# AN EVALUATION OF THE WATER QUALITY AND TOXICITY OF WASTEWATER AT SELECTED CAR WASH FACILITIES IN TSHWANE, GAUTENG

by

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# DECLARATION

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Exact wording of the title of the dissertation or thesis as appearing on the copies submitted for examination:

**An Evaluation of the water quality and toxicity of wastewater at selected carwash facilities in Tshwane, Gauteng.**

I declare that the above dissertation/thesis is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

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## DEDICATION

I dedicate my dissertation to my husband and best friend Malusi Phungula and my only son Olwethu Phungula. The love and encouragement you gave me through my studies meant everything to me.

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## ABSTRACT

Car washing consumes large quantities of water and results in large amounts of wastewater effluent being generated, but has received little attention as a potential source of water pollution globally. The study investigated the water use, wastewater effluent quality and toxicity of selected carwashes in City of Tshwane. Ten carwashes in the City of Tshwane were purposively selected and analysis done on a variety of water quality aspects including microbiological, toxicity, BOD,COD, oil and grease, anionic surfactants, sulphates, phosphates and heavy metals. The results obtained show that oil and grease exceeded the WHO and National Water Act standards of 2.5mg/L in all sites except CW2 and Diesel range organics were significantly high in some sites (CW4, 7 & 8) at 60.5, 40 and 48.8mg/L. COD and BOD of the waste water exceeded the WHO standards of 30mg/L and 60mg/L in all sites except CW2. Bacteria contamination was very high in all wastewater samples and all samples exhibited (mild to high) toxicity to *Vibrio fischeri* and high toxicity to *Daphnia pulex* except CW2. These results suggest that wastewater from carwashes is high in some pollutants that may interfere with the receiving environment and municipal treatment systems and there is a need for responsible authorities to regulate the quality of effluent discharged into the environment.



**Keywords**

Wastewater, carwash, toxicity, impact, environment, pollution, water quality, vehicle

**Contents**

## List of figures

## List of tables

## CHAPTER 1: INTRODUCTION

### 1.1 Background

Water is very scarce but an important commodity in many countries worldwide. The major problems nowadays are severe water contamination and insufficient water resources (Enoh & Christopher, 2015). South Africa is the 30th driest country in the world with an average annual rainfall of 495mm as compared with the world's average of 1033mm of rainfall. South Africa is said to be a water scarce country, with evaporation losses at three times more than rainfall, therefore great attention must be paid to the efficient management and use of water (Hedden & Cilliers, 2014).

Despite the scarcity of this valuable natural resource, they are polluted everyday due to improper effluent treatment and disposal of polluted wastewater leading to public and environmental concerns. This pollution caused by environmental degradation has now become an alarming problem as a result of rapid and unplanned urbanization, high population growth and unskilled utilisation of water resources (Singh & Singh, 2006 and Enoh & Christopher, 2015).

Water has been under—valued worldwide and many of the shortages of water emerging around the world are due to failures to value water and the illusion created that water is plentiful (Al-Odwani *et al.,* 2007). It is predicted that in countries in Northern and Southern Africa water availability will decline, impacting on freshwater ecosystems. Twenty five countries are expected to experience water scarcity or water stress over the next 20-30 years (Alemayehu *et al.,* 2012).

In urban areas, the continuous population growth demands that public services such as transportation increase and that includes public and private cars, buses and trucks. As a result of increased number of vehicles carwash facilities also increases (Rubi-Juarez *et al*., 2015). Car washing is one of the activities that consume large quantities of water, and results in large amounts of wastewater generated by the car wash facilities containing highly hazardous pollutants, but it has received very scant attention as a potential source of water pollution globally as compared to other high profile environmental threats, such as global warming.

Vehicles often need to be washed to remove dust, and to keep them in a good condition and also to expand their lifespan (Al-Odwani *et al.,* 2007; Yasin *et al.,* 2012). People in the past used to wash their cars by hand in their backyards of their homes or at any convenient place to them. In the present days there are designated areas called carwashes with new technologies to carry out this task of car washing, however whether the car is washed in the backyard or in a designated area, the water used to wash the car gets polluted from different pollutants such as car wash chemicals and traffic pollutants such as traffic grime, grease, dust, oil and metal particles (Janik & Kupiec, 2007).

Nadzira *et al.,* (2015), defines a car wash as a "non-domestic installation for external cleaning of cars, offering consumers a practical way to wash dirt from their automobiles". The world's first car wash was opened in 1914 in Detroit in the United States and was called "The automated laundry". The first automatic conveyer car-washing was developed twenty five years later in Hollywood, California (Al-Odwini *et al*., 2007). The car washing process involves:

i. Applying degreasing agent on surface to absorb all dirt and grit that has accumulated on the vehicle.

ii. Addition of acid and alkaline cleaners to solubilise the dirt.

iii. Final coating to add gloss and protect the vehicle against any abrasion (Kiran *et al*., 2015).

According to Brown, (2002b) and Koeller & Brown, (2006) a professional car wash process includes the following steps:

i. Pre-soak – vehicle is sprayed with water using a hand spray or an automated nozzle.

ii. Wash – washed with a detergent solution using a cloth material or a high pressure spray.

iii. First rinse – rinsed with water using a high pressure.

iv. Wax /sealer/ polishes – surface finish sprayed on the vehicle as an option

v. Final rinse – rinsed with fresh or membrane filtered or deionised water using low pressure.

vi. Air blowers – air is blown on the vehicle to assist in drying process.

vii. Hand drying - vehicles wiped with chamois cloths or towels.

Car washes can be divided into many different types depending on how it is constructed and their washing technologies. The most popular type of car wash found in Tshwane is the conveyor car washes, where the interior and exterior of the vehicle can be cleaned (Figure. 2). The vehicles moves in a conveyor belt inside the wash bay and either friction (brushes or curtains) or frictionless (pressure nozzles or touch-less wash) washes are used. Another popular type of car wash is the hybrid car wash which is the combination of high pressure washing and brush or soft cloth washing (Figure. 3) (Janik & Kupiec, 2007).

Possible water cycle in car wash facilities includes the usage of freshwater to wash the cars and the wastewater either discharged to the municipal sewer or if improperly managed flows to the storm drainage. In some facilities the wastewater is treated and reused to wash the cars (figure. 1)

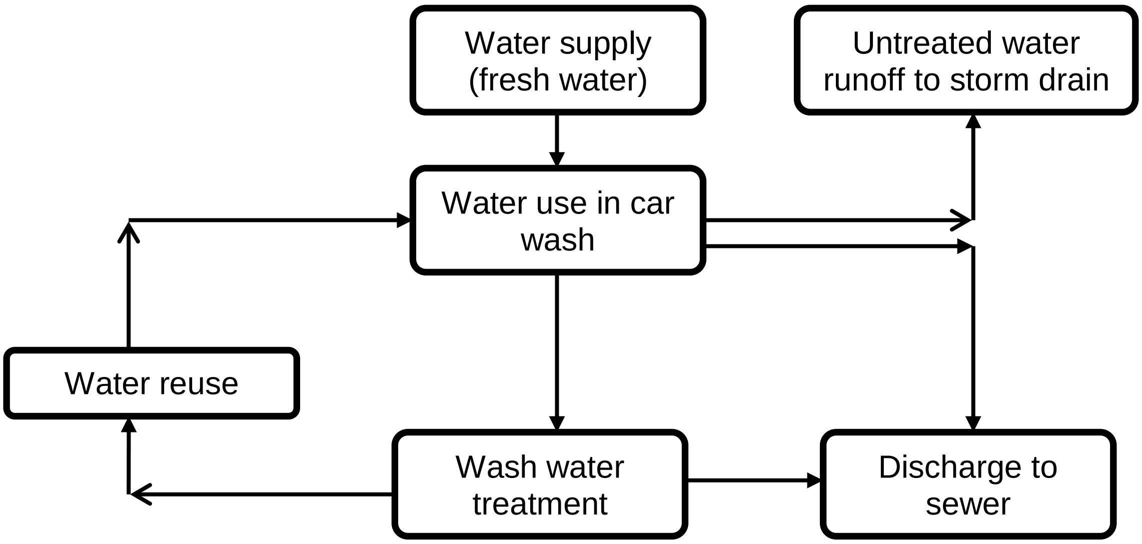



**Figure 1: Possible water cycles in a car wash (Janik & Kupiec, 2007)**


**Figure 2: Conveyor car wash (by author)**

**Figure 3: High pressure wash (The Times, 2015)**

Society is often very slow in realising that their individual behaviour and practices may have detrimental impacts on the environment especially the natural aquatic resources, and one of these practices is car washing (Smith & Shilley, 2009). The public generally does not see that car wash waste water can extremely contaminate the environment as other industrial waste waters (Lau *et al.,* 2012), but car washing does severely impact the environment because many chemical pollutants and particles can be found in carwash wastewater, such as heavy metals, salts, oil and grease, organic matter, sand and microorganisms (Oknich, 2002; Lau *et al.,* 2012). What is important from an environmental perspective is the carwash waste drainage, that is, where exactly does the waste water go to and how that water impacts upon where it is discharged. It is important that commercial car washes contain and pre-treat their wash waters to prevent it from entering the storm drain systems and end up contaminating water resources such as lakes, rivers and oceans.

In some instances car washing is carried out directly in the rivers or alongside river banks, and in some countries such as in Zimbabwe, mushrooming of illegal car washes has become a problem and is posing serious threats to the Harare water resources, and health hazards to the residents because the pollution ends up in the city's drinking water resources (Mbanje, 2014). In Ghana washing of vehicles on the river banks seems to be a common practice and is a problem because these activities of car washing near river banks can pose a health risk to the communities and also downstream (Aikins & Boakye, 2015).

With rapid urbanisation and industrial growth in South Africa, the number of small sized industries is growing very fast, and this implies that industrial waste is also increasing and this creates a problem because proper disposal of these pollutants is limited (Mohamed *et al*., 2008). Scarcity of water can be handled if proper planning is done regarding wastewater management and treatment, reuse and discharge in water resources. In developed countries they are very conscious of the needs for recycling, whereas developing countries such as South Africa are still behind in developing that conscious for the wastewater produced in car wash industries (Bhatti *et al*., 2011).

### 1.2 Problem statement

Water is a crucial resource and with the population increasing and the climate changing, the shortage of freshwater resources worldwide will become more critical (Ghadouani & Coggins, 2011). Cleaning of a car is basically removing of oil and dirt and then treating the car to provide protection, and car wash facilities offer an easy way for consumers to clean their cars. Degreasing agents and cleaning agents are used to remove these traffic grimes and particulate matter from the cars and also wax polishes are used to protect the cars (Genuino *et al.,* 2012).

Effluent from car washing can be very detrimental to the environment and can flow into the storm water drainage system and enter our surface water resources untreated if not managed properly. It can also contaminate groundwater by infiltrating through the soil (U.S.EPA, 2001). Carwash effluent pollutants such as dirt, brake dust, oils, greases and cleaning agents used to wash cars can be very harmful to river life and can cause a variety of health effects to humans such as kidney problems, high risk of cancers and circulatory system problems if they are exposed (U.S.EPA, 2001; Lau *et al.,* 2012). The problem becomes even worse in some areas in developing countries that have high population and increased volume of cars, causing a further boost in the car wash industry and generating huge quantities of effluent (Lau *et al.,* 2012).

Gauteng as one of the most industrialised and densely populated Province in South Africa (Tshwane, 2013), has numerous car washes and of different scales of operation releasing large volumes of waste water into the municipal systems. A number of different kinds of car washes are located in Petrol garages, shopping centres, taxi ranks, car dealerships, truck companies, and many informal carwashes located in the townships of Tshwane. According to the National traffic information system (eNaTIS), Gauteng has the highest number of live vehicles in South Africa with 4 532 121 vehicles. Tshwane alone has 1 114 973 live vehicles and an additional 42 375 unlicensed vehicles as of 31 October 2015 (eNaTIS, 2015). These large numbers of vehicles are washed either at car wash facilities or at the homes of the owners, and with such large number of vehicles in Tshwane the number of car washes are also increasing, leading to increased car wash services. The most problematic car washes are the informal car washes found in the townships, taxi ranks and in most street corners in Tshwane central.

Cars washed in streets can pollute water resources such as rivers, streams and estuaries. Pollutants from these cars run off into gutters and into storm water drainage systems, which is not treated before being discharged into waterways. These pollutants from storm drainage end up in rivers, lakes, oceans and are considered non-point source pollution (Bhatti *et al.,* 2011). This creates a need to evaluate the quality and the toxicity of the carwash wastewater and the impact it could have on the natural resources and environment.

## 1.3 Rationale

The existence of an increased number of car wash facilities worldwide exerts an increased demand on the amount of water used and wastewater discharged from the car washes, which in turn increases the amount of pollution that goes into the environment. Wastewaters from car washing often find their way into the drainage systems at home and in carwashes. In some areas often people wash their cars in the river banks, but there have been very limited scientific studies in South Africa focusing on carwash wastewaters and the potential impacts these may have on the quality of water resources and the aquatic flora and fauna. As a result the public has no information on the amount of pollution that washing their cars can result in, and the impact it has on the environment. The present study represents a first contribution to the study of the water quality and toxicity of wastewater in the car wash industry in City of Tshwane. The study is expected to provide new scientific information on the amount of pollution car washing generates in the City of Tshwane and the study can also be used as a source of information to educate the general public on water quality impacts of car washing activities and assist in the reduction of prohibited discharges and reduce resultant pollution of the natural resources. The study is also expected to make significant knowledge contributions, because new knowledge will be generated on carwash water quality and conservation in Gauteng and this will also improve human health and also water quality management.

## 1.4 Aims and Objectives

### 1.4.1 Overall aim

The main focus of the study was to evaluate the quality of the waste water in selected carwash facilities in City of Tshwane, and its potential toxic impacts on the environment.

### 1.4.2 Objectives

* To determine the level of car wash activities and water use at selected carwash facilities in Tshwane.
* To determine the physicochemical wastewater quality from the carwash facilities in selected areas in Tshwane.
* To determine selected microbial characteristics of carwash wastewaters.
* To carry out whole effluent toxicological studies on the car wash waste water using *Vibrio fischeri* and *Daphnia pulex* species.

## 1.5 Limitations to the study

The study had the following limitations:

The number of Carwash facilities that participated in the study was limited. Many facilities were approached by the researcher to participate in the study but declined and only 10 facilities accepted and were part of the study.

The number of samples taken and frequency in each facility was limited due to budgetary constraints for the sample analyses.

## 1.6 Ethical considerations

The study required participation of human respondents, which are the car wash facility managers; therefore ethical considerations in the conduct of research were followed. Among the significant ethical issues that were considered in the research process were consent and confidentiality. Permission to conduct the study and permission to collect water samples were obtained from the carwash facilities through an official letter before the study commenced. Important details of the study including the aim and purpose of the study were explained to participants and they were also advised that they could withdraw from the study at any time. Confidentiality of the participants was ensured by not disclosing their personal information and also by not disclosing the names of their facilities. Informed consent was obtained from each participant.

Project Ethical clearance was obtained by the researcher from University of South Africa, College of Agriculture and Environmental Science (Ref.nr: 2014/CAES/115).

# CHAPTER 2: LITERATURE REVIEW

## 2.1 Carwash activities

There is an increasing public health concern on the quality of water in rivers and streams and this has led to many countries having regulations and constant monitoring to protect their drinking water. In many countries car washes are regulated more and more, in search for a cleaner environment (Genuino *et al.,* 2012). Most of the times these regulations are directed towards the professional car washes, ignoring the driveway or home car washes which in fact use similar products used in commercial car washes and they discharge directly to the storm drain without treatment (Janik & Kupiec, 2007). Some developed countries have been successful in setting up regulations, but in some countries they still lack adequate planning and regulations. In some countries like Germany, Netherlands and Switzerland, citizens are not even allowed to wash their cars at their homes (Janik & Kupiec, 2007). The primary concern of car washing is the contamination of groundwater, surface water and soil (Genuino *et al.,* 2012).

Car washing may include cleaning of privately owned vehicles such as trucks, cars, public vehicles such as buses, fire trucks, and school buses, and also industrial vehicles such as tractors and trucks. This can be done in many different places for example in commercial car wash facilities, where the wash waters are contained before being released or disposed of. These commercial car washes may be located at garages, truck shops and even in car dealerships (U.S.EPA, 2001). Car washing can also be carried out by individuals at home on their lawns, in side yards or in gravelled areas, which all allow for infiltration of the wash water into the soil. It can also be carried out in driveways or streets, where that wash water goes straight to storm water drainage systems (Smith & Shilley, 2009). In some instances where water resources are scarce or the water supply infrastructure poorly developed car washing is carried out directly in rivers or alongside river banks (DWAF, 2003).

Often society does not realise the impact of washing a car has on the environment. One thing that is important is where the wash water is discharged.

Cities often have their own different methods of directing water, depending on the source of the water. For example water from the household such as toilet water, bathtubs, sinks, washing machines and dishwashers are directed to the sanitary sewer system, and this water is treated before it is discharged. Water from drainage points in streets and parking lots for example is directed to the storm water drainage system, which is discharged untreated into rivers, streams and lakes.

## 2.2 Carwash water effluent characteristics

There are different factors that affect the level of contamination in different carwash stations. Figure 4 shows a summary of pollutants that come from car washing. These depend on the cars washed in these facilities, and many environmental factors affect the rate of contaminant deposition on each vehicle washed. These factors include: the distance travelled by the car, the road service the car travelled on, whether the car was parked in a garage, covered area or uncovered parking, and whether it was used during rush hour or weekend, the temperature and rainfall during which the car was used, or if the car was parked under trees or nesting areas (O'Sullivan *et al.,* 2011). Other sources of pollutants in the carwash wastewater include chemicals used for cleaning the cars, traffic pollutants and materials from the cars itself. These pollutants can be very detrimental to the ecosystem if discharged untreated (Genuino *et al.,* 2012).

Considering the potentially huge amount of water used to wash each car and the various chemicals used in the car wash industry, it is very important to treat the effluent properly before discharging it into the environment (Lau *et al*., 2012). The amount and type of pollution that carwash water release to the drainage system or water resource depends on the location and the types of pollutants the car may have been exposed to. Most cars however would at least have sediment and heavy metals on them (Metzler, 2009). A study that was conducted by Oknich, (2002), found that the major contribution of lead, zinc, chromium and cadmium to the waste water treatment plant in Stockholm was from commercial car washes. Another study conducted by Pak & Chang (2000) also found high phosphorus levels chemical oxygen demand and low organic content in commercial car wash waters (Oknich, 2002).

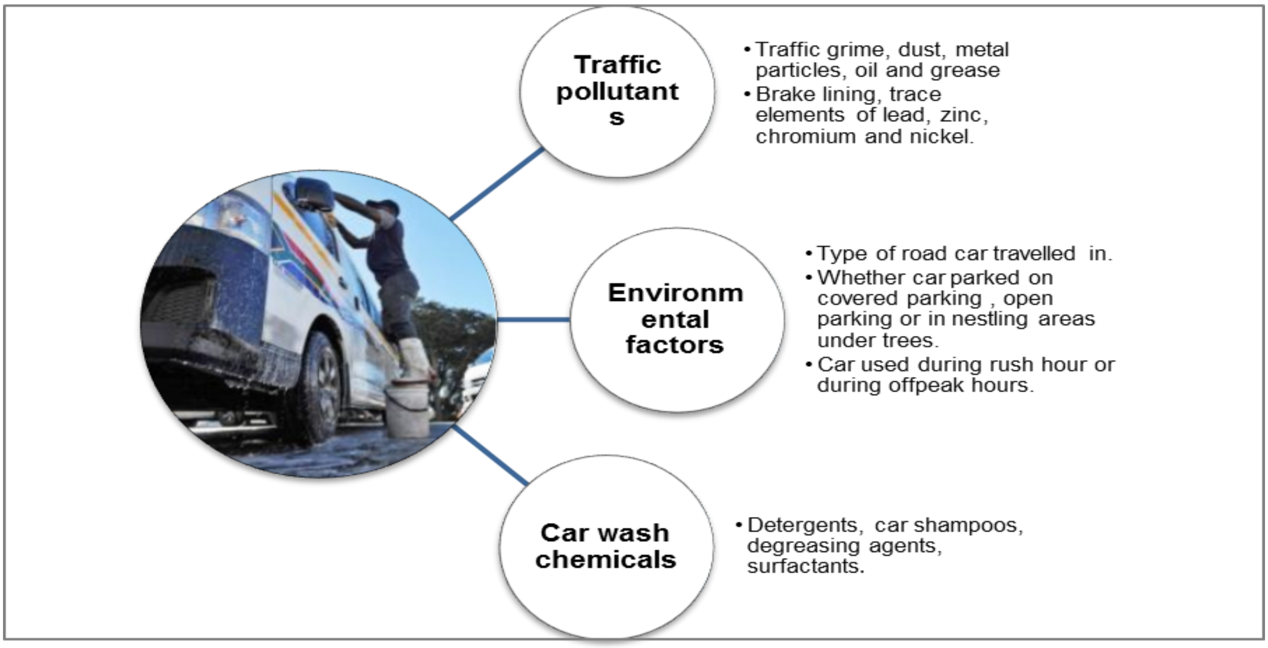



**Figure 4: Summary of pollutants coming from car washing (O'Sullivan *et al.,* 2011; Genuino *et al.,* 2012)**

### 2.3 Toxicity effects of pollutants in the car wash wastewater

Pollution from car wash wastewaters can have a detrimental impact on the environment especially on the aquatic environment. This is because car wash effluent is known to contain traces of heavy metals, detergents containing surfactants, oils and greases and these are sometimes classified as hazardous (Danha *et al*., 2014).

#### 2.3.1 Trace metals

The most common pollutants found in industrial wastewater in high concentrations are heavy metals such as chromium, zinc, copper and cadmium. These heavy metals can threaten human health and damage the aquatic environment (Kashefi *et al*., 2014). Zinc can be found from being washed off from tyres and brakes, while lead can be found in the brake lining and tyres (Oknich, 2002; O'Sullivan *et al.,* 2011). Brake dust is also recognised as a significant contributor of copper, and tyres as sources of calcium, cadmium and zinc. Traffic also plays a major role as it is attributed to the high levels of chromium, lead, copper and zinc. Chromium and lead are mainly from the yellow road line markings during heavy traffic road dust (Genuino *et al.,* 2012). According to Abagale *et al.,* (2013), chromium is a common metal surface coating, so its presence in carwash waste can be attributed to washing of chromium coated parts of the cars like car bumpers and wheels, and also sources of lead can be attributed to car engine washing, lead paints and car batteries. Manganese on the other hand is used in steel production along with cast iron to improve strength, stiffness and hardness. Manganese can be released when iron parts of the cars are washed and when the car engine blocks are washed thoroughly higher levels of manganese can be released (Abagale *et al*., 2013).

Zinc is essential to humans and plants, but can be harmful to the body in very high concentrations (Abagale *et al.,* 2013). Zinc can inhibit algal photosynthesis and prolonged exposure to sub-lethal concentrations of zinc in Fish causes liver necrosis and oedema (DWAF, 1996).

The toxicity of copper is dependent on the local water quality, it increases when it is present in combination with other metals, and when dissolved oxygen and water hardness decreases. It also decreases when alkalinity increases and in the presence of chelating agents such as amino acids and suspended solids. Copper toxicity also decreases in the presence of zinc, molybdenum, sulphate, calcium or magnesium (DWAF, 1996). Copper can become toxic to the larval stages of marine invertebrates in concentrations above those required as a micronutrient, and also accumulation of copper over a long time in soil can reduce food quality and quantity (Abagale *et al.,* 2013), dissolved copper can also cause harm to salmon in aquatic life and may also be toxic to phytoplankton (Smith & Shilley, 2009). Toxicity effects of copper are seen at concentrations above 140µg/L (Frances, 2009).

Chromium can occur in a number of oxidation states, but the two states that are of biological relevance are trivalent chromium (III) and hexavalent chromium (VI). These two states are very different in terms of their toxicological and environmental properties, and the trivalent chromium is generally less toxic than the hexavalent chromium (Baysal *et al.,* 2013). Chromium exerts a toxic effect at different concentrations in different groups of aquatic organisms.Chromium in its hexavalent form can have a harmful effect on human health (Abagale *et al.,* 2013), and has been shown to have a number of adverse effects on humans such as causing irritations and cancer.  Chromium also has effects on fish by making them more susceptible to infections, and it effects reproduction of the water flea Daphnia (Baysal *et al.,* 2013). At 62ppb chromium inhibits growth in algae and at 16ppb inhibits growth in Chinook salmon. Toxicity of chromium is also dependant on pH, temperature and salinity. As pH and salinity decreases and temperature increases, toxicity of chromium also increases. Additionally chromium is more toxic in soft water then in hard waters (Frances, 2008).

Lead can have harmful effects in humans and aquatic life. In humans it can accumulate in bones and teeth, and although it does not harm the bones and teeth, they are reservoirs for realising the lead into the bloodstream where it travels and reaches the brain. At more than 500ppb lead inhibits enzymes involved in algal photosynthesis (Abagale *et al.,* 2013). At concentrations exceeding 100ppb lead affect gill function in fish (Frances, 2008). Lead also has an effect on the central nervous system, and haemoglobin synthesis, and has been known to cause kidney damage (Baysal *et al.,* 2013) (Kiran *et al.,* 2015).

### 2.3.2 Surfactants and inorganic determinants

Surfactants are from detergents and cleaning agents, they help with removing greases and dirt from the cars. Detergents that are used in cleaning the cars and making the cars exteriors more appealing contain nitrogen and phosphorus and may have an opposite effect on the environment (Oknich, 2002; Smith & Shilley, 2009). Surfactants from the detergents biodegrade very slowly into the environment and lower the oxygenation potential in the water killing water borne organisms (Nadzirah *et al*., 2015). Soaps have the same impacts as detergents and they also cause an increase in the bacterial population. Chemical oxygen demand and organic matter can also be attributed to the detergents being used to wash cars (Oknich, 2002).

Surfactants compounds have high foaming capabilities and low oxygenation potential so they can cause problems in sewage aeration and treatment facilities thus consequently killing waterborne organisms (Shabhazi *et al.,* 2013). Nutrients such as phosphates released from carwash wastewaters promote weed growth toxic algal bloom, which can pose human health concerns (Alede *et al.,* 2011). According to (Oknich, 2002), the pollutants found in the detergents can destroy the mucus membranes and gills of fish in surface water environments, and when the gills are destroyed they lose their natural oils which interrupt oxygen transfers and when mucus membranes are destroyed they leave the fish susceptible to bacteria and parasites. Ammonia in combination with pH and temperature variations can be toxic to fish and other aquatic organisms (Oknich, 2002; Smith & Shilley, 2009).

### 2.3.3 Petroleum hydrocarbon waste: diesel, gasoline, motor oil

According to Alede *et al*., (2011), oil and grease can be defined as a group of related materials extractable by certain solvents, such as hexane. Oil and grease has been regarded as an emerging pollutant of concern in wastewater because of the large amounts of oil pollution in wastewater from a variety of sources (Alede *et al.*, 2011). Wastewaters can be contaminated with oil from different sources such as from restaurants, petrochemical industries, oil refineries, metal processing as well as from car washes (Alede *et al.,* 2011). Gasoline, diesel, fluids, lubricants and motor oil are from engine leaks and fuel combustion processes in car wash wastewater (Oknich, 2002; Smith & Shilley, 2009). These wastewaters then becomes oily and contain toxic substances such as petroleum hydrocarbons, phenols and polyaromatic hydrocarbons which inhibit animal and plant growth and are also mutagenic and carcinogenic to human beings (Smith & Shilley, 2009; Alede *et al*., 2011). Oily wastewater has a high chemical oxygen demand (COD), high oil content and color. Because of the large amounts of oil from the different sources and industries, the world water bodies are becoming increasingly polluted with oily wastewater. The consequences of these effects are irreversible for aquatic living organisms and can affect humans directly or indirectly through the food chain ecosystem (Alede *et al*., 2011).

The presence of oil and grease in water resources:

- Results in oil attaching to leaves and sediments reducing gaseous diffusion in plants.

* Hinders oxygen transfer which leads to decreased amounts of dissolved oxygen (DO) at the bottom of water affecting survival of aquatic life.
* Causes formation of oil layer in water casing significant problems by reducing visibility and light limiting photosynthesis.
* Causes physical blockages in sewers, filter distribution arms, pumps and screens which leads to increased maintenance costs.
* Causes difficulties in sludge pressing and Interferes with aerobic biological wastewater treatment process by reducing oxygen transfer rates.
* Reduces the efficacy of anaerobic treatment process by reducing the transport of soluble substrates to the bacterial biomass.
* Can cause objectionable taste and odor, turbidity and film and can make filtration treatment difficult (Alede *et al*., 2011; Danha *et al*., 2014).

### 2.3.4 Solids

Sediments are the most common pollutants in storm water runoff and make lakes and streams less suitable to fish life, plant growth and recreation. Uncontrolled sediments can clog storm drains which can lead to increased maintenance costs and also flooding problems. Sediments can smother trout and salmon eggs and can destroy insect habitats (Smith & Shilley, 2009). Total suspended solids (TSS) are solid materials suspended in water which include organic and inorganic matter. Total suspended solids can occupy egg laying sites for fish and macro invertebrates therefore reducing the availability of habitat. They can harbor microorganisms which use up oxygen from the water causing an increased biochemical oxygen demand (COD) therefore causing a stressful environment for aquatic life (O'Sullivan *et al.,* 2011). TSS can cause respiratory difficulties in fish and invertebrates by clogging their gills and can increase the turbidity which prevents predator species from seeing their prey (O'Sullivan *et al.,* 2011).

## 2.4 Whole Effluent Toxicity (WET) testing

Whole Effluent Toxicity is the term used to describe the toxic effect of an aqueous solution such as wastewater effluents to a population of aquatic organisms when exposed to the sample. These tests are used to determine the combined effects of the complex effluent, rather than the conventional methods used to determine the toxicity of single chemicals or constituents in a sample (SETAC, 2004).

### 2.4.1 Importance of toxicity testing of wastewaters

Effluent discharge from many different industries are very complex and may contain different components of different quality and quantity, and can be also polluted by toxic or by non-biodegradable organic compounds. The chemicals found in these wastewaters are generally a serious threat to the environment and can cause diseases to aquatic organisms (Cebere *et al.,* 2009).

Toxicity evaluation is a very important parameter in wastewater quality monitoring because it provides a complete response of test organisms to all compounds in wastewater. In some cases the effluent might meet the physico-chemical requirements but it might cause significant negative effects in the receiving waters when considering its toxicity (Bina & Asghari, 2005). Chemical analysis alone is not sufficient to evaluate the toxicity of wastewaters on receiving waters and its potential harmful effects on the aquatic environment, and prediction of toxicity from chemical data is very limited. According to Mendoca *et al.,* (2011), the best way to evaluate the effluent toxicity effects is to use toxicity tests in combination with the routine tests. These tests are called bio toxicity tests, where a variety of types of organisms of different trophic levels are used such as algae, fish, bacteria and other microorganisms (Bina & Asghari 2005; Cebere *et al.,* 2009).

### 2.4.2 Effluent toxicity tests

There are different types of toxicity tests that can be done namely, acute or short term tests where mortality of the test organism is measured and chronic or long term tests which measure toxicity effects over the life time of an organism such as reduced growth and reduced reproduction. The acute toxicity tests that can be done are; screening tests which determine if an effect is likely to be observed and 100% sample concentration is used and a definitive test where different concentrations of samples are used to determine concentration at which a particular endpoint occurs (American Public Health Association *et al.,* 2012). The main advantages in using multiple species to test for toxicity, such as an invertebrate, a fish and an algae in freshwater studies, is that the different organisms represent different trophic levels and functional niches and are therefore unequally sensitive to various toxicants (Naddy *et al*., 2011).

The species that are mostly used in toxicity testing include *Daphnia magna*, *Vibrio fischeri,* algal tests and fish tests. Daphnia are amongst the most common and most widely distributed freshwater plankton. *Daphnia magna Straus* is highly sensitive to toxic substances, multiplies rapidly and has a short generation time. The use of *Daphnia magna* in toxicology has been accepted in many countries to monitor wastewater treatment systems (Tyagi *et al.,* 2007).

The bioluminescence test has been widely used in toxicity testing and is reported as one of the most commonly applied. It is based on a naturally occurring luminescence marine bacterium *Vibrio fischeri* which emits light as a result of the biochemical activities (Cebere *et al.,* 2009).

## 2.5 Regulatory

Under the Water Services Act 108 of 1997, municipalities in South Africa have the responsibility to issue bylaws with effluent limitations and guidelines for a number of different industries. The City of Tshwane metropolitan municipality sanitation bylaws provide guidelines and limitations for industrial effluent discharged into the municipal sewers (Table 1). The guidelines are for all industrial effluent and there are no regulations specific to carwash effluent discharges. The bylaw clearly states that all persons who discharge industrial effluent into the sewer must have written permission from the municipality to discharge the effluent. It also states that industrial effluent that is likely to contain oil, grease, fats and or inorganic solids must be passed through tanks or chambers that intercept and retain grease, oil, fats and solids before it can be discharged into the sewer. The bylaw further states that any facility that generates any liquid or effluent other than potable water must prevent any discharge, leakage or escape of such liquid into the streets, watercourse and storm water drain and that no person may discharge industrial effluent or any other liquid with any of the limits or concentrations of substances in Table 1.

In addition the National Water Act 36 of 1998 ensures that South Africa's water resources are protected and managed in the correct manner. In accordance with the act a government gazette no 9225 was published which contains standards for discharge of wastewater or any effluent resulting from the use of water for industrial purposes into water resources and disposal of any water containing waste into a water resource (South Africa, 1984). In addition the World Health Organisation (WHO) effluent standards will also be used to compare results in this study.

**Table 1: Recommended limits for wastewater effluent discharge for industries**

| Parameter | Tshwane sanitation by-laws | SA National Water Act 36 of 1998: Discharge of wastewater | World Health Organization effluent standards |
|---|---|---|---|
| Faecal coliforms/100mL | n | 1000 | N |
| TSS (mg/L) | n | 25 | 25 |
| NH4 (mg/L) | n | 6 | N |
| Cl (mg/L) | n | n | N |
| Conductivity (mS/m) | <300 | maximum 150 | N |
| Nitrite+Nitrate as N (mg/L) | n | n | N |
| pH (pH units) | 6.0-10 | 5.5 – 9.5 | N |
| SO4 (mg/L) | 1800 | n | N |
| Temperature (ºC) | n | n | N |
| Total alkalinity (mg/L CaCO3) | 2000 | n | N |
| Cd-Diss | 20 | 0.005 | N |
| Cr-Diss | 20 | 0.05 | 0.2 |
| Cu-Diss | 20 | 0.01 | 2.0 |
| Fe-Diss | 20 | 0.3 | 0.3 |
| Mn-Diss | 20 | 0.1 | 0.4 |
| Ni-Diss | 20 | n | N |
| Pb-Diss | 5 | 0.01 | 0.01 |
| Zn-Diss | 20 | 0.1 | 3.0 |
| Oil & Grease mg/L | 2000 | 2.5 | 2.5 |
| BOD | n | n | 30 |
| COD | 5000 | 75 | 60 |
| Surfactants | 500 | n | N |

n = no limit for determinant
(Note: Where there are no limits gazetted by City of Tshwane, national limits prevail)

# CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

## 3.1 Study area

The study was conducted in the City of Tshwane (CoT) municipality located in Gauteng province (Figure 4). In terms of land area, City of Tshwane is the third largest metropolitan in the world after New York in USA and Tokyo in Japan (City of Tshwane, 2013). CoT is also the largest of the three metropolitans in the Gauteng province and it covers an area of 6345 $km^2$. CoT has a population estimated at just above 2.9 million (City of Tshwane, 2013 and SA cities Network, 2014). The City houses a number of head offices of government departments, several big companies and several embassies. City of Tshwane as the capital city automatically becomes one of the major cities where people flock into from various provinces and countries in search of better living conditions and opportunities for work (City of Tshwane, 2013; Mokgatetswa, 2014). The city has ten wastewater treatment plants namely Rooiwal, Klipgat, Sandspruit, Temba, Babelegi, Daspoort, Baviansspoort, Zeekoegat, Sunderland Ridge and Rietgat, where wastewater is treated before it is discharged back into river systems (City of Tshwane, 2013).

### 3.1.1 Geographical and climatic description of the study area

#### 3.1.1.1 Precipitation

The annual average rainfall in the City of Tshwane is about 670mm. City of Tshwane winters are very dry, whilst summers are very wet with lots of rainfall. The rainy season usually begins in October and ceases at the end of April. Isolated thunderstorms and hailstorms associated with damaging winds and floods are very common in City of Tshwane during the warmer months (City of Tshwane and SA cities Network, 2014)

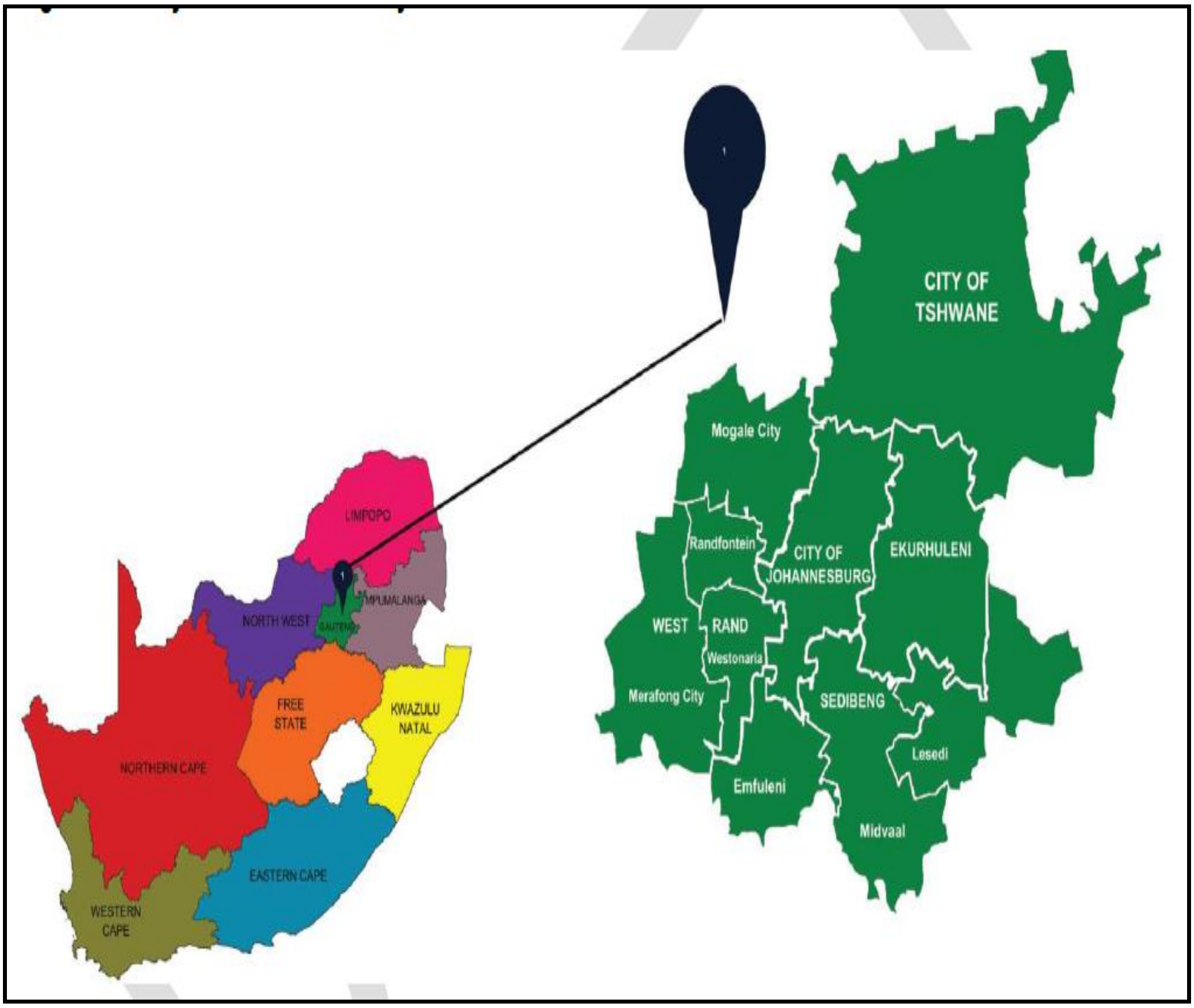



**Figure 5: Location of Tshwane in South Africa (City of Tshwane and SA Cities Network, 2014)**

### 3.1.1.2 Temperature

During the summer periods the average temperatures in City of Tshwane are about 22ºC, whilst the winters are mild with an average temperature of about 12ºC. Occasionally temperatures may drop to below freezing point during winter periods, and frost occasionally occurs in the region (City of Tshwane and SA cities Network, 2014).

## 3.2 Sampling sites

According to Smith *et al.,* (2009) sampling wastewater from individual household driveways or street locations can be difficult and time consuming. Therefore for this study different types of fixed type perennial car wash facilities were used for sampling because they presented a more simplified sampling opportunity and one would expect that the potential pollution source is much greater via this route than domestic car washing. The different car wash facilities in Tshwane were requested for permission to conduct the study and collect water samples.

Given the large number of car washes in Tshwane and the limited resources, it was impossible to sample each and every car wash facility in Tshwane. Ten car wash facilities were selected purposively as sampling sites in Tshwane (Figure 6), based on the accessibility to the researcher and the willingness of the owners and managers to participate, and also due to budget constrains for sampling costs and also sample analysis costs. The type of purposive sampling that was used is convenient sampling, because the researcher selected the car washes that were accessible and easiest to obtain consent from. The car wash facilities were categorised into commercial car wash facilities situated at garages and car washes facilities in high density areas also regarded as informal carwashes (Figures 7 & 8). The sampling facilities were denoted as CW from number 1-10, where CW was the acronym for Car Wash and 1-10 represents the 10 car wash facilities. Table 2 shows a description of each sampling site. In each facility the manager was given a questionnaire to complete. The questionnaire was structured to gain information on car wash activities, chemicals used in facilities, amount of water used and wastewater management related issues.

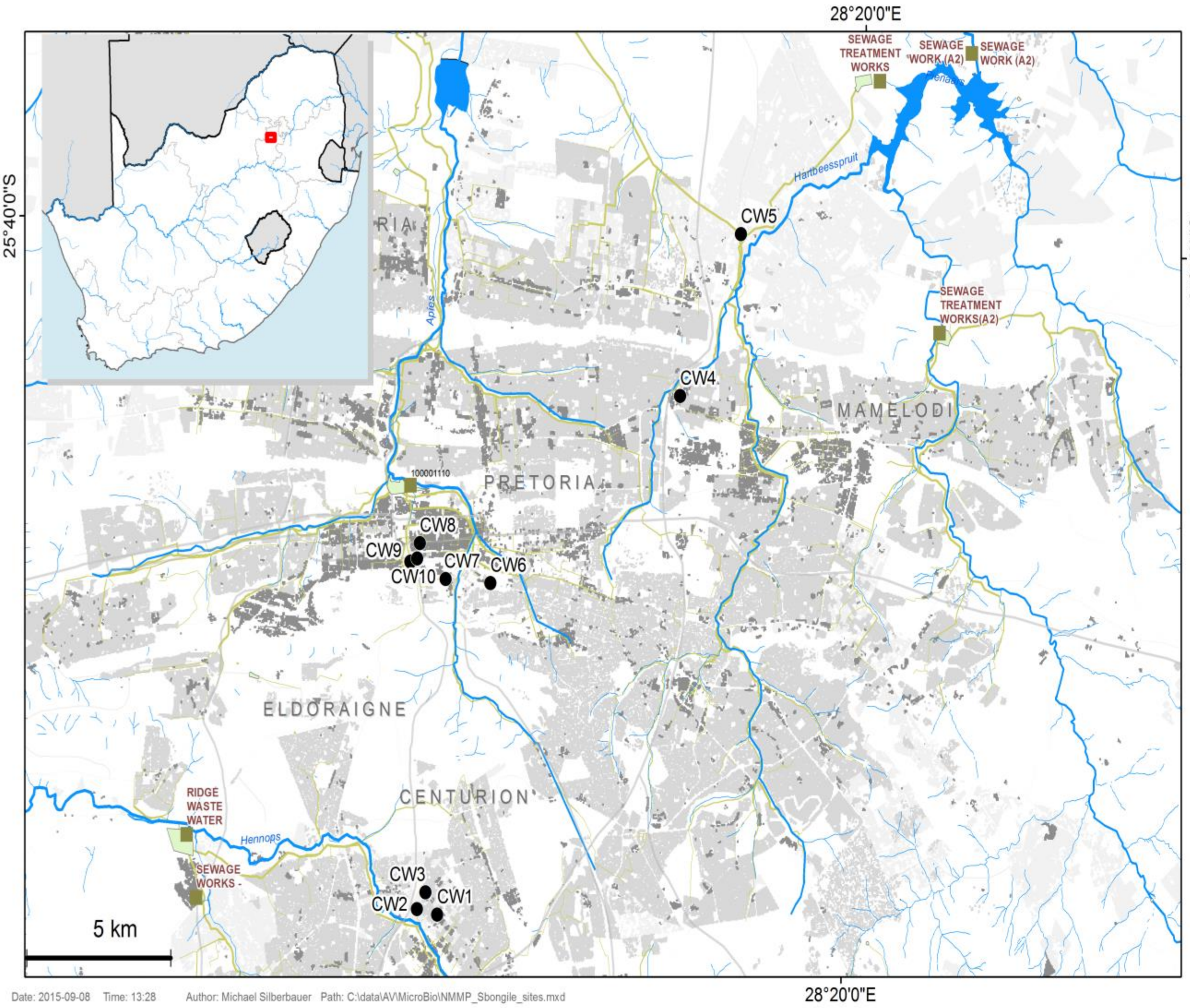



**Figure 6: Location of sampling sites in City of Tshwane (CW1-CW10)**


**Figure 7: Commercial car wash (By author)**

**Figure 8: Non-commercial car wash (Mahlangu, 2016)**

**Table 2: Description of carwash facilities where samples were collected**

| Sample collection site | Description of the car wash facility where samples were collected. |
|---|---|
| CW1 | Full service commercial car wash located within a petrol station/garage. It is a conveyor car wash with a concrete wash bay. The facility is supplied with fresh water from the municipal supply and from a private installed borehole. The facility also has a recycling system. |
| CW2 | Low density/informal car wash, stand-alone car wash located within a braai restaurant with butchery also known as a shisanyama. The facility uses fresh water from the municipal water supply. The vehicles are washed under carports manually using potable karcher pressure washers connected to taps. |
| CW3 | Full service commercial car wash located within a petrol station/garage. The facility has a concrete wash bay and makes use of installed high pressure washers to wash vehicles manually. The facility is supplied with fresh water from the municipal supply. |
| CW4 | Low density car wash located within a small shopping centre. The vehicles are washed under carports manually using potable karcher pressure washers connected to taps. |
| CW5 | Low density car wash located at a petrol station/garage backyard. The facility has concrete wash bay with no side walls and vehicles are washed manually using high pressure washers. |
| CW6 | Full service commercial car wash located within a petrol station/garage. The facility has a concrete wash bay and makes use of installed high pressure washers to wash vehicles manually. The facility is supplied with fresh water from the municipal supply. |
| CW7 | Commercial car wash located next to a petrol station/garage. The facility has concrete wash bays with no side walls and vehicles are washed manually using high pressure washers. The facility also has a recycling system installed. |
| CW8 | Low density car wash located at a small petrol station/garage backyard. The vehicles are washed under carports manually using potable hosepipes connected to taps. |
| CW9 | Car wash located in a car dealership Truck depot. The facility has a concrete wash bay and makes use of installed high pressure washers to wash vehicles. |
| CW10 | Commercial car wash located within a petrol station/garage. The facility has a concrete wash bay and makes use of installed high pressure washers to wash vehicles. |

### 3.3 Sampling procedure

At each facility the following bottles were used to collect composite water samples:

* One white 250mL plastic bottles for the macro analysis. The samples were preserved by adding one ampoule containing mercury chloride to the sample.
* One green 250mL plastic bottle for the turbidity analysis
* One red 250mL plastic bottle for the trace metals analysis
* One 500mL sterile plastic bottle for microbiological analysis
* Two 1L sterile plastic bottles for aggregate organic constituents
* One 250mL sterile glass bottle for the toxicity analysis

Samples were collected in ten facilities. Figure 9 show a picture taken at one facility during sampling. In four facilities (CW1, 3, 4 and 6) samples were collected twice to compare the results. The averages for these samples were calculated. Only one sample was taken in other facilities due to financial constraints. The samples were transported to the laboratory in cooler boxes for analyses. The samples were sent to Waterlab (Pty) Ltd an accredited laboratory in Pretoria for the Oil & grease, gasoline, motor oil, diesel, anionic surfactants, COD, BOD, TDS, and toxicity analysis and the rest of the samples were analysed at the Department of Water and Sanitation, Resource Quality Information Services laboratories in Roodeplaat. The microbiological samples were analysed within 24 hours after sampling. Each waste water sample from the car wash facilities were collected on a specific date, and were marked accordingly with the name of sampler, name of site, date and time of sampling.

**Figure 9: Sampling wastewater in a car wash facility (By author)**

## 3.4 Analytical procedures

Based on the information from previous studies by Brown, (2002); Fall *et al.,* (2007) and Smith & Shilley, (2009) conducted in car wash facilities, a list of parameters were generated to be analysed in this study. Each water sample was analysed for the following parameters following procedures in the standard methods for examination of water and wastewater (American Public Health Association, 2012) : total bacterial counts, total coliform counts, faecal coliform, oil and grease (O&G), nitrate/nitrite, conductivity (Cond), pH, hardness, chemical oxygen demand (COD), total dissolved solids (TDS), biological oxygen demand (BOD), total suspended solids (TSS), sulphates, chloride, turbidity, total phosphorus, surfactants as MBAs, ammonia, copper (Cu), chromium (Cr), lead (pb), nickel (Ni), zinc (Zn), calcium (Ca2+), magnesium (Mg2+), fluoride (F), Kjeldalhl nitrogen. Total petroleum hydrocarbons (gasoline range organics & diesel range organics) was analysed following EPA methods. An overview of the analytical methods used is presented in table 3.

**Table 3: List of analytical methods used in the study**

| Parameter | Analytical methodology |
|---|---|
| Total bacterial count (cfu/1ml) | Standard plate count – pour plate method |
| Total coliform counts (cfu/100ml) | Membrane filtration method |
| Faecal coliform (cfu/100ml) | Membrane filtration method |
| pH (pH units) | Radiometer TTT85 Titrator pH meter |
| Turbidity (NTU) | Hatch model 2100AN laboratory turbidimeter |
| Electrical conductivity (mS/m) | Radiometer conductivity meter model CDM83 |
| TPH-Gasoline Range Organics | EPA method 8260 |
| TPH-Diesel Range Organics | EPA method 8015 and 8270 |
| oil and grease | 5520 Oil and grease –Partition gravimetric method |
| Anionic surfactants (MBAs) | Standard methods 5540C |
| chemical oxygen demand | 5220 COD test |
| total dissolved solids | 2540 solids-total dissolved dried at 180°C |
| Biological oxygen demand | 5210 BOD-5 day BOD test |
| total suspended solids | 2540 solids-total dissolved dried at 103 - 105°C |
| Sulphates (sulphate/L) | Aquachem 250 |
| Chloride (Cl/L) | Aquachem 250 |
| total phosphorus (phosphorus/L) | Aquachem 250 |
| ammonia (ammonia/L) | Aquachem 250 |
| Calcium (Ca/L) | Aquachem 250 |
| Magnesium (mg/L) | Aquachem 250 |
| nitrate/nitrite (Nitrite/L) | Aquachem 250 |
| Phosphates as P | Aquachem 250 |
| Kjeldalh Nitrogen | Aquachem 250 |
| copper | Perkin Elmer ICP |
| chromium | Perkin Elmer ICP |
| lead | Perkin Elmer ICP |
| nickel | Perkin Elmer ICP |
| zinc | Perkin Elmer ICP |
| Hardness | Calculated using formula |
| Toxicity | Bioluminescent bacteria test: *Vibrio fischeri* *Daphnia pulex* Screening test. |

### 3.4.1 Microbiological Analysis

Microbiological analysis was performed following procedures in the standard methods for examination of water and wastewater (American Public Health Association, 2012).

For quality control each batch of samples that were analysed, the analytical procedures were checked by testing a known positive and negative control culture. The replicate sample was tested on at least one sample per test run to determine the method precision. The sterility of the media, membrane filters, dilution and rinse water were also checked. The results were accepted if positive control plates produced typical total coliform colonies or faecal colonies and negative control plates produced no growth or atypical colonies.

#### 3.4.1.1 Total bacterial count/Heterotrophic plate count (cfu/mL)

Total bacteria count gives an indication of the total bacterial load in a given sample. The pour plate method was used to assess the total bacteria per sample using plate count agar. Dilutions were prepared for each sample and 1mL of the sample or dilutions were aseptically pipetted into a petri dish and within 30 minutes approximately 18mL sterile, standard plate count agar was added. Before the agar began to solidify the medium was mixed thoroughly with the sample in the petri dish by swirling the petri dish on the bench top. The plates were placed undisturbed on a level surface until the agar was solid and were inverted and incubated at 35ºC for 48 hours.

After incubation all plates with counts between 30 and 300 colonies were counted and results recorded. The counts were calculated by dividing the means of the two counts by the volume in mL of the original sample pipetted into the petri dish to give the results in cfu/mL.

#### 3.4.1.2 Total coliform count and faecal coliform count

Total Coliform bacteria are bacteria that produce colonies with a golden green metallic sheen within 24 hours when incubated at 35ºC on m-Endo medium. Faecal coliforms are bacteria that produce various shades of blue colonies on m-FC medium within 24 hours when incubated at 44.5 ºC. The membrane filtration method was used to assess the amount of total coliform and faecal coliform per sample. The necessary dilutions were prepared using sterile ringers' solution and the desired volume of sample was filtered through a membrane filter paper and the filter paper was transferred into a petri dish containing m-Endo agar. For the same dilutions the same was done and transferred into the m-FC agar dish. The plates are then incubated within 30 minutes, m-Endo at 35ºC for 24 hours and m-FC at 44.5ºC for 24 hours.

For total coliform bacteria all colonies that were golden green with a metallic sheen were counted and recorded and for faecal coliform bacteria all typical blue colonies were counted after incubation. Total coliform bacteria and faecal coliform were calculated using the formula:

$$\text{FC or TC/100mL} = \frac{\text{No of colonies} \times 100}{\text{Volume of sample filtered}}$$

### 3.4.2 Physical parameter analysis

#### 3.4.2.1 pH

pH was measured using the radiometer TTT85 titrator pH meter.

#### 3.4.2.2 Turbidity

Turbidity is the measure of the cloudiness or muddiness of water. Turbidity was measured using Hatch model 2100AN laboratory turbidity meter.

#### 3.4.2.3 Electrical conductivity

Electrical conductivity (EC) is the measurement of the ease with which water conducts electricity. Conductivity of the water also indicates what the total dissolved solid (TDS) content of the water is. EC was measured using Radiometer conductivity meter model CDM83.

#### 3.4.2.4 Hardness

Hardness was determined by calculation using results of separate determinations of calcium and magnesium. The following formula was used:

Hardness as $CaCO_3$/L = 2.497 [Ca] + 4.118 [Mg]

### 3.4.3 Inorganic compounds determination by Aquachem 250

Inorganic compounds were determined in the water samples by first filtering the samples through a pre-washed 0.45µm membrane filter. For the Kjeldalh Nitrogen and total phosphorus analysis the samples were first digested before filtering. These filtered samples were then analysed using the Aquachem 250 instrument. The following inorganic determinants were obtained: Alkalinity, Ca, Cl, Mg, $NH_4$-N, $NO_2$-N, $PO_4$-P, $SO_4$, TKN, and TP.

#### 3.4.3.1 Principle of the Aquachem 250 instrument

The sample is incubated with reagents in the cuvettes for a method specific period and is then moved through the photometer where absorbance is measured. After measurement the cuvette is discarded in the waste compartment. Table shows a list of reagents used for each determinant and their concentration ranges.

**Table 4: List of reagents used and optimum concentration range in Aquachem 250 instrument**

| Parameter | Reagents used | Optimum concentration range |
|---|---|---|
| Alkalinity as $CaCO_3$ | Phthalate buffer (pH 3.5), Milli-Q water, bromophenol blue solution (0.05%), alkalinity reagent, ethylenediaminetetra-acetic acid (EDTA) solution 1% | 5.0 – 400mg/L |
| Calcium (Ca) | Calcium reagent | 1.0 – 200mg/L |
| Chloride (Cl) | Mercuric thiocynate stock solution, ferric nitrate stock solution, colour reagent | 0.090 – 300mg/L |
| Magnesium (Mg) | Magnesium reagent | 1.5 – 75.0mg/L |
| Ammonia ($NH_4$-N) | Nitric acid 0.4%, sodium salicylate solution (reagent 1), DIC solution (reagent 2) | 0.050 – 2.0mg/L |
| Nitrite ($NO_2$-N) | Colour reagent (TON 3) | 0.025 – 2.00mg/L |
| Phosphate ($PO_4$-P) | Antimony potassium tartrate stock solution, ammonium molybdate stock | 0.010 – 0.500mg/L |

| | | |
|---|---|---|
| | solution, sulphuric acid stock solution, reagent 1, ascorbic acid solution | |
| Sulphate ($SO_4$) | Precipitating solution, sulphate reagent | 3.0 – 240mg/L |
| Kjeldalh Nitrogen (TKN) | Sodium hydroxide stock, complexing buffer, working buffer, sodium nitroprusside solution, sodium hypochloride, digestion mixture, TKN dilution solution, working phenate solution | 0.100 – 4.0mg/L |
| Total Phosphorus (TP) | Antimony potassium tartrate stock solution, ammonium molybdate stock solution, sulphuric acid stock solution, reagent 1, ascorbic acid solution (reagent 2) | 0.012– 0.5mg/L |

### 3.4.4 Aggregate organic constituents

#### 3.4.4.1 Total Petroleum Hydrocarbons

Total Petroleum hydrocarbons were determined by gas chromatography. Petroleum hydrocarbons include gasoline range organics (GROs) and diesel range organics (DROs). GROs correspond to the range of alkanes from $C_6$ to $C_{12}$ and covering a boiling point range of approximately $60^0$C - $170^0$C. DROs correspond to the range of alkanes from $C_{10}$ to $C_{28}$ and covering a boiling point range of approximately $170^0$C - $430^0$C. DROs were prepared using solvent extraction method, and GROs were introduced into the gas chromatography/flame ionization detector (GC/FID) by purge and trap method. An appropriate column and temperature program was used in the gas chromatograph to separate the organic compounds. Detection was achieved by a flame ionization detector.

#### 3.4.4.2 Oil and Grease

The partition-gravimetric method was used to determine the amount of oil and grease in the sample. The sample bottle was weighed when received in the lab for later determination of sample volume. The samples were acidified with 1:1 HCL to pH 2 or lower. The sample was then transferred to a separating funnel using a liquid funnel. The sample bottle was rinsed with 30mL of extracting solvent and the solvent washing was added in the separating funnel. This was shaken vigorously for two minutes and the layers let to separate. The aqueous layer and small amount of organic layer was drained into the original sample container and the solvent layer was drained through a funnel containing a filter paper and 10g $Na_2SO_4$ both of which has been solvent rinsed into a clean distilling flask containing boiling chips. The solvent from the flask was distilled in a water bath at $85^0$C. To maximise solvent recovery distillation flask was fitted with a distillation adapter equipped with a drip tip and solvent collected in an ice-bath-cooled receiver. The bent distillation apparatus was replaced with a vacuum/air adapter when visible solvent condensation stopped. Air was drawn through the flask with an applied vacuum for one minute and the flask removed from bath and cooled in desiccators until a constant weight was obtained. Oil and grease was calculated using formula:

$$\text{Oil and grease/ L} = \frac{W_r}{V_s}$$

Where: $W_r$ = total weigh of flask and residue, minus tare weight of flask in mg, and $V_s$ = initial sample volume in L.

### 3.4.4.3 Anionic surfactants as MBAS

A calibration curve was prepared consisting of at least five standards or desired concentration range. A series of separating funnels for reagent blank and selected standards was prepared. A portion of standard LAS solution was pipetted into funnels. Sufficient water was added to make the total volume100mL in each separating funnel. Each standard was treated and a calibration curve of absorbance vs. Micrograms LAS was taken specifying the molecular weight of LAS used. MBAS was calculated using the formula:

$$\text{MBAS (mg)/ L} = \frac{\text{µg apparent LAS}}{\text{mL original sample}}$$

### 3.4.4.4 Biological Oxygen Demand

The 5-day BOD test was used to measure BOD in the samples. The samples were prepared and pre-treated by adjusting the temperature to 20 ± $3^0$C and pH 7.0-7.2

by adding a solution of sulphuric acid or sodium hydroxide. A seed suspension which is a population of microorganisms capable of oxidising the biodegradable organic matter in the sample was prepared and added to the sample. The volume of seed suspension added was recorded. Dilution water was prepared and the sample diluted. Each bottle was sealed by filling the bottle with enough dilution water that insertion of the stopper leaves no bubbles in the bottle. The initial Dissolved oxygen (DO) was determined and the sample incubated at $20^0$C for five days. After five days the dissolved oxygen was determined. For each test bottle having 2.0mg/L minimum DO depletion and at least 1.0 mg/L residual DO, BOD was calculated as follows:

$$BOD_5 \text{ (mg/L)} = \frac{(D_1 - D_2) - (S)\, V_s}{P}$$

Where: $D_1$ = DO of diluted sample immediately after preparation, $D_2$ = DO of diluted sample after five day incubation, $S$ = Oxygen uptake of seed, $V_s$ = volume of seed in test bottle and $P$ = decimal volumetric fraction of sample used.

#### 3.4.4.5 Chemical Oxygen Demand

The open reflux method 5220 B was used to determine COD in the samples. The samples were first treated by blending and the 50mL pipetted into a 500mL refluxing flask. 1 g $HgSO_4$ and several glass beads were added and very slowly 50 mL of sulphuric acid was added to dissolve $HgSO_4$. The mixture was cooled while mixing to avoid loss of volatile materials. 25mL of 0.04167M.$K_2Cr_2O_7$ solution was added. The flask was attached to condenser and cooling water turned on. 70mL of sulphuric acid reagent was added through the open end of the condenser while swirling and mixing was continued. The open end of the condenser was covered with a beaker and refluxed for two hours. The condenser was then cooled and washed with distilled water. The reflux condenser was disconnected and mixture diluted to twice its volume with distilled water. The mixture was cooled to room temperature. Access $K_2Cr_2O_7$ was titrated with FAS using 0.10 to 0.15mL of Ferron indicator. The end point of titration was the first sharp colour changes from blue-green to reddish-brown that persisted for one minute or longer. A blank containing the reagents and a volume of distilled water equal to that of the sample was refluxed and titrated in the same manner.

COD was calculated using formula:

$$\text{COD as mg } O_2/L = \frac{(A\text{-}B) \times M \times 8000}{\text{mL sample}}$$

Where: A = mL FAS used for bank, B = mL FAS used for sample, *M* = morality of FAS and 8000 = milliequivalent weight of oxygen x 1000mL/L.

#### 3.4.4.6 Total dissolved solids

TDS was determined by filtering a well-mixed sample volume through a prepared glass fibre filter and the total filtrate with washings transferred to a prepared pre weighed evaporating dish and evaporated to dryness in a drying oven. The evaporated sample was dried for at least one hour in an oven at $180^0$C and allowed to cool in a desiccator to balance the temperature and weighed. TDS was calculated using formula:

$$\text{TDS (mg/L)} = \frac{(A - B) \times 1000}{\text{Sample volume mL}}$$

Where: A = weight of dried residue + dish in mg and B = weight of dish.

#### 3.4.4.7 Total suspended solids

TSS was determined by filtering a well-mixed sample volume through a prepared pre weighed glass fibre filter and the retained matter on the filter was dried to a constant weight in an oven at $104^0$C for about two hours. After drying the filters were removed from the oven and allowed to cool in a desiccator containing dried silica gel for approximately one hour. The watch glass containing filters were reweighed and results recorded. TSS was calculated using the formula:

$$\text{TSS (mg/L)} = \frac{(A - B) \times 1000}{\text{sample volume mL}}$$

Where: A = weight of filter + dried residue in mg and B = weight of filter prior to filtration.

### 3.4.5 Metals determination by Inductively Coupled Plasma (ICP)

Dissolved metals were determined in the water samples by first passing the sample through a 0.45 micron filter. The samples were then acidified with concentrated nitric acid. This procedure was intended to change the sample into a form suitable for ICP aspiration. The prepared samples were analysed using the Perkin Elmer Dual view ICP instrument. The following metals are obtained with this instrument: chromium, copper, lead, nickel, zinc, iron and manganese.

#### 3.4.5.1 Principle of the Perkin Elmer Dual View ICP method

This method is a technique for the simultaneous determination of elements in solution using axially orientated torch plasma. The basis of the method is the measurement of atomic emission by an optical spectroscopic technique. The samples were nebulised and the aerosol that was produced was carried by the argon to the plasma were excitation occurred. Characteristic atomic and anionic line emission spectra were produced by a radio frequency ICP. The ICP source consists of a torch through which ionized argon was passed. The samples aerosol was subjected to temperatures of approximately 6000K and this dissociated the sample molecules into free atoms and ions that emit light at wavelengths characteristic of the elements present in the samples. The intensity of light at a given wavelength was measured by a detector. Table 5 shows the wavelengths and limit of quantitation for each element.

**Table 5: Analysis wavelengths for different elements and LOQ for each element**

| Element | wavelengths (nm) | Limit of quantitation in mg/L |
|---|---|---|
| copper | 324,752 | 0,001 |
| chromium | 267,716 | 0,007 |
| lead | 220,353 | 0,004 |
| nickel | 231,604 | 0,001 |
| zinc | 206,200 | 0,002 |
| Manganese | 257,610 | 0,001 |
| Iron | 259,939 | 0,001 |

### 3.4.6 Whole effluent toxicity analysis

#### 3.4.6.1 Bioluminescence Bacteria test

Toxicity of the water samples was determined using the bioluminescence bacteria *Vibrio fischeri*. A definitive test was performed. The pH of the samples was adjusted to 7 by adding NaOH or HCL if the measured pH was outside the range 6.0 – 8.5. Dissolved oxygen was determined for all samples and if the dissolved oxygen was less than 40% saturation, the test solution was aerated until just above 40%. The samples were diluted using a 2% NaCl solution. The samples were diluted to the following concentrations: 6.25%, 12.5%, 25% and 50% and the original sample were also used which was 100%. The luminescent bacterium *Vibrio Fischeri* was used for the test. The bacterium suspension was added to the different concentrations of the samples and after 15 minutes and 30 minutes; the decrease in light intensity was measured for each concentration. The value was plotted against the dilution factor and the resultant curve was used to calculate $EC_{20}$ and $EC_{50}$ which is the (Effective Concentration giving 20% and 50% inhibition of light output) of the sample. The toxicity unit (TUa) for each sample was calculated using the formula:

$$\text{Toxicity units} = \frac{100\%\ \text{(full strength effluent)}}{EC_{50}\ \text{(effective concentration)}}$$

If there was not sufficient toxicity in the sample to enable determination of an $EC_{50}$ value, then a toxicity unit of <1 was assigned to the sample. Table 6 shows the guidelines to assign toxicity units.

**Table 6: Toxicity Units (Tonkes & Baltus, 1997)**

| Toxicity Units | Conclusion |
|---|---|
| <1 | Limited to not acutely toxic |
| 1-2 | Negligibly acute toxic |
| 2-10 | Mildly acutely toxic |
| 10-100 | Acutely toxic |
| >100 | Highly acutely toxic |

#### 3.4.6.2 *Daphnia pulex* acute toxicity test

The *Daphnia pulex* acute toxicity test was also used to determine the toxicity of the water samples. The freshwater crustaceans *Daphnia pulex* species were cultured in the laboratory. *Daphnia pulex* less than 24 hours of age were exposed to samples for a period of 24 hours and 48 hours at $21^{0}$C. After the 24 hours and 48 hours exposure the % mortality of the organisms was recorded

### 3.5 Data collection

Additional data was collected through structured questionnaires with the carwash site managers to gain sufficient information concerning water use, car washing activities, and issues relating to water use licensing, water quality monitoring and waste water discharge. A copy of the questionnaire used can be found in Appendix B. The research question in the questionnaire was based on knowledge that the researcher gained in the literature review.

### 3.6 Data analysis

Water quality data from the laboratory and data gathered from the completed questionnaires from facility management respondents were recorded in a spreadsheet on Microsoft excel for each sampling site. The water quality data obtained were compared to the different water quality and effluent discharge guidelines in Table 1 and toxicity guidelines in Table 6. Microsoft excel was used for data analysis and graphical representation of data. The results of the data analysis will be presented in the next chapter.

# CHAPTER 4: RESULTS AND DISCUSSION

## 4.1 Survey results on car wash facilities and activities

This section outlines the key findings from the questionnaires answered by the car wash facility managers and or owners. The questionnaire was designed to provide an overview of the different activities and water management at the facilities.

### 4.1.1 Number of years in operation

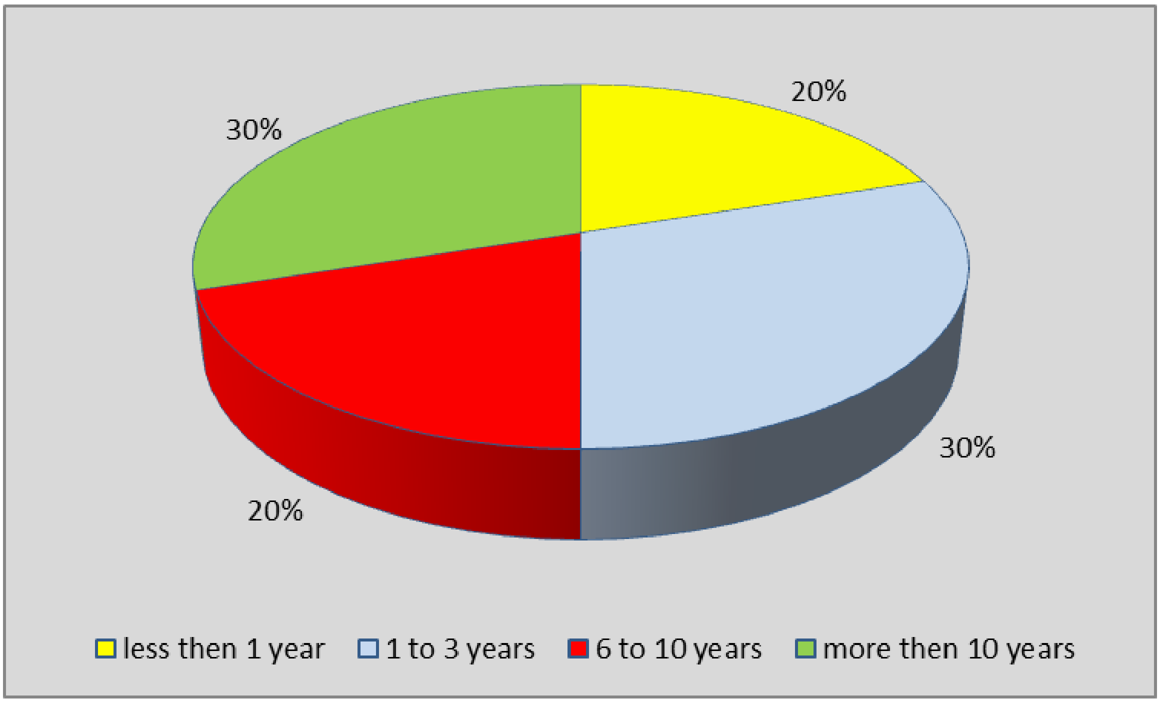



**Figure 10: Number of years of the car washes operation (*Source: Primary data from questionnaire survey)***

Twenty percent (20%) of the car washes had been operating for less than 1 year, while 30% had been in operation for more than 10 years mostly being the professional commercial car washes at service stations, 30% had been operating for 1 to 3 years while the other 20% between 6 to 10 years (Figure 10). The years of operation were well spread over the different years. Seemingly there appears to be a link between the number of years in operation and the quality of operation in relation to good environmental practice. The facilities that had operated for many years show better environmental practices then those who had operated for fewer years (Table 7).

**Table 7: Number of years in operation in relation to good environmental practice**

| | Less than 1 year | | 1 year to 5 years | | | More than 6 years | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Low density | commercial | commercial | Low density | Low density | commercial | Low density | commercial | commercial | commercial |
| | CW2 | CW9 | CW3 | CW4 | CW8 | CW1 | CW5 | CW6 | CW7 | CW10 |
| Recycle water | | ✓ | | | | ✓ | | | ✓ | |
| Discharge into municipal sewer | | | | | | ✓ | | ✓ | ✓ | |
| Has oil water separator | | | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ |
| Has grit chamber | | | | | | ✓ | | | ✓ | |
| Have concerns with chemicals in their wastewater | | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ |

*Source: Primary data from questionnaire survey*

### 4.1.2 Car wash activities, chemicals used and water consumption

The type of car wash activities are represented in table 8 and the list of chemicals used are listed in table 9. The majority of the facilities perform the normal activities in a car wash such as washing the interior and exterior of the vehicle, washing the carpets and vacuuming (Table 8).The car wash facilities use a variety of chemicals to perform the different types of washes in the car wash (Table 9). The most commonly used chemicals in the facilities were the car shampoo, engine cleaner degreaser and the tar remover. The usage of these different chemicals in the car washes together with other pollutants from the cars causes the generation of particularly complex effluent, which could adversely affect the environment if not managed properly.

Seventy percent of the facilities were concerned with detergents, oils, greases, and chemicals in their wastewater while 30% did not have any concerns regarding their wastewater (Table 7).

**Table 8: Type of carwash activities**

| Car wash activities | CW1 | CW2 | CW3 | CW4 | CW5 | CW6 | CW7 | CW8 | CW9 | CW10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Wash & go exterior | * | * | * | * | * | * | * | * | * | * |
| Full valet | * | nd | * | nd | nd | nd | * | * | * | nd |
| Carpet cleaning | * | * | * | * | * | * | * | nd | nd | * |
| Engine wash | * | nd | * | nd | nd | * | * | nd | nd | nd |
| Vacuum | * | * | * | * | * | * | nd | nd | nd | * |
| Mini valet | * | nd | * | * | nd | * | nd | nd | nd | nd |
| Engine & chassis | * | nd | nd | nd | nd | nd | nd | nd | nd | nd |

= activity in facility and nd = not done in facility (*Source: Primary data from questionnaire survey*

**Table 9: Type of chemicals used in the different carwashes**

| Chemicals used | CW1 | CW2 | CW3 | CW4 | CW5 | CW6 | CW7 | CW8 | CW9 | CW10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Blue car shampoo | * | nu | * | * | * | * | * | * | **nu** | * |
| Wash and wax | nu | * | nu | * | * | nu | nu | nu | nu | nu |
| Engine cleaner degreaser | * | nu | * | * | nu | * | * | * | * | nu |
| Gp cleaner | * | nu | nu | * | nu | nu | nu | nu | nu | nu |
| Leather cleaning fluid | * | nu | * | * | nu | * | nu | nu | nu | * |
| Tar remover | * | nu | * | nu | nu | * | * | * | * | nu |
| silicon | nu | nu | nu | * | nu | nu | nu | * | nu | * |
| Sunlight liquid | nu | * | nu | nu | * | nu | nu | * | nu | nu |
| Handy Andy | nu | * | nu | nu | nu | nu | nu | nu | nu | nu |
| Wash and way soap | nu | * | nu | nu | * | nu | nu | nu | nu | nu |

= Chemicals/detergents used in facility and nu = not used at facility (*Source: Primary data from questionnaire survey)*

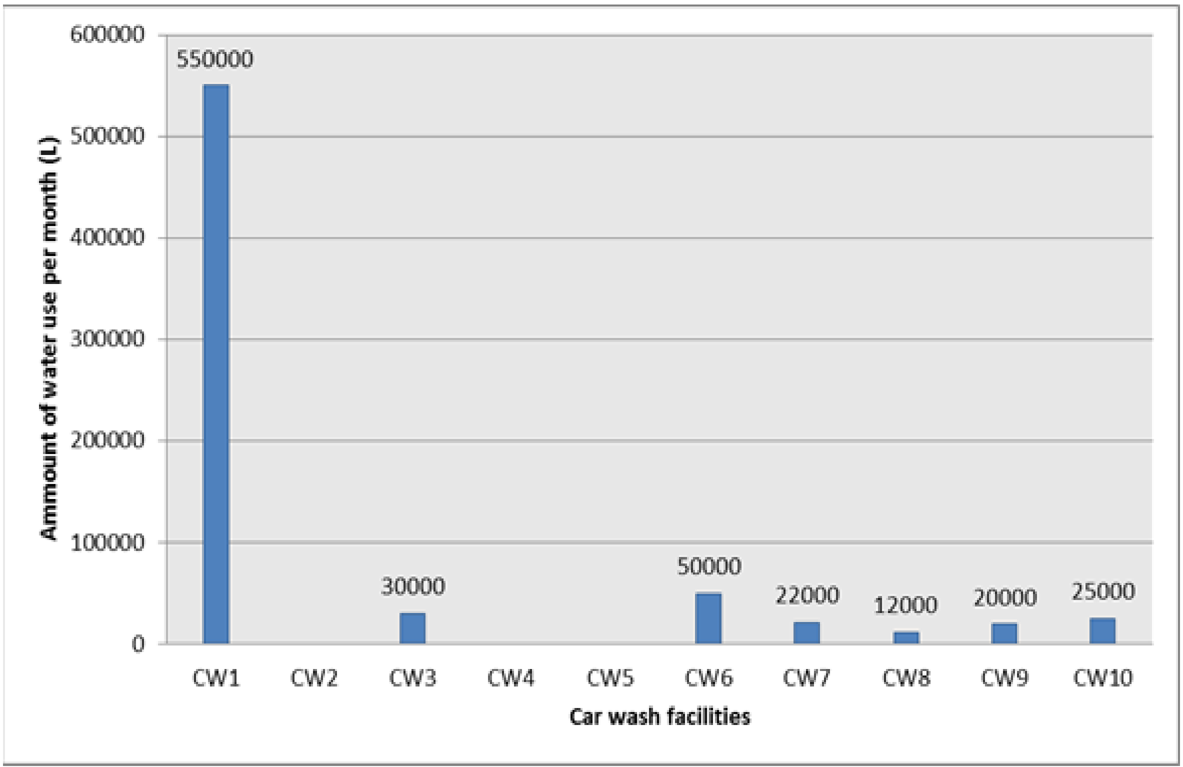



**Figure 11: Amount of water used in each facility per month (Source: questionnaire data)**

Figure 11 shows a graphical representation of the amount of water used in each facility per month. Three facilities (CW2, CW4, and CW5) which are Informal carwash facilities could not provide data of the amount of water they use. The facility CW1 used the highest amount of water per month of 550 000 litres. This could be that CW1 is a very busy facility and washes a large number of vehicles each day and also this facility has an installed borehole and this amount of water was the total amount of water used which is a combination of the borehole water, recycled water and fresh water. In addition, CW1 as compared with the other commercial car washes in the study is a touch-less in bay car wash facility, and this type of facility is known to use more water than other types of car washes such as the ones that uses hand held high pressure nozzles etc. (Janik & Kupiec, 2007). The other facilities used an average of 12 000 litres to 50 000 litres of water per month depending on the type of equipment they use to wash the cars, the number of vehicles their washed per month and how busy the facility is.

**Water discharge and pre-treatment**

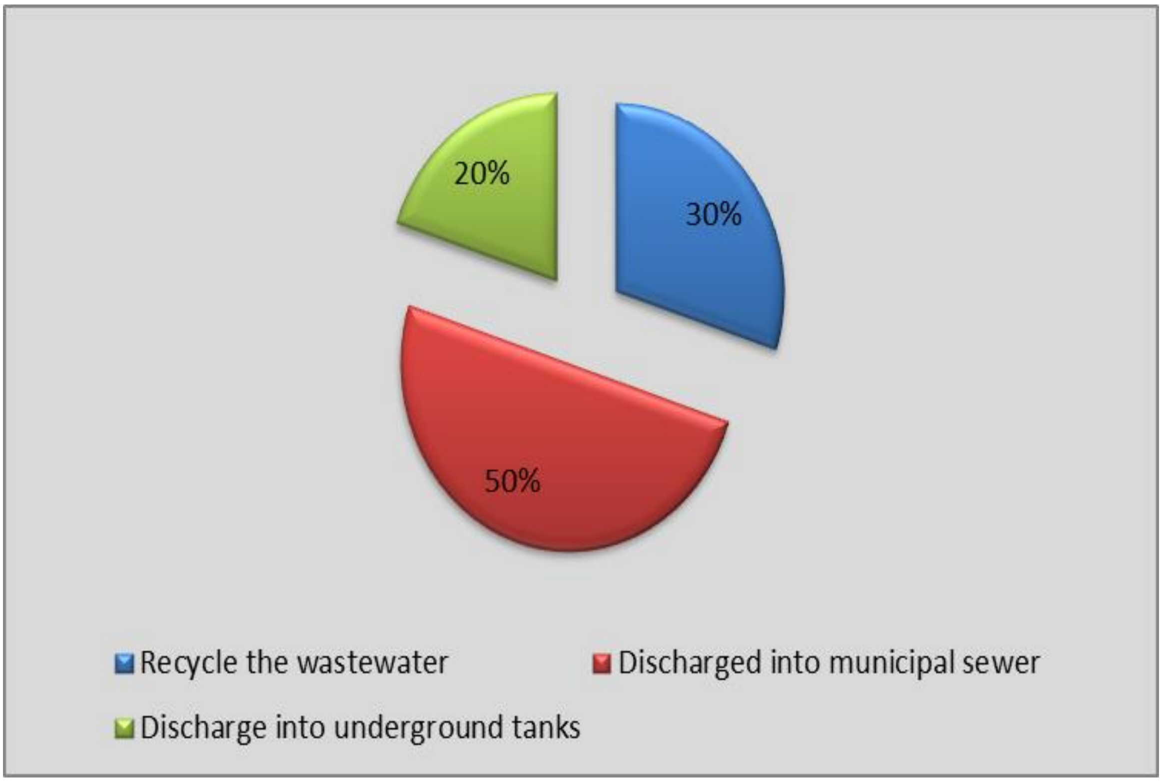



**Figure 12: Point of wastewater discharge (Source: questionnaire data)**

Only 30% (CW1, CW7 & CW9) of the facilities recycle and reuse the wastewater (Figure 10). A small amount of that pre-treated water is discharged into the municipal sewer only when the tanks become too full. CW1 has in addition an installed borehole and use the water from the borehole to dilute the recycled water and reuse for washing. The majority of the facilities (50%) discharge the wastewater into the municipal sewer, and only 20% discharge the water into underground tanks.

**Table 10: Water treatment systems in place at each facility**

| Water treatment systems | CW1 | CW2 | CW3 | CW4 | CW5 | CW6 | CW7 | CW8 | CW9 | CW10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Oil water separator | * | np | * | np | np | * | * | * | np | * |
| Wastewater recycling | * | np | np | np | np | np | * | np | * | np |
| Grit chamber | * | np | np | np | np | np | * | np | np | np |
| None | np | * | np | * | * | np | np | np | np | np |

= Water treatment system used in facility and np = not present (*Source: Primary data from questionnaire survey)*

Sixty percent of the facilities have an oil water separator, while only 30% have wastewater recycling systems in place to treat the wastewater before it is discharged (Table 10). Only 30% of the facilities have a grit chamber which separates the solid wastes such as dirt, sands and solids from the water. These wastes are removed by waste disposal companies. Only 30% of the facilities which are the informal car washes do not have any wastewater treatment systems. Figure 13 illustrate the wastewater recycling system in a commercial carwash and Figure 14 illustrates an example of a grit chamber.


**Figure 13: Wastewater recycling system in a carwash facility (By author)**

**Figure 14: Grit chamber at one commercial carwash facility (By author)**

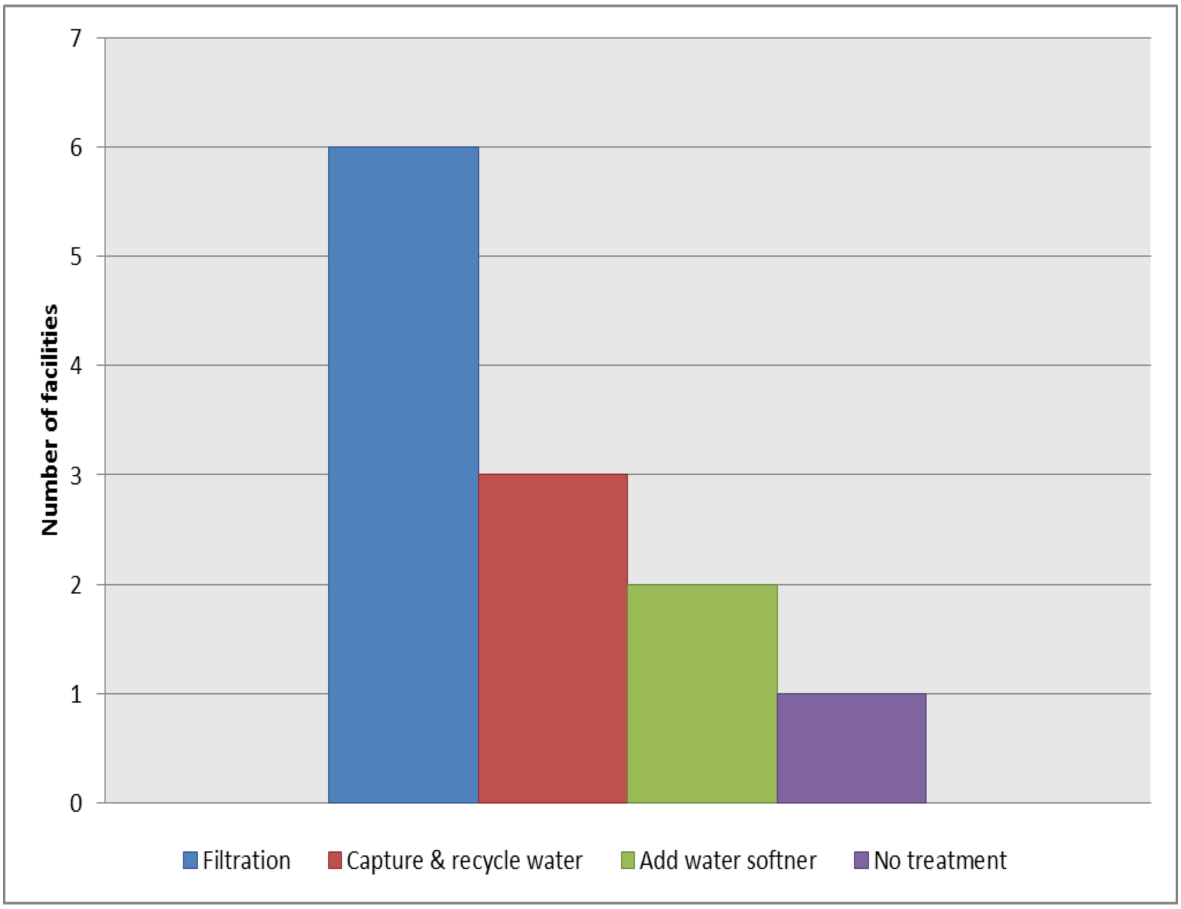



**Figure 15: Treatment done before waste water is discharged**

Majority of the facilities have filtration systems as a pre-treatment of the wastewater (Figure 15). Only the 3 car washes (CW1, 7 and 9) recycle the wastewater and add water softeners which remove certain minerals and other cations in hard waters. The low density car washes do not do any treatment before the waste water is discharged.

The majority of the facilities do not have any water conservation measures in place at their facilities. The 3 (30%) commercial facilities out of 5 commercial facilities have recycling systems as water conservation measures. They monitor the water usage and possible water leaks and 1 (10%) facility also has an installed borehole at their facility. Although a majority of these facilities did not have water conservation measures they believe that filtering and water recycling was a better way to manage their carwash wastewater. Eighty percent of the facilities indicated they were willing to participate in any wastewater management programs.

### 4.1.3 Water quality, monitoring and wastewater regulations

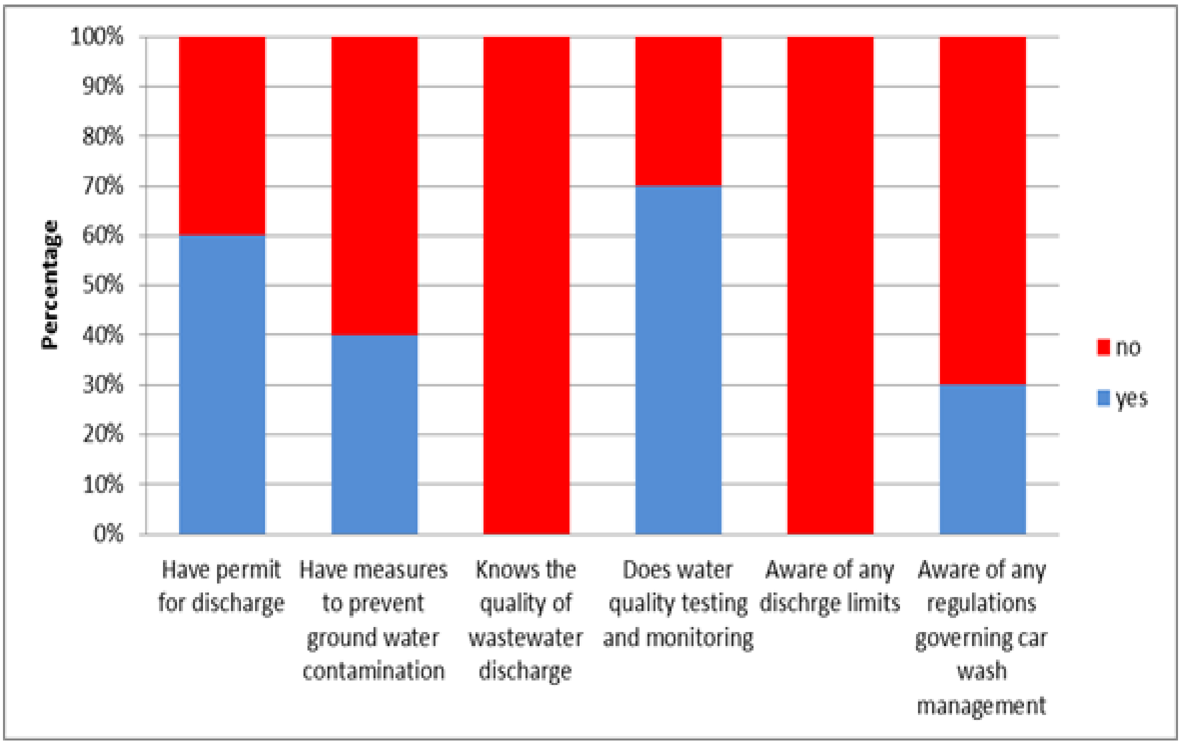



**Figure 16: Water quality, monitoring and regulations results from questionnaires**

Ironically, Sixty percent of the facilities indicated they have permits to discharge wastewater into the municipal sewer (Figure 16), which means that they should be aware of the city bylaws regarding wastewater discharge, which was not the case. Forty percent indicated they did not have any permits. Sixty percent did not have any measures in place to prevent groundwater contamination. All the facilities did not know the quality of their wastewater, although the City of Tshwane municipality does water quality monitoring monthly in 70% of the facilities, the facilities do not receive any data from the municipality. The 30% of the facilities indicated they are aware of regulations governing the carwash wastewater management such as that water from the carwash must be directed into the municipal sewer and should not flow into the storm drainage systems the other 70% had no knowledge of the regulations. All facilities were not aware of any wastewater discharge limits from the municipality.

The City of Tshwane municipality has a monitoring programme where they collect wastewater samples from approximately 300 car wash bays on regular basis within the Tshwane district including 7 of the facilities in the study (F. Van Weele, personal communication, 28 October 2015). Although the municipality does not share the results of their monitoring with the car wash owners, the results of the wastewater using the COD value and permanganate value (PV) is used to calculate a tariff that must be paid by the facility owners for discharging into the municipality sewer. This tariff is based on the Polluters Pays Principle and the higher the COD value in the wastewater effluent the more the tariff to pay (F. Van Weele, personal communication, 28 October 2015).

**Observations**

The researcher observed during the facility visits that the informal low density wash bays did not have facilities to contain the wastewater and most of the wastewater just flows and eventually end up in the storm drainage systems. The researcher also observed that in some instances in the commercial car wash facilities the operators start washing the cars before they enter the wash bay area (Figure 7) because most of the wash bays would be occupied and as a result this water may also flow into the storm drainage without going through proper treatment processes.

## 4.2 Microbiological results for wastewater samples collected in carwash facilities

Results of the microbiological analysis in the collected wastewater samples from the car wash facilities are represented in table11.

**Table 11: Average results of microbiological analysis of wastewater samples collected in Carwash facilities**

| Parameter | Sampling sites | | | | | |
|---|---|---|---|---|---|---|
| | CW1 | CW2 | CW3 | CW4 | CW5 | CW6 |
| **TC (cfu/100ml)** | $2.45 \times 10^7$ | $1.29 \times 10^8$ | $1.18 \times 10^8$ | $2.05 \times 10^6$ | $2.15 \times 10^7$ | $7.00 \times 10^5$ |
| **FC (cfu/100ml)** | $9.94 \times 10^3$ | $4.6 \times 10^4$ | $5.51 \times 10^3$ | $9.60 \times 10^3$ | $1.25 \times 10^5$ | $2.15 \times 10^3$ |
| **Heterotrophic count/ ml** | >100000 | >100000 | >100000 | >100000 | >100000 | >100000 |

| | Sampling Sites | | | |
|---|---|---|---|---|
| | CW7 | CW8 | CW9 | CW10 |
| **Fungi/ 1ml** | 19 | 8 | 12 | 6 |
| **Heterotrophic count/ 1ml** | $6.34 \times 10^4$ | $4.67 \times 10^4$ | $5.87 \times 10^3$ | $4.32 \times 10^4$ |

Although there are no limits for bacteria in the guidelines for the wastewater discharge in the Tshwane sanitation by-laws, the results indicate very high bacterial counts in the wastewater in all sites and fungi counts were generally low. These results are in agreement with previous studies done by Zaneti *et al*., (2012), where the car wash wastewater showed high faecal and total coliforms. Besides the anti-floral attributes of car wash chemicals given in literature and results of toxicity in the study, the microbial results show high bacterial counts. This could be because some bacteria are facultative anaerobes, which means that they can survive in environments with or without free oxygen (Cheesbrough, 2006). Furthermore, some bacteria found in wastewater are tolerant to toxic heavy metals in the wastewater so they can survive in toxic environments (Mohamed & Normala, 2015). The National Water Act states that faecal coliform counts in wastewater discharged into a water resource should be a maximum of 1000/ 100mL, and faecal coliform bacteria exceeded this limit in all facilities. FC and TC bacteria were not measured in CW7-10 and instead fungi was analysed. This is because the facilities CW7-10 was included later in the study and bacterial analysis could not be performed at the Water and Sanitation laboratories due to laboratory consumables exhausted. High bacterial counts could have been from the dirt washed off from the cars such as bird droppings and decomposing organic wastes from tyres.

## 4.3 Physical properties of wastewater collected from different carwash facilities

### 4.3.1 pH

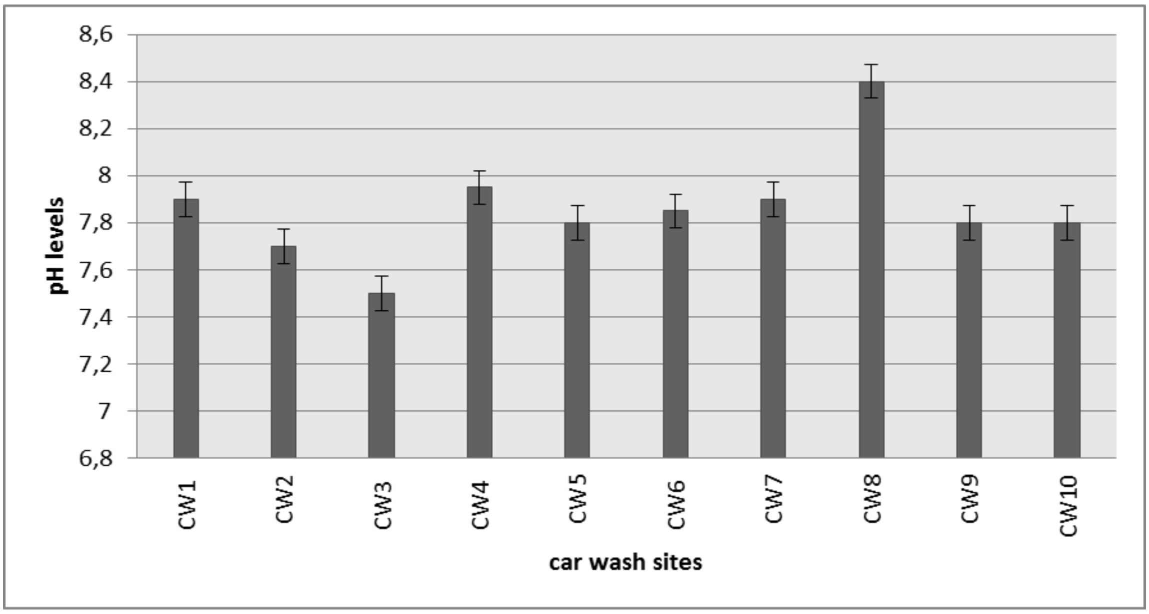



**Figure 17: pH data of wastewater samples collected in carwash**

The pH of wastewater in all the facilities ranged between 7.5 and 8.4 and was within the recommended pH limit for wastewater discharged into municipal sewer by Tshwane municipality of 6 – 10 pH units (Figure 17).

### 4.3.2 Electrical conductivity

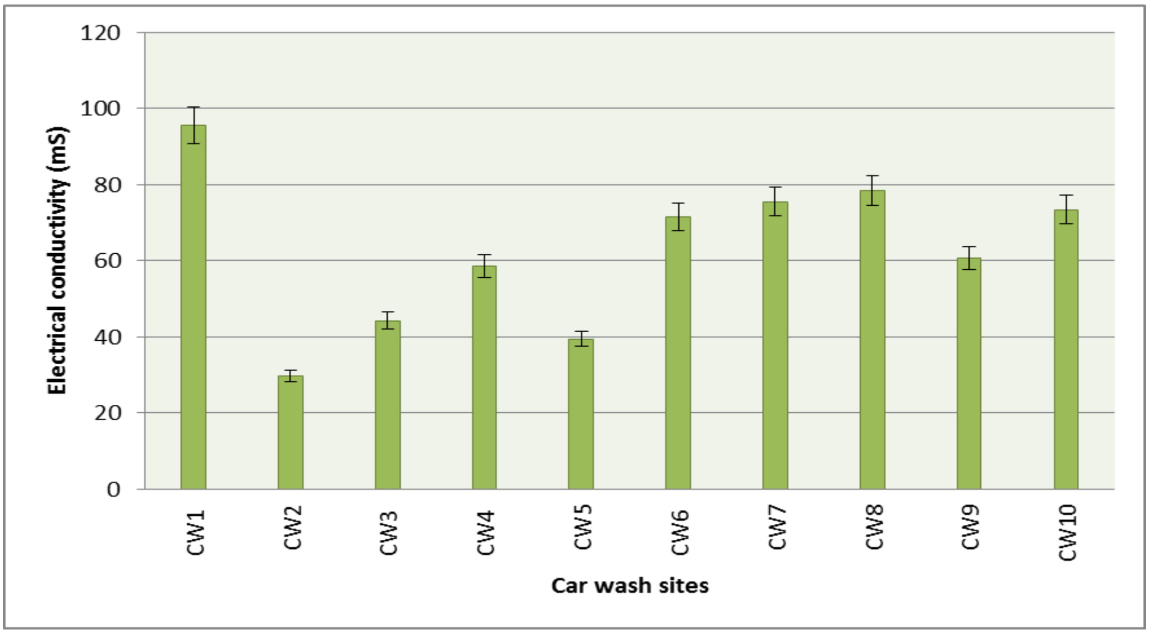



**Figure 18: Conductivity data of wastewater samples collected in carwash facilities**

Electrical conductivity in all the facilities was below 150mS which is the maximum allowable limit for wastewater discharge by the National Water Act and City of Tshwane (<300mS) (Figure 18).

#### 4.3.3 Turbidity

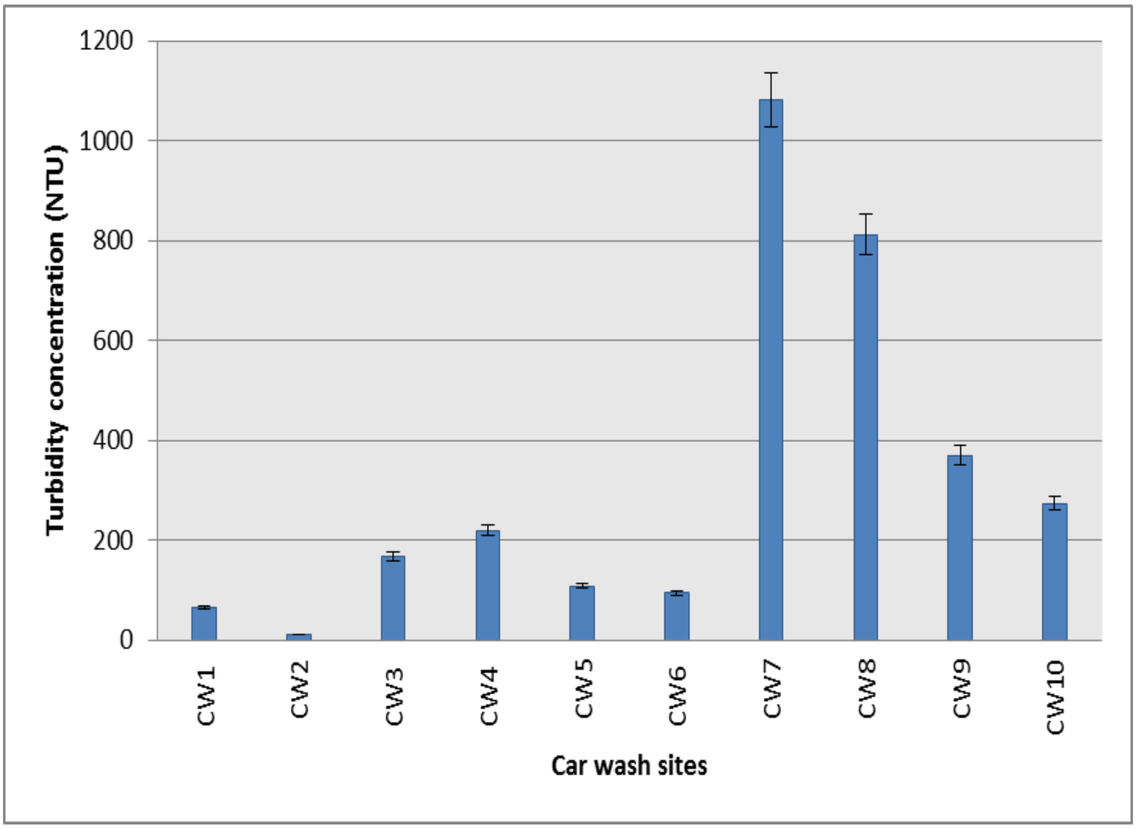



**Figure 19: Turbidity data of wastewater samples collected in carwash facilities**

Turbidity concentrations were below 300 NTU in all facilities except for CW7, CW8 and CW9 where turbidity was exceedingly high with 1081 NTU, 811 NTU and 370 NTU respectively (Figure 19). The wastewater from the carwash contains materials that can make it very turbid such as detergents, diesel and shampoo (Mohamed *et al*., 2014). The car washes that had significantly high turbidly are big facilities located in the central parts of Tshwane and are very busy, and the high turbidity could be attributed to the large number of vehicles being washed there.

#### 4.3.4 Hardness and total alkalinity

The results in Figure 20 show that alkalinity in the wastewater was below 350mg/l in all facilities and was below the recommended Tshwane limit of 2000mg/l for wastewater discharged into a municipal sewer. There are no limits for hardness in the guidelines for wastewater discharge however it was noted that the wastewater in the facilities was moderately hard (CW3, 4, 7) to hard water (CW1,6, 8, 9, and 10) and only CW2 and CW5 had moderately soft water. According to U.S.EPA (2001) the disadvantage of hard waters is that they neutralise the lathering power of soap and most importantly can cause blockages of pipes and the effects increases as hardness increases to 200mg/l $CaCO_3$ and above.

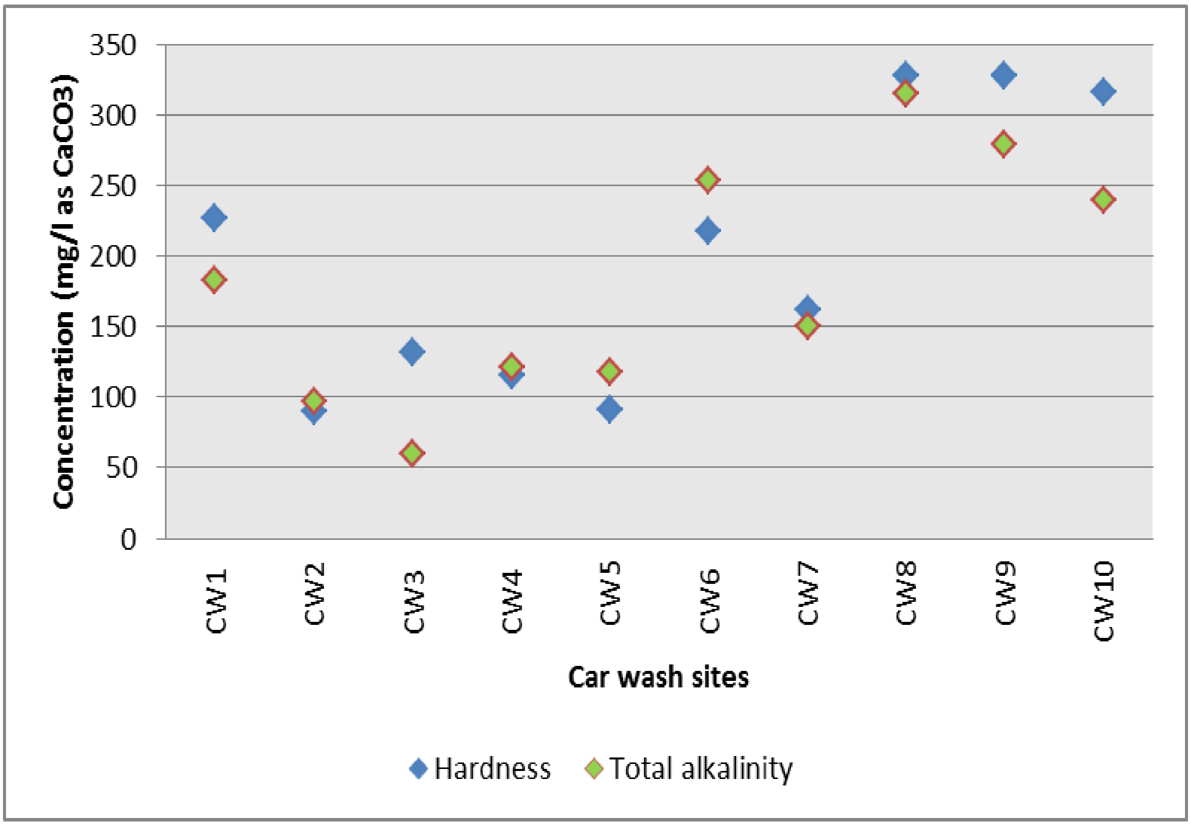



**Figure 20: Hardness and total alkalinity data of wastewater samples collected in carwash facilities**

### 4.4 Inorganic compounds in wastewater samples collected from carwash facilities

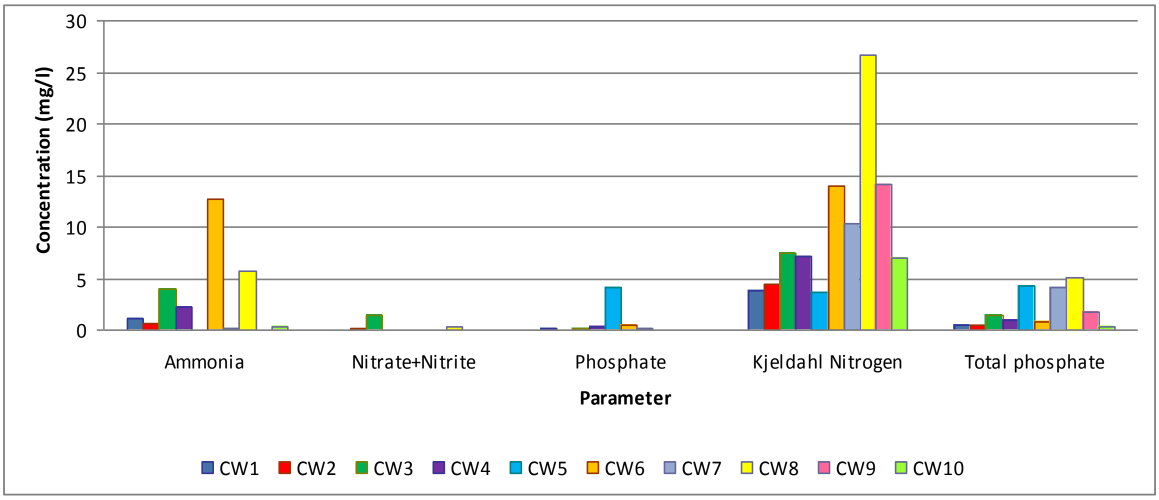



**Figure 21: Summary of inorganic compounds in the wastewater samples collected in carwash facilities.**

Ammonia levels were very low in wastewater of CW2, 5, 7, 9, 10. Although there are no limits for ammonia, total phosphates, nitrates and Kjeldahl nitrogen in the Tshwane sanitation bylaws, only CW6 exceeded the National Water Act standard of 6mg/L (Figure 21). Nitrates and total phosphates levels in all sites were below 5mg/L and the wastewater in CW6, 7, 8 and 9 was above 10mg/l. Phosphates can be found in the detergents used in the car wash and can cause excess algae to grow in the drains or waterways (Mohamed *et al*., 2014).

**Table 12: Average results of cations and anions in the wastewater samples used in Maucha diagram**

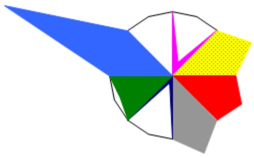
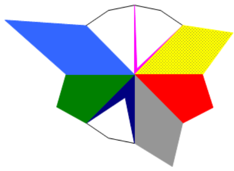
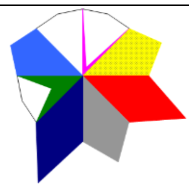
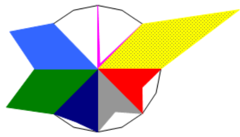
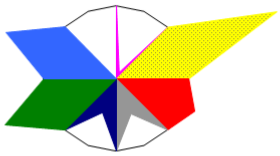
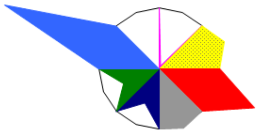
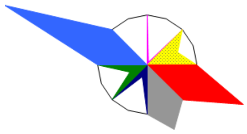
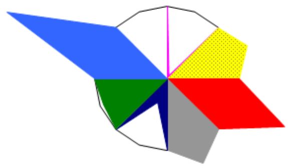
| Car wash site | Ca | Cl | Mg | SO4 | TAlk | Na | K |
|---|---|---|---|---|---|---|---|
| **CW1** | 45.9 | 59.4 | 27.35 | 32.6 | 183.65 | 52.4 | 5.1 |
| **CW2** | 25.7 | 23.3 | 6.2 | 13.2 | 97.2 | nd | nd |
| **CW3** | 31.65 | 18.15 | 12.75 | 76.75 | 59.2 | 31.2 | 5.5 |
| **CW4** | 25.55 | 78.35 | 12.55 | 58.75 | 121.3 | 121.4 | 7.3 |
| **CW5** | 20.8 | 35.2 | 9.4 | 8.9 | 117.7 | nd | nd |
| **CW6** | 36.15 | 75.35 | 18.45 | 60.4 | 186.1 | 121.4 | 7.3 |
| **CW7** | 44.6 | 111.9 | 12.1 | 46.1 | 150 | 104.8 | 7.1 |
| **CW8** | 80.7 | 53.9 | 30.7 | 69.8 | 314.4 | 63.7 | 5.2 |
| **CW9** | 78.3 | 25 | 32 | 23.2 | 279.1 | 28.4 | 4.6 |
| **CW10** | 73.4 | 70 | 32.4 | 35.4 | 239.2 | 57.5 | 4.1 |

nd = test not done

Sulphates in the wastewater in all facilities were within the Tshwane effluent limits of 1800mg/l (Table 12). Although there are no limits for calcium and magnesium in the guidelines, these are important variables because they contribute to the hardness of the water.

The maucha ionic diagram (Figure 22) summarises the ratios of the major ions present in the water sample and was first developed in 1932 by Reszo Maucha. The maucha diagram is mainly useful to compare water chemistry types. Table 13 shows the maucha diagrams for wastewater samples collected in the car wash facilities. CW1, 6, 8, 9 and 10 have high total alkalinity, with an increase in the contribution of magnesium and calcium. CW4 and CW7 had a lower alkalinity with an increase in proportion of sodium and chloride, while CW3 has relatively low alkalinity with a higher proportion of calcium, magnesium and sulphate.

**Table 13: Maucha diagrams for wastewater samples collected in car wash facilities**

| CW6 | CW1 | CW3 | CW4 |
|---|---|---|---|
|  |  |  |  |
| **CW7** | **CW8** | **CW9** | **CW10** |
|  |  |  |  |

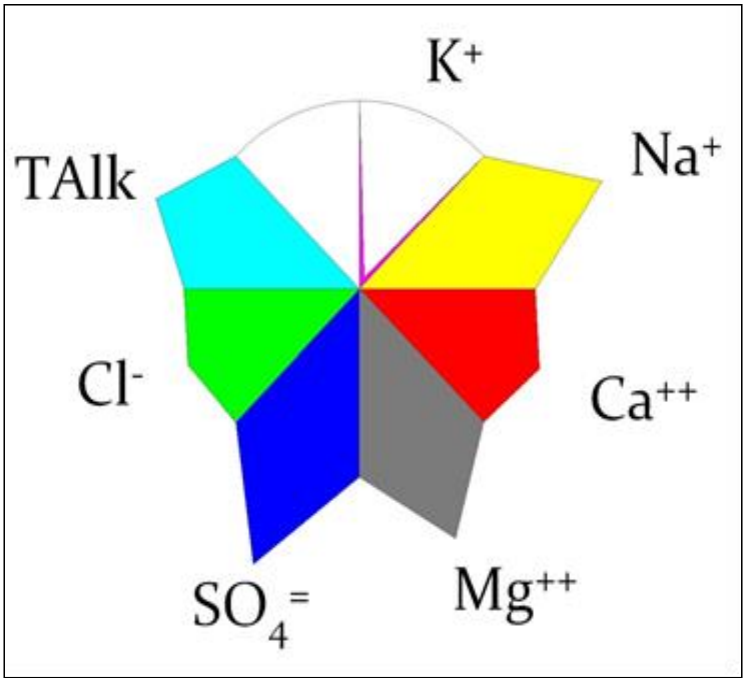



**Figure 22: Maucha ionic diagram (Maucha, 1932)**

#### 4.5 Aggregate organic constituent's results for wastewater samples collected in carwash facilities

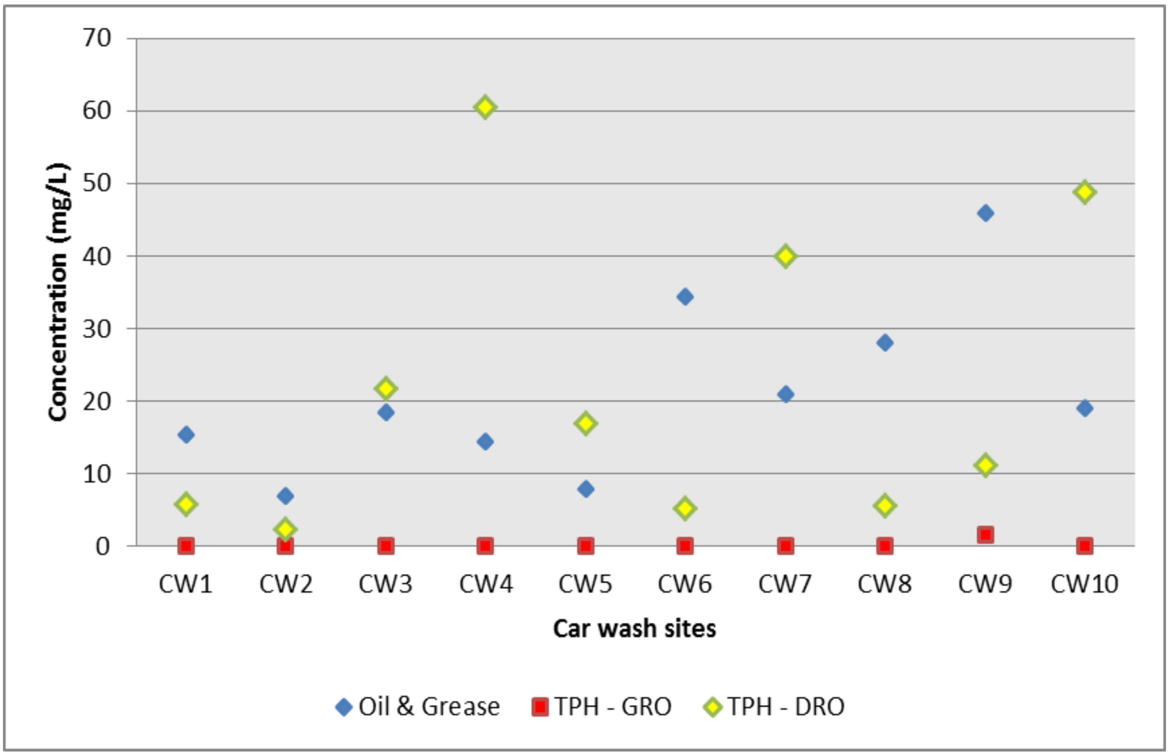



**Figure 23: Results for oil & grease and total petroleum hydrocarbons in the wastewater samples collected in carwash facilities.**

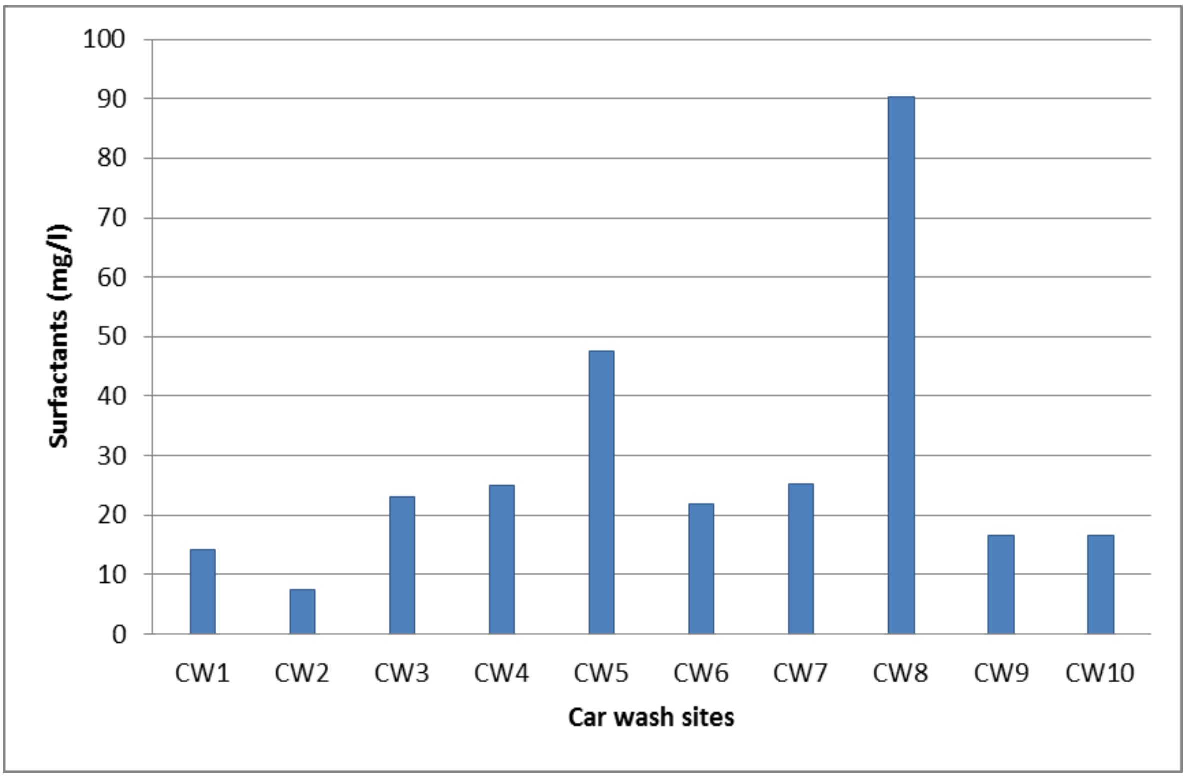



**Figure 24: Surfactants in the wastewater samples collected in carwash facilities.**

Oil and grease concentration in wastewater from all sites ranged between 3mg/l to 46mg/l and was within the Tshwane bylaws limit of 2000mg/l (Figure 23). The Tshwane limits for oil and grease is higher than the other guidelines, because the wastewater is discharged into the municipal sewer which will still undergo treatment before being discharge into the water resource. All sites exceeded the general limit in the National Water Act and the WHO effluent standards for effluent which is 2.5mg/l. There are no limits for total petroleum hydrocarbons in the Tshwane sanitation by-laws, National water act and WHO guidelines, but it is noted that in CW4, 7 and 10 diesel range organics were significantly higher than in other facilities with 60.56mg/L, 40mg/L and 48.85mg/L respectively . Oil and grease and diesel in the wastewater can be attributed to engine leaks from the vehicles or lubricant leakages in the car wash equipment's.

The Tshwane limit for surfactants is 500mg/l (Table 1) and the surfactant concentration in all the sites was within this limit (Figure 24). Surfactants can be attributed to the use of different detergents in the facilities.

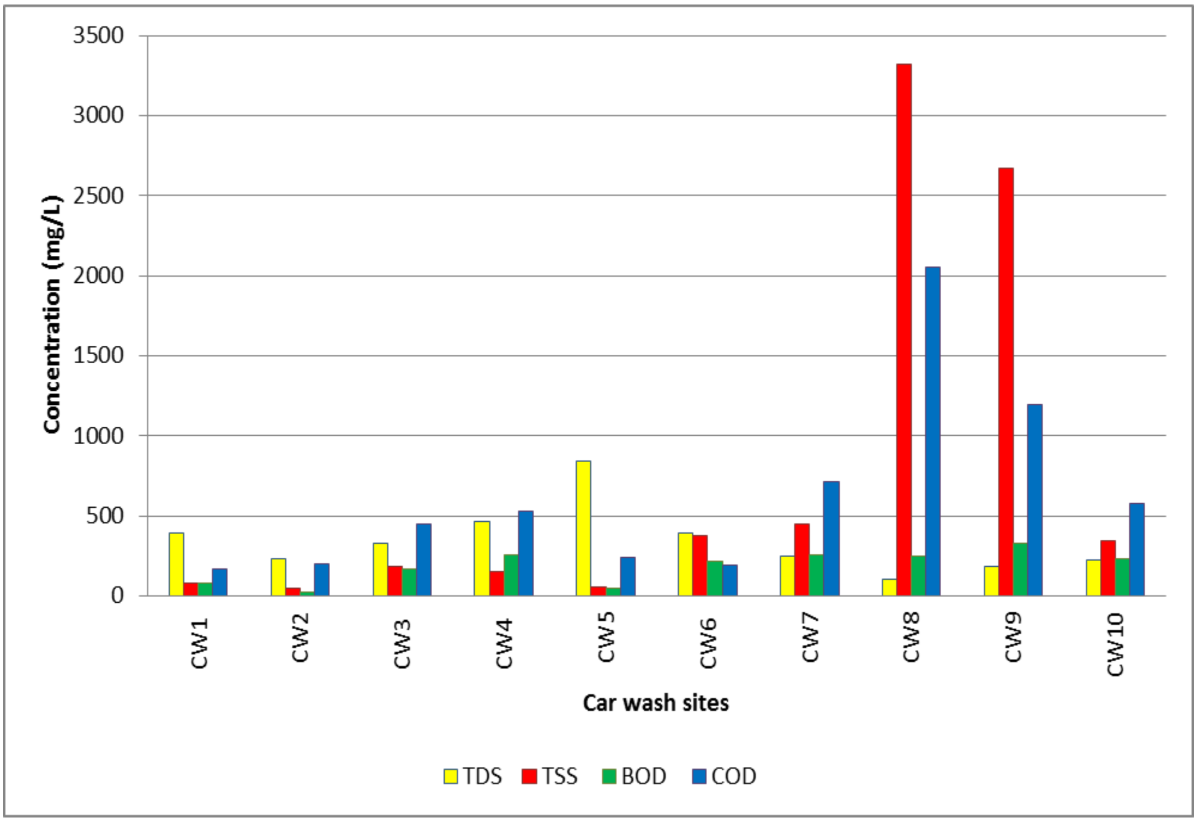



**Figure 25: TDS, TSS, BOD and COD in the wastewater samples collected in carwash facilities.**

It was found that the wastewater in all facilities had total suspended solids levels which exceeded the national water act and WHO standards of 25mg/l (Figure 25). Total suspended solids were very high in CW8 (3321mg/l) and CW9 (2670mg/l). Total suspended solids in the wastewater are contributed by the dirt, mud and debris that are washed off from the cars. The total dissolved solids concentration in all facilities was below 500mg/L except in CW5 which was 842mg/L. Biological oxygen demand and chemical oxygen demand levels in the wastewater for all facilities was high and exceeded the WHO limit of 30mg/l (BOD) and 60mg/l (COD) except CW2 with BOD of 27mg/L. The Tshwane limit for COD is however 5000mg/l and COD in all facilities were within this limit. COD can also be attributed to the higher suspended solids in the wastewater and chemical substances from detergents used to wash the cars, oil, greases and tyres (Mohamed *et al*., 2014).

## 4.6 Trace metal results for wastewater samples collected from carwash facilities

**Table 14: Trace metals results for wastewater samples collected from car wash facilities**

| Car wash sites | Cr (mg/l) | Cu (mg/l) | Fe (mg/l) | Mn (mg/l) | Zn (mg/l) | Pb (Mg/l) | Ni (mg/l) |
|---|---|---|---|---|---|---|---|
| **CW1** | <0.025 | 0.028* | 0.038 | 0.243* | 0.30* | <0.010 | <0.025 |
| **CW2** | <0.003 | 0.008 | 0.972* | 0.465* | <0.005 | <0.008 | <0.004 |
| **CW3** | <0.025 | 0.201* | 1.243* | 0.454* | 1.431* | <0.010 | 0.025 |
| **CW4** | <0.025 | 0.091* | 2.285* | 0.366* | 0.603* | 0.011 | <0.025 |
| **CW5** | <0.003 | <0.005 | 0.044 | 0.103 | <0.005 | <0.008 | <0.004 |
| **CW6** | <0.025 | 0.026* | 0.530* | 0.163* | 0.419* | <0.010 | <0.025 |
| **CW7** | <0.025 | 0.082* | nd | Nd | 1.41* | <0.010 | <0.025 |
| **CW8** | <0.025 | 0.108* | nd | Nd | 1.96* | <0.010 | <0.025 |
| **CW9** | <0.025 | 0.087* | nd | Nd | 1.65* | <0.010 | 0.040 |
| **CW10** | <0.025 | 0.102* | nd | Nd | 1.71* | <0.010 | <0.025 |

* Exceeded the limit, nd = test not done, <=below detection limit

Trace metal concentration in wastewater (Table 14) were generally low and were within the Tshwane limit of 20mg/l for all metals and 5mg/l for lead. The concentration of copper, iron, manganese and zinc although low exceeded the acceptable limits wastewater discharge into water resource by the National Water Act in most facilities. Zinc could come from the brake pads of the vehicles washed; copper and iron in the wastewater could have come from the rusted parts of the washed vehicles. Lead also present in the wastewater could have come from the tyres, car batteries and leaded fuel.

## 4.7 Toxicity results for wastewater samples collected in carwash facilities

For the single concentration screening tests, the toxicity was determined in the form of % inhibition and % stimulation for *Vibrio fischeri* and % mortality for *Daphnia pulex*. For the definitive tests the toxicity effects were determined as EC50 values and a toxicity unit (TUa) were then calculated. The toxicity screening test results for the wastewater samples are shown in Table 15 and 16.

**Table 15: Summary of *Vibrio Fischeri* bioluminescent screening test**

| Car wash sites | Average % inhibition (-) or stimulation (+) after 15 minutes | Average % inhibition (-) or stimulation (+) after 30 minutes | Toxicity unit (TUa) |
|---|---|---|---|
| CW1 | -31 | -35 | <1 |
| CW1 2nd sample | -53 | -53 | UR |
| CW2 | + 7.2 | + 6.9 | <1 |
| CW3 | -56 | -53 | 2.5 |
| CW3 2nd sample | -96 | -97 | UR |
| CW4 | -98 | -99 | 8.3 |
| CW4 2nd sample | -98 | -99 | UR |
| CW5 | -54 | -43 | <1 |
| CW6 | -24 | -23 | <1 |
| CW6 2nd sample | -34 | -37 | <1 |
| CW7 | -78 | -75 | UR |
| CW8 | -97 | -97 | UR |

| | | | |
|---|---|---|---|
| CW9 | -72 | -70 | UR |
| CW10 | -88 | -85 | UR |

UR = Insufficient toxicity data available from the screening results to determine TUa with certainty, [blue box] = limited to not acutely toxic and [yellow box] =mildly acutely toxic.

The results show that the wastewater samples were 100% toxic to *Daphnia pulex*, while population inhibition to *Vibrio fischeri* was also present in all wastewater samples except in CW2 which showed least toxicity with a population growth of 7.2% after 15 minutes and 6.9% after 30 minutes exposure. CW3, CW4 and CW8 showed the highest toxicity to *Vibrio fischeri* with CW3 and CW8 showing inhibition of 97%, and CW8 99% after 30 minutes of exposure.

The calculated toxicity units for CW3 and CW4 are 2.5 and 8.3 TUa respectively and according to the guidelines show mildly acute toxicity. In some sites only screening tests were performed for both *Daphnia pulex* and *Vibrio fischeri* and not definitive tests due to budget constraints and therefore toxicity units could not be calculated with certainty, thus the symbol UR is used.

**Table 16: Summary of *Daphnia pulex* acute toxicity screening test results**

| **Car wash sites** | **% mortality after 24 hours** | **% mortality after 48 hours** | **Toxicity unit (TUa)** |
|---|---|---|---|
| CW1 | 100 | 100 | UR |
| CW3 | 100 | 100 | UR |
| CW4 | 100 | 100 | UR |
| CW6 | 100 | 100 | UR |
| CW7 | 100 | 100 | UR |
| CW8 | 100 | 100 | UR |
| CW9 | 65 | 100 | UR |
| CW10 | 100 | 100 | UR |

UR = Insufficient toxicity data available from the screening results to determine TUa with certainty

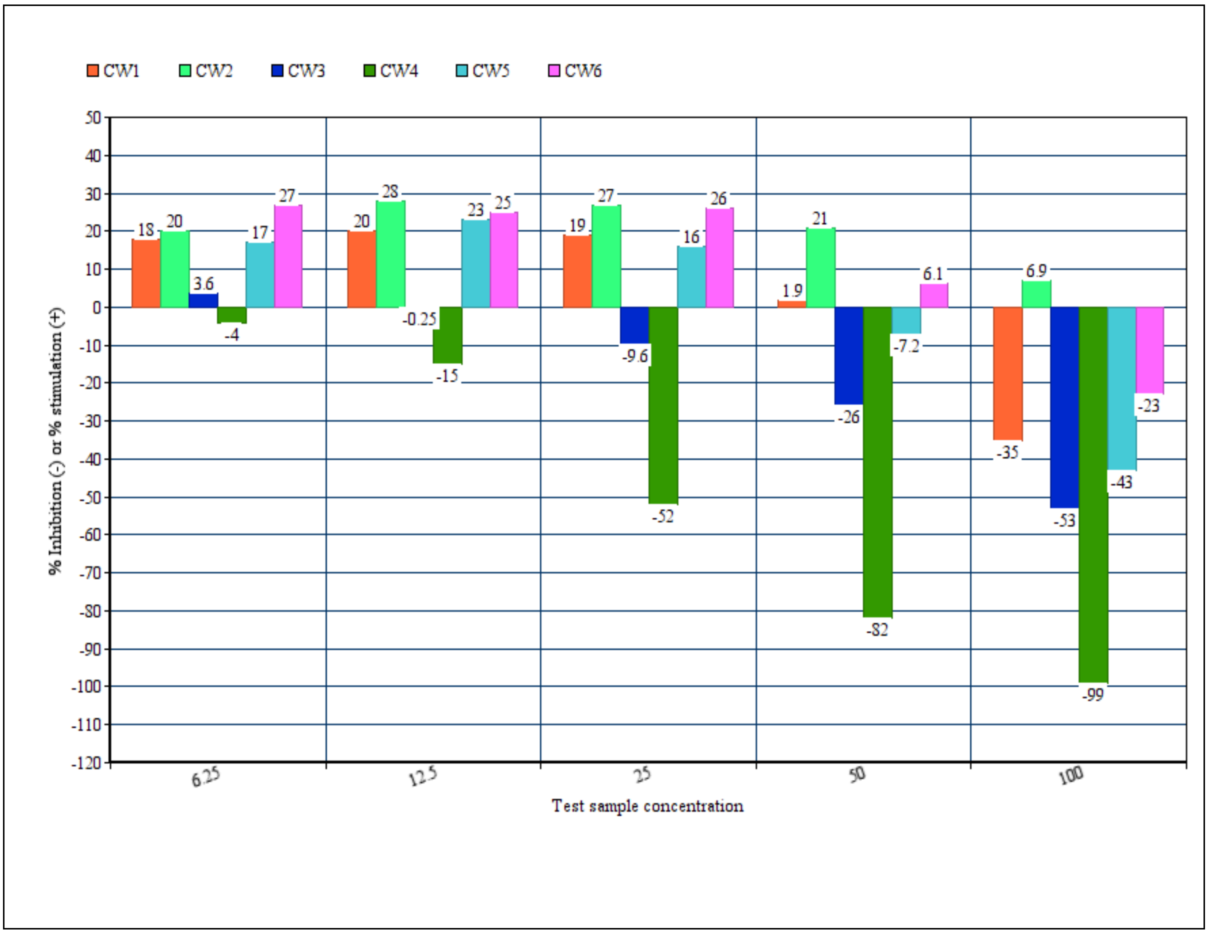



**Figure 26: Thirty minutes Vibrio fischeri bioluminescent toxicity test results**

The definitive test for *Vibrio fischeri* was only done for CW1 to CW6. The results for the definitive tests performed are shown in figure 26. The results show that CW3 and CW4 had the highest toxicity even in lower concentration of the sample there is still toxicity. CW2 does not show any toxicity.

## 4.8 Discussion of results

The results of the study show that most of the car wash facilities especially the commercial car washes had been operating for more than 1 year and only 20% had been operating for less than a year (Figure 10). The majority of the facilities perform the normal activities in a car wash such as washing the interior and exterior of the vehicle, washing the carpets and vacuuming using a variety of chemicals and detergents in the process. These facilities use huge amounts of drinking water every month and majority of them have no water conservation measures in place to conserve water. It is worth noting the large variation in water consumption between the facilities, and the most contributing factors to this difference is the type of equipment used to wash the cars and the number of cars washed in each facility. With South Africa currently facing water shortages and drought water conservation is of utmost important, especially drinking water. Although 60% of the facilities indicated they have permits to discharge wastewater effluent into the municipal sewer, no water quality monitoring of the wastewater is done by the facility owners and they are not aware of the quality of wastewater they discharge on a regular bases to the municipal sewer. In most developed countries car wash facilities are moving towards water reclamation, recycling and reuse technologies, to prevent pollution in the limited water resources and also to conserve the already scarce water resources. Studies conducted have shown that recycled water is acceptable to use in some processes in car washing as most of the pollutants have decreased (Al-Odwani *et al*., 2007; Zaneti *et al*., 2012). Although some facilities in this study did have water recycling systems many of the facilities did not have such facilities and it would be ideal if all car wash facilities could have recycling facilities to conserve the very limited water resources in South Africa.

The majority of the car wash managers/ owners were not aware of any guidelines and regulations governing carwash wastewater management and only 30% indicated that they have an idea that the wastewater should be managed such that there is no runoff to the storm water drains.

The study further demonstrate that carwash wastewater effluent mainly comprises of Surfactants, Oils and greases, suspended solids and trace metals which can have negative impacts on municipal wastewater purification facilities and can potentially impact on the water quality of the receiving waters. The results showed that some of the most problematic parameters in the wastewater of carwashes were turbidity, oil and grease, diesel, surfactants, suspended solids, chemical oxygen demand, biological oxygen demand, copper, iron, manganese and zinc. The pollutants found in the wastewater in this study are comparable with results from studies conducted in Ghana (Aikins & Boakye, 2015), Zimbabwe (Danha *et al*., 2014) and Washington (Smith & Shilley, 2009). These pollutants could have direct implications on the water quality of water resources; especially in informal carwash facilities that discharge water into storm drainage systems thus pollution surface water resources.

It was also discovered that the water from carwash effluent in most sites were hard waters. Hardness is due to the presence of ions such as calcium and magnesium. Hard water can be problematic especially to those facilities that recycle and reuse the water because hard waters neutralize the lathering power of soap thus more soap needs to be used representing an economic loss to the user (Spellman, 2014). In order to overcome this problem most of the facilities that recycle the water use water softeners to soften the hard water. Hard waters can also be problematic in municipal treatment works because they can cause blockages in pipes (U.S.EPA, 2001). Furthermore the present study revealed that the effluents from selected car washes also contained surfactants, greases and oils (Figure 23 & 24). According to Spellman (2004), surfactants and greases are of concern as they reduce the oxygen uptake in biological processes and affect wastewater treatment processes. Grease in the wastewater is also incriminated as the course of fouling in the wastewater treatment plant leading to the reduction of hydraulic capacity of sewers (Yasin *et al*., 2012). The high presence of grease, oils and surfactants were also noted by the presence of high concentration of COD and BOD in the collected effluents (Figure 25).

COD and BOD were problematic in the carwash wastewater and this was also the case in a study conducted in Pakistan by (Yasin *et al*., 2012). Oil, diesel and gasoline together with animal dung and bird droppings from the cars washed contribute to high levels of BOD and COD in the wastewater. Another contributing factor in BOD levels were detergents and shampoos used to wash the cars (Yasin *et al*., 2012). Regardless of high concern of organic matters, inorganic matters such as heavy metals have also been reported in the collected samples although at very low concentration with exception of Zn, Cu, Fe and Mn which exceeded the maximum limits as set by WHO (Table 1).

The study results also revealed that the wastewater from the carwash bays showed toxicity to the crustacean species *Daphnia pulex* and bacteria *Vibrio fischeri*. Toxic wastewater can also be problematic in the treatment processes because the pollutants can kill important microorganisms that are required in the biological treatment processes thus stopping the process. These toxicity test results support the intuitive expectation that car wash wastewaters may adversely affect surface receiving waters and municipal wastewater treatment processes. It should however be noted that the definitive tests were not done in all wastewater samples and the toxicity units could not be calculated for all the sites therefore the level of toxicity could not be determined with certainty.

Results show that the differences in car wash type whether commercial or informal car wash are not the determinant factors in the variation that was observed. The contributing factors to the differences observed in the different facilities could have been the types and concentrations of cleaning solutions used, the number of cars washed in each facilities and the way of washing, whether the facility has water treatment facilities in the car wash or not.

# CHAPTER 5: CONCLUSIONS & RECCOMMENDATIONS

## 5.1. Conclusion

Water pollution is a problem worldwide and this is demonstrated in research quoted in this study. The results obtained in this study indicate that carwash wastewater effluents can have impacts on some aspects of water quality in surface waters and in wastewater treatment works. Although sampling in this study could have been increased to improve quality of results, it is demonstrated by the study that if carwash wastewaters are not properly managed, it can contribute to pollution in water resources.

Commercial carwashes discharge their wastewater into the municipal sewer system which undergoes treatment in the municipal waste water treatment system prior to discharge into water resources, but compared to home car washing that is performed in driveways and parking lots, informal carwashes, city streets, taxi ranks and informal carwashes in the townships, these contaminants from the surface of the cars are not captured and can be assumed to be entering the storm water systems and thus into local surface or groundwater's. These are the more problematic facilities and if not properly managed can deteriorate the quality of the very scarce water resources in South Africa.

The results from this study demonstrate that although the pollution from car washing might be considered insignificant, however when considering the number of car washes discharging effluent every day for a whole year, this pollutant loadings become more significant especially the informal wash bays that discharge untreated wastewaters into natural resources.

The local municipality manages the sewage works where different industries discharge their effluents including car washes, and although the municipality has monitoring programmes in place to ensure environmental protection, the challenge remains with the informal and illegal car washes which are difficult to manage or enforce regulations.

## 5.2. Recommendations

The following are recommended based on the results obtained from the study:

### Recommendations to the municipality

- More should be done by the municipality to ensure that car wash owners & managers are informed on carwash wastewater management and regulations policies, and are given copies of the bylaws with limits for their wastewater discharged.
- Training programmes and initiatives must be developed for operators in the carwashes and they must be encouraged to properly manage water and wastewater to avoid wastewater running off to storm drains.
- The municipality must take action to regulate the informal car washing facilities in the city.
- In light of the Provincial government's objective to revitalise township communities by building township car washes, careful consideration should be taken to balance job creation and environmental protection. What could be considered in the introduction of these facilities, together with recycling technologies already considered, is rainwater harvesting systems and using waterless car wash technologies.
- Effective public education efforts must be initiated to change behaviours and encourage car owners to wash their cars in professional car washes and if they wash their cars at home to wash in gravelled areas and avoid runoff to storm drains.

### Recommendations to car wash facilities

- Car wash facility managers should put more efforts into learning and understanding the cities regulations/ bylaws governing car washes and should make sure that they abide by them.
- Harsh and toxic detergents use at the car washes such as detergents containing sulphates, phosphates and substances classified as carcinogenic, mutagenic and toxic should be avoided and discouraged.

**Recommendations for future research**

- Further and future research studies that can be considered include widening the scope of this research by including more samples and looking at the distribution of microbes in the car wash and adding more tests in toxicity studies.
- Looking at the volume of discharge from car washes into municipal sewers, sampling river sites located near carwash facilities, options for pre-treatment and water reuse/recycling.
- Options such as using harvested rainwater in the carwashes should be looked at as a means to conserve water.
- Further survey studies on car washing practices to obtain knowledge on public perceptions regarding car washers and to discover car washing attitudes and behaviours, this can assist in developing informational campaigns on car washing.

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## APPENDICES

**APPENDIX A**

**CONSENT FORM**

**TITLE OF RESEARCH PROJECT**

**An evaluation of water quality and toxicity of wastewater in selected carwash facilities in Tshwane, Gauteng.**

**Dear Mr/Mrs/Miss/Ms________________________________Date: 06/05/2014**

I write to request for permission to carry out a research study titled: An evaluation of water quality and toxicity of wastewater in the carwash industry in Gauteng province. The study is for a Masters dissertation by Mrs. Sbongile Phungula, conducted under the supervision of Prof M. Tekere and Mr. K.W. Maphangwa at UNISA, 2014 to 2015.

**NATURE AND PURPOSE OF THE STUDY.**

The purposes of the study are to evaluate the level of car wash activities, water management, water quality analyses and opportunities for bio-monitoring, water conservation and regulatory structure review in the car wash industries. Evaluation of car wash water conservation and reclamation allows for an understanding of the different systems in use, their efficiency, possibilities for improvement and may assist responsible authorities to create and institute laws on car wash water use.

**RESEARCH PROCESS**

The study will involve the use of interviews and observations including some site photography, to get an overview of the facility operations and practices. Additionally water samples for water quality analysis will also be collected.

**NOTIFICATION THAT PHOTOGRAPHIC MATERIAL, TAPE RECORDINGS, ETC WILL BE REQUIRED**

- No tape recording will be done during the interview and questionnaire answering but the researcher will take photographs during site observations and water sampling.

**CONFIDENTIALITY**

The researcher guarantees that the information gathered in this study is for research purposes and possible conference presentations and publication in scientific journals. Issues of privacy and confidentiality with regards to respondents and data will be observed at all times during the research and publication process. In addition, neither the researcher nor UNISA will take responsibility for a respondent who provides information that harms the reputation of their company.

**WITHDRAWAL CLAUSE**

- A company and/ or representative thereof have the right to pull out of the research process at any time by notifying the researchers.

**POTENTIAL BENEFITS OF THE STUDY**

It is hoped that among others the study will add to knowledge on water quality and conservation by car wash facilities in Gauteng. The potential, challenges and incentives for water use minimization and recycling in the car wash industry in South Africa will also be documented. Additionally efficiency in water management can lead to reduced water costs and future job security.

**INFORMATION (contact information of your supervisor)**

- If you have any question concerning the study you may contact the project leader, Prof Memory Tekere, at the Department of Environmental Sciences, Florida Campus, UNISA.
- Tel +27 11 471 2270. Fax +27 11 471 2866 email tekerm@unisa.ac.za

**CONSENT**

I, the undersigned………………………………………………………, (full name) have read the above information relating the research and have also heard the verbal version, and declare that I understand it. I have been afforded the opportunity to discuss relevant aspects of the research with the researcher, and hereby declare that I agree voluntarily to participate in the project.

I indemnify the university and any employee or student of the university against any liability that I may incur during the course of the project.

I further undertake to make no claim against the university in respect of damages to my person or reputation that may be incurred as a result of the research or through the fault of other participants, unless resulting from negligence on the part of the university, its employees or students.

I have received a signed copy of this consent form.

Signature of participant…………………………………………………………………

Signed at ………………………………… on …………………………………………….

WITNESSES

1 .........................................................................................................................

2 ..........................................................................................................................

**APPENDIX B**

**QUESTIONAIRE**

**Dear Respondent.**

This data generation instrument has been developed as part of a research process leading to the research on: **An evaluation of water quality and toxicity of wastewater in selected carwash facilities in Tshwane, Gauteng**. The study is being undertaken by Sbongile Phungula a Masters student at the University of South Africa. The research study aims to evaluate the level of car wash activities, water management and water quality in the car wash industries in Gauteng, addressing sustainable water use and management in the car was businesses. Your voluntary participation in this study is being requested.

The researcher guarantees that the information gathered through this instrument is for research purposes and possible conference presentations and publication in scientific journals. Issues of privacy and confidentiality with regards to respondents and data will be observed at all times during the research and publication process. A company and/ or representative thereof have the right to pull out of the research process at any time with notification to the researchers. The researchers will try their best not to cause physical or emotional harm in any way. In addition, neither the researcher nor UNISA will take responsibility for a respondent who provides information that harms the reputation of their company.

Thank you

Mrs Sbongile Phungula

---

## Questionnaire/Interview Guide

Name of Company: ---------------------------------------------------------------------------

Location of business ---------------------------------------------------------------------------

Classification of carwash ---------------------------------------------------------------------

(Researcher to complete)
Name of Researcher(s): ----------------------------------------------------------------------

Name of Respondent:------------------------------------------------------------------------------

Title of Respondent:--------------------------------------------------------------------------------

Contacts of Respondent:--------------------------------------------------------------------------

1. How many years has your car wash been operating?

| | |
|---|---|
| Less than 1 yr | |
| 1-3yrs | |
| 4-5yrs | |
| 6-10yrs | |
| More than 10 yrs | |

2. List all your car wash business activities.

| |
|---|
| 1. |
| 2. |
| 3. |
| 4. |
| 5. |
| 6. |

3. How much water (volume) do you use a month? (Provide annual consumption data/records)

4. How and where do you discharge wastewater from your operations?

5. Provide a list of chemical inputs used in your operations

| | |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |

6. Which ones of the following are of concern in your wash wastewater? (Tick as many as possible)

| | |
|---|---|
| Oil and grease, | |
| Detergents | |
| Phosphates | |

| | |
|---|---|
| Phosphates, | |
| Chemicals, such as hydrofluoric acid and ammonium bifluoride products (ABF), and solvent-based solutions | |
| Chemicals and oils used for the maintenance of cleaning machinery (for automatic systems) | |
| Debris that can clog storm sewer inlets and grates and thereby prevent storm water drainage to the sewer | |

7. Do you have a permit for waste water discharge?

| | |
|---|---|
| Yes | No |

8. Do you have any measures in place to prevent groundwater contamination? (Provide details)

| | |
|---|---|
| Yes | No |

9. Do you know the quality of your waste water discharge?

| | |
|---|---|
| Yes | No |

If yes provide water quality data

10. Do you do water quality testing and monitoring? If Yes, how often? Tick

| | |
|---|---|
| Yes<br>Daily<br>Weekly<br>Monthly<br>Any other | No |

11. Which of the following water treatment systems do use at your facilities:

| | |
|---|---|
| An oil/water separator | |
| Wastewater recycling system | |
| Grit chamber | |
| Any other | |

12. What do you do before waste water is discharged:(Tick)

| | |
|---|---|
| Filtration | |

| | |
|---|---|
| Capture and recycle as much wastewater | |
| Add water softener | |
| Any other | |

13. List all the measures you have in place for water conservation.

| |
|---|
| |
| |
| |
| |
| |
| |

14. Would you be willing to be involved in waste water management programs to improve water and waste water management in your operations?

| | |
|---|---|
| Yes | No |

15. In your own view, how can you better manage your waste water?

| | |
|---|---|
| Filtering | |
| Recycling | |
| | |
| Any other | |

16. Are you aware of any regulations governing car wash water and waste water management?

| | |
|---|---|
| Yes<br>(if Yes, write those you are aware of) | No |

17. Are you aware of any waste water quality discharge limits imposed on your operations by the local authorities?

| | |
|---|---|
| Yes | No |

If yes, give further details.

18. If you have any other issues, please elaborate accordingly.

Thank you for taking time to respond.

**APPENDIX C**

## CAES RESEARCH ETHICS REVIEW COMMITTEE

Date: 03/09/2014

Ref #: **2014/CAES/115**
Name of applicant: **SP Phungula**
Student #: **55773397**

Dear Ms Phungula,

**Decision: Ethics Approval**

---

**Supervisor:** Prof M Tekere

**Proposal:** An evaluation of the water quality and toxicity of waste water in the car wash industry in Gauteng

**Qualification:** Postgraduate degree

---

Thank you for the application for research ethics clearance by the CAES Research Ethics Review Committee for the above mentioned research. Final approval is granted for the duration of the project.

Please consider point 4 below for further action.

*The resubmitted documentation was reviewed in compliance with the Unisa Policy on Research Ethics by the CAES Research Ethics Review Committee on 03 September 2014.*

*The proposed research may now commence with the proviso that:*

1) *The researcher/s will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.*
2) *Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study, as well as changes in the methodology, should be communicated in writing to the CAES Ethics Review Committee. An amended application could be requested if there are substantial changes from the existing proposal, especially if those changes affect any of the study-related risks for the research participants.*
3) *The researcher will ensure that the research project adheres to any applicable*

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Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

*national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study.*

4) *The accreditation of the laboratory is noted, as well as the fact that the student is an employee at this laboratory and has access to the facilities. However, the Committee still requires a permission letter from the laboratory indicating that she may use the facility for study purposes.*

*Note:*
*The reference number [top right corner of this communiqué] should be clearly indicated on all forms of communication [e.g. Webmail, E-mail messages, letters] with the intended research participants, as well as with the CAES RERC.*

Kind regards,

well done

Signature
CAES RERC Chair: Prof EL Kempen

Signature
CAES Executive Dean: Prof MJ Linington

Approval template 2014

University of South Africa
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CITY OF
TSHWANE
IGNITING EXCELLENCE

Office of the Executive Mayor
Research and Innovation Unit

Innovation Hub| Mark Shuttleworth Street | Sappi Technology Centre I Lynwood I 0087
PO Box 440 I Pretoria I 0001
Tel: 012 358 2000 I Fax: 012 358 4464
Email: Zukiswanc@tshwane.gov.za I www.tshwane.gov.za | www.facebook.com/CityOf Tshwane

| | | | |
|---|---|---|---|
| My ref: | Research Permission | Tel: | 012 358 2000 |
| Your ref: | | Fax: | 012 358 4464 |
| Contact person: | Zukiswa Ncunyana | Email: | Zukiswanc@tshwane.gov.za |
| Section/Unit: | Research and Innovation | | |

**TO:** **Ms Sbongile Phungula**
118 Piccolo, 270 Von Willich ave,
Centurion
0157

**DATE: 17 August 2015**

Dear Ms Phungula,

**Approval to Conduct Research within the City of Tshwane Metropolitan Municipality**

I have the pleasure to inform you that your request to conduct research on the topic ***"An Evaluation of the Water Quality and Toxicity of Wastewater in the Car Wash Industry in the City of Tshwane,Gauteng"*** has been reviewed and permission is hereby granted for you to conduct research in the City of Tshwane Metropolitan Municipality.

It is noted that your research seeks to evaluate the level of car wash activities and waste water use in the carwash industry and to collect and analyse wastewater quality from the carwash industries in selected areas. The City of Tshwane further notes that all ethical aspects of your research study will be covered within the provisions of the University of South Africa's Research Ethics Policy. In addition, as a researcher you are required to sign the Confidentiality Agreement Form with the City of Tshwane prior to conducting the research.

Research and Innovation Unit will be facilitating the process; therefore all correspondence should be directed through the Unit. Upon completion of your research, you are required to present and submit final report on the findings to the City of Tshwane Metropolitan Municipality.

Yours faithfully

**Dorah Nteo (Ms)**
Acting Chief of Staff
Office of the Executive Mayor

**Date**

C40 CITIES
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Kgoro ya Dinyakišišo le Mpšafatšo Umnyango • Wezokucwaninga Nezobuchule • Departement Navorsing en Innovering •
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