption Spectrophotometer (AAS), whereas sulphates were analyzed using the turbid metric techniques fluoride by the ion selective electrode method (Troll et al.1997).

3.3 Soil and Rock analysis

Crushed and powdered soil and rock samples (minus 200 meshes) were subjected to aqua regia leach (Johnson and Maxwell 1981). SiO_2 and TiO_2 were determined using acetylene nitrous oxide flame as described by Langmyhr and Paus (1968), whereas the presence of Na_2O, K_2O, CaO, MgO, Fe_2O_3, MnO_2 and P_2O_5 was determined using acetylene air flame.

Loss on Ignition (LOI) was determined by heating the soil and rock samples to 1000^oC (Johnson and Maxwell 1981). A total of 14 thin sections were prepared for petrological identification of rock types and analysed using a Nikon 092 Polarizing microscope at the University of Dar es Salaam.

4 Geological Setting

The investigated area consists of three morphological units; Kilimanjaro Mountain, Pare and Lelatema mountains and Kahe Miwaleni basin

4.1 Overburden

The overburden within the study area consists of transported and residual materials. Fluvial glacial sands obscure the volcanic rocks near the summit of Kilimanjaro Mountain (3000 to 5000m.a.s.).

Drilling for groundwater on alluvial and volcanic terrains have indicated that the increase of overburden is increasing from the slopes to the plains where more than 200m thick unconsolidated sediments. Erosion is very active on the slopes of Zone I and; II; as a result the weathered mantle has largely been stripped off and transported to lower zones III and IV.

Soils overlying basic volcanic rocks; SiO_2 25.03-44.19%, Al_2O_3 15.27-27.89%, Fe_2O3 11.78-24.23%, CaO .08-7.41%, MgO .01-4.54%, Na_2O .04-1.43%, K_2O .06-1.19%, and LOI 6.13-26.99%. Statistical evaluation shows that the soils are rich in silica. This may be derived from both physical and chemical weathering of intermediate and basic volcanic rocks. Quartz being very stable in alteration forms the major constituent of both transported and residual soils. K_2O is more than Na_2O indicating high bonding to some clay minerals as compared to sodium (Hem 1970). LOI is high in all soils indicating high proportions of water and organic matter.

4.2 Bedrock

The bedrock of the study area comprises of Neogene’s volcanic in the north for example vesicular lavas, pyroclastics of trachybasalts, rhomb-porphyries, phonolytes, andesites, volcanic mudstones, lahars (Blatt, H. and Robert J. 1996). Precambrian metamorphic rocks of Usagaran system consisting of lower member which is characterized by granulites, hornblende and biotitic gneisses and upper member characterized by magnesium rich crystalline limestone often associated with graphitic schist’s, gneisses and quartzite’s (Harris 1981).

Litho logical profile and representative drilled wells, field studies and laboratory analytical work have confirmed that the volcanic rocks on the Kilimanjaro block range from intermediate to basic.

The representative litho logical profiles (MAJI 2009) typify the bedrock of the southern part of Kilimanjaro as mainly gneisses and granulites. From thin sections the minerals present are pyroxenes, olivines, orthoclase, alkali feldspars and plagioclase (which form more than 90%). Olivines and pyroxenes are altered to yellow colour. A thin section from metamorphic terrain consists of hornblende, pyroxene, plagioclase, garnets, quartz and biotite.

5 Hydrogeological setting

5.1 Climate and Vegetation

The study area has two distinct wet and dry seasons. The short rains (locally known as "Vuli") caused by NE monsoon winds, are in October to December. The long rains (locally known as "Masika") caused by SE trade winds are in March to May with heaviest rains in April.

The distribution of rainfall within the region is rather uneven. The highest rainfall between 1000 to 2000mm per year falls on the southern and eastern slopes of Kilimanjaro Mountain. This is the major source of ground water recharge. The plains have rain between 200 to 800 mm per year or even lower. The western part of both Kilimanjaro and Pare mountains receive a very little amount of mean annual rainfall, less than 600mm per year due to their position as a rain shadow to the orographic type of rain.

It has been observed during the field trips that most of the areas with high water tables or springs courses in both Arusha and Kilimanjaro regions are characterized a dominant tree species known as Ficus ("Mkuyu") (Mr. Mwasumbwi L.B. pers. Commun., 2009). This tree follows linearly the direction of spring or groundwater.

5.2 Surface water

The surface waters in the study area comprise 10 dams, 2 lakes, numerous seasonal streams and few perennial rivers originating from the slopes of Kilimanjaro at an elevation of 3939 m.a.s.l.

5.3 Groundwater

Statistical evaluation of boreholes drilled in alluvial, volcanic and metamorphic formations show that the deepest borehole (160m) has been drilled in volcanic formation. The mean depth of the three formations, alluvials, volcanics, and metamorphics is below 100 meters. Statistical evaluation of borehole data shows that the most boreholes are drilled between 90 to 110m, 90 to 100m and 85 to 105m in alluvial, volcanic and metamorphic aquifers respectively.

The mean yields of groundwater are $28m^3$ per hour, $15m^3$per hour and $10m^3$ per hour in alluvials, volcanics and metamorphics respectively. However, values up to about $500m^3$/hour have been recorded from a single borehole in Kahe-Miwaleni alluvial basin.

For economical exploration and development boreholes with sufficient amount of yields, drilling up to <10-25, 50-60 and 65-85m.b.g.l. in alluvial, volcanic and metamorphic aquifer respectively is recommended. However in the eastern part of Kilimanjaro mountain i.e. Rombo district ground water aquifers are deeper than the rest of the study area, that is down to 100-150m.ab.g.l.

5.4 Aquifer types

The present evaluation based on lithogical criteria and classification by (Meinzer 1923), revealed that the study area is composed of three main lithological aquifers; i.e. Neogene alluvials, the weathered Neogene volcanics, and fissured Precambrian metamorphics.

5.5 Hydrochemistry of Water

The chemical analysis of 60 water samples from boreholes, sprigs and streams, Na+ varies from 3 to 61 ppm in both surface and groundwater samples representing the most dominant cation. K^+ lies between 1 to 12ppm. In most samples of water analyzed K^+ is less than 10ppm which is in agreement with the relationship established (Davis et al 1966).

Na^+ and K^+ have been observed to behave dissimilarly in weathering process. K^+ tends to be enriched in weathering products due to strong bonding with Aluminium in tetrahedral layer whereas Na^+ is dissolved and leached more easily (Rankama and Sahama 1950, Hem 1970). The sources of Na^+ are probably due to weathering of plagioclase in the sediments (Davis and Dewiest 1966). Soil zone seems to be depleted with K^+. Since this element, is essential plant nutrient, it may be removed from soil by plants.

Ca^{2+} and $Mg^{2+}$are lying between 1 to 6 ppm and 1 to 20 ppm respectively The major sources of Mg^{2+} are ferromagnesian minerals such as olivine and pyroxene observed from thin sections. Generally concentration of both Ca^{2+} and Mg^{2+} are less than that of Na^+. The low concentration of Ca2+ in the study area indicates the absence of readily soluble Ca^{2+} bearing salts(gypsum, anhydrite or carbonates minerals), in the soil zone or aquifer material.

$SO4^{2-}$ within the study area are below detectable limits (<5ppm) and thus not included in this discussion. The only place with high concentration (18ppm) is Sanya town which may be due to anthropogenic activities.

HCO_{3-} varies between 4.27 to 311.1ppm. Since the study area is poor in carbonates, the carbon content of both surface and groundwaters is derived from atmospheric CO_2, respiration of plants roots and decay of organic matter. (the carbon species occur practically as HCO_{3-} (Hem 1970). The ppm values of Ca^{2+} in all samples are very much less than that of HCO_{3-} This fact agrees with the hypothesis of atmospheric origin of carbon species in both surface and groundwaters. It can also hypothesized to be biogenic.

Cl^- varies between 2.9 to 20.38ppm. Its concentration is generally very low. Since Cl^- is unaffected by secondary reaction and tend to remain in solution (Davis and De Wiest 1966, Hem 1970), the low concentration indicate non-anthropogenic effects such as infiltration of irrigation water.

F^- varies between 0.1 to 0.3ppm. In all samples studied, it is below the International recommended limit.

5.6 Geochemical classification of waters

Classification of waters was based on trilinear diagrams (Hill 1940, Piper 1944).

1. Sodium bicarbonate type in both surface and groundwaters dissecting intermediate volcanic rocks.
2. Magnesium bicarbonate type in both surface and groundwaters dissecting basic volcanic rocks.
3. Non-dominant types in alluvial deposits.

From the present study it can be concluded that both surface and groundwaters are of primary type (bicarbonate type). The primary type of water is generally associated with alluvium and weathered mantle.

5.7 Hydro chemical facies

The hydrochemical facies are distinct zones that have cation and anion concentrations describable within defined compositions (Freeze and Cherry 1979). Two anion hydrochemical facies have been identified as bicarbonate facies for groundwaters dissecting alluvials and bicarbonate chloride sulphate facies for both surface and groundwaters dissecting all rock types of the study area.

Similarly two cation hydrochemical facies have been identified as calcium-sodium facies for groundwaters in alluvial and stream waters dissecting basic volcanic rocks, and sodium-calcium facies for groundwaters dissecting intermediate rocks as well as stream waters dissecting alluvial deposits.

The dominating facies in the study area are calcium-sodium facies for cations and bicarbonate chloride sulphate facies for anions.

5.8 Water Quality

The PH values of waters in the study area (5.5 – 8.5), lie within the range of most natural waters (6.0 – 8.5), (Hem 1970).

With respect to TDS and major dissolved constituents, all samples studied display concentrations within the recommended International Standards (WHO 1958) and Tanzania Standards.
Groundwater and surface water of the study area could be described as mostly soft to moderately hard (Freeze and Cherry 1979).

6 Discussions and recommendations

The bed rock is composed of intermediate to basic volcanic rocks on the northern part of the region. In the southern part, the bedrock is composed of Precambrian metamorphic rocks of Usagaran system. Despite the low rainfall (<600mm per year) on these metamorphic rocks, they have potential groundwater due to sand nature of the soil cover which is good for recharge. The overburden within the study area is composed of transported and in situ materials.
Desk studies, field and laboratory studies have demarcated three lithological aquifer types i.e. Neogene alluvials with water shrikes extending 1 – 70m.b.g.l., weathered Neogene volcanics with water strikes extending between 1-133 metres below the ground and fissured Precambrian metamorphics extending between 10 –150 metres below the ground. Alluvial aquifers from the major sources of water for irrigation, hence the most developed. For economical exploration and development of boreholes with sufficient amount of yields, drilling up to <10-25m, 50-60m and 65-85m.b.g.l., in alluvial, volcanic and metamorphic aquifers respectively is recommended. However in the eastern Kilimanjaro mountain i.e. Rombo district ground water aquifers are deeper than the rest of the study area, that is down to 100-150m.b.g.l. This is due to its position as water divide zone, high slope angles combined with pervious ness of lava flows which allow groundwater to infiltrate deep into the ground only to be discharged as large springs outside the National boundary.

The hydrochemical facies of the study area are characterized by bicarbonate facies and bicarbonate chloride sulphate facies for actions, and calcium facies together with sodium ions. The possible reason for this may be cation exchange.

From chemical analysis of water sodium is the dominant cation. This may be due to weathering of plagioclase, leaching and action exchange. It suggests also that the original parent magma through which the waters are dissecting was enriched in sodium as one of the main alkali component. Bicarbonate is the dominant anion whose possible source may also been inferred from the high values of L.O.I. and low epm values of Ca^{2+} as compared to those of bicarbonate.

The present hydrogeological investigation has enabled compiling, synthesizing and evaluating rocks, soils, water and updating borehole data which can be utilized for selecting site where occurrence of groundwater of adequate quantity and acceptable quality is most probable. The information synthesized from rocks, soils, waters and borehole data has facilitated the classification of waters and zoning of the region with distinct hydro geological characteristics.

In conjunction with morphological profile the uplands between 1500-3000m.a.s.l. (zone III) form the recharge areas and the lowlands below 1500m (zone IV) the discharge areas. Having potential surface water on recharge zone, proper and effective water conservation measures must be taken in order to preclude surface and subsurface runoff by means of percolation tanks, trenches and underground dam structures (Winter et al. 1998). Afforestation must be enforced especially in zone II and III to prevent runoff and to enable large quantities of water to percolate into the soil and recharge groundwater reservoirs.

From the present study the following are recommendation:

1. Groundwater monitoring work to be carried in areas where ground water is extensively used especially Kahe-Miwaleni basin. The monitoring work to involve water level fluctuations, discharged, chemical and bacteriological quality of water.
2. Having known the general hydrogeological characteristics of the region, in future isotopic analysis of Kilimanjaro waters need to be carried out so as to establish groundwater flow direction, velocity, source and its absolute age.

In conclusion, the Kilimanjaro region need further detailed meteorological, hydrological, groundwater exploration, and development studies that can provide safe and economical planning of water resources.

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Groundwater dynamics, flow and aquifer behaviour in the Naukluft Nappe Complex and the Nama Group in the Naukluft area of Namibia.

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Abstract. Groundwater chemistry, pump tests, and lithological mapping has been done in the Naukluft Nappe Complex in order to ascertain groundwater flow, quantity and aquifer division. The Naukluft groundwater aquifers have been supplying water to the surrounding farmers and tourist establishments, but the quantity, recharge and mode of movement has never been studied.

In order to explain the trends in groundwater levels in the Naukluft area, an attempt has been made to fully characterize the nature of groundwater flow in the system by using a variety of techniques, such chloride mass balance for recharge; pump tests for aquifer delineation and storativities and transmissivities and ground water chemistry. The Groundwater flow model provides a framework for studying system dynamics and organizing field data being collected during this project.

Nine lithostratigraphic formations and six major nappe units, which have a large scale imbricate structure make up the Naukluft Nappe Complex. The major rock units within the area are dolomites, limestones, shales, phyllites, slates, quartzites and breccias. The shales, phyllites and slates have low primary and secondary permeability. The dolomites and limestones have low primary permeability but have high secondary permeability due to their high competence and tendency to deform by fracturing and solution weathering along fracture planes. The different lithostratigraphic units have been divided into hydrostratigraphic units on the basis of their hydraulic properties obtained from pumping test data, geological maps and down-hole geophysical log data.

The Groundwater flow model has also been used to study the hydraulic connectivity of the groundwater system between the thrust nappes in the hanging wall and the Nama formations in the footwall. The base of the Naukluft Nappes is formed by a dolomite horizon varying in thickness between zero and about 30 metres, the Sole Dolomite. The base of the sole dolomite forms a sharp boundary against the limestones of the underlying autochthonous-parautochthonous Nama Group.

Pump tests have shown that the dolomites are the major aquifers, and that some aquifers are clearly interconnected and behave as one. This suggests that there may be several types of aquifers that feed into the Namib desert, i.e., carbonate aquifers, alluvial aquifers and combined carbonate aquifers.

Groundwater Pollution Assessment for the NW of Auja Tamaseeh Basin in Tulkarem, West Bank

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Abstract. A hydrogeological and hydrochemical study was conducted for the north western part of the Auja Tamaseeh basin in Tulkarem area in order to evaluate the human effect activities on the quality of the groundwater. A steady state calibration flow model as well as solute transport model were built using the visual Modflow software. A stress period of 10 years (2005-2015) was assigned to study its tendency to contamination. The model results shows that there is a pollution risk due to the human activities

1 Introduction

Palestine suffers from water scarcity and groundwater acts as the main source of water in the West Bank. So, it is essential to preserve the quality of groundwater from deterioration and contamination especially when it is subjected to human activities. Groundwater in Tulkarm area is being utilized through 10 domestic and 53 irrigation wells with total discharge of 21.25MCM per year (MOPIC, 1998). The main objectives of this study is to analyze and predict the groundwater contamination in the study area.

2 Study Area

Tulkarm area is located in the north western part of the West Bank (Fig. 1).

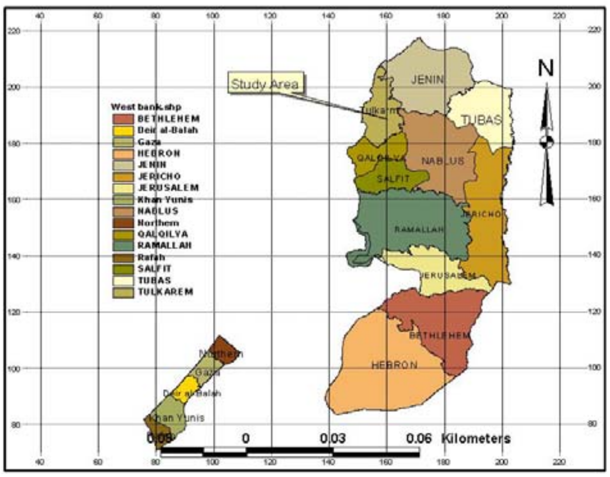

Fig. 1: The location map of the study area

The total area of Tulkarm is about 246 km² and its current population is estimated at 166,832 people, representing 12.4% of the total population of the West Bank (PCBS, 1996). The majority of Tulkarm area rocks are composed of carbonate rocks such as limestone, dolomite, marl and chalk ranges from Cretaceous to Quaternary (Rofe and Raffely, 1965).

3 Results

3.1 Hydrochemical Data and Water Type Classification

The hydrochemical investigation of the groundwater in Tulkarm area (in two catchments of Alkhodera and Iskandaron) was based on the data of 11 wells from (PWA Master Data Bank, 2003 & 2004) for the major ions in mg/L of HCO_3^- , Cl^- , SO_4^{2-} , NO_3^- , Ca^{2+} , Mg^{2+} , Na^+ and K^+ as well as the Physical parameters of pH and Temperature. The software of hydrowin was used to perform chemical analysis and graphical representation of the hydrochemical parameters. The water type in the area is of the type of earth alkaline water with increased alkalis and with prevailing bicarbonate with no observable change between the years of 2003 and 2004 (Fig. 2 a and b).

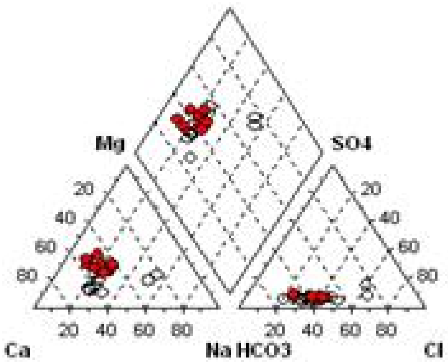

Fig. 2a: Piper Plot for Alkhodera Wells

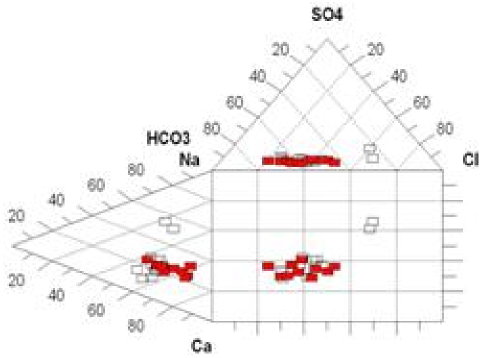

Fig. 2b: Durov Diagram for Alkhodera Wells

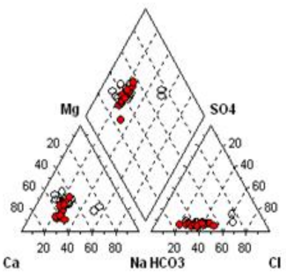

Fig. 2a: Piper Plot For Iskandaron wells

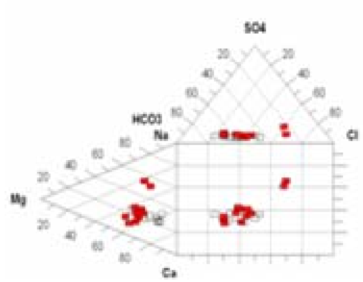

Fig. 2b: Durov Diagram for Iskandaron Wells

4 Groundwater Model Development

The model study area is located within the Western Aquifer Basin (WAB) and is a part of the hydrogeological system of the WAB. It has an area of 214km^2. The model domain is located in the western portion of the Iskandaron drainage –north west of Auja Tamaseeh Basin- (highly sensitive area of Tulkarm Area). The model development was based on previous studies conducted by the SUSMAQ model (2003), and Sabbah model (2004). A three dimensional grid with 500 meters X 500 meters cell size was used. The metric system of units was used in this model; meters per day for the hydraulic conductivity, meters for head, cubic meters (m3) for volume, and days for time The steady state flow model is firstly simulated, developed and calibrated. Then the solute and transport model is developed using the MT3D package under the visual Modflow software. A stress period of 10 years was assumed to perform the model by assuming a contaminated area within the model domain with specified initial concentration, and then, several runs and animations were conducted to study the response of the aquifer system to a contamination event.

4.1 Conceptual Model

The aim of the conceptual model is to define the requirements for the numerical model to be able to simulate water flow and with some restrictions transport phenomena for the region under steady state and transient conditions. The description of the model study area. The upper aquifer layer has a variable thickness ranging from 494 meters in the north western part of the model study area to 249 meters in different places. The second layer acts a confining layer (Aquitard-Yatta formation) separating the upper and lower aquifer and behaves as an aquifer in some other places which merges the upper and lower aquifers into a single layer aquifer. The aquifer system is highly affected by geological faults and folded structures which make the possibility of a hydraulic connection between the different aquifers very high.

4.2 Boundary Conditions

The horizontal boundaries of the model domain are shown in Fig. 3. The northern and southern boundaries of the study area are all of the no-flow boundary type. The eastern boundary is no flow boundary (water divide boundary). The western boundary is a specified head boundary of 24 m. The boundary conditions for the model were defined based on the static groundwater levels performed by SUSMAQ(2003).

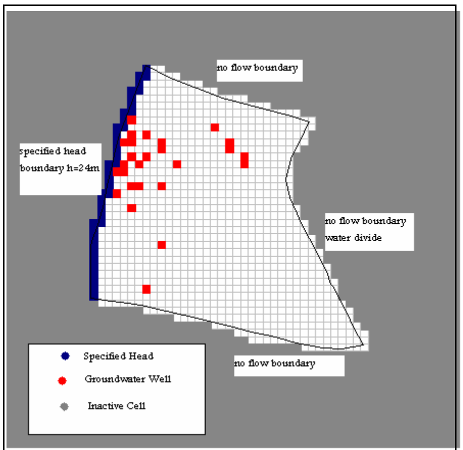

Fig. 3: Model Boundary Conditions

4.3 Aquifer Geometry and Aquifer Properties

There are no available hydraulic conductivity measurements for different aquifer layers of the WAB. The hydraulic conductivity of the fractured limestone and dolomite, which is characterizing the WAB area, is ranging from 1E-07 meters per second (0.00864 meters per day) to 6E-04 meters per second (51.84 meters per day) (Bedient, et al. , 1999). The Upper Aquifer is mainly composed of fractured limestone and dolomite which gave it relatively higher hydraulic conductivity. The Aquitard layer (Yatta Formation) is mainly composed of crystalline limestone and massive dolomite which gave it much lower hydraulic conductivity relative to upper layers. The average initial value of the horizontal hydraulic conductivity of the upper layer used in this model was 20 meters per day. The average initial value of the horizontal hydraulic conductivity of the aquitard layer used in this model was 0.1 meters per day and the vertical hydraulic conductivities assumed 1/10 of the horizontal conductivities for both layers. These values were based on the spatial distribution of the calibrated hydraulic conductivities done by SUSMAQ-2003. The pumpage of groundwater wells located within the model study area, was assumed to be (0.07 – 1)mcm\year for each well in the model study.

4.4 Model Simulation and Presentation

The result of the static groundwater level is shown in Fig. 4.

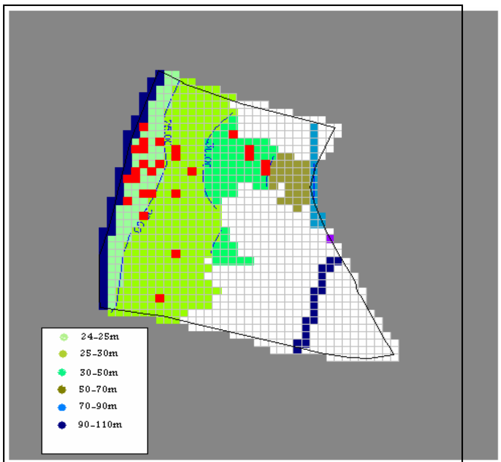

Fig. 4: Static Water Level for the Model Domain

The results of the groundwater flow model can be listed as follows:

1- The groundwater head starts at an elevation of 110 meters above sea level in the south east of the area, 70 meters above sea level in the north east of the model and then it decreased gradually to a value of 24 meters above sea level in the western boundary of the model domain.

2- The model cells in the eastern part of the model area were dry which means that the computed head is lower than the bottom of the aquifer at these cells. That could be attributed to the fact that the model layers there are outcropped and to the absence of observation heads at that area. The presence of dry cells may be justified by the recharge zone of the water divide boundary (no flow boundary).

3- The recharge to the aquifer in this model was calculated to be 25.15 MCM/year and the recharge through constant head was found to be 5.07 MCM/year. The discharge of groundwater wells was considered as outflow from the whole aquifer system and was calculated to be 21.5 MCM/year and the discharge through constant head was found to be 8.72 MCM/year. Table 1 shows the water flow budget of the whole model calculated on a yearly basis. inflow – out flow = 0.

Table 1. Water Flow Budget of the Whole Model Domain**.**

Flow Term	In (MCM/year)	Out (MCM/year)	In – Out (MCM/year)
Constant Head	5.07	8.72	-3.65
Wells	0	21.50	-21.5
Recharge	25.15	0	25.15
Sum	**30.22**	**30.22**	**0**

DISCREPANCY [%] 0.0

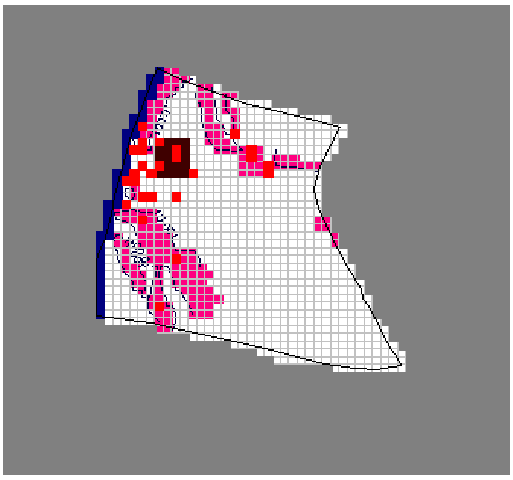

Fig. 5: Chloride Concentration at the End of Simulation

The solute and transport model was simulated to investigate the movement of conservative pollutant using MT3D model. In this study a pollutant source of 2000mg/L represented by built up areas (contaminated area in Fig. 5) was used for model simulation. The input parameters affecting the movement of pollutant was also assumed to be 0.1 for effective porosity (SUSMAQ, 2003) and 50m for dispersivity, which is typical of karstic aquifer system.

5 Conclusions

A 3-dimentional model of 2 layers system in the western portion of the Iskandaron drainage (representing a highly sensitive area of Tulkarm) was built using the Modflow software package. The pollution model was built using the MT3D package under Modflow. The model output indicates that the response of pollution due to contaminant area chosen within the built-up areas shows that the tendency of contamination and pollutant spreading occurs due to dispersion. The results show that there is a gradual increase in chloride concentration with time during the period of simulation.

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Can hot-springs pollute the environment?

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Abstract. The Rift Valley in Ethiopia is endowed with many beautiful lakes and landscapes, different soil types, vegetation, etc. Hot springs are also common occurrences in the Ethiopian Rift Valley. Although hot-springs are used for a variety of purposes in different parts of the world, in Ethiopia they are primarily utilized in relation to recreational purposes and healing of different sicknesses. Studies in other parts of the world reveal that hot-springs comprise of a great geothermal potential where a lot of environmentally friendly energy can be produced for domestic and industrial uses. Since they also are ejected from the inner part of the earth they carry with them different chemical components such as heavy metals. Some of these chemical constituents are found to have healing effect. Contrarily, they are observed to bring into the ecosystem some heavy metals which may have an adverse effect on life if found in excess concentrations. An investigation on the status of some toxic metals in some of the hot-springs in the Ethiopian Rift Valley indicates that all of the metals studied do not pose great threat for irrigation, livestock watering and recreational purposes. The waters are unsafe for drinking particularly because of high As levels. Cd, Cu and Zn levels make the waters unsafe for aquatic life.

1 Introduction and Background

In Ethiopia, the spots in which hot springs are found are considered as sacred healing places where people get healed and cured from different diseases and pains. The hot water is considered to give relief to back pains, rheumatism, allergies, etc. Some people believe and exercise drinking of water from hot springs gives relief from some internal pains or from diseases inflicted by bad spirits.

There are scientific supports too about hot springs being source of healing. “Sodium thiosulfate” is a natural substance found in hot water springs. It is one of the secret ingredients that gives hot springs their healing power (Hay and Sircus, 2007). Sodium thiosulfate not only removes heavy toxic metals from the body, but also, with the help of magnesium, will cause children with austism to sleep restfully. Sodium thiosulfate offers protection against nephrocalcinosis, and renal failure. Sodium thiosulfate is emerging as a treatment for calciphylaxis.

Because of both the folklore and the claimed medical value some of these springs have, they are often popular tourist destinations, and locations for rehabilitation clinics for those with disabilities (Wikipedia, 2007). Unfortunately, hot springs could also be causes for the spread of infections from amoeba, bacteria and viruses.

Hot springs are also sources of energy for domestic and industrial use. In the hot springs near Lake Shalla in Ethiopia, people in the local community cook maize, eggs and similar stuff, in the hot water. This shows that there is a huge potential for energy to generate electricity and heat up houses and use for cooking, boiling, bathing, etc.

The United States, the world’s largest producer of geothermal electricity, generates an average of 15 billion kilowatt hours of power per year, comparable to burning close to 25 million barrels of oil or 6 million short tons of coal per year (Kagel et al., 2007).

On the other hand, hot springs could also be seen as a menace in an ecosystem, serving as natural sources of environmental pollution. Craw and Chappell (2007) indicate that hot spring systems deposit high concentrations of metals (including gold) at and near the surface of the Earth. These metal deposits can become significant point sources for heavy metal pollution of streams (e.g. arsenic, mercury, cadmium, zinc, lead). Mining, e.g., for gold, can accelerate the release of these metals by exposing (e.g. in tailings or mine walls) large amounts of metallic minerals to atmospheric oxygen, causing rapid decay. High metal contents in streams can be toxic to plant and animal life, including humans. Sabadell and Axtmann (1975) discuss the potential for contamination of the environment by heavy metals from geothermal sources.

This study is about the current status of heavy metals in some lakes and water bodies in the Ethiopian Rift Valley and the potential of contamination of soils in the vicinity.

2 Materials and Methods

2.1 The Ethiopian Rift Valley

The climate of the Ethiopian Rift Valley is diverse and ranges from hot and arid to cool (subtropical) and humid. In general most of the Ethiopian Rift Valley is similar to the semiarid and sub-humid regions of East Africa with its bimodal rainfall. There is also an area in the north of the valley with a climate similar to that of the Sahel region of West Africa (Smith, 1984).

The soils of the Rift Valley are largely derived from recent volcanic rocks and, by comparison with many areas of Africa, their base status is generally good. Constraints to production include low phosphorus levels, micronutrient imbalances and in some cases poor physical structure. The areas with soils most similar to those of the Rift Valley of Ethiopia are the equivalent rifts in Kenya, Tanzania and Zambia.

Thirteen major units and a further six subunits in the FAO/UNESCO soil classification are of importance in the Rift Valley (Smith, 1984). The most important groupings in terms of total area covered are thus: Vertisols (19.2%), Cambisols (17.9%), Fluvisols (16.2%), Regosols (15.8%), Lithosols (9.5%), Andosols (7.1%) and Acrisols (6.1%). All remaining soil units taken together account for less than 10% of the total area.

2.2 The Study Sites

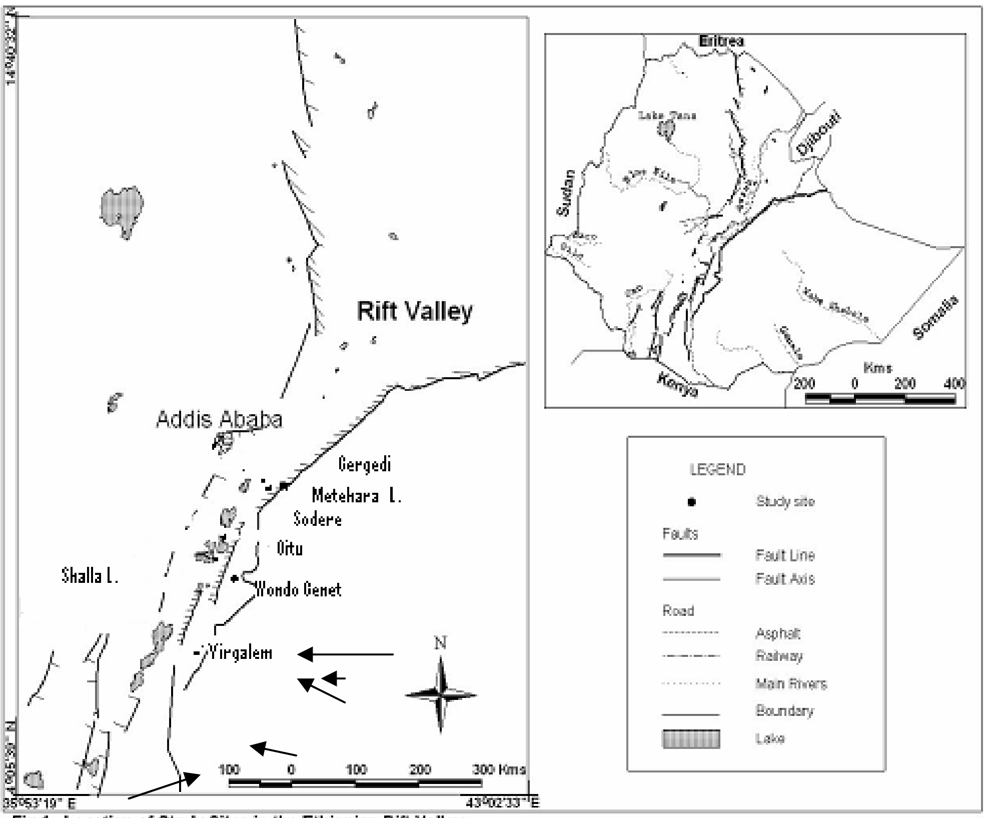

Fig.1. Location of Study Sites in the Ethiopian Rift Valley

2.3 Water samples

As far as possible, water samples were taken from the headwaters as they come out of the hot springs. Extreme caution was exercised not to mix the water with the nearby soils. Triplicate samples were collected from 7 hot springs and one volcanic lake (Metahara Lake). About 5 ml of conc. HNO_3 acid was added in clean polyethylene bottles (ca 250 ml) and stored in a fridge before shipment to Germany for analysis.

The samples were collected from Oitu hot spring on an open field between Zway and Langano, Shalla hot spring (near Lake Shalla), Wondo Genet hot springs (from mountainside near swimming pool at Wondo Genet), hot springs at Sodere (near Sodere resort hotel), at Metehara, Gergedi hot springs near Wonji Shoa, from Yirgalem hot springs (near Yirgalem Tebel) and from the Addis Ababa Filwuha site near the palace.

2.4 Metal analysis

Different chemical analyses were conducted on water samples collected from Ethiopia, at the Institute of Agricultural Chemistry of the University of Hohenheim. The concentration of metals in extraction solutions and aqua regia digestions were determined by ICP-OES (Inductively coupled plasma- optical emission spectrometry, EN ISO 11885) or ICP-MS (Inductively coupled plasma mass spectrometry, DIN 38406-29) depending on the concentration of the elements in the solutions. Accordingly, Al, Ba, Be, Cd, Co, Cr, Ni, Pb, Rb, Sr, Ti, U, and Vanadium were determined by ICP-MS.

Mercury was determined by CV-AAS (cold vapour atomic emission spectrometry, DIN EN 1483). Arsenic was determined by HG-AAS (Graphite Furnace fitted to Atomic Absorption Spectrometer).

3 Results and Discussion

3.1 Arsenic

According to US EPA (2006a) guidelines for national primary drinking water standards, except in Wondo Genet springs, As in all other hot springs and Lake Metehara exceeds the maximum contaminant level (MCL) in drinking water and hence water from these springs and lake is unsafe for drinking. While Gergedi and Yirgalem springs have slightly higher arsenic than the MCL, all the rest of the springs and Lake Metahra contain 5 to 8 times as high arsenic as the MCL.

The prevalence of arsenic (As) above the MCL will have several health effects such as skin damage or problems with circulatory systems, and may have increased risk of getting cancer too (US EPA, 2006a). Erosion of natural deposits; runoff from orchards, runoff from glass and electronics production wastes are the common sources of this contaminant in drinking water. The public health goal is to bring down As concentration in drinking water to 0.

As far as other uses derived from the water are concerned, all the hot springs and Lake Metehara consist much lower concentrations of arsenic than the Criterion for the Maximum Concentration (CMC) based on US EPA (2006b) limits for water quality of priority toxic pollutants.

Table 1. Concentrations (µg/l) of some priority toxic metals in some Ethiopian Rift Valley hot springs and Lake Metehara

Site	Priority toxic metals						
	As	Cd	Cr	Cu	Hg	Pb	Zn
AA	56±0.58	0.13±0.03	7.6±2.53	1.2±0.41	< 0.1	1.8±0.68	11.1±2.48
Gergedi	13±0.00	0.15±0.04	6.5±3.02	1.1±0.35	< 0.1	2.3±0.83	25.5±3.82
Metehara	84.7±0.33	0.67±0.06	16±5.54	9.5±0.59	0.1±0.0	2.6±0.31	32.2±2.14
Oitu	65.3±6.74	< 0.1	0.9±0.11	2.03±0.75	< 0.1	0.2±0.00	5.4±2.43
Shalla	16.7±1.76	0.15+0.02	1.2±0.16	1.8±0.25	< 0.1	0.5±0.17	8.3±2.56
Sodere	59.3±0.33	0.19±0.02	12.4±2.2	2.0±0.08	0.1±0.0	0.9±2.0	18.2±3.65
Wondo Genet	4.9±0.4	< 0.1	2.6±0.44	0.2±0.10	< 0.1	2.2±1.50	2.3±0.28
Yirgalem	49.3±0.33	0.29±0.05	19.3±5.44	3.7±0.60	< 0.1	12.8±1.38	35.9±2.34

3.2 Cadmium

Based on Cd concentrations in all of the hot springs and Metehara Lake, the water could be used safely for drinking, livestock watering, irrigation and recreational purposes. However, except Oitu and Wondo Genet springs all the rest have Cd more than ten times higher than concentrations deemed maximum for aquatic life. Highest Cd is recorded for Metehara followed by Yirgalem.

3.3 Chromium

According to US EPA’s (2006a), national primary drinking water standards, Cr in all hot springs and Lake Metehara is in trace concentrations and hence from the standpoint of Cr concentrations, the water from all these sources is potable. When chromium exceeds the MCL in drinking water it could cause allergic dermatitis and other health problems. Common sources of Cr contamination in drinking water are discharges from steel and pulp mills and erosion of natural deposits (US EPA, 2006a).

Considering use of water for different other purposes, the chromium in the water from all hot springs and Lake Metehara is generally below the criterion for maximum concentration (CMC) and criterion continuous concentration (CCC) both for freshwater and saltwater (US EPA, 2006b). Hence, the water from the hot springs and Lake Metehara is safe for other uses such as irrigation, wildlife, recreation, etc.

3.4 Copper

Similar to Cd, Cu in the hot springs and Lake Metehara could be regarded as trace and hence water from the hot springs could safely be used for drinking, wildlife, livestock watering, irrigation and recreational purposes. However, Cu in Metehara and Gergedi could be unsafe for aquatic life especially if the hardness is equal to 50 mg/L.

3.5 Lead

Except Yirgalem spring, the Pb from the other water sources is generally low and hence water from the other hotsprings could safely be used for drinking, food processing, aquatic life, livestock watering, irrigation, and wildlife, from the standpoint of the current Pb level. Yirgalem springs may not be suitable for drinking, recreation and food processing purposes, since the Pb level slightly exceeds the maximum recommended levels.

Many, especially sick people, from Yirgalem city and beyond come for healing from the springs and take along the water to drink for healing. The results of metal analyses however reveal that such an exercise could be risky from the standpoint of Pb level.

3.6 Mercury

Mercury is found in trace concentrations in almost all of the hot springs. The water from all hot springs and Lake Metehara is hence safe for drinking, food processing, aquatic life, wildlife, livestock watering, irrigation and recreational purposes. Hg in Sodere and Yirgalem springs and in Lake Metehara is just equal to the maximum concentration allowed for aquatic life.

3.7 Zinc

The water from all hot springs and Metehara Lake is safe for drinking, livestock watering, irrigation and recreation, as far as the Zn level in the water is concerned. On the other hand, it may not be safe for aquatic life, especially the hardness exceeds 100 mg/L. Below a hardness of 100 mg/L, it may be safe for aquatic life only from water sources from Oitu, Shalla, Wondo Genet, and AA Filwuha hot springs.

4 Conclusions and recommendation

Apparently the current status of toxic metals in the Ethiopian Rift Valley hotsprings does not seem to pose great risk for agricultural and livestock use and for recreational purposes as well. Drinking of the water from the hot-springs is certainly unsafe from the standpoint of high As levels. Unfortunately many of the patients who come for healing purposes drink the water from hotsprings. Cd, Cu and Zn may affect the life of fish and some aquatic life. This may be the reason why there is no much catch of fish at Shalla and Metehara Lakes. Most of the hotsprings however flow on lands and hence the threat is not high. Regular monitoring and evaluation of the water from the hotsprings is recommended to observe the effect on life.

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Multiple water uses in Aguas Claras pit lake, Brazil

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Abstract. The paper deals with the current filling of Lake Aguas Claras, which is located near the city of Belo Horizonte, Brazil, in the geological region known as Iron Quadrangle. The water used for the filling of the lake comes from rain, ground water and the complementary pumpage from a close river. An extensive monitoring program (monthly samples) has been carried out since 2001. The results show a very good water quality, practically free from contaminants. Due to this favourable characteristic the possible uses of the lake will be directed to recreation (swimming, diving, sailing, fishing), amenity value and water supply.

1 Introduction

Aguas Claras mine is located south of the city of Belo Horizonte, capital of the State of Minas Gerais, Brazil in the geological region known as Iron Quadrangle (Figure 1). The mining activity started in 1973 and since that time about 300 million tones of high-grade iron ore have been extracted. The average annual production was around 12 million tones. Since the original rock is hematite, which is free from sulphur content, there are no problems related with acidic drainage. Dewatering of this mine started in 1981 by gravity and, in 1988 several wells started to operate. The water table reached the maximum depth of 275 m below its original position. After the depletion of the mine (in the year 2001), the pit was flooded, generating a deep lake which is still in the stage of formation. This will be the first large pit to be flooded in Brazil. In 1981 the water level of the Águas Claras mine reached the altitude of 1,165 meters. From that date up till 1990, the drainage was done by open channels, while the mine was in flank. The hydrogeological studies to project the dewatering started in 1986 and recommended the previous dewatering through tubular deep wells. The drilling of the wells started in 1988 and, since that time up till 1999, a group of wells have been operating with a total average outflow of 73 l/s.

Aguas Claras pit lake will have a final area of 0.7 km^2 and the impressive depth of 234 m, which will make it the deepest lentic system in the country. The water used for filling up the lake comes from rain, ground water and the supplementary pumpage of river water from the vicinity of the lake. Rainy season lasts from October to March, while the dry period extends from April to September. The fact of being located in the tropical region of our planet causes an acceleration of all metabolic processes in the warm waters of the lake. This enhanced dynamics is one of the most relevant features of tropical environments. Consequently changes in the water quality don't follow regularly an annual pattern and daily variations can be often more significant.

Open pit mining creates a new type of aquatic habitat, which is formed by force flooding or natural filling of the pit when it is mined out. Pit lakes are generally narrow and deep, enclosed by steep rock walls and usually without a littoral zone. Their morphological features, with a marked meromitic (only partial circulations) character, restrict the hydrobiological growth and the biodiversity in these habitats. Most of the technical papers related to the ecology of pit lakes deals with the formation of acidic environments (Klapper and Schultze 1995; Miller et. al. 1996; Levy et. al. 1997; Geller et. al. 1998; Stevens and Lawrence 1998; Packroff, 2000; Lessmann et. al. 2000; Kalin et. al. 2001; Boland and Padovan 2002; Hindak and Hindáková 2003, España et. al. 2009).

2 Methods

A monthly monitoring programme has been carried out since the beginning of the lake formation (August/2001).The most relevant physical, chemical and biological indicators for the evaluation of the water quality have been continuously analyzed. All employed analytical methods are based on the recommendations of the *Standard Methods for the Examination of Water and Wastewater* (APHA 1998).Due to the small surface of the lake, there is just one sampling point, which is located in the central part of the water body, corresponding to its maximum depth. Samples have been taken at the surface (Secchi depth) and at the bottom of the lake.

3 Results and discussion

A summary of the evolution of the most relevant water quality parameters is presented below:

Water temperature (Fig. 1): seasonal distribution, according to the local climatology: winter time (May-September), summer time (October-April); the lake presents a monomitic pattern, with only one period of circulation (June-August). In the rest of the year the lake remains stratified.

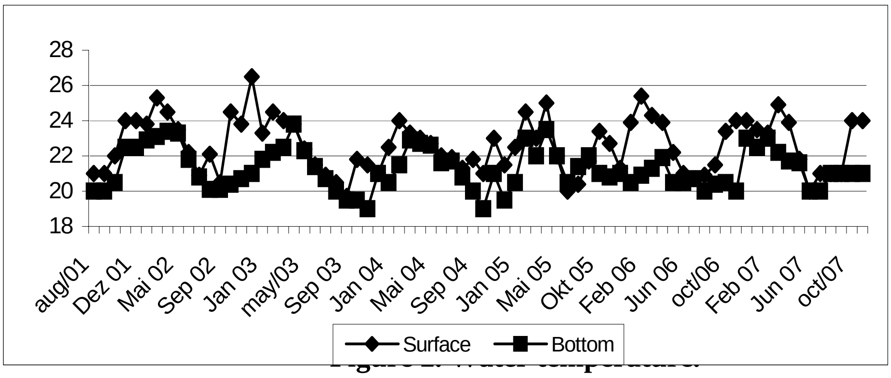

Fig.1. Water temperature

Dissolved oxygen (Fig. 2) There is an influence of the temperature in the rate of atmospheric oxygen transfer to the water, with higher values being obtained in colder months. Algae photosynthetic activity increases DO concentrations in the upper layers, with occasional records of supersaturation .

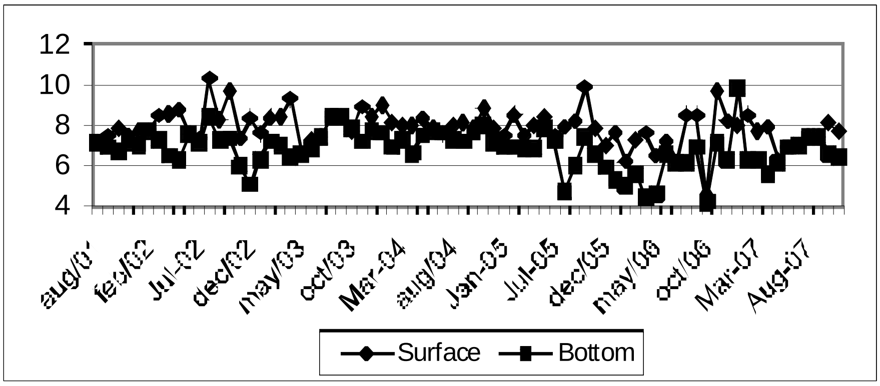

Fig. 2. Dissolved oxygen.

Hardness: values between 33 mg/L and 55 mg/L; low to moderate hardness; ***Turbidity:*** clear seasonal variations (increase in the rainy period); 84 % of the recorded values are under 10 NTU, indicating the prevalence of very clear waters; ***Colour:*** very low values, most of them under 1 mg/L; ***pH:*** ranges from 6.4 to 9.6 (Fig. 3), with higher values at the surface of the lake (primary prodution, CO_2 absorption) in comparison with the bottom (decomposition of organic matter, CO_2 release).

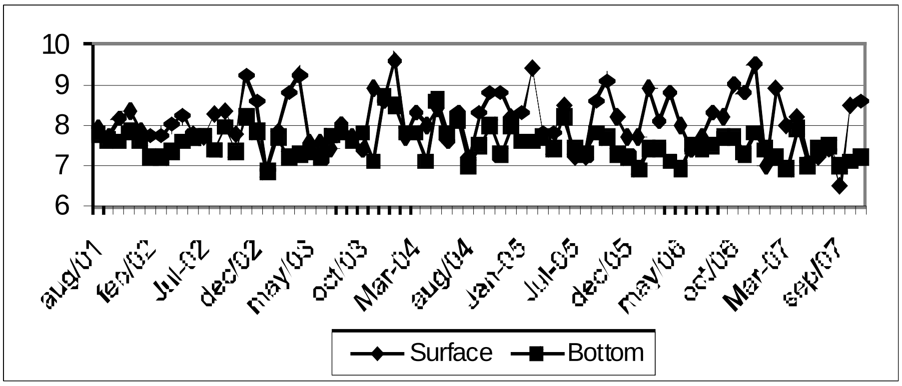

Fig. 3. pH.

Secchi depth (Fig. 4)*:* between 0.5 m and 6.5 m, with higher values registered at the winter time; an increasing trend can be observed.

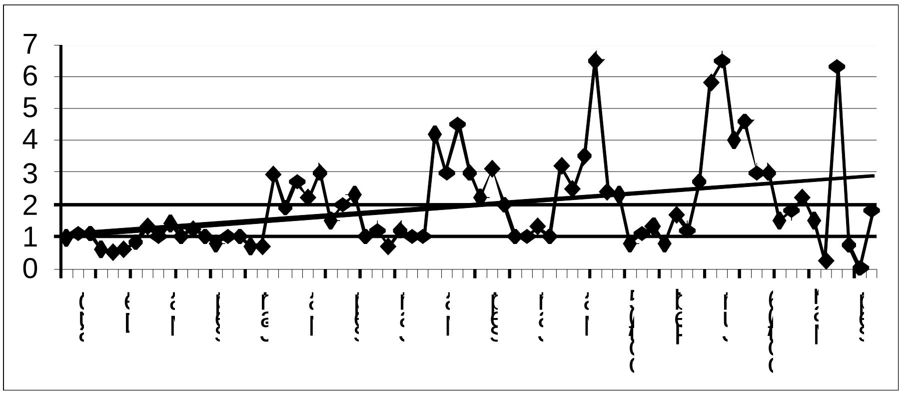

Fig. 4. Secchi depth.

Nutrients: almost all values of soluble phosphorus are below 0.01 mg/L, with a maximum concentration of 0.02 mg/L. In a future scenario this soluble fraction will probably predominate at the bottom of the lake as consequence of internal fertilization process. Ammonium nitrogen shows values between < 0.05 mg/L and 0.9 mg/L, while for nitrate nitrogen the concentrations range from < 0.01 mg/L to 1.3 mg/L; these results are consistent with the good oxygenation conditions in the lake. There is a trend in decreasing TN/TP values as the lake is being filled, indicating a possible nitrogen limitation in the future; ***Electric conductivity:*** Values range from 55 µS/cm (surface) to 113 µS/cm (surface); since May/04 they are situated in the narrow range of 70-80 µS/cm, indicating that a stability in the amount of dissolved salts has been reached; ***BOD:*** Around 96 % of the concentrations are under 2 mg/L, with the maximum value of 5.8 mg/L; these results point out to a virtual absence of organic contamination, ***Fe and Mn:*** Iron concentrations range from < 0.05 mg/L (surface) to 1.73 mg/L (bottom). These values are typical for drainage basins with high iron contents from geochemical origin, as is the case of Lake Aguas Claras; manganese concentrations range between < 0.05 mg/L and 0.17 mg/L (at the bottom); ***Chloride:*** constant low values, from < 0.25 mg/L to 1.7 mg/L; ***Heavy metals*** *(Al, As, Cd, Cr, Cu, Hg, Pb) and other pollutants (phenols, oil and grease, cyanide):* virtually absent, only aluminium has been occasionally detected (0.12 to 0.22 mg/L)

Bacteriology: very good bacteriological quality; about 90 % of the results of faecal coliforms, *Escherichia coli* and faecal streptococci are lower than 2 MPN/100mL.

Hydrobiology: the most relevant aspect in the hydrobiology of Lake Aguas Claras is the frequent shift in algae dominance (Fig. 5). In a first phase (some few months after the beginning of the filling) there was the dominance of *Chlorophyta* and *Cyanophyta*; in a second moment (period of about 4 years): dominance of *Chrysophyta* and *Pyrrophyta*; in a third phase (2006) a short period of *Cyanophyta* dominance, followed by the current prevalence of *Chlorophyta* and *Chrysophyta*. It should be stressed that blue-green algae are a serious concern in Brazilian lentic waters, since the first worldwide registers of human deaths due to ingestion of cyanotoxins happened in 1996 in the city of Caruaru, Brazil (Azevedo et. al. 1996). These frequent alternations in the algae dominance are typical of aquatic systems that are undergoing a process of formation, such as mining lakes. Due to an enhanced nutrient concentration in the dry season there is a trend in obtaining higher algal densities in the winter time (May to August) and in the period following the end of the rainy season. This pattern is a common feature in many Brazilian lentic systems (Esteves 1998; Pinto-Coelho et. al. 2003), possibly as a consequence of the onset of favourable limnological conditions (decrease in turbidity, weaker winds) after the end of the wet period.

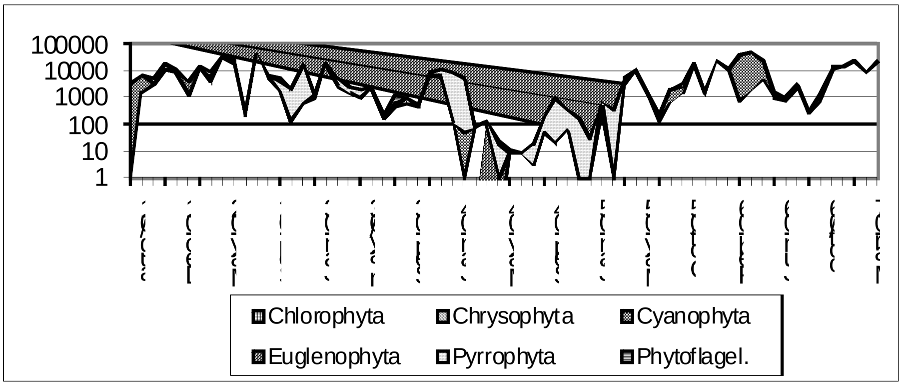

Fig. 5. Phytoplankton.

A clear alternation in the dominance of Rotifera and Crustacea can be observed In the composition of the zooplankton community . The occurrence of frequent density variations can be probably associated to the natural instability of the new aquatic system. Peaks in the zooplankton population have been observed in the dry period (winter time), which could be caused by enhanced salinity due to evaporation. Researches in Brazilian lakes have shown an increase in zooplankton abundance in the rainy season (Sendacz 1984), while some authors present rain as a lost factor for the zooplankton (Campbell et. al. 1998). A well established correlation between rotifers and algae can also be observed (Fig. 6), confirming the pattern which is extensively found in temperated lakes (Kalff 2002).

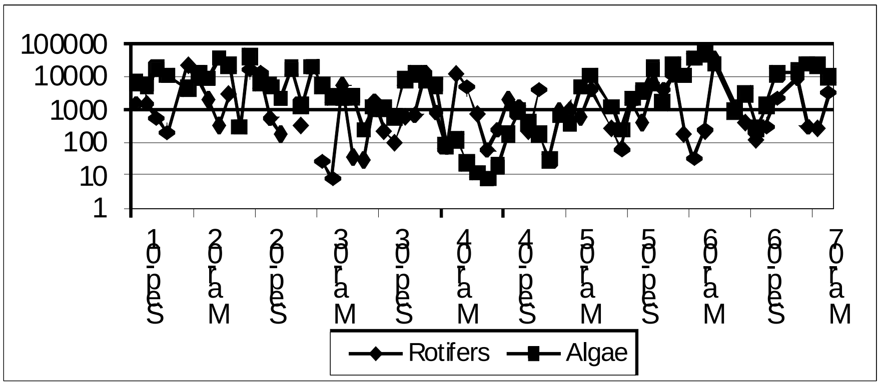

Fig. 6. Rotifers x Algae.

4 Conclusions

The evaluation of a long term monthly monitoring programme in Lake Águas Claras shows that the lake presents a very good water quality (well oxygenated, low values of colour and turbidity, limited degree of mineralization, pH slightly alkaline, low nutrient concentrations, excellent bacteriological conditions), together with a marked shift in the dominance of phytoplanktonic groups, indicating the high instability of lakes that are undergoing a process of formation. The possible uses of the lake will be directed to recreation (swimming, diving, sailing, fishing), amenity value and water supply. This late use is favoured by the high altitude of the pit lake, which allows water transport by gravity till the city of Belo Horizonte. Moreover the definition of multiple water uses in Aguas Claras lake could be used as a pioneer example for other Brazilian pit lakes originated from iron mining activities.

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