UNIVERSITY OF EDUCATION, WINNEBA

CONTRIBUTION OF WASHING BAYS TOWARD URBAN AQUATIC POLLUTION: A CASE STUDY OF TECHIMAN AND NKORANZA MUNICIPALITIES

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CANDIDATE'S DECLARATION

I, GEORGE GYIMAH ACHEAMPONG, hereby declare that except references to other people's works which have been duly acknowledged, this thesis is my own original work towards the award of a Master of Philosophy in Environmental and Occupational Health Education, and that this thesis or part has not been accepted for the award of a degree in this university, or elsewhere.

SIGNATURE:……………….……………………

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SUPERVISORS' DECLARATION

We hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of thesis as laid down by the University of Education Winneba.

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DEDICATION

I dedicate this work to my lovely and caring wife Theresa Gyimah Acheampong (Mrs.)

ACKNOWLEDGEMENT

My profound gratitude goes to JEHOVAH for the guidance and protection throughout my work. I owe great debt to my supervisors Prof. Richard Amankwah Kuffour, Dr. Isaac Monney and Dr. Bismark Dwumfour-Asare for their effective criticisms toward the attainment of this research work. May JEHOVAH continually bless you all.

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ABSTRACT

Washing bays businesses have gained popularity in urban Ghana. These washing bays use huge volumes of water and discharge dangerous chemicals into the environment through their activities. There is therefore the need to regulate the operations of the vehicle washing bays to ensure water conservation and its associated environmental and social impacts. This study estimated the water quantities used to wash different vehicles types and the pollution loads of the resulting wastewater in Techiman and Nkoranza Municipalities, Ghana. Twenty-two functional washing bays were purposively selected and monitored to estimate the water used to wash six different categories of vehicles and wastewater generated. Composite wastewater samples from two washing bays were analysed for concentrations of different contaminants which were used to calculate pollution loads. Data was entered on excel sheet and transported to SPSS for analysis. Frequencies and percentages were developed. The level of significance was set at $P \leq 0.05$. The study showed that average volume of water used for washing each category of vehicle per day were as follow: Motorbike/Mopeds 107 L, Saloon car 162 L, Pickups 249 L, Buses/Coaches 266 L, Graders/Loaders 1159 L, Heavy articulators 1246 L. The wastewater was characterized by pH (7.4-7.6), TSS (857-2624 mg/L), TDS (125.5-148.6 mg/L), SO_4^{2-} (66-68 mg/L), PO_4^{3-} (0.37-0.41 mg/L) and turbidity (1190-1680 NTU). Pollutant loads for BOD up to 0.9 tons from Techiman and 0.8 tons from Nkoranza could be released in a year. COD up to 2 tons from Techiman and 2 tons from Nkoranza could also be released in a year. The wastewater has a low biodegradability index of 0.4. The study therefore concluded that, activities of washing bays in Techiman and Nkoranza pollute water bodies. It was recommended that washing bays adopt recycling method so that wastewater can be reused.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Sustainable water resources are essential for socioeconomic development, and yet water is often misused and wasted in today's society (Assayed, 2003). One potential source of water for supplementing fresh water resources which is gradually becoming scarce around the world due to high pressure and cost is wastewater. When a vehicle is washed, a large volume of otherwise potable water is turned into heavily polluted water which ends up in streams, rivers and oceans. Per available literature, about 150 L of water is used to wash a car in a commercial car wash facility (Tammiazo *et al.*, 2015) while between 400-600 L of water is required to wash trucks and buses.

Water is a strategically limited natural resource, and currently some cities in Ghana are in the grip of persistent water shortage (Grönwall & Oduro-Kwarteng, 2018). Sustainable management of water is crucial for every country. Water reuse succeeds in saving money spent by water authorities, reduces sewage flows and reduces the public demand on potable water supplies. By reusing wastewater, water is conserved and money is saved.

Worst of all, the resulting wastewater from the carwash facilities is usually loaded with dirt, oils and grease, heavy metals and detergents mostly ending up in streams (Bhatti *et al.*, 2011). When fishes are exposed to oils in wastewater, they may experience reduced growth, enlarged livers, and changes in heart and respiration rates. Wastewater may also inhibit plant growth (Kirby *et al.*, 2019). Heavy metals that come from brake linings, tyres and engine oils can bioaccumulate in fish tissue and move up the food chain to reach humans (Tiwary, 2001).

Access to safe and clean water is important as a health and development issue at national, regional and local levels (WHO, 2006). A large proportion of the World's population do not have access to improved or microbiologically safe sources of water for drinking and other essential purposes. In 2015, the percentage of those with an adequate supply of water was found to be 94% in urban areas and 71% in rural areas worldwide. About 2 million deaths per year were reported worldwide due to unsafe water, mostly due to waterborne, preventable diarrheal diseases.

According to UNICEF (2012), worldwide, 780 million people do not have access to safe water, and an estimated 2.5 billion people in developing world lived without access to adequate sanitation. The Pruss-Ustun *et al.*, (2008) estimated 6.3% of all deaths are caused by limited access to safe drinking water. Without doubt, the unreasonable water usage by the carwash facilities weakens water security and impends poor ecosystem health, especially in the urban setting.

According to Fewtrell *et al.*, (2005), improvement in water supply, management practices and water quality, reduced the risk of diarrheal-related morbidity by 25%, 31%, and 32%, respectively. Bhavnani *et al.,* (2014) concluded that unimproved water source (rivers, ponds, lakes and unprotected springs) and unimproved sanitation are the major risk factors of diarrhoea in Ghana. In some cities the water systems abstract unsafe water from unprotected or contaminated sources and deliver it to consumers with no or inadequate treatment, yet these water systems are classified or categorized as improved and safe. Another problem contributing to the underestimation of the population served by unsafe water is water scarcity due to poor water management practices and contamination of water during distribution whether water is piped or carried into the home (WHO, 2002).

In Ghana, washing of vehicles on the banks of streams and rivers is a common practice. Urbanization has provided an opportunity for individuals sustaining livelihoods through washing of vehicles along river banks. Activities of washing bays very close to streams pose a substantial health risk not only to the communities concerned but also to those downstream. Washing bays produce large volumes of wastewater which may contain high levels of suspended solids, elements from brake linings, rust, oil and grease, heavy metals, phosphorous and organic matter (Aikins & Boakye, 2015). Unavailability of right structures for preventing discharge into water bodies as well as detergents, engine leaks and spills (e.g. oil, coolant, brake fluid) entering water bodies untreated have contributed to the pollution of water bodies (Delcarme & Daries, 2018). Thus, this study sought to assess the contribution of washing bays toward urban water pollution in Techiman and Nkoranza Municipalities in the Brong East Region of Ghana.

1.2 Problem Statement

Ghana has a tropical climate and is gifted with plentiful water resources. The mean annual rainfall is 1180 mm (MoFA, 2016), but generally decreases from the South-West of the country (2,000 mm/year) towards the north (950 mm/year) and the southeast (800 mm/year) (Monney *et al.*, 2020). The Volta River is the largest river in the country and includes the largest non-natural lake in the world (Monney *et al.*, 2020).

Water resources in the country are generally under the threat of pollution and climate change. Most vehicle owners in the country resort to car washing bays and pay an amount of money for washing of their cars. These car washers at the washing bays resort to all kinds of activities such as using soap and detergent to wash car engines, interior, undercarriage, exterior cleaning and among others. The wastewater generated is left untreated and channelled directly into nearby streams and rivers (Tembo *et al.*, 2017;Edokpayi *et al.*, 2017). The washing bays appear to be unregulated and personnel in the car wash business seem not to understand the impact of their practices on local water quality degradation (Aikins & Boakye, 2015).

1.3 Objective of the Study

The main objective of this research was to assess contribution of washing bays toward urban water pollution in Techiman and Nkoranza Municipalities in Ghana.

1.4 Specific Objectives

The specific objectives were:

1. To quantify the volume of water used by the washing bays for various or specific cars;
2. To estimate the volume of wastewater generated per day;
3. To characterize car wash wastewater generated per day;
4. To determine pollutant loads associated with car wash wastewater generation.

1.5 Research Questions

To achieve the objectives of this research, the study was guided by the following questions:

1. What materials are used in washing of vehicles?
2. How often are vehicles washed?
3. What volumes of water are used for specific vehicles or car type?
4. How is the wastewater discharged?
5. What are the characteristics of water and wastewater generated?
6. What is the magnitude of the pollutant loads for the wastewater and to receiving water bodies?

1.6 Justification

In Ghana, most vehicle owners do resort to car washing bays for washing of their cars. The wastewater from these washing bays directly flows into nearby streams and rivers. As a result, the receiving streams and rivers become polluted (Edokpayi *et al*., 2017). The inhabitants use the water for domestic purposes and farmers also use it to irrigate their crops. Aquatic animals are also likely to be affected. By far there is no available data that describes the characteristics of wastewater generated from washing bays in Techiman and Nkoranza Municipalities. This study helped to quantify the volume of water used, estimate the volume of wastewater generated in a day, characterize car wash wastewater and estimate the pollutant load.

1.7 Significance of the Study

The study was of immense benefit to the car washers because most people do not know the dangers of polluting water bodies through their activities. The study also served as medium through which various institutions involved in water conservation will use in educating people especially those in washing bays. The study also served as a basis/springboard for further research.

1.8 Limitation and Scope of the Study

The study focused on the water used, the wastewater generated and wastewater characterization. A general study would have been better since the problem is countrywide. However, due to resource constraints, the study was restricted to Techiman and Nkoranza Municipalities. Nonetheless, it is worth noting that this limitation did not to affect the objectives and findings of this research work in any significant way. Despite this limitation, analyses from the data which were obtainable were sufficient to provide meaningful conclusions to the research questions.

1.9 Organization of the Report

Chapter one introduces the study and provides the outline of the study. It also captures the background information, problem statement, objective of the study, research questions, significance of the study, scope of the research, limitations and delimitations of the study. Chapter two dealt with the review of literature related to the subject of study. The review involved in-depth studies related to the problem under study. The third chapter describes the methodology used in the study. Specifically, the research design, the research instrument, sample and sampling technique, water quality analysis, the procedures for data collection and the data analysis were discussed. The analysis, results and discussion were presented in chapter four. This chapter captured the interpretation of all the interview responses and content analysis of the data collected on the field of study. The data analysis was done using the Statistical Package for the Social Science. The interpretations were presented in the form of graphs and pie charts. Explanations to the data analysis were done using some of the responses collected during the field study and the available secondary data. In chapter five, the main focus was the summary, conclusions and recommendations. This chapter provided a summary of all the chapters in the study. In addition, the chapter also made few recommendations on alternative development approach before drawing a conclusion on the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

A car wash station or otherwise known as washing bay is defined as a non-domestic installation for external and internal cleaning of vehicles (Phungula, 2016; Zayadi, 2017). The car washing process consists of two to three steps (Akafuah *et al*., 2016): High pressure water used to remove soil particles in the first step which is called the dust cleaning step. The second step involves degreasing agent which is sprayed over the car surface. The degreasing agent solubilizes the pollutants and removes them from the car body. In the third stage, the car is washed with water including wax to keep water away from the surface of the car and to protect the surface from abrasion (Boussu *et al.,* 2014). When a car is washed, high volume of wastewater is generated and released into the environment.

There are different sources of wastewater which include domestic, industrial, commercial, agricultural activities, surface runoff or storm water, any sewer inflow or sewer infiltration, horticultural, aquaculture effluent. Commercial wastewater comes from non-domestic sources, such as beauty salon, taxidermy, furniture refinishing, musical instrument cleaning, or auto body repair shops, vehicle washing stations (Peter, 2015). Huge volumes of wastewater is generated from these areas especially the vehicle washing bays. For instance, a regular tunnel car washes wastes as much as 120 L of water per vehicle. Also, self-washing of cars wastes about 800 L of water with every wash. According to Monney *et al.,* (2020), washing bays in Kumasi Metropolis could use about 1,000m^3 of fresh water to wash vehicles per day. Zangmo,

(2016) stated that a study conducted by the Asian Development Bank (ADB) Bhutan, recorded approximately 6.5 million liters of vehicle wash wastewater every year.

These washing bays use water from rivers and streams, hand dug well/boreholes, pipe borne and water from tankers for their operations. Car washers in these washing bays are usually school drop outs and senior high school leavers.

In Ghana, the Environmental Protection Agency Act of 1994 (ACT 490) prescribes standards and guidelines relating to safeguarding environmental pollution including the discharge of wastes and control of toxic substances. Regrettably, Abraham, (2011) highlighted that most vehicle washing bays are violating the Environmental Protection Agency ACT by discharging untreated wastewater directly into streams and rivers.

2.2 Car Wash Wastewater Characteristics

Wastewater has been defined slightly different by experts across the world. Allen *et al.*, (2010) stated that wastewater is the water generated from household uses such as bathing and washing clothes. Sources of wastewater include bathtubs, showers, sinks, floor drains and washing machines, which although no longer clean, is not as contaminated as toilet water. In many utility systems around the globe, wastewater is pointed out as combined with black water in a single domestic wastewater stream. Yet wastewater can be of far higher quality than black water because of its low level of contamination and higher potential for reuse (Mohammed *et al.*, 2012).

2.2.1 Car wash wastewater quality

The determination of car wash wastewater quality can be assessed by its Physical, Chemical and Biological Characteristics.

2.2.2 Physical characteristics

The physical parameters of wastewater include temperature, turbidity, total suspended solids, conductivity, total dissolved solids etc. These characteristics are used to assess the reuse potential of wastewater and to determine the most suitable type of operation and processes for its treatment (Bener *et al*., 2019).

2.2.2.1 Temperature

The temperature of the wastewater is a very important parameter as it affects the rate of both the chemical and biological treatment. High temperatures increase the solubility of the chemicals for treatment and microbial action is more effective. However low temperatures slow microbial activity and more chemicals will be required (Baveye *et al*., 2018). Wastewater temperature also affects receiving waters. Hot water when discharged in large quantities raises the temperature of receiving streams and disrupt the natural balance of aquatic life. Increased temperature, for example, could cause a change in the species of fish that could exist in the receiving water body (Gallardo & Aldridge, 2018) . Another important example of the effects of temperature on water chemistry is its impact on oxygen. Warm water holds less oxygen than cool water, so it may be saturated with oxygen but still not contain enough for survival of aquatic invertebrates or certain fishes. Some compounds are also more toxic to aquatic life at higher temperatures since the rate of reaction increases with increasing temperature. Generally, high temperatures favour pathogen removal. However, in some instances, it leads to increase in numbers of pathogens (Al-Gheethi *et al*., 2018). High temperature is good for removing wastewater constituents like nitrogen through volatilisation (Kube *et al.,* 2018).

2.2.2.2 Turbidity

Turbidity is an expression of the optical property of water/wastewater that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. Turbidity is caused by suspended and colloidal particulate matter such as clay, silt, and finely divided organic and inorganic matter, plankton and other microscopic organisms. It is another test used to indicate water quality of waste discharges and natural waters with respect to colloidal and residual suspended matter. It is measured in NTU (Nephelometric turbidity units) using a turbidity meter, however different readings can be obtained using different kinds of meters (Trevathan *et al*., 2020). As observed by Fish *et al.*, (2020) high levels of turbidity can protect microorganisms from the effects of disinfection, stimulate the growth of bacteria and exert a significant chlorine demand. In all processes in which disinfection is practised, therefore, the turbidity must always be low, preferably below 1 NTU for effective disinfection. The recommended guideline is 5 NTU (El-Ziney *et al*., 2018).

2.2.2.3 Conductivity

Conductivity is the ability of water to conduct electrical current. This depends on the ionic strength of the water sample. Conductivity increases as the concentration of ions increases, since electrical current is transported by ions in solution. The determination of electrical conductivity provides a rapid and convenient way of estimating the concentrations of dissolved ions or estimating the amount of total dissolved salts (TDS). Conductivity is also a good measure of salinity in water. The measurement detects chloride ions from the salt. Salinity affects the potential dissolved oxygen levels in water. The greater the salinity level, the lower the saturation point (Shahid *et al*., 2018). Salinity is the total amount in grams of inorganic materials dissolved in

1kg water when all the carbonate has been converted to oxide, all the bromide and iodine have been replaced by chlorine and all organic matter have been completely oxidized (Schubert *et al.*, 2017). The ability of the water to conduct a current is very temperature dependent. All specific electrical conductivity (EC) readings are referenced to 25°C to eliminate temperature difference associated with season and depth.

2.2.2.4 Total dissolved solids (TDS)

TDS is a measurement of inorganic salts, organic matter and other dissolved materials in water and are commonly correlated to Electrical conductivity (EC). TDS includes positive and negative ions, such as dissolved chloride, sulphate, phosphate, carbonate, bicarbonate, sodium, calcium, magnesium, potassium and other inorganic and organic matter. They can be naturally present in water or the result of mining or some industrial or municipal treatment of water. In the water industry, TDS are critical contaminants commonly used as general indicators of salinity. TDS cause toxicity through increases in salinity, changes in the ionic composition of the water, and toxicity of individual ions. Salinity affects the beneficial reuse of effluent for irrigation and can also impact the quality of fresh water streams. A high salt content in water can increase the salinity of soil and hence affect the growth and productivity of plants and/or crops (Safdar *et al.*, 2019).

2.2.2.5 Total suspended solids (TSS)

Total Suspended Solids (TSS) is a common measure of water quality and refers to all suspended particulate matter in the water column. Suspended solids are the solids retained by a filter of 2.0 um (or smaller) pore size under specific conditions (Hansen *et al*., 2021). High TSS is indicative of poor water quality (Rakotondrabe *et al*., 2018). The suspended solids are a collection of organic and inorganic materials of various sizes and density. TSS can also be categorized into settleable and non settleable components, where settleability is a function of particle size (mass), flow and turbulence (Majuri, 2020). Total suspended solids test results are used routinely to assess the performance of conventional treatment processes and the need for further effluent filtration for reuse applications (Warsinger *et al*., 2018).

2.2.3 Chemical characteristics

Chemical parameters associated with the organic content of wastewater include biochemical oxygen demand (BOD) and chemical oxygen demand (COD). Inorganic chemical parameters include pH, acidity and alkalinity, as well as concentrations of ionized metals such as iron and lead, and anionic entities such as sulphates, nitrites, nitrates and phosphates.

2.2.3.1 pH

The pH of a sample of water or wastewater is a measure of the concentration of hydrogen ions. It is the negative logarithm of hydrogen-ion ($H+$) concentration (Magder & Chivukula, 2021). The pH scale ranges from 0 to 14. A pH of 7 is considered to be neutral. Substances with pH less than 7 have increased hydrogen- ion concentration and are acidic, while substances with pH greater than 7 are basic and show less hydrogen- ion concentration. All micro-organisms have an optimum pH at which they grow best; a minimum pH which is the most acid range in which they will not grow and a maximum pH which is the most alkaline range that enhances their growth. Smith *et al.*, (2017), observed that the concentration range suitable for the existence of most biological life is quite narrow and critical; it is from 6 to 9. Levels of pH greater than 9 are effective in pathogen removal (Gersberg *et al.*, 2020). pH is measured using a portable pH meter.

2.2.3.2 Biochemical oxygen demand (BOD)

One of the most commonly measured constituents of wastewater is the Biochemical Oxygen Demand, or BOD. Wastewater is composed of a variety of inorganic and organic substances. BOD measures the oxygen consumed by microorganisms as they decompose organic matter and includes any chemical oxidation of inorganic compounds. Effluents high in BOD can deplete oxygen in receiving waters, causing fish to die and changes ecosystem. The BOD test measures the amount of oxygen consumed during a specified period of time, usually 5 days at 20°C and so is called BOD5. By measuring the initial concentration of a sample and the concentration after five days of incubation at 20°C, the BOD5 can be determined (Kamaruddin *et al.*, 2019).

2.2.3.3 Chemical oxygen demand (COD)

COD is often measured as a rapid indicator of organic pollutant in water. It is attractive as the test yield results within two hours. It is normally measured in both municipal and industrial wastewater treatment plants and gives an indication of the efficiency of the treatment process. COD measures biodegradable and non-biodegradable organic matter of wastewaters. COD test is used to measure the oxygen equivalent of the organic material in wastewater that can be oxidized chemically using dichromate in acid solution.

2.2.3.4 Ammonia-nitrogen, nitrate-nitrogen and nitrite-nitrogen

Nitrogen occurs in natural waters as nitrate (NO3), nitrite (NO2), ammonia (NH3), and organically bound nitrogen. All these forms of nitrogen as well as nitrogen gas (N2), are components of the nitrogen cycle and are biochemically interconvertible (American Public Health Association, 1989). Total nitrogen TN, is simply the sum of the various nitrogen forms. The total nitrogen concentration in municipal wastewaters ranges from 15 to over 50 mg/L, on average (Capodici *et al.*, 2019). As aquatic plants and animals die, bacteria break down large protein molecules containing nitrogen into ammonia. Sewage is the main source of nitrates added by humans to water bodies. Another important source is fertilizer, which could be carried into natural waters by storm water runoff. Nitrate levels in surface water are found to be generally low. However, some ground waters may attain high levels. In excessive amounts, it contributes to the illness known as methemoglobinema in infants ("blue-baby syndrome").

In excess amount, nitrate leads to eutrophication in freshwaters (Usharani & Keerthi, 2020). Excessive nitrate stimulate growth with algae and other plants, which later decay and increase biochemical oxygen demand as they decompose. In a wastewater treatment plant, ammonia is normally oxidised to nitrites and then to nitrates. The first oxidation to nitrite sometimes referred to as notrosofication is by *Nitrosomonas* bacteria. The second groups of bacteria (Nitrobacter) take the nitrite and oxidize it to nitrate. Nitrite concentration in wastewater effluent is from 15 to 20 mg/l as N. Nitrite is extremely toxic to most fishes and other aquatic species so usually present in low concentrations. Ammonia, nitrite, nitrate and organic nitrogen concentrations are determined by colorimetric method (Heo *et al.*, 2020).

2.2.3.5 Phosphorus

Phosphorus is usually present as phosphate (PO_4^{3-}) in water medium. Phosphorus is found in wastewater in three principal forms: orthophosphate ion, polyphosphates or condensed phosphates and organic phosphorus compounds (Lajci *et al.*, 2017). Organically bound phosphorus originates from body and food waste and, upon biological decomposition of these solids, is converted to orthophosphates. Polyphosphates are used in synthetic detergents, and used to contribute as much as one-half of the total phosphates in wastewater. Polyphosphates can be hydrolysed to orthophosphates. Thus, the principal form of phosphorus in wastewater is assumed to be orthophosphates, although the other forms may exist. Orthophosphates consist of the negative ions PO_4^{3-}, HPO_4^{2-}, and $H_2PO_4^{-}$. These may form chemical combinations with cations (positively charged ions). According to Barco & Borin, (2020), the phosphorus concentrations in secondary effluent stand usually within the range of 3-7 mg/L, which mostly consist of orthophosphate and about 1 mg/L of organic phosphorus. Thus, it is necessary to reduce the concentration of phosphorus in secondary wastewater to prevent the algal bloom. Other sources of phosphorus aside human waste include animal wastes, industrial waste, soil erosion and fertilizers.

2.2.3.6 Trace metals

Heavy metals are the group of metals that have density greater than 4 g/cm3. Under this group, the following elements are included: arsenic, cadmium, chromium, copper, lead, mercury, zinc, iron, nickel, molybdenum, and manganese (Ashraf *et al.*, 2017). Heavy metals are important because they are often toxic and they impede or interfere with the biological treatment process when in excessive quantities. They are essentially non-biodegradable and therefore accumulate in the environment. The accumulation of heavy metals in soils and waters pose risks to the environment and human health. These elements accumulate in the body tissues of living organisms (bioaccumulation) and their concentrations increase as they pass from lower trophic levels to higher trophic levels (a phenomenon known as biomagnification). Depending upon the metal and the species, all the reactions are pH dependent (Russel *et al.*, 2006). Most heavy metals are essential to plant growth at low concentrations. Nevertheless, these heavy metals become toxic and harmful at high concentrations. Toxicity generally results in impaired growth, reduce yields and cause plant death (Ashraf *et al.*, 2017). Heavy metals have adverse effects on human health and therefore heavy metal contamination of food chain deserves special attention. Another reason for concern is that heavy metals may be transferred and accumulated in the bodies of animals or human beings through food chain, which will probably cause DNA damage and carcinogenic effects due to their mutagenic ability (Mishra *et al.*, 2019).

2.2.4 Biological characteristics

Biological parameters include coliforms, faecal coliforms, and specific pathogens, and viruses.

2.2.4.1 Coliforms and faecal coliforms

Wastewater usually contains millions of microorganisms per millilitre. However, many of these organisms are harmless. Few disease-causing microorganisms called pathogens invade some part of the host and either grow and multiply or produce toxin which interferes with normal body processes. They are divided into categories with the most common groups associated with water pollution being bacteria, viruses, protozoa, helminths (intestinal worms) and algae. These can exist naturally or can occur as a result of contamination from human or animal waste. Contact with the contaminated water may lead to diseases such as typhoid, cholera and gastrointestinal problems.

Coliform tests are useful for determining whether wastewater has been adequately treated and whether water quality is suitable for drinking, recycling or reuse. Coliforms are a family of bacteria common in soils, plants and animals. Because they are very abundant in human wastes, coliform bacteria are much easier to locate and identify in wastewater than viruses and other pathogens that cause severe diseases. For this reason, coliform bacteria are used as indicator organisms for the presence of other, more serious pathogens. Coliforms are frequently monitored as total or faecal coliforms. Total coliform (TC) is defined as a large group of anaerobic, nonspore forming, rod -shaped bacteria that ferment lactose with gas formation within 48 hours at 35°C (Okwelle & Kpea, 2019). Total coliform bacteria are a collection of relatively harmless microorganisms that live in large numbers in soils, plants and in intestines of warm-blooded (humans) and cold-blooded animals. Some pathogens enter the human body through the skin but more commonly they are ingested with drinking water. Faecal coliform (FC) is a subgroup of TC that comes from the intestines of warm-blooded animals. However, since they do not include soil organisms, they are preferable to TC as an indicator organism. World Health Organization Guidelines for Drinking Water Quality states that as an indicator organism, faecal coliform *Escherichia coli (E-coli*) provides conclusive evidence of recent faecal pollution and should not be present in water meant for human consumption. It is generally assumed that the higher the number of coliform organisms found in a 100 ml sample, the higher the risk for waterborne disease.

They are measured by running the standard total coliform test at an elevated temperature (44 °C) (Islam *et al*., 2020). There are two commonly used methods for determining the presence and density of coliform bacteria. The membrane filter (MF) technique provides a direct count of colonies trapped and then cultured. The multiple tube fermentation method provides an estimate of the most probable number (MPN) per 100 millilitres from the number of test tubes in which gas bubbles form after incubation.

2.3 Trace Metals in Wastewater and their Impact on Human Health and the Environment

2.3.1 Iron

Iron (Fe) is a metallic element that makes up about 5 percent of the Earth's crust. It occurs mainly in Fe2+ (ferrous iron) and Fe3+ (ferric iron) (Gopinathan *et al*., 2020). Usually, iron occurring in ground water is in the form of ferric hydroxide, in concentrations less than 500 mg/L (Deutsch, 2020). In its pure form, iron is a dark-grey metal, but it is exclusively found in combination with other elements called ores. Most common iron-containing ores are hematite, magnetite, and taconite. When in the presence of oxygen, iron is a reactive element that oxidizes (rusts) very easily. The red, orange, and yellow colours visible in many soils and rocks all over the world are usually iron-oxides. Ferric iron deposits within corroded pipes can break free and generate rusty tap water (Fish *et al*., 2020).

2.3.1.1 Adverse human impacts of iron

The shortage of iron causes disease called "anaemia''(Cappellini *et al*., 2020). Although iron is an essential mineral, prolonged consumption of drinking water with high concentration of iron may lead to liver disease called Hemosiderosis (Khan *et al*., 2013). Diseases of aging such as Alzheimer's disease, other neurodegenerative diseases, arteriosclerosis, diabetes mellitus, and others have been linked to excess iron intake (Popa-Wagner *et al*., 2020). High concentrations of dissolved iron can result in poor tasting, unattractive water that stains both plumbing fixtures and clothing. (Yuvaraj *et al*., 2018). Previous studies conducted in an industrial area Sialkot, Pakistan, shown high levels of Fe which varied between 0.004 and 0.828 mg/l, well above WHO Maximum Contaminant Level (MCL) of 0.3 mg/l (Ullah *et al*., 2009).

2.3.1.2 Adverse impacts of iron on the environment

Iron can also cause algae blooms, which create biological oxygen demand, can kill fish, smother aquatic plants and produce potent neurotoxins. Even low concentrations of iron (0.1-1.0 mg/L) may cause nuisance algae species to replace inoffensive species (Mohan *et al*., 2020). Water collects iron in several ways. Even as it falls through the air, water acquires small amounts of the oxides of iron found in the atmospheric dust. Water rich in carbon dioxide, readily dissolves iron from the earth's plentiful deposits as it leaches these in its underground flow. Elevated levels of iron in storm water can be caused by rusting steel in constant contact with water.

2.3.2 Lead

Lead is the most significant of all the heavy metals because it is toxic, very common and harmful even in small amounts (Rehman *et al.,* 2018). Lead is a toxic metal whose high potency makes it a dangerous environmental threat to human health (Barcelos *et al*., 2020).

2.3.2.1 Adverse human impact of lead

People are exposed to lead through water, the air they breathe and through food/ ingestion (Yang & Massey, 2019). Most of the lead we take is removed from our bodies in urine; however, as exposure to lead is cumulative over time, there is still risk of build-up, particularly in children (Ab Latif Wani & Usmani, 2015).

A recent report suggests that even a blood level of 10 micrograms per decilitre can have harmful effects on children's learning and behaviour (Lanphear *et al*., 2019). Exposure to lead through water is generally low in comparison with exposure through air or food (Grant, 2020). Lead from natural sources is present in tap water to some extent, but analysis of both surface and ground water suggests that lead concentration is fairly low.

The main source of lead in drinking water is (old) lead piping and lead-combining solders (Kumar & Puri, 2012). Studies on lead are numerous because of its hazardous effects. Lead is a metal with no known biological benefit to humans. Too much lead can damage various systems of the body including the nervous and reproductive systems and the kidneys, and it can cause high blood pressure and anaemia (Brochin *et al*., 2014; Debnath *et al*., 2019). Lead accumulates in the bones and lead poisoning may be diagnosed from a blue line around the gums. Lead is especially harmful to the developing brains of foetuses and young children and to pregnant women. Lead interferes with the metabolism of calcium and Vitamin D.

High blood lead levels in children can cause consequences which may be irreversible including learning disabilities, behavioural problems, and mental retardation (Sankhla *et al*., 2017). At very high levels, lead can cause convulsions, coma and death (WHO, 2012). Studies conducted in some of the Great Cairo Cities, Egypt aimed to determine the relationship between the contaminant drinking water and its impact on human health. It was revealed that Patients who suffer from renal failure were related to contaminant drinking water mainly with lead and cadmium (Salem *et al*., 2001). Previous studies conducted in an industrial area Sialkot, Pakistan, shown high levels of Pb with maximum mean concentration of 0.81 mg/l, were above WHO Maximum Contaminant Level (MCL) of 0.01 mg/l (Ullah *et al*., 2009). Also, studies conducted by Egbueri *et al* 2020, regarding heavy metal groundwater pollution at automobile mechanic villages in Ibadan, Nigeria showed that, Pb concentration measured in hand-dug wells was lower than the limits set by WHO guideline for drinking water (Buah *et al*., 2016).

A maximum level of Pb (1347 mg/L) was found in drinking water sampled from north-western West Virginia, United States. More than 70.15% of the samples analysed contain lead concentration within the WHO (2008) MCL of lead in drinking water (10 mg/L) (Harkness *et al*., 2017). Not only does lead poisoning stunt a child's growth, damage the nervous system, and cause learning disabilities, it is now linked to crime and anti-social behaviour in children (Sankhla *et al*., 2017).

2.3.2.2. Adverse impact of lead on the environment

Lead (Pb) is the most common environmental contaminant found in soils. Unlike other metals, Pb has no biological role, and is potentially toxic to microorganisms (Ali *et al.*, 2019). Its excessive accumulation in living organisms is always detrimental (Bhat, 2019). Adejumo *et al.*, (2018) found Pb concentrations which were described as being highly elevated in soil and vegetation in an abandoned battery factory site. Lead is found in trace amounts in various foods, notably in fish, which are heavily subjected to industrial pollution. Some old homes may have lead water pipes, which can then contaminate drinking water. In the analysis of some wells and boreholes water samples collected, 36.73% of the total contained Lead in levels above the Maximum Contaminant Level (MCL) (0.01 mg/L) with maximum concentration of 0.024 mg/L, in a study conducted by. Lead has been recognized for centuries as a cumulative general metabolic poison (Buah *et al.*, 2016).

2.4.4 Sulphates

Sulphates are found appreciably in all natural waters, particularly those with high salt content (Smith *et al.,* 2017). Besides industrial pollution and domestic sewage, biological oxidations of reduced sulphur species also add to sulphate content. Soluble in water, it imparts hardness with other cations. Sulphate causes scaling in industrial water supplies, and odour and corrosion problems due to its reduction to hydrogen sulphide (Capocidi *et al.*, 2019). It can be calculated by turbidometric method.

Principle: Sulphate ions are precipitated in acetic acid medium with barium chloride to form barium sulphate crystals of uniform size. The scattering of light by the precipitated suspension (barium sulphate) is measured by a Nephelometer and the concentration is recorded.

2.5 Water Consumption and Wastewater Generation

The gross consumption of water in the car wash industry mainly depends on the type of washing (Sarmadi *et al.*, 2020). Water consumption can vary a lot from one facility to another, especially in roll-over and pull-along car washes. The type of facility, the size of the vehicle and the program chosen by the customer (number of washing stages) influences water consumption.

In Spain, currently, most vehicle washing facilities are connected to the drinking water distribution network and make use of high quality water for all stages of the car wash (Sachidananda *et al.*, 2016). The use of this water can be minimized using rainwater and/or recovered wastewater from washing to use it again in a new cycle. One of the main effluent generated in car washing facilities is dirty water (Sarmadi *et al.*, 2020). Depending on the water consumed (as facility type and number of vehicles washed), a flow of wastewater of similar dimensions is generated. This flow will be slightly lower than water consumption in the washing facility, as there may be losses of about 10 litres in cars and 25-30 litres in trucks, for evaporation and dragging by washed vehicles (Huybrechts *et al.,* 2002). Should it not be reused, this effluent must be expatriated from the facility either through connection to a sewage system or through discharge into the environment (Banjoko & Sridhar, 2016). This type of activity requires prior discharge permission and, in no case, it can be poured without a proper pre-treatment according to the type of permission of the facility.

Generally, if the discharge is done into a sanitation system, the treatment includes solid decantation and hydrocarbon separator. If the discharge is done into the environment, a higher treatment (usually biological) is needed to achieve the required discharge limits. The composition of wastewater from car washing varies (it depends on factors such as location of the facility, season, load of washed vehicles, etc.) (Schubert *et al.*, 2017).

2.6 Chemical Products of Car Washing

The car wash industry uses a wide range of products that can be grouped in three sets:

• Products to wash the vehicle (detergents) and finishing or polishing (waxes).

• Products for maintenance and cleaning of the facility.

• Products to treat wastewater and/or to control bad smells (if necessary).

According to the different exterior car wash stages, used products can be divided in the following groups:

2.6.1 Products in the pre-washing:

Intended for the most stuck dirt (gasoline residues, bird droppings, insects, etc.). These products are degreasing or descaling and are generally alkali in liquid (sodium hydroxide is the most common component in these formulations). Its concentration varies depending on the application (in tyres, car bodyworks, trucks, etc.) and its application form (spray, high-pressure, manual sprays, etc.). They are used in a limited ways.

2.6.2 Products in the washing:

A significant part in the car wash process is the application of detergents (Torkashvand *et al.*, 2020). Detergents are defined as "any substance or mixture containing soap or other surfactants used in washing and cleaning processes (Landeck *et al.*, 2020). The detergents may take any form (liquid, powder, paste, bar, etc.) and be marketed for domestic, institutional or industrial use. The active ingredients of detergents are surfactants, organic substances or mixtures used in detergents having certain properties such as: detergent (to detach the layer of dirt); foamy, with solubilisation capacity; emulsifier (they surround fat particles, so they lose adhesion with the metal surface, allowing dirt to be easily removed); moisturising and dispersing (Moazzem *et al.*, 2019). Cleaning products tend to be pH neutral or slightly acidic (Bush *et al*., 2018). The type and concentration will also depend on the stage of the washing and how they are applied (shampoo arch, active foam arch, brushes arch, high pressure sprinklers, etc.).

2.6.3 Products for the finishing or polishing:

They are applied to the vehicle after the washing stage, which cleans the surface of the vehicle. To achieve a bright and long-lasting finish, special products such as waxes are applied. After the finishing stage with wax or other polishing products, waste is removed with a rinsing application which often uses osmosis-purified water. The finishing products can be formulated in the form of pastes, liquids or sprays and contain some of the following components (Bråtveit & Moen, 2001).

1. **Waxes**. For the polishing of surfaces, they give strength and bright to paint, improve opacity and provide lubrication and durability. The most used waxes are paraffins, polyethylene, carnauba, microcrystalline and mixtures.
2. **Abrasives.** To polish and remove traces of tar and other substances strongly adhered and for small imperfections on the bodywork. They usually contain tiny particles of clay or similar materials,
3. Soft calcium carbonate, silicone, aluminium silicates, etc.

4. **Emulsifiers**. Generally used to mix (together with dispersants, thickeners and preservatives). They include fatty alcohol ethoxylates, sorbitan esters, fatty acid soaps and polydimethyl siloxane ethoxylates, among other components.
5. **Silicones and derivatives**. They improve the resistance and enhance the shine of the protective coating. They are mainly polydimethyl siloxanes.
6. **Solvents**. They have a double function; as a base for waxes, silicones and other components, and as a help in cleaning dirt and oils. Their choice is critical when it comes to avoiding damage to the paint and plastic elements. The water insoluble solvents, such as aliphatic hydrocarbons, are the most used ones.
7. **Thickeners**. Emulsions of oil and water, needed to keep abrasive materials in suspension if the formulation has low viscosity. Some of the most typically thickeners used in polishes are cellulose ethers, magnesium, aluminium, silicate and carpool resins.

All products used to clean the same machinery and facilities (flooring, toilets, etc.) will also get into wastewater and, therefore, will be discharged into the treatment system. In facilities where water is reused, additives or other products can be used in order to have the right quality. Depending on the technique used, the following are some of the products used:

1. **Flocculant.** It contains, among others, inorganic salts, polyelectrolytes and bentonite. This ensures that dirt particles join each other in flakes, they can quickly decant and be ready to be filtered (physicochemical treatment) (Yuzik, 2020).
2. **Products to clean the filters** (ultrafiltration / membranes).
3. **pH regulators.**

4. **Anti-foaming.** They reduce the formation of foam in the recycling system.
5. **Products to control odour in water recycling.** They can be activated charcoal, natural minerals and gels and especially hydrogen sulphide removal by filtration (filtration materials). Filtration media are installed in special cartridges under sewage covers in locations where the irritating odour is formed (Hluštík & Novotný, 2018).

Applying the correct dose is very important. All products mentioned in this section are applied with water. Therefore, they will get into the sewage system and so into the aquatic environment. Some of the impacts they may cause are:

1. They are organic substances, so they can degrade in the environment, consume oxygen and cause anoxia.
2. They can inhibit biological and chemical oxidations, which produce, in highly contaminated water, low levels of Biological Oxygen Demand (BOD). This phenomenon is due to the fact that, in the presence of detergents, bacteria are surrounded by a layer of detergent that isolates them from the environment and prevents their activity.
3. Beside surfactants, detergents have other components which may cause eutrophication.
4. Formation of unwanted foams (depending on the kind of surfactants and additives). Generally, anionic surfactants produce a lot of foam, cationic surfactants produce it in limited quantities and non-ionic surfactants produce just a bit. Foam is promoted, basically, to produce a visual effect to the client, but too much foam can be harmful for treatment plants and rivers.

5. They have effects on coagulation and sedimentation, they inhibit them in wastewater treatment plants.
6. They increase wastewater alkalinity and can reach pH over 12, caused by caustic soda or potash.
7. Pollution of underground waters (not frequently); surfactants are usually absorbed in solids and are kept in the soil.

These impacts may worsen in self-service car wash facilities where there is no permanent staff and the operator has little control over the quality of the generated wastewater (Heo *et al.*, 2020): the customer can use the opportunity to discharge products to the system, such as used oils, refrigerants and other specific cleaning products, regardless of the products provided by the facility. In the ecological evaluation of surfactants for industrial use, the fact that aquatic biodegradation and toxicity are contradictory must be taken into account. The bigger the chain carbonate, the higher toxicity. And the longer and less branched, better biodegradation (Ong *et al*., 2017). From an ecological point of view, we should select surfactants that degrade completely and as quickly as possible (Venhuis & Mehrvar, 2004). At the same time, needs must be adjusted. Nowadays, more and more manufacturers take into account biodegradation (since it must meet European regulations, Directive 73/404/EEC) and short-term emulsifying action (important for the proper functioning of the hydrocarbon separator) (Fish *et al.*, 2020). It would be interesting that, for the proper functioning of any unit of water recycling, the finishing products are free of silicones, mineral oils and hydrocarbons (if they are not, waters must often be collected with finishing products, separately to the rest of the washing waters). It is noteworthy to know that in the Netherlands and in Scandinavia there is a specific Ecolabel for car washing products (De Chiara, 2016).

In Spain there are no specific criteria, but existing regulations must be accomplished and good practices must be followed providing opportunities for improvement (Baveye *et al.*, 2018).

2.7 Solid Waste from Washing Bays

The most important solid waste generated in the vehicle washing is sludge. It mainly comes from points of collection of washing water, hydrocarbon separators and settling tanks. In the event that the facility has a water recycling plant, sludge will also accumulate at some points. The amount and composition of sludge will depend on the type of products used, the degree of dirt of the washed vehicles, the treatment applied to water, etc. Sludge must be collected and treated by an authorized waste manager (Alibardi & Cossu, 2016). Collection is carried out once or twice a year. Besides sludge, there is other waste, which will also be considered in the application of good practices. This is mainly empty containers of chemicals and detergents and, less frequently, brushes, textile curtains and other worn down items (Fleet *et al.*, 2021).

2.8 Car Wash Process

Four general stages may be considered in this process:

1. Pre-washing;
2. Washing (maybe in various stages);
3. Finishing (which may include a first rinsing, waxing and final rinsing);
4. Drying (optional)

2.8.1 Pre-washing

During pre-washing, the vehicle is sprayed with descaling product (Masotti *et al.*, 2019). They are specially designed to begin to undo the most stuck dirt, such as mosquitoes, bird excreta, etc., which, at a later stage, will be eliminated with the help of mechanical brushes or high-pressure washing. After the spray with the descaling product, the vehicle is washed with high-pressure water (usually with a lance) (Zhang & Peng, 2018). The aim is to leave the vehicle ready for the next phase (leave the surface wet and ready for the application of detergents). At this stage, a large part of the deepest dirt is already removed.

2.8.2 Washing

The vehicle is sprayed with a mixture of water and shampoo through sprinklers (Tidwell & Wills, 2019). Its function, in addition to cleaning, is to soften the surface of paint, to maximize the later mechanical action of the brushes and to prevent scratches. Another detergent (known as "active foam") is often applied; its aim is to create a dense foam completely covering the paint. The foam ensures the cleaning action, because it slowly removes the dirt remaining on the surface, which makes the later rinsing easier (Galimberti, 2017). This phase may also include specific arches for the wheels and lower lateral parts of the vehicle (where mud easily adheres), to make a deeper washing. The washing phase includes, besides arches with shampoo and active foam, arches with brushes (vertical and/or horizontal).

There are different types and materials and, in general, they are classified in nylon or, increasingly, Carlit brushes (a foamed polyethylene) or systems with textile curtains.

The first ones (nylon brushes) provide a good washing result, but there may be problems related to the formation of grooves or scratches in the paint (Fullagar, 2016). However, if they are properly used, there is a regular maintenance and they are regularly replaced, the risk of scratches is very limited. It is important that they are accompanied by plenty of water and applying a minimum of detergent (Kube *et al.*, 2018).

Currently, an alternative to nylon is carlite, because it is softer, but requires the same type of application (abundant water and soap). The second one (textile curtains) is a solution used in combination with high pressure. It leaves no traces, but its disadvantage is that it absorbs a lot of water and, therefore, only vertical curtains are used (the horizontal ones take too overweight). It is a solution more applied in North America; however, soft washing version is also beginning to be implemented in Europe with some variations and combinations (Huybrechts *et al.,* 2002).

2.8.3 Finishing

The finish includes a rinse with clean water after washing and waxing (Bashari *et al.*, 2020). The wax application is optional, but it is a widespread phase in all the washings and it is usually done through the washing machine and in cold. Various waxes can be applied according to the aim (Schubert *et al.*, 2017). If so, first polish wax that covers the possible scrapes on the painting and provides a smooth surface is applied. Now the vehicle is in the best possible conditions to be applied a protective or drying wax which, with its hydrophobic nature, reduces the surface tension of the rinse water. The water layer is broken and forms large droplets which are easily removed (either by the effect of a drying stage with turbo fans or by gravity). Some washing systems apply, after waxing, a final phase rinsing with soft water (i.e., free from calcium and other ions). This is to avoid droplets once dry. This step usually uses tap water and, depending on its hardness, a treatment to soften it or demineralized it is applied. It is usually water that has passed through an ion exchanger and/or reverse osmosis. Reverse osmosis is a growing application in vehicle washing; especially if cars are dried in air, a high-quality water is required to avoid stains (Moazzem *et al.*, 2018).

2.8.4 Drying

The last stage of the washing process is drying the vehicle (Sarmadi *et al.*, 2020). It is optional and it is mainly offered in the roll-over type. Generally, it is done via blowers or turbo fans dragging the remaining water droplets on the vehicle surface (Marshall *et al.*, 2019).

2.9 Car Cleaning Systems

According to the International Carwash Association (ICA) (Brown, 2002), this industrial sector includes the automatic commercial services of car washing. ICA classifies them in three large groups (Ndi, 2018):

- Rollover or in-bay automatic car wash
- Pull-along or conveyor car wash
- Self-service car wash

There are also other modes, although rare in Europe: companies that clean vans and trucks at the customer's facilities, known as mobile washings, and companies that wash cars by hand. In these cases, it is very important to avoid diffuse pollution and to provide for a collecting system for washing water and its subsequent treatment.

The three main types of car washing systems are described below.

2.9.1 Rollover car wash

It is a computer-controlled washing system. During the process, the vehicle stays parked in one place while the washing equipment moves back and forth on the rails, according to the program chosen. Washing is usually done using brushes, textile curtains or frictionless washing with high-pressure sprayers. General stages of the washing process with detergents and finishing products are applied according to the program. It is the most used system for washing trucks, buses, etc. It is usually complemented with a manual prewash with pressure and hot water. The speed of a rollover car wash, depending on the programs and models, is usually about 8 to 12 vehicles per hour and 4-5 trucks per hour.

2.9.2 Conveyor car wash

In this computer-controlled system, the vehicle moves through a conveyor belt, whereas tunnel elements are fixed. If staff is present, there is often a pre-treatment (descaling and pressure lance). There are three types of conveyors or in-bay automatic car wash: with nylon or PE brushes, with textile curtains and contactless or frictionless wash with high-pressure sprinklers. The entire washing process is usually carried out in cold water. A conveyor car wash may have capacity for 50-60 car/hour.

2.9.3 Self-service car wash

The self-service equipment is staffed by a compressor that propels water and equipped with two guns: one with a brush and another one the car propels water with pressure. The car owner washes it himself using the machinery available. Depending on the coins the owner introduces into the machine, he can choose the washing cycle, which will last more or less time: pre-washing, washing, rinsing and waxing. Unlike the rollover and conveyor car wash, the washing phase is usually done with warm water to ensure a good result. Self-service car wash machines do not dry, so this stage is outdoors. To avoid lime stains from droplets, most of the boxes have osmosis-purified water equipment for the rinsing phase. The washing capacity of a self-service car wash can vary and depends on the duration the customers choose. Maximum 7 cars/hour.

2.10 Energy

Energy cost in washing facilities is mainly attributed to three aspects:

1. Operation and water treatment control: it makes reference to the brushes operation, the movement of the car wash conveyor belt, pumps, etc. Energy use in water recycling depends mainly on the need for aeration.
2. Hot water production: Energy consumption will also depend on the amount of hot water required for washing. Generally, conveyor car washes completely work with cold water, whereas rollover truck washes with pre-washing often use hot water. As for the self-service car wash, pre-washing or washing phases usually use warm water.
3. Drying: in automatic car washes, most of the energy is consumed in drying stage, as it uses blowers or turbofans (Marshall *et al.*, 2019).

CHAPTER THREE

METHODOLOGY

3.1 Study Areas

The study areas of this research work were Techiman and Nkoranza Municipalities in the Bono East Region of Ghana. The region has eleven (11) Assemblies under its jurisdiction: four (4) Municipal Assemblies and seven (7) District Assemblies. The Municipal Assemblies are Techiman, Kintampo, Nkoranza South and Atebubu Amantin.

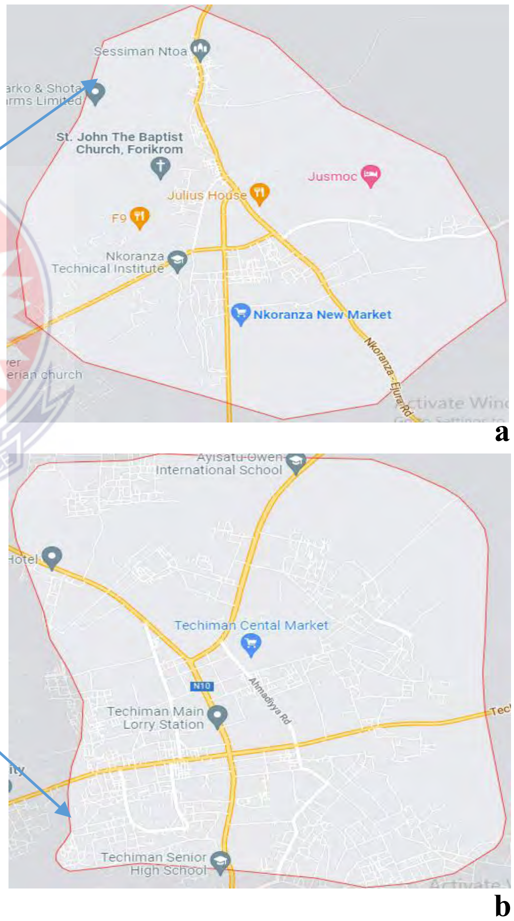

Figure 3.1: Map of Ghana

Adapted from google map (2021)

Figure 3.2: Map of Techiman and Nkoranza Municipalities

Adapted from google map (2021)

3.1.1 Location

Geographically, Techiman Municipality lies at the centre of Ghana with a link road from Techiman to Kumasi to the south, Sunyani to the East, Wa to the West and Tamale to the North. It shares boundaries with Sunyani, Wenchi, Nkoranza, Akomadan and Kintampo. It lies between longitude $1'49^0$ East and $2'30^0$ West and latitude $8'00^0$ North and $7'35^0$ South (Darkwah *et al.*, 2019). Figure 3.2(a)

Nkoranza Municipality also lies within longitude $1^0 42'19''$ West and latitude $7^0 33'15''$ North and shares boundary with Techiman Municipality, Amantin, Kintampo and Ejura Districts (Donkoh *et al.*, 2016). Figure 3.2(b)

3.1.2 Climatic conditions

Techiman Municipality has a bi-modal rainfall system and experiences humid temperatures for most parts of the year, allowing for two farming seasons (Ghana Statistical Service, 2010). It constitutes major agriculture zone in the country especially, with regards to food crops such as yam, maize, cassava, cocoyam, potatoes and vegetables (MoFA, 2016).

Nkoranza Municipality also experiences a bi-modal rainfall pattern. The major raining season starts from April to July and the minor from September to October. The dry season which is highly pronounced in the savannah zone starts in November and ends in March (Donkoh *et al.*, 2016).

3.1.3 Demography

The total population of Techiman Municipality as at 1960 was 8,755. The population has grown rapidly in recent decades doubling between the 1970 (12,068) and 1984

(25,264) census and again doubling by the next census in 2000 (56,187). The Municipality recorded a total population of 147,788 in 2010 which represent 6.4% of the total population of Brong Ahafo Region (Darkwah *et al.*, 2019). The Nkoranza Municipality covers a land area of 923 square kilometres. The population was estimated at 100,929 in the 2010 Population and Housing Census (Adu & Amponsah, 2017; Sowah *et al.*, 2020).

3.2 Data Collection

3.2.1 Research design

The study was a longitudinal survey design. The study areas for this research were Techiman and Nkoranza Municipalities. The study consisted of twenty-two (22) functional washing bays (Fifteen (15) from Techiman and seven (7) from Nkoranza). With respect to the twenty-two (22) washing bays, the type of vehicle washed, quantity of water used for washing vehicles per day (both spray gun and manual), number of category of vehicles washed in a day and volume of wastewater generated for washing daily (both spray gun and manual) were estimated. Two (2) washing bays were purposively selected based on the method of washing cars, nature of washing surface and number of vehicles washed per day. These washing bays were used as proxy stations for all the twenty-two (22) washing bays and monitored by trained field assistants for a 3-week period including weekends. First-hand information on the number of vehicles washed per day and the quantity of water were used as a representation to estimate daily water consumption for all the twenty-two (22) washing bays identified in the municipalities. The vehicles monitored at the washing bays were grouped into six categories; articulators, saloon cars, pickups, buses (coaches, vans), motorcycles/moped, and graders (loaders, tractors) (Monney *et al.*, 2020).

3.2.2 Sample size and sampling procedure

A random sampling technique was used to select respondents to administer a baseline assessment form. A total of twenty-two (22) respondents were made to answer the questionnaire for the study. It involved the operations managers for each washing bay within the two (2) Municipalities. The baseline assessment form was designed using semi structured questions which was self-administered in places where the operations managers felt reluctant to write or could not write.

Observation was also done to know how the car washers carried out their activities at the washing bays in other to ascertain if the answers provided in the assessment forms were accurate or matched what was actually on the grounds.

3.2.3 Specific objective 1

1. To quantify the volume of water used in a day by the washing bays

To achieve this objective, two methods were employed according to existing literature (Monney *et al.*, 2020).

1. Manual: A graduated bucket of known volume was provided and filled to a specified volume. The number of times that volume of water in the bucket was used to wash a particular car was the volume of water used to wash that car. Therefore, the volume of water used to wash the car was then multiplied by the number of cars washed in a day.

2. Use of spray gun: The flow rate of the spray gun was first determined. To measure the flow rate, a bucket of known volume was provided and filled up to a specified volume using the spray gun. A timer was used to check the time (seconds) it took the bucket to get filled to a specific volume and was then recorded. The volume of water in the bucket was divided by the time (seconds) it took the bucket to be full. So, the flow rate of the spray gun was multiplied by the time it took to wash a particular car in order to determine the volume of water used.

3.2.4. Specific objective 2

Estimate the volume of wastewater generated in a day by a washing bay. This objective was achieved by using this formula to compute for the wastewater generated

$$qd = R \times Wd + \sum_{i=l}^{n} pi \times vi$$

where;

qd = daily volumetric flow rate of wastewater of a washing bay

R= estimated return flow of the washing bay (0.8 for paved washing surface; 0.5 for unpaved washing surface) (Monney *et al.*, 2020).

i = category of car

W_d = median number of cars washed per day (due to high variation in daily vehicles washed).

p_i = proportion of vehicles in the ith category (%)

v_i = volume of water used to wash car in the ith category (L).

3.2.5 Specific objective 3

Characterization of car washed wastewater.

This objective was determined by characterising:

1. Source of water used at the washing bays
2. The wastewater generated from the washing bays
3. The receiving stream/river.

Water quality analysis was used to determine the physicochemical parameters of the water samples collected. The physicochemical parameters included turbidity, TS, TDS, TSS, temperature, pH, acidity, alkalinity, conductivity, sulphate, phosphate, nitrite, nitrate, BOD and COD.

Table 3.1: Analytical methods/equipment used for measuring wastewater parameters

Parameters	Method/Equipment
pH	EUTECH PC300
EC (µS/cm)	EUTECH PC300
TDS (mg/L)	EUTECH PC300
TSS (mg/L)	Gravimetric method
Turbidity (NTU)	HANNA HI93414 Turbidimeter
COD (mg/L)	HACH 21259 Vial Digestion Solution for COD;HACH DR3900 Spectrophotometer
BOD (mg/L)	Winkler Method
Nitrates (mg/L)	Nitraver 5 Nitrite Reagent Powder Pillows;HACHDR3900 Spectrophotometer
Nitrites (mg/L)	NitriVer 3 Nitrite Reagent Powder Pillows;HACHDR3900 Spectrophotometer
Sulphate (mg/L)	Phosver 3 Phosphate Reagent Powder Pillows;HACHDR3900 Spectrophotometer

Water Quality Analysis

Two (2) proxy washing bays (Joe Thousand-Techiman and Alhaji Iddrisu Ayiku-Nkoranza) were used for the water quality analysis.

The various water samples (source of water, wastewater and stream) were taken using new empty plastic water containers. Composite samples were collected from each washing bay in the morning (9am-11am) and pH and temperature of the water samples were measured in-situ using pH meter and thermometer respectively. Since the study involved two (2) proxy washing bays in the Municipalities, three (3) water samples (source of water, wastewater, and river-Tano and Tanko) were taken from each washing bay making a total of six (6) water samples. Additional six (6) samples were collected and a concentrated nitric acid was added to each sample before transporting to Kwame Nkrumah University of Science and Technology, Department of Civil Engineering Laboratory, Kumasi, Ghana. The concentrated nitric acid was added to reduce the pH of the samples to 2 and prevented the heavy metals from adsorbing to the suspended solids.

The borehole samples were collected after the taps had been opened and allowed to flow for 2 to 3 minutes. The stream samples were also collected by gently immersing the plastic containers in the river to collect them.

The wastewater samples were collected from the outfalls of the washing bays before joining the public drains.

3.2.6 Specific objective 4

Determination of the pollutant loads associated with wastewater generation.

This objective was achieved by multiplying the average volume of wastewater generated per day by the various values of the physicochemical parameters and the heavy metals. The average volume of wastewater was obtained by multiplying the volume of water used for washing daily by the values of the nature of washing surface that is whether paved or not paved (Table 4.8).

3.3 Statistical Analysis

Data entry was done using MS Excel and standard analysis done using SPSS. Frequencies and percentages were developed. The level of significance was set at $P \leq 0.05$.

CHAPTER FOUR

RESULTS

4.1 Sources of Water

Sources of water for washing bays were mainly borehole and Ghana Water Company Limited (GWCL). Borehole was the most used source of water for washing bays representing 20(91%) whereas GWCL was 2(9%). All washing bays in Techiman used mechanized borehole representing 15(68%) and majority 5(23%) of washing bays in Nkoranza used mechanized borehole (Table 4.1).

Table 4.1: Sources of water

Location of washing bays	Source of water		Total
	Mechanized borehole n(%)	GWCL n(%)	n(%)
Techiman	15(68)	0(0)	15(68)
Nkoranza	5(23)	2(9)	7(32)
Grand Total	**20(91)**	**2(9)**	**22(100)**

4.2 Types and Quantity of Vehicles Washed

Averagely, spray gun washed 50 vehicles daily whereas manual mode washed 30 vehicles daily. Overall, 3348 vehicles were washed at the two car washing bays during the 3-weeks monitoring period. Saloons were the most daily washed vehicles representing 36% of all types of vehicles. Heavy articulators and graders/loaders were all washed by spray gun and not manual mode of washing (Figures 4.2 and 4.3). Averagely, about 80 vehicles were washed per station daily.

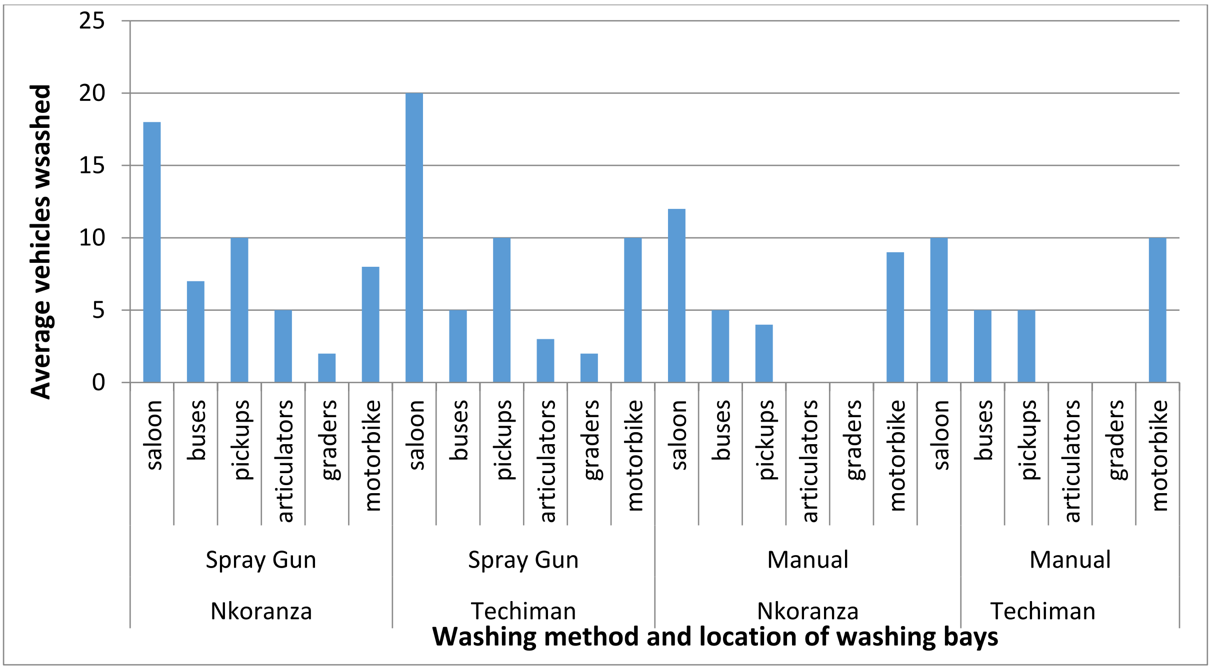

Figure 4.1: Types and quantities of vehicles washed and location

4.3 Quantity of Water Used By Spray Gun

The results showed that washing with spray gun in Techiman used 190.76 L, 300.98 L, 246.60 L, 1277.32 L and 1169.12 L of water for saloon, buses, pickups, heavy articulators and graders/loaders respectively. The use of spray gun for washing vehicles at Nkoranza recorded different quantities of water for various vehicles as follows; saloon (149.19 L), buses (286.40 L), pickups (260.00 L), heavy articulators (1230.20 L), graders (1176.22 L) and motorbikes (116.04 L) (Figure 4.2). Heavy articulators and graders/loaders were not washed manually in both Techiman and Nkoranza.

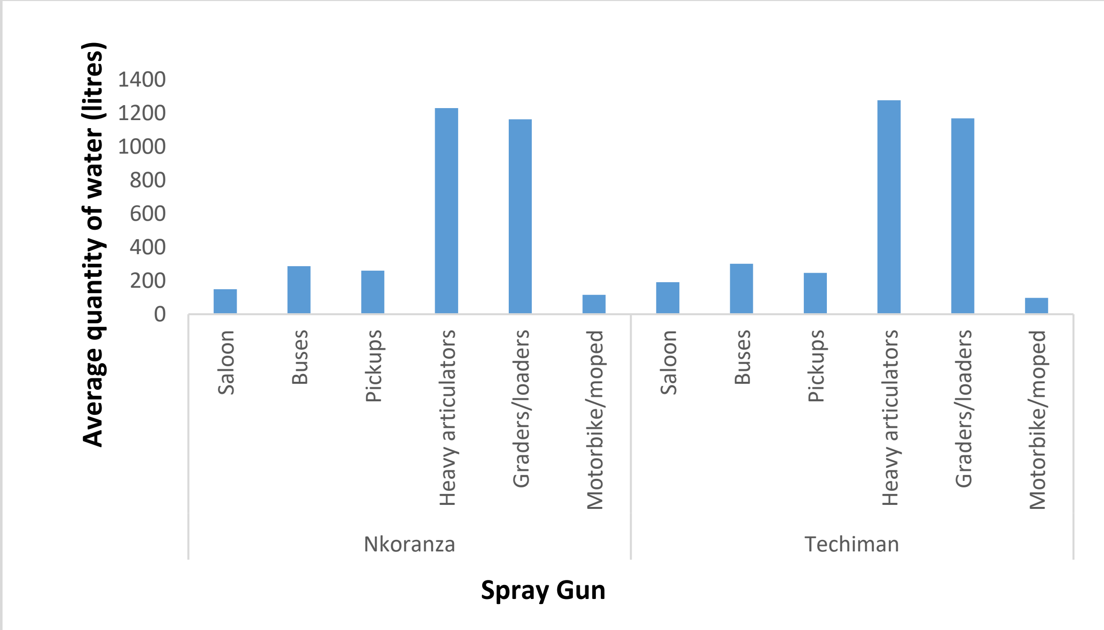

Figure 4.2: Average quantity of water used per vehicle by spray gun method

4.4 Quantity of Water Used by Manual Washing System

The volume of water used by the manual washing in Techiman for the various vehicles were motorbikes (100 L), saloon (230 L), pickups (250 L) and buses (280 L), whereas at Nkoranza the quantity of water used for washing the various vehicles were motorbikes (195 L), saloon (200 L), buses (275 L) and pickups (277 L). Articulators and graders/loaders were not washed manually in both Techiman and Nkoranza (Figure 4.3).

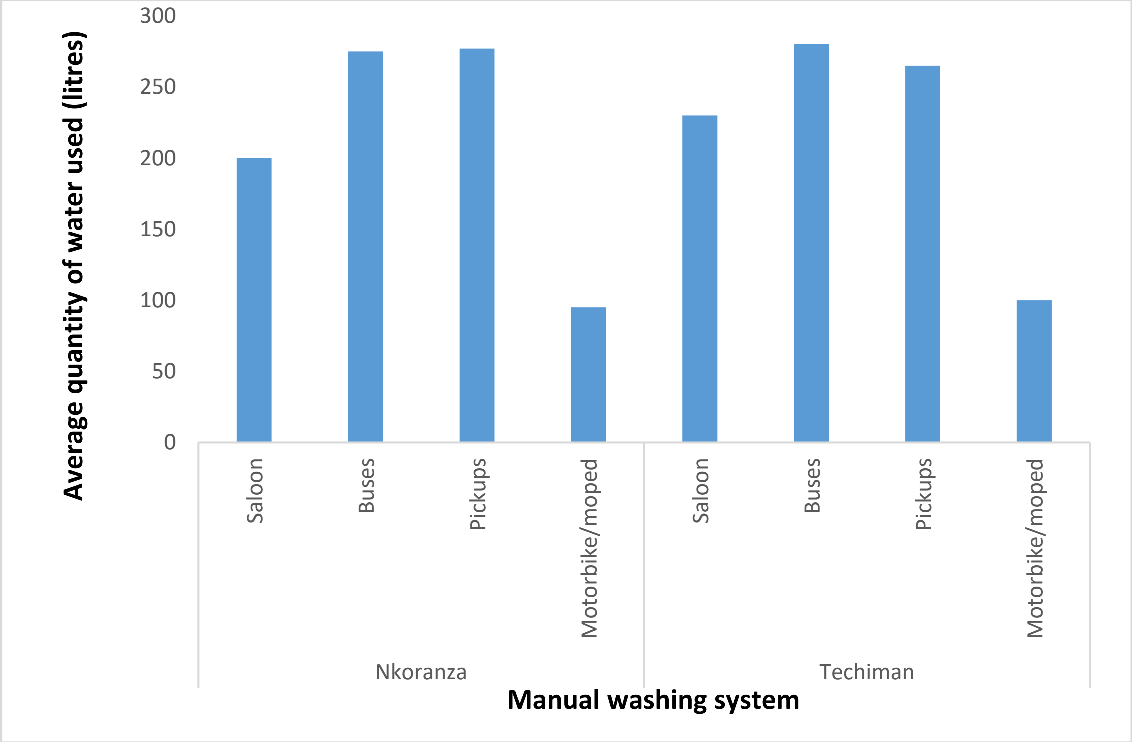

Figure 4.3: Average quantity of water used by manual washing system

4.5 Volume of Water Used for Washing Vehicles Daily in the Two Locations

A total of 160 (80 from Techiman and 80 from Nkoranza) vehicles were observed at the two washing bays per day. Quantity of water used for washing the different types of vehicles daily by spray gun varied between 97 L and 1277 L. Average volume of water used for washing vehicles daily by spray gun varied between 970 L and 6150 L. The mean quantity of water used to wash saloon car by spray gun was 170 L, buses 294 L, pickups 254 L, articulators 1254 L, graders 1167 L and motorbike 107 L. The mean quantity of water used to wash salon car by manual mode was 215 L, buses 278 L, pickups 271 L and motorbike 98 L. The results showed that heavy articulators used higher volume of water (6150 L) in washing vehicles in both Techiman and Nkoranza. This was followed by 3831 L for heavy articulators in Techiman, 3820 L for saloon in Techiman and 2685 L for saloon in Nkoranza. Motorbikes/moped used the least volume of water (928 L) daily in washing and this occurred in Nkoranza.

Articulators and graders/moped were not washed manually in both Techiman and Nkoranza. An average of 15814 L of water was used by spray gun daily for the two study locations, while 5382 L was used by manual method daily for the two study locations. There was a statistically significant difference between the volume of water used in these two locations (Table 4.2).

The volume of water used daily to wash vehicles from all the twenty-two (22) washing bays in both Techiman and Nkoranza Municipalities can be found in Appendix C.

Table 4.2: Average volume of water used for washing vehicles daily

Location of washing bays	Method of washing	Type of vehicle	Quantity of water used for washing (L)	Average number of vehicles	Volume of water used for washing daily (L)
Nkoranza	**Spray Gun**	Saloon	149±28	18±5	2685±425
		Buses	286±44	7±3	2002±397
		Pickups	260±37	10±4	2600±415
		Heavy Articulators	1230±355	5±2	6150±858
		Graders/loaders	1164±288	2±1	2328±413
		Motorbike/moped	116±25	8±4	928±158
		Total	**3205**	**50**	**16693**
		Average (Mean)	**534**		**2782**
Techiman	**Spray Gun**	Saloon	191±31	20±7	3820±589
		Buses	301±51	5±2	1505±325
		Pickups	247±36	10±4	2470±405
		Heavy Articulators	1277±377	3±2	3831±590
		Graders/loaders	1169±301	2±1	2338±415
		Motorbike/moped	97±21	10±4	970±170
		Total	**3284**	**50**	**14934**
		Average (Mean)	**547**		**2489**
Nkoranza	**Manual**	Saloon	200±39	12±5	2400±400
		Buses	275±42	5±2	1375±252
		Pickups	277±44	4±2	1108±155
		Motorbike/moped	95±19	9±4	855±145
		Total	**847**	**30**	**5738**
		Average (Mean)	**212**		**1435**
Techiman	**Manual**	Saloon	230±30	10±4	2300±350
		Buses	280±43	5±2	1400±250
		Pickups	265±33	5±2	1325±222
		Motorbike/moped	100±24	10±4	1000±250
		Total	**875**	**30**	**5025**
		Average (Mean)	**219**		**1256**

4.6 Surface Area of Vehicles and Water Used Ratio

The surface area of vehicles and water used ratio was analysed. This was done in order to estimate the vehicles that used more water. The higher the water used per surface area the higher the volume of water used and vice versa. From the results presented in Table 4.3, the surface area of saloon cars, buses, pickups, heavy articulators, graders/loaders and motorbike/moped were 12,224m^2, 30,235m^2, 1,632m^2, 28,580m^2, 23,022m^2 and 290m^2 respectively. The average volume of water used to wash saloon cars, buses, pickups, heavy articulators, graders/loaders and motorbike/moped at both Techiman and Nkoranza using spray gun method were 170 L, 294 L, 254 L, 1030 L, 1167 L, and 107 L (Table 4.2) respectively. Despite buses recording the highest surface area, water used per surface area (0.01) was the lowest. Heavy articulators and graders recorded the highest water use of 1200 L and 1167 L, respectively. The water used per surface areas were not as high as compared to pickups and motorbikes/moped. Although motorbikes/moped recorded the lowest surface area and water used, it recorded the highest water used per surface area (Table 4.3).

Table 4.3: Surface area of vehicles and water used ratio

Vehicle	Surface area	Water used (L)/Vehicle	Water used per surface area
Saloon	12,224m^2	170	0.01
Buses	30, 235m^2	294	0.01
Pickups	1, 632m^2	254	0.16
Heavy articulators	28, 580m^2	1200	0.04
Graders/loaders	23, 022 m^2	1167	0.05
Motorbike/moped	290m^2	107	0.37

Source: (Gürbüz *et al.*, 2016), DVLA, Ghana, 2021.

4.7 Nature of Washing Surfaces of Washing Bays

The grounds for operation were either cemented or not cemented. The study showed that majority representing 15(68%) was operating on cemented surfaces whilst 7(32%) were not cemented (Table 4.4).

Table 4.4: Nature of washing surfaces of washing bays

Location of washing bays	Nature of washing surface Cemented n(%)	Not cemented n(%)	Total n(%)
Nkoranza	5(23)	2(9)	7(32)
Techiman	10(45)	5(23)	15(68)
Grand Total	**15(68)**	**7(32)**	**22(100)**

4.8 Wastewater Disposal

Wastewater generated from the washing bays flowed directly into nearby streams. Wastewater generated from the washing bays flowed through multiple and single sewer drains. At Nkoranza, multiple sewers were 4(18%) and single sewers were 3(14%) whereas that of Techiman were 10(45%) and 5(23%) for multiple and single sewers respectively (Table 4.5).

Table 4.5: Wastewater disposal

Location	Wastewater disposal Multiple sewer n(%)	Single sewer n(%)	Total n(%)	P-value
Nkoranza	4(18)	3(14)	7(32)	0.665
Techiman	10(45)	5(23)	15(68)	
Grand Total	**14(64)**	**8(36)**	**22(100)**	

4.9 Nature of Washing Surface and Means of Wastewater Disposal

The results showed that, 9(41%) of washing bays with cemented surface disposed their wastewater through multiple sewers while 6(27%) disposed through single sewer. Again, 5(23%) of washing bays with non-cemented surface disposed their wastewater through multiple sewers while 2(9%) disposed in single sewer (Table 4.6).

Table 4.6: Nature of washing surface and methods of wastewater disposal

Nature of washing surface	Means of wastewater disposal		Total	P-value
	Multiple sewer	Single sewer		
	n(%)	n(%)	n(%)	
Cemented	9(41)	6(27)	15(68)	0.604
Not cemented	5(23)	2(9)	7(32)	
Grand Total	**14(64)**	**8(36)**	**22(100)**	

4.10 Actual Volume of Wastewater Generated Per Day

The volume of wastewater generated and released into the stream was calculated based on the 160 vehicles observed in the two washing bays. Average quantity of wastewater generated by spray gun daily for the two study locations varied between 742 L and 4921 L (Table 4.7). Average quantity of wastewater generated by manual washing varied between 800 L and 1920 L (Table 4.7). The mean quantities of wastewater generated for washing vehicles per day using spray gun were 2600 L, 1404 L, 1992 L, 3994 L, 1917 L and 760 L for salon cars, buses, pickups, articulators, graders and motorbikes, respectively, for both Techiman and Nkoranza (Table 4.7).

The mean quantities of wastewater generated by manual washing method were 1880 L, 1110 L, 973 L and 843 L for salon cars, buses, pickups, and motorbikes, respectively, for both Techiman and Nkoranza (Table 4.7). Spray gun method of washing used in Nkoranza generated 13358 L of wastewater while Techiman generated 11942 L of wastewater daily. Manual mode of washing used in Nkoranza generated 4590 L of wastewater while Techiman generated 4020 L of wastewater daily (Table 4.7).

The average volume of wastewater generated was obtained by multiplying the 0.8 in Table 4.7 for paved surfaces by the volume of water used for washing daily.

The volume of wastewater generated daily from all the twenty-two (22) washing bays from both Techiman and Nkoranza can be found in Appendix D.

Table 4.7: Volume of wastewater generated daily for the different vehicles in the two locations

Location of washing bays	Method of washing	Type of vehicle	Volume of water used for washing daily (L) (From Table 4.3)	Paved/Not paved (0.8/0.5)	Average volume of wastewater generated (L)
Nkoranza	**Spray Gun**	Saloon	2685±425	0.8	2148
		Buses	2002±397	0.8	1604
		Pickups	2600±415	0.8	2080
		Heavy Articulators	6150±858	0.8	4921
		Graders/loaders	2328±413	0.8	1863
		Motorbike/moped	928±158	0.8	742
		Total	**16697**		**13358**
Techiman	**Spray Gun**	Saloon	3820±589	0.8	3052
		Buses	1505±325	0.8	1203
		Pickups	2470±405	0.8	1973
		Heavy Articulators	3831±590	0.8	3066
		Graders/loaders	2338±415	0.8	1870
		Motorbike/moped	970±170	0.8	777
		Total	**14927**		**11942**
Nkoranza	**Manual**	Saloon	2400±400	0.8	1920
		Buses	1375±252	0.8	1100
		Pickups	1108±155	0.8	886
		Motorbike/moped	855±145	0.8	684
		Total	**5738**		**4590**
Techiman	**Manual**	Saloon	2300±350	0.8	1840
		Buses	1400±250	0.8	1120
		Pickups	1325±222	0.8	1060
		Motorbike/moped	1000±250	0.8	800
		Total	**5025**		**4020**

4.11 Wastewater Characterization

The results of the characteristics of carwash wastewater generated from washing bays at Techiman and Nkoranza compared with their respective EPA guidelines and P-values were presented (Table 4.8). The carwash wastewaters generally had slightly alkali pH (7.35-7.55). pH values of carwash wastewaters from Nkoranza and Techiman were 7.55 and 7.35 respectively. Temperature (18°C) was the same for both Nkoranza and Techiman. Electrical conductivity (EC) of carwash wastewaters from Nkoranza and Techiman showed 118.80 µS/cm and 997.90 µS/cm respectively. Turbidity values were 1190.00 NTU for Nkoranza and 1680.00 NTU for Techiman. TDS and TSS values of carwash wastewater from Nkoranza showed 125.00 mg/L and 857.00 mg/L respectively. At Techiman, TDS of (148.60 mg/L) and TSS of (2624.00 mg/L) were recorded. Other parameters analysed included Phosphate (0.37 mg/L), BOD (120.00 mg/L), COD (314.00 mg/L), Nitrate (1.86 mg/L), Nitrite (1.40 mg/L), lead (0.2524 mg/L) and iron (2.05 mg/L) were recorded for carwash wastewater from Nkoranza whereas Phosphate (0.41mg/L), BOD (160.00mg/L), COD (382 mg/L), Nitrate (2.20mg/L), Nitrite (2.4mg/L), Lead (0.43mg/L), Iron (2.38mg/L), were recorded for car wash wastewater from Techiman (Table 4.8). With the exception of pH, there were significant differences ($P<0.05$) for the remaining parameters. Levels of COD, BOD, TSS, TDS, turbidity, EC and pH were above the EPA recommended guideline values

Table 4.8: Characteristics of wastewater generated from the washing bays

Parameter	Nkoranza	Techiman	EPA (Effluent discharge)	P-value
pH	7.55±0.87	7.35±1.32	6-9	0.720
Temperature (°C)	18±2.00	18±3.50	-	0.000
EC (µS/cm)	111.8±20.66	997.9±198.12	1500	0.000
Turbidity (NTU)	1190±355.39	1680±417.97	75	0.000
TDS (mg/L)	125.5±25.00	148.60±27.54	1000	0.000
TSS (mg/ L)	857±14.00	2624±1047.20	50	0.000
SO_4^{2-} (mg/ L)	68±20.30	66±15.00	-	0.000
PO_4^{3-}(mg/L)	0.37±0.16	0.41±0.11	-	0.002
BOD_5 (mg/ L)	120±13.23	160±17.32	50	0.000
COD (mg/ L)	314±33.29	382±17.10	250	0.000
Nitrate (mg/ L)	1.86±0.31	2.20±0.53	-	0.034
Nitrite (mg/ L)	1.40±0.10	2.4±0.40	-	0.027
Lead (as Pb) (mg/ L)	0.25±0.08	0.43±0.23	-	0.003
Iron (Fe) as (mg/ L)	2.05±0.55	2.38±0.11	-	0.042

4.12 Stream and Borehole Water Characterization

Table 4.9 shows the results of the physico-chemical quality of the nearby drinking water sources (stream and borehole) analysis compared with the respective EPA guidelines and P-values. The nearby water sources were affected by the activities of washing bays. For streams, Nkoranza recorded higher values in almost all the parameters determined than Techiman. Total Suspended Solids (TSS) for stream for both Techiman and Nkoranza were 26.00 mg/L and 71.00 mg/L respectively. There was absence of SO_4^{2-} (mg/L) in Nkoranza mechanized borehole as against 1.00 mg/L in the mechanized borehole water samples from Techiman. For Nkoranza streams,

PO_4^{3-} (0.23 mg/L), BOD_5 (15.00 mg/L), COD (42.00 mg/L), Lead (0.02 mg/L) and Iron (0.36 mg/L) were recorded.

At Techiman PO_4^{3-} (0.22 mg/L), BOD (10.00 mg/L), COD (40.00 mg/L), Lead (0.02 mg/L) and Iron (0.19 mg/L) were recorded. Total suspended solids (TSS) and BOD_5 in borehole water samples from Techiman and Nkoranza were below detection. COD levels were (3.00 mg/L) for borehole water samples from both Techiman and Nkoranza. PO_4^{3-} value was (0.23 mg/L) at Nkoranza for stream and (0.22 mg/L) for Techiman. Lead for borehole water samples from both Techiman and Nkoranza recorded 0.01 mg/L. Iron in Nkoranza and Techiman boreholes recorded (0.07 mg/L) and (0.05 mg/L) respectively. Borehole levels of SO_4^{2-} at Techiman was above the EPA recommended levels whereas stream levels of BOD_5 and COD were above EPA recommended levels (Table 4.9).

Table 4.9: Mean values of stream and borehole water quality characterization

Parameters	Mechanized Borehole		Stream		EPA
	Nkoranza	Techiman	Nkoranza	Techiman	
TSS (mg/L)	0.00	0.00	71.00±12.32	26.00±3.10	-
SO_4^2 (mg/L)	0.00	1.00±0.43	3.00±0.76	3.00±0.76	0.5
PO_4^{3-} (mg/L)	0.09±0.02	0.12±0.01	0.23±0.03	0.22±0.02	0.5
BOD_5 (mg/L)	0.00	0.00	15.00±2.34	10.00±2.20	5
COD (mg/L)	3.00±0.76	3.00±0.76	42.00±10.20	40.00±9.31	40
Lead (mg/L)	0.01±3.00	0.01±3.00	0.02±5.00	0.02±2.00	0.05
Iron (mg/L)	0.07±0.00	0.05±0.00	0.36±0.00	0.19±0.01	0.3

4.13 Pollutant Loads Associated With Wastewater Generation

The pollutant loads were determined by the different parameters analysed and the volume of wastewater generated daily from the different washing bays. The results showed that washing bays from Techiman produced high level of pollution load for almost all the parameters (Table 4.10). Levels of pollutant load of TDS were between 2.25 kg and 2.37 kg per day for washing bays at Nkoranza and Techiman respectively. Washing bay from Techiman produced higher level of TDS pollution whereas washing bay at Nkoranza produced lower. TSS ranged between 15.38 kg and 41.88 kg. Similar to TDS, washing bay at Techiman produced higher level of TSS pollution. The rest of the results followed similar pattern as explained above. In all, TSS and TDS were high as compared to PO_4^3, Nitrite, Nitrate, Lead and Iron.

Levels of pollutant load of COD were 5.64 kg and 6.10 kg at Nkoranza and Techiman respectively. Washing bay at Techiman produced higher level of COD whilst manual mode of washing in Nkoranza produced lower. BOD levels ranged between 2.15 kg and 2.55 kg. Washing bay at Techiman produced higher level BOD pollution whereas washing bay at Nkoranza produced lower (Table 4.10).

Table 4.10 Pollutant loads associated with wastewater generated at the various washing bays per day

Parameter	Nkoranza (kg/day)	Techiman (kg/day)	Pollution load (kg/year)
TDS	2.25	2.37	821.98-865.78
TSS	15.38	41.88	5,614.43-15,287.66
SO_4^{2-}	1.22	1.05	445.30-384.35
PO_4^{3-}	0.01	0.01	2.56-2.56
BOD_5	2.15	2.55	786.21-932.21
COD	5.64	6.10	2,056.78-2,225.77
Nitrate	0.03	0.04	12.41-12.78
Nitrite	0.03	0.04	9.13-14.24
Lead (Pb)	0.00	0.01	1.46-2.92
Iron (Fe)	0.04	0.04	13.14-13.87

CHAPTER FIVE

DISCUSSION

5.1 Vehicles Washing Patterns at the Washing Bays

Washing bays used in this study were found on roadsides. The location of the washing bays was similar to that of Kumasi Metropolis in a study conducted by (Monney *et al*, 2020). The purpose of operators choosing such location is to ensure conspicuity to drivers and usually concentrated in areas of high traffic density (Monney *et al,* 2020). Most of these stations depended on groundwater sources (mechanized boreholes) with two of the washing bays using water from GWCL. Until recently, most of washing bays obtained their source of water from public water supply (Tekere *et al*, 2016). The sources of water for washing bays in the Techiman and Nkoranza Municipalities were mechanized boreholes and GWCL. Owing to the dependency on groundwater, the impact of washing bays on urban water supply is insignificant as opposed to findings in Cape Coast, Ghana (Quayson & Awere, 2017) where most washing bays depended mostly on water supplied by the urban water utility. The type of vehicles that were washed at the washing bays were heavy articulators, saloon, pickups, vans/buses/coaches, motor/moped and graders/loaders. Averagely, spray gun was used to wash 50 vehicles (including all types) daily, whereas manual washing was used for 30 vehicles daily. Overall, 3348 vehicles were washed at the two selected car washing bays during the three weeks monitoring period. Saloons were the most washed vehicle representing 36%. The findings were similar to other studies (Monney *et al,* 2020; Quayson & Awere, 2017). Heavy articulators and graders/loaders were all washed by spray gun and not manual mode of washing. This corroborates with findings in the study conducted by Monney *et al.,* (2020) in Kumasi, Ghana.

Averagely, about 80 vehicles were washed per station daily. Quayson & Awere (2017) stated that, the number of vehicles washed per day was dependent on the season, weather conditions, constant supply of water and uninterrupted power supply. They stated that when conditions were favourable, an average of 248 vehicles were washed daily and an average of 96 vehicles were washed daily when conditions were not favourable.

5.2 Quantification of Volume of Water Used

The findings of quantity of water used to wash saloon cars, pickups and buses were consistent with other reported values (Monney *et al.*, 2020; Tamiazzo *et al.*, 2015). The washing bays in the study areas did not use manual washing mode to wash heavy vehicles due to the surface areas and high volumes of water they consumed per wash. Manual washing was perhaps also not convenient for vehicles with large surface are. The water quantities used to wash vehicles in Techiman and Nkoranza were relatively higher than the quantities reported by Quayson & Awere (2017) in their studies in Cape Coast, Ghana. Irrespective of the fact that heavy trucks and graders were rarely washed, they consumed the highest water quantities per wash. The estimated total volumes of water used per day were 19,959 L and 22,431 L at Techiman and Nkoranza Municipalities respectively. This could be as a result of the laterite nature of the roads. According to Monney *et al.* (2020), averagely, water used to wash vehicles in these categories at a time could equally wash between 7 and 9 saloon cars. It was observed that total volume of water used for washing vehicles increased with increasing number of vehicles and this was confirmed by other report (Tamiazzo *et al.*, 2015). Motorbikes used the least volume of water for washing, while Graders/Loaders used the highest volumes of water for washing. Manual mode of washing used high volume of water per vehicle compared to spray gun. This is because the manual washing has low pressure and therefore cannot remove dirt particles effectively so large volume of water is needed to remove the dirt. Monney *et al*., (2020) stated that the volume of water used per vehicle was influenced by the method of washing.

5.3 Volume of Wastewater Generated

Most of the washing bays identified released their wastewater into public drains which eventually emptied into streams and rivers (Personal observation). The total volume of wastewater expected to join these streams and rivers per day at the selected washing bays were 15,962 L and 17,948 L at Techiman and Nkoranza Municipalities respectively. This is expected to contribute to pollution of water bodies. Another study suggested that commercial car washing bays could generate up to 10,000 L of car wash wastewater daily (Boluarte *et al.,* 2016). This means that the washing bays in Techiman and Nkoranza Municipalities generated more wastewater as compared to existing literatures due to the long distances these vehicles travel from the neighbouring cities. Another reason could also be the fact that the areas have many laterite roads and the vehicles accumulate large quantities of dirt.

From the studies, wastewater from cemented washing surface was mostly disposed through single sewer whereas wastewater from non-cemented washing surface was mostly disposed through multiple sewers. Volume of wastewater generated was dependent on the amount of water used for washing the vehicles.

5.4 Characterization of Water and Wastewater

5.4.1 Stream and Borehole Quality

Stream and borehole water quality analysis showed some levels of pollution. Differences existed in the level of pollution of the water samples collected from the sites. Despite TSS and BOD which were below detection levels in borehole samples, borehole levels of SO_4^{2-} and Iron were above the EPA recommended levels, whereas the levels of BOD_5 and COD in stream were above EPA recommended levels. The findings in this study showed that TSS was below detection in the borehole water and this is in conformity with a study conducted by Jagaba *et al.*, (2020). This means that the borehole water was clean. However, Terebo *et al.* (2019), recorded TSS of 31.45 mg/L and 46 mg/L in borehole water samples for both rainy and dry seasons, respectively. This could be as a result of either high or low levels of silt and organic matter in the boreholes. Though BOD in this research was below detection in borehole, Annan *et al*. (2022), recorded a minimum BOD of 0.30 mg/L and a maximum of 3.30 mg/L in a hand dug well in Accra, Ghana. The levels of SO_4^2 in borehole can be attributed to cleaning supplies products used by washing bay attendants that make its way towards borehole. Again, they are often derived from the sulphides of heavy metals (iron, nickel, copper and lead). Though sulphates in small amounts do not affect the users, those who are not used to the compound may suffer from dehydration and diarrhoea (Sharma and Kumar, 2020). As such users of boreholes near washing bays are likely to experience health effects. High levels of iron in borehole water samples can be ascribed to corrosion of car parts such as the engine, the frame rails which run underneath a car's doors on each side, the wheel wells, the exhaust and any underside components made of steel or metal that find its way in the discharged wastewater. High levels of Iron can damage the heart, liver

(Zhan *et al.*, 2019). Higher BOD indicates more oxygen is required, which is less for oxygen-demanding species to feed on, and signifies lower water quality. Inversely, low BOD means less oxygen is being removed from water, so water is generally purer. Higher COD levels on the other hand means a greater amount of oxidizable organic material in the sample**,** which will reduce dissolved oxygen (DO) levels. A reduction in DO can lead to anaerobic conditions, which is deleterious to higher aquatic life forms.

5.4.2 Characterization of Wastewater

The carwash wastewater from the various locations had an alkaline pH (7.35-7.55) values. This was within the recommended limit by EPA. Electrical conductivity, TDS, TSS and turbidity for Nkoranza were very low as compared to Techiman. Conductivity is the result of the presence of mineral salts of elements like sodium, calcium and magnesium. These salts when dissolved in water, produce free ions that are capable of passing electrical current in water (Rathore and Singh, 2021). Mucha and Kułakowski, (2016) stated that turbidity is dependent on the particulate matter in wastewater. High levels of TSS of wastewater in Nkoranza washing bays translate into a high turbidity. The turbidity values reported in this study were not far from that reported by Monney *et al.* (2020), but higher than the one reported by Aikins and Boakye, (2015). The difference could be related to the type of vehicles, the presence of dirt, mud and brake particles in the wastewater which were washed off from the vehicles (Talebzadeh *et al.,* 2021). It has been reported that sulphate is a common additive in detergents and contributes to foaming when released on water pathways (Stringfellow *et al.*, 2014). Nitrates and Nitrites were lower in the wastewater. Nitrite value in this study was higher than nitrate. This could be as a result of nitrifying bacteria which was not present to convert nitrate to nitrite (Ahmed *et al*., 2022).

5.5 Pollutant Loads Associated With Wastewater Generation

Washing bay at Techiman produced high levels of pollution load in the wastewater. This could be attributed to the fact that spray gun used at Techiman used high pressure therefore small volume of water was able to remove high amount of dirt. TSS and TDS were in high levels but PO_4^{3-}, Nitrite, Nitrate, Lead and Iron were in low levels. This was in line with the research work done by Samal *et al.* (2018). The reported high levels of pollution load by TSS might be from the tyre dust, rust stains, dirt, films from brakes and grimes being washed away during the cleaning processes (Hashim & Zayadi, 2016). In Malaysia, a study reported TSS of (75.00 mg/L), (89.00 mg/L) and (44.00 mg/L) in three different stages (pre-stock, wash, rinse) of car wash for one washing bay (Hashim & Zayadi, 2016) which is higher than the results recorded in this study. It was reported that TSS usually contains high amount of fine coal particles. This makes surface water blackish and reduces the appealing values of receiving water bodies. This might also block the sunlight required for photosynthesis by the bottom vegetation (Islam *et al.*, 2016). TDS is dependent on turbidity. It was reported that high turbidity is due to high particulate matter in wastewater (Mucha & Kułakowski, 2016). TDS content of ions and minerals contained in water bodies can accumulate in the body and cause kidney disorders (Sidabutar *et al.*, 2017). The COD level recorded in this study was the highest as compared to the other parameters (Table 4.11). The high levels of COD in the wastewater could come from the use of non-biodegradable surfactant with dirt during car washing (Lau *et al.*, 2013). High level of COD shows the existence of chemical oxidants in the wastewater. High COD could likely cause nutrient fixation in the soil resulting in reduced rate of nutrient available to plants. Chemical oxidants affect water treatment plants by causing rapid development of rust (Ojekunle & Lateef, 2017).

BOD level in this study ranged between 2.15 and 2.55 mg/L. In Sunyani-Ghana, a study conducted by Saah *et al.,* recorded BOD levels of 0.3-20 mg/L kg which is much lower than what was recorded in this study. Pollutants such as detergents, grease and oils, and organic matter increase the amount of BOD in wastewater. If large amounts of such effluents are discharged into water bodies, increased aerobic microbial decomposition of organic matter could lead to hypoxic conditions which could in turn lead to a number of negative effects ranging from reproductive failure in adult fish to mortality in juveniles (Davarnejad *et al.*, 2019). BOD and COD are important measurements to determine the extent of water pollution (Bader *et al.*, 2022). The ratio of BOD:COD indicates the biodegradability of wastewater, the higher the value of BOD:COD ratio, the lower biodegradability of wastewater and vice-versa (Ghanbari *et al.*, 2021). BOD/COD ratio of the wastewater in this study was 0.4 for both Techiman and Nkoranza Municipalities which is typical of industrial wastewater and makes it difficult to biodegrade in the environment. Dancer, (2020), recorded BOD/COD ratio of 0.46 in a study conducted in Switzerland which is a little higher than what was recorded in this study. The lowest ratio of BOD:COD for wastewater to be easily biodegradable is 0.4 and that the best value is greater than 0.5 (Andrio *et al.*, 2019). Zhang *et al.*, (2019) asserted that, biodegradability of wastewater should be close to 1 to make it readily biodegradable so that it can be easily treated by natural means.

Phosphate (PO_4^{3-}) and sulphate (SO_4^{2-}) ranged between 1.05-1.22 and 0.00-0.01 mg/L respectively in the wastewater generated in this study. Monney *et al.*, (2020) recorded between 0.04-0.07 mg/L for sulphate (SO_4^{2-}) and 0.01-0.01 mg/L for phosphate (PO_4^{3-}). Sulphate in its high amount makes water tastes bitter and also cause digestion problems in humans (Naghizadeh *et al.*, 2017). Phosphate on the other hand causes increased growth of algae and large aquatic plants, which can result in decreased levels of dissolved oxygen– a process called eutrophication (Boyd, 2020).

Nitrate levels in this study ranged between 0.03-0.04 mg/L as opposed to findings in Malaysia by Hashim and Zayada, (2016) where nitrate ranged between 0.00-2.16 mg/L. Nitrates in excess amounts can accelerate eutrophication, causing dramatic increases in aquatic plant growth and changes in the types of plants and animals that live in the stream (Wurtsbaugh *et al.*, 2019). Nitrite in this study ranged between 0.03-0.04 mg/L but 0.00 mg/L in findings in Malaysia by Hashim and Zayadi, (2016) which oppose the findings in this study. However, Monney *et al.*, (2020) recorded nitrite which ranged between 0.30-0.50 kg which corroborates with the findings in this study. Higher levels of nitrite than nitrate in this study could be as a result of nitrifying bacteria which was not present to convert nitrate to nitrite. High levels of nitrites are toxic to humans and animals, especially infants (Ziarati, 2018). High levels of nitrite are indications of disturbance of microbiological processes, of an overloaded plant or insufficient aeration capacity (Bachi *et al.*, 2020).

Lead (Pb) ranged between 0.00-0.01 mg/L in this study which was below EPA recommended level (Table 4.11). In other study conducted by Owusu-Asante *et al.,* (2022) in the Ashanti Region of Ghana, lead content ranged between 0.30- 0.53 mg/L which was higher than the results recorded in this study. The presence of Lead could be attributed to Lead paints and car batteries. Lead in irrigation water can inhibit plant cell growth at very high concentrations. Also in humans, lead accumulates in bones and teeth, where it has a biological half-life of 20 years. Though the presence does not harm bone and teeth, they function as reservoirs for releasing lead into the blood stream (Abdallah & Mourad, 2021).

Looking at the huge volumes of pollutants that were released into streams and rivers within a day in this study, pollution load for Phosphate and Sulphate, up to 2.56 and 445.30 mg/year were recorded. Lead and Iron were up to 2.92 mg/year and 13.87 mg/year respectively, Nitrate and Nitrite were up to 12.78 mg/year and 14.24 mg/year respectively. BOD up to 0.9 tons from Techiman and 0.8 tons from Nkoranza could be released in a year. COD up to 2 tons from Techiman and 2 tons from Nkoranza could also be released in a year. Similarly, a study conducted by Monney *et al*., (2020), pollution load of BOD and COD were up to 2 tons and 6 tons/year respectively.

The values of pollution load of the carwash wastewater are important in the design of appropriate treatment systems to ensure wastewater reuse.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The volume of water used for washing vehicles daily at Nkoranza by both spray gun method and manual ranged between 5738 L and16693 L.

The average volume of water used for washing vehicles daily at Nkoranza by both spray gun method and manual ranged between 1435 L and 2782 L.

The volume of water used for washing vehicles daily at Techiman by both spray gun and method and manual ranged between 5025 L and 14934 L.

The average volume of water used for washing vehicles daily at Techiman by both spray gun method and manual ranged between 1256 L and 2489 L.

The volume of wastewater generated daily at Nkoranza by both spray gun method and manual ranged between 4590 L and 13358 L.

The volume of wastewater generated daily at Techiman by both spray gun and manual method ranged between 4020 L and 11942 L.

The level of pollutant load of COD were 5.64 mg/L and 6.10 kg at Nkoranza and Techiman respectively per day. Wastewater from Techiman produced higher level of COD pollution whilst Nkoranza produced lower.

BOD levels of pollution load were 2.15 mg/L and 2.55 mg/L at Nkoranza and Techiman respectively per day.

All the washing bays identified released their wastewater into public drains which eventually empty into rivers. This eventually led to pollution of water bodies

6.2 Recommendations

Washing Bays

- Must adopt recycling method so that wastewater can be recycled and reused.
- Must have a storage unit which will store wastewater so that the pollutants will settle to make recycling and reuse easy.

Municipal Assemblies

- The Environmental unit must educate and monitor the operations of these washing bays.

Environmental Protection Agency (EPA)

- Environmental laws and policies must be enforced so that washing bay owners do what is right in terms of wastewater discharge.
- The carwash stations must also be compelled by the legal provisions in 1999 Environmental Assessment Regulations to install water recycling technologies.

Need for further studies

- Further studies are required to develop appropriate wastewater treatment systems for the car washing bays and assess the financial implications of wastewater recycling on the carwash business in the Municipalities.

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APPENDICES

APPENDIX A

1. Measurement of pH of water

pH was measured using a pH meter (JENWAY 3071, model pH 82; degree of accuracy 0.01) equipped with a temperature probe. The pH meter was initially calibrated by dipping the electrode into a buffer solution of known pH (pH 4) and the asymmetric potential control of the instrument altered until the meter read the known pH value of the buffer solution. The standard electrode after rinsing with distilled/deionized water was then immersed in a second buffer solution (pH 9) and the instrument adjusted to read the pH value of this buffer solution. With the pH meter calibrated, it was immersed in the water sample, allowed to stabilize and the pH value read from the instrument. The beaker and the electrode were washed in between samples with deionized water in order to prevent contamination by other samples.

2. Measurement of Electrical Conductivity (EC)

A high powered microcomputer conductivity meter JENWAY 40710 model HI 9032 with a degree of accuracy of 0.01µS/cm was used to measure the conductivity of the water samples in the laboratory. The instrument was initially calibrated using standard solution of conductivities 500 µS/cm and 1500 µS/cm. Duplicate values were taken.

3. Temperature, pH, TDS and EC

Apparatus

Palintest Micro 800 Multi pH/Conductivity/TDS/Temperature meter

Procedure

A digital reading appears upon inserting the probes into the sample indicating first the values of pH and temperature. The sample is stirred and the digital reading allowed stabilize before recording. The "MODE" button which allows switching to other parameters was then used to read the values of TDS and EC

4. Measurement of Total Suspended Solids (TSS)

Procedure

100mL of a well-mixed sample was filtered through a weighed standard glass-fiber filter. The residue retained on the filter was then dried in an oven at 103 to 105°C for 1 hour. It was then cooled in a dessicator and weighed. The increase in weight of the filter represents the total suspended solids.

Calculation

The TSS was computed for using the formula below:

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

A = weight of filter + dried residue, mg, and

B = weight of filter, mg.

5. Measurement of Turbidity

For water to be aesthetically accepted its clarity must be ensured. Presence of suspended matter such as silt, clay, organic and inorganic matter and microorganisms in water affect the clarity of it and give rise to turbidity in the water. Furthermore floating particulates could easily hide inside bacteria, which are difficult to eliminate after adding a disinfectant as for instance chlorine.

Turbidity is defined as the light scattering and absorbing property that prevents light from being transmitted in straight lines through the sample. Whereas most suspended matter scatter light waves, optically black particles such as activated carbon adsorb light and increased turbidity readings.

Procedure

1) Measure 10ml of the sample with the measuring cylinder and pour into the sample cell.

2) Clean the surface of the sample cell carefully with tissue paper.

3) Place the sample cell into the instrument light cabinet and cover with the light shield.

4) Read the turbidity. (If the reading is beyond range, repeat the procedure using different ranges and different standards).This is the reading obtained for the turbidity of the sample in NTU.

5) Remove the light shield and sample cell and clean cell after emptying the sample.

6. Measurement of Nitrate

Method

In the Palintest Nitratest method nitrate is first reduced to nitrite, the resulting nitrite is then determined by a diazonium reaction to form a reddish dye.

The reduction stage is carried out using the unique zinc-based Nitratest Powder, and Nitratest Tablet which aids rapid flocculation after the one minute contact period. The test is conducted in a special Nitratest Tube – a graduated sample container with hopper bottom to facilitate settlement and decanting of the sample.

The nitrite resulting from the reduction stage, is determined by reaction with sulphanilic acid in the presence of N-(1naphthyl)-ethylene diamine to form a reddish dye. The reagents are provided in a single Nitricol tablet which is simply added to the test solution.

The intensity of the colour produced in the test is proportional to the nitrate concentration and is measured using a Palintest Photometer

Reagents and Equipment

Palintest Nitratest Powder (Spoon Pack)

Palintest Nitratest Tablets

Palintest Nitricol Tablets

Palintest Nitratest Tube, 20 ml (PT 526)

Palintest Automatic Wavelength Selection Photometer

Round Test Tubes, 10 ml (PT 595)

Test Procedure

1. Fill the Nitratest Tube with sample to the 20 ml mark.
2. Add one level spoonful of Nitratest Powder and one Nitratest tablet. Do not crush the tablet. Replace screw cap and shake tube well for one minute.
3. Allow tube to stand for about one minute then gently invert three or four times to aid flocculation. Allow tube to stand for three minutes or longer to ensure complete settlement.
4. Remove screw cap and wipe around the top of the tube with a clean tissue. Carefully decant the clear solution into a round test tube, filling to the 10 ml mark.

5. Add one Nitricol tablet, crush and mix to dissolve.
6. Stand for 10 minutes to allow full colour development.
7. Select Phot 23 on Photometer for result as mg/l N, or Phot 63 for result as mg/l NO_3.
8. Take Photometer reading in usual manner.

7. Measurement of Nitrite

Nitrites and Nitrite-based formulations are widely used for corrosion control in cooling water systems. The Palintest Nitrite test provides a simple means of measuring nitrite for the control of such treatment products in cooling water.

Method

Nitrites are readily oxidised by potassium permanganate under acidic conditions. The Palintest Nitrite test is based on two tablet reagents –an acidifying tablet and a tablet containing a standardised amount of potassium permanganate. The test is carried out by acidifying the sample with the first tablets and then adding the second tablets one at a time until a pink colour persists. The results is calculated from the number of the second tablets used in the test.

Reagent and Equipment

Palintest Nitrite No 1 Tablets

Palintest Nitrite No 2 Tablets

Palintest Sample Container, 50/ ml plastic (PT 506, PT 519) or

Palintest Sample Container, 100/50/10 ml plastic (PT 510)

Test Procedure

1. Filter sample if necessary to obtain a clear solution.
2. Fill the Palintest sample container to the 10 ml mark. Make up to the 50 ml mark using distilled water or tap water.
3. Add two Nitrite No 1 tablets, cap the container and shake until the tablets disintegrate.
4. Add one Nitrite No 2 tablet, cap the container and shake until the tablet disintegrates
5. Continue adding Nitrite No 2 tablets one at a time in this manner until a pink colour persists for approximately one minute.
6. Note the number of Nitrite No 2 tablets used and calculate the results from the formula below:-

$$\text{Nitrite (Mg/l } NaN0_2) = \text{No of Tablets} * 140$$

8. Measurement of sulphate

SulfaVer 4 Method

Principle

Sulphate ions in the sample react with barium in the SulfaVer 4 and form a precipitate of barium sulphate. The amount of turbidity formed is proportional to the sulphate concentration. The SulfaVer 4 also contains a stabilizing agent to hold the precipitate in suspension.

Procedure

Sulphate was determined by selecting Program 680 Sulphate from the Hach Programs. A clean, round sample cell was filled with a known sample volume diluted to 10mL and the contents of one SulfaVer 4 Reagent Powder Pillow added to it. The sample cell was swirled to mix the contents and the timer icon pressed to begin a five-minute reaction period. Another sample cell was filled with 10 mL distilled water (the blank) and placed in the cell holder of the spectrophotometer after thoroughly wiping it. The 'Zero' button was pressed and a 0.00 mg/L SO_4^{2-} concentration was displayed. After the five-minute reaction period, the prepared sample was also placed in the cell holder after wiping the sample cell and the 'Read' button was pressed. The concentration of sulphate was displayed in mg/L SO_4^{2-}.

9. Five day Biochemical Oxygen Demand (BOD_5)

Dilution method

Principle

The biochemical oxygen demand (BOD) determination is an empirical test in which standardized laboratory procedures are used to determine the relative oxygen requirements of wastewaters, effluents, and polluted waters. It is computed from the initial and final DO of a sample after incubating at 20°C for five days.

Procedure

A known volume of the sample was poured into a 300ml BOD bottle and mixed with dilution water until it overflowed and then stoppered. Another standard 300mL BOD bottle was filled with dilution water to represent the blank. The initial dissolved oxygen concentrations of the blank and diluted sample were determined using a DO meter. Both bottles were stored at 20°C in the incubator for five days. After 5 days the amount of dissolved oxygen remaining in the samples were measured with a DO meter.

Calculation

The 5-day BOD was computed using the equation below:

$$BOD_5, mg/L = \frac{D_1 - D_2}{P}$$

D_1 = DO of diluted sample immediately after preparation, mg/L,

D_2 = DO of diluted sample after 5 day incubation at 20°C, mg/L,

P = decimal volumetric fraction of sample used.

10. Chemical Oxygen Demand (COD)

Open Reflux method

Principle

A boiling mixture of chromic and sulphuric acids oxidises most types of organic matter. In this method, a sample is refluxed in strongly acid solution with a known excess of potassium dichromate ($K_2Cr_2O_7$). After digestion, the remaining unreduced $K_2Cr_2O_7$ is titrated with ferrous ammonium sulphate to determine the amount of $K_2Cr_2O_7$ consumed and the oxidizable matter is calculated in terms of oxygen equivalent.

Procedure

1g of $HgSO_4$ was transferred into the reflux flask followed by a known volume (10mL) of the sample and mixed. 10mL of 0.0417M $K_2Cr_2O_7$ solution was also added to the flask and mixed. 20mL of conc. H_2SO_4 was added slowly to the flask whiles simultaneously cooling the outside of the flask under running water after which 1mL of silver sulphate solution was added. The procedure was repeated for the same volume of distilled water as the blank. The solution was then boiled under reflux for 2 hours after which 45mL of distilled water was added and subsequently cooled under running water. 2 to 3 drops of ferroin indicator was added after which a light blue/green colour appeared. The residual solution was titrated with 0.1M Ferrous Ammonium Sulphate (FAS) solution to reddish brown endpoint. The COD was calculated using the formula below:

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

Where:

A = mL FAS used for blank,

B = mL FAS used for sample,

M = molarity of FAS (0.1M)

8000 = milliequivalent weight of oxygen × 1000 mL/L

11. Iron

FerroVer Method

Principle

FerroVer Iron Reagent converts all soluble iron and most insoluble forms of iron in the sample to soluble ferrous iron. The ferrous iron reacts with the 1, 10 phenanthroline indicator in the reagent to form an orange colour in proportion to the iron concentration.

Procedure

The concentration of iron was determined by initially selecting Program 265 Iron, FerroVer from the Hach Programs. A clean, round sample cell was filled with a known sample volume diluted to 10mL and the contents of one FerroVer Iron Reagent Powder Pillow added to it. The sample cell was swirled to mix the contents and the timer icon pressed to begin a three-minute reaction period. Another sample cell was filled with 10mL distilled water (the blank) and placed in the cell holder of the spectrophotometer after thoroughly wiping it. The 'Zero' button was pressed and a 0.00 mg/L Fe concentration was displayed. After the three-minute reaction period, the prepared sample was also placed in the cell holder and 'Read' button pressed. The concentration of iron was displayed in mg/L Fe.

12. Heavy metals determination

The samples were also analysed for heavy metals including Fe and Pb. The above mentioned parameters were analysed using Atomic Absorption Spectrophotometer (AAS)

APPENDIX B

Baseline assessment form on assessing contribution of washing bays toward urban aquatic pollution

I ....a student of University of Education, Winneba-Mampong Campus, undertaking a study on contribution of washing bays toward urban aquatic pollution, I therefore seek your support by participating in a survey as a respondent and any information you provide will be treated with anonymity and will remain confidential.

Informed **CONSENT**: Agreed [ ]

GPS Coordinates: ……………………………..

S/N	QUESTIONS AND FILTERS	CODING CATEGORIES
1.	Date of interview :	
2.	Name of washing bay/GPS Code :	
3.	Location of washing bay :	

4.	Source of water	1. Mechanized Borehole [ ] 2. Pipe borne water [ ] 3. Other …………………………..
4.	Type of cars washed	1. Articulators [ ] 2. Saloon [ ] 3. Pick-ups [ ] 4. Vans/Buses/Coaches [ ] 5. Motor/Moped [ ] 6. Graders/Loaders [ ]
5.	Nature of washing surface	1. Cemented/Paved [ ] 2. Not cemented/Not paved [ ]
6.	Number of cars washed in a day	…………………………………………………..
7.	Number of category of vehicles washed per day	1. Articulators [ ] 2. Saloon [ ] 3. Pick-ups [ ] 4. Vans/Buses/Coaches [ ] 5. Motor/Moped [ ] 6. Graders/Loaders [ ]
8.	Method of washing	1. Semi-automated [ ] 2. Manual [ ]
9.	Type of equipment used	3. Spray gun [ ] 4. Bucket [ ] 5. Foam [ ]

		6. Brush [ ] 7. Duster [ ]
10.	Wastewater disposal	1. Single sewer [ ] 2. Multiple sewer [ ]
11.	Other facility attached	1. Fuel station [ ] 2. Drinking bar [ ] 3. Other ………………………………

APPENDIX C

Volume of water used daily

Location	Washing bay/ GPS Co-ordinates	Vehicle	Quantity of water used for washing (L)		Number of category of vehicles washed in a day		Volume of water used for washing daily (L)	
			Spray gun	Manual	Spray gun	Manual	Spray gun	Manual
Techiman	Joe thousand/ B T-0021-7821	Saloon	190.76	230.00	20	10	3815.20	2300.00
		Buses	300.98	280.00	5	5	1504.00	1400.00
		Pickups	246.60	265.00	10	5	2466.00	1325.00
		Heavy articulators	1277.32	Nil	3	Nil	3831.96	-
		Graders	1169.12	Nil	2	Nil	2338.24	-
		Motor bike	97.14	100.00	10	10	971.40	1000.00
		Total					**14926.80**	**5025.00**
	Yadumsu/ BT-0127-	Saloon	145.00	195.00	18	15	2610.00	2925.00
		Buses	277.84	385.00	10	3	2778.40	1155.00

4441	Pickups	238.08	297.00	7	3	1666.56	891.00
	Heavy articulators	1230.80	Nil	2	Nil	2461.60	-
	Graders	1164.08	Nil	2	Nil	2329.60	-
	Motor bike	99.00	110.00	11	9	1089.00	990.00
	Total						**5961.00**
Ambassador/	Saloon	160.30	204.00	15	15	2404.50	3060.00
BT-0219-	Buses	261.90	374.00	10	3	2619.00	1122.00
6656	Pickups	257.51	285.00	10	3	2575.10	855.00
	Heavy articulators	1226.34	Nil	3	Nil	3679.02	-
	Graders	1092.36	Nil	2	Nil	2184.72	-
	Motor bike	98.68	100.00	10	9	986.80	900.00
	Total					**144449.14**	**5937.00**
Sulemantwi/	Saloon	160.30	204.00	25	15	4007.50	3060.00
Unesco/	Buses	261.90	374.00	5	3	1309.50	1122.00
BT-0002-	Pickups	257.51	Nil	3	-	772.53	-

6943	Heavy articulators	Nil	Nil	-	-	-	-
	Graders	Nil	Nil	-	-	-	-
	Motor bike	98.68	100.00	15	5	1480.20	500.00
	Total					**7569.73**	**4682.00**
GMT	Saloon	155.71	230.00	10	5	1557.10	1150.00
cleaning and	Buses	Nil	Nil	-	-	-	-
laundry/	Pickups	246.60	265.00	2	1	493.20	265.00
BT-0089-	Heavy articulators	Nil	Nil	-	-	-	-
4312	Graders	Nil	Nil	-	-	-	-
	Motor bike	95.95	100	10	5	959.60	500.00
	Total					**3009.90**	**1915.00**
SEC./	Saloon	165	225	10	5	1650	1125
BT-0332-	Buses	268	302	5	2	1340	604
4209	Pickups	254	275	5	1	1270	275
	Heavy articulators	Nil	Nil	-	-	-	-

	Graders	Nil	Nil	-	-	-	-
	Motor bike	100.02	121	10	5	1000	605
	Total					**5260**	**2609**
Joyce	Saloon	155	195	15	10	2325	1950
Ameyaw/	Buses	Nil	Nil	-	-	-	-
BT-0006-	Pickups	259	315	3	1	777	315
8861	Heavy articulators	Nil	Nil	-	-	-	-
	Graders	Nil	Nil	-	-	-	-
	Motor bike	100	129	10	7	1000	903
	Total					**3202**	**3168**
Asuo Tano/	Saloon	149	214	15	8	2235	1712
BT-0031-	Buses	Nil	Nil	-	-	-	-
2666	Pickups	260	318	7	5	1820	1590
	Heavy articulators	Nil	Nil	-	-	-	-
	Graders	Nil	Nil	-	-	-	-

	Motor bike	116	125	10	10	1160	1250
	Total					**5215**	**4552**
Jah bless/	Saloon	191	234	20	15	3820	3510
BT-0003-	Buses	301	310	5	3	1505	930
1158	Pickups	247	298	2	1	494	298
	Heavy articulators	Nil	Nil	-	-	-	-
	Graders	Nil	Nil	-	-	-	-
	Motor bike	97	116	15	10	1455	1160
	Total					**5769**	**5898**
Big Jeffrey/	Saloon	185	205	10	8	1850	1640
BT-0008-	Buses	Nil	Nil	-	-	-	-
8680	Pickups	Nil	Nil	-	-	-	-
	Heavy articulators	Nil	Nil	-	-	-	-
	Graders	Nil	Nil	-	-	-	-

	Motor bike	99	123	15	12	1485	1476
	Total					**3335**	**3116**
Owura	Saloon	196	221	15	10	2940	2210
Barima/	Buses	305	337	10	8	3050	2696
BT-0047-	Pickups	256	311	10	5	2560	1555
7410	Heavy articulators	1253	Nil	5	-	6265	-
	Graders	1162	Nil	2	-	2324	-
	Motor bike	114	132	10	8	1140	1056
	Total					**18279**	**7517**
Kasapa/	Saloon	146	216	20	15	2920	3240
BX-0309-	Buses	279	309	15	10	4185	3090
6419	Pickups	265	275	5	3	1325	825
	Heavy articulators	1242	Nil	3	-	3726	-
	Graders	1160	Nil	1	-	1160	-
	Motor bike	103	100	15	10	1545	1000

	Total					**14861**	**8155**
Sir Oti	Saloon	140	198	15	10	2100	1980
Akenten/	Buses	266	271	10	5	2660	1355
BT-0009-	Pickups	246	295	10	5	2460	1475
3764	Heavy articulators	1259	Nil	5	-	6295	-
	Graders	1153	Nil	2	-	2306	-
	Motor bike	113	120	10	10	1130	1200
	Total					**16951**	**6010**
Big Apples/	Saloon	150	193	20	15	3000	2895
BT-0391-	Buses	281	314	7	5	1967	1570
7995	Pickups	234	274	5	3	1170	822
	Heavy articulators	Nil	Nil	-	-	-	-
	Graders	Nil	Nil	-	-	-	-
	Motor bike	106	112	15	15	1590	1680
	Total					**7727**	**6967**

	Alhaji Samu/	Saloon	149	200	20	15	2980	3000
	BX-0368-	Buses	286	275	10	5	2860	1375
	0250	Pickups	269	277	9	5	2421	1385
		Heavy articulators	1230	Nil	5	-	6150	-
		Graders	1169	Nil	1	-	1169	-
		Motor bike	116	123	5	5	580	615
		Total					**16160**	**6375**
Nkoranza	Alhaji Iddrisu	Saloon	149	200	18	12	2682	2400
	Ayiku/BO-	Buses	286	275	7	5	2002	1375
	0070-7899	Pickups	260	277	10	4	2600	1108
		Heavy articulators	1230	Nil	5	Nil	6151	Nil
		Graders	1164	Nil	2	Nil	2328	Nil
		Motor bike	116	95	8	9	928	855
		Total					**16691**	**5738**

Oh Black Man/BO-0005-0691	Saloon	185	255	5	3	925	765
	Buses	-	-	-	-	-	-
	Pickups	236	315	3	1	708	315
	Heavy articulators	Nil	Nil	-	-	-	-
	Graders	Nil	Nil	-	-	-	-
	Motor bike	105	115	15	15	1575	1725
	Total					**3208**	**2805**
Gaso/ BO-0021-5585	Saloon	158	163	15	10	2370	1630
	Buses	265	269	5	3	1325	807
	Pickups	248	320	5	3	1240	960
	Heavy articulators	Nil	Nil	-	-	-	-
	Graders	Nil	Nil	-	-	-	-
	Motor bike	96	107	15	10	1440	1070
	Total					**6375**	**4467**

Adehyeman/	Saloon	176	221	5	5	880	1105
BO-0045-	Buses	260	320	2	1	520	320
2080	Pickups	234	312	2	1	468	312
	Heavy articulators	Nil	Nil	-	-	-	-
	Graders	Nil	Nil	-	-	-	-
	Motor bike	97	105	5	5	485	525
	Total					**2353**	**2262**
Poku Dum/	Saloon	161	201	20	15	3220	3015
BO-0006-	Buses	252	248	10	8	2520	1984
9164	Pickups	247	317	5	3	1235	951
	Heavy articulators	Nil	Nil	-	-	-	-
	Graders	Nil	Nil	-	-	-	-
	Motor bike	97	99	15	10	1455	990
	Total					**8430**	**6940**

Jomo	Saloon	170	235	7	5	1190	1175
Services/	Buses	153	320	3	1	459	320
BO-0042-	Pickups	223	275	2	1	446	275
4987	Heavy articulators	Nil	Nil	-	-	-	-
	Graders	Nil	Nil	-	-	-	-
	Motor bike	96	125	20	15	1920	1875
	Total					**4015**	**3645**
Frimps/	Saloon	136	168	10	5	1360	840
BO-0102-	Buses	218	284	8	5	1744	1425
0451	Pickups	235	320	5	2	1175	640
	Heavy articulators	1269	Nil	1	-	1269	-
	Graders	1196	Nil	1	-	1196	-
	Motor bike	103	120	10	10	1030	1200
	Total					**7774**	**4105**

APPENDIX D

Volume of wastewater generated daily

Location	Washing bay	Type of Vehicle	Volume of water used for washing daily (L)		Paved/Not paved (0.8/0.5)	Average quantity of wastewater generated daily(L)	
			Spray gun	Manual		Spray gun	Manual
Techiman	Joe thousand	Saloon	3815	2300	0.8	3052	1840
		Buses	1504	1400		1203	1120
		Pickups	2466	1325		1973	1060
		Heavy articulators	3832	-		3066	-
		Graders	2338	-		1870	-
		Motor bike	971	1000		777	800
		Total	**14926**	**5025**		**11941**	**4020**
	Yadumsu	Saloon	2610	2925	0.8	2088	2340
		Buses	2778	1155		2222	924
		Pickups	1667	891		1334	713
		Heavy articulators	2462	-		1967	-
		Graders	2330	-		1864	-
		Motor bike	1089	990		871	792
		Total	**12936**	**5961**		**10349**	**4769**

Ambassador	Saloon	2405	3060	0.8	1924	2448
	Buses	2619	1122		2095	898
	Pickups	2575	855		2060	684
	Heavy articulators	3679	-		2943	-
	Graders	2185	-		1748	-
	Motor bike	987	900		790	720
	Total	**14450**	**5937**		**11560**	**4750**
Sulemantwi/	Saloon	4008	3060	0.8	3206	2448
Unesco	Buses	1310	1122		1048	898
	Pickups	773	-		618	-
	Heavy articulators	-	-		-	-
	Graders	-	-		-	-
	Motor bike	1480	500		1184	400
	Total	**7571**	**4682**		**6057**	**3746**
GMT	Saloon	1557	1150	0.5	779	575
cleaning and	Buses	-	-		-	-
laundry	Pickups	493	265		247	133
	Heavy articulators	-	-		-	-
	Graders	-	-		-	-
	Motor bike	960	500		480	250
	Total	**3010**	**1915**		**1505**	**958**

Sec.	Saloon	1650	1125	0.8	1320	900
	Buses	1340	604		1072	483
	Pickups	1270	275		1016	220
	Heavy articulators	-	-		-	-
	Graders	-	-		-	-
	Motor bike	1000	605		800	484
	Total	**5260**	**2609**		**4208**	**2087**
Joyce	Saloon	2325	1950	0.5	1163	975
Ameyaw	Buses	-	-		-	-
	Pickups	777	315		389	158
	Heavy articulators	-	-		-	-
	Graders	-	-		-	-
	Motor bike	1000	903		500	452
	Total	**4102**	**3168**		**2051**	**1584**
Asuo Tano	Saloon	2235	1712	0.5	1118	856
	Buses	-	-		-	-
	Pickups	1820	1590		910	795
	Heavy articulators	-	-		-	-
	Graders	-	-		-	-
	Motor bike	1160	1250		580	625
	Total	**5215**	**4552**		**2608**	**2276**

Jah bless	Saloon	3820	3510	0.8	3056	2808
	Buses	1505	930			
	Pickups	494	298			
	Heavy articulators	-	-		-	-
	Graders	-	-		-	-
	Motor bike	1455	1160			
	Total	**5769**	**5898**			
Big Jeffrey	Saloon	1850	1640	0.8	1480	1312
	Buses	-	-	-	-	-
	Pickups	-	-		-	-
	Heavy articulators	-	-		-	-
	Graders	-	-		-	-
	Motor bike	1485	1476		1188	1181
	Total	**3335**	**3116**		**2668**	**2493**
Owura	Saloon	2940	2210	0.8	2352	1768
Barima	Buses	3050	2696		2440	2157
	Pickups	2560	1555		2048	1244
	Heavy articulators	6265	-		5012	-
	Graders	2324	-		1859	-
	Motor bike	1140	1056		912	845
	Total	**18279**	**7517**		**14623**	**6014**

Kasapa	Saloon	2920	3240	0.5	1460	1620
	Buses	4185	3090		2093	1545
	Pickups	1325	825		663	413
	Heavy articulators	3726	-		1863	-
	Graders	1160	-		580	-
	Motor bike	1545	1000		773	500
	Total	**14861**	**8155**		**7431**	**4078**
Sir Oti	Saloon	2100	1980	0.8	1680	1584
	Buses	2660	1355		2128	1084
	Pickups	2460	1475		1968	1180
	Heavy articulators	6295	-		5036	-
	Graders	2306	-		1845	-
	Motor bike	1130	1200		904	960
	Total	**16951**	**6010**		**13561**	**4808**
Big Apples	Saloon	3000	2895	0.5	1500	1448
	Buses	1967	1570		984	785
	Pickups	1170	822		585	411
	Heavy articulators	-	-		-	-
	Graders	-	-		-	-
	Motor bike	1590	1680		795	840
	Total	**7727**	**6967**		**3864**	**3484**

	Alhaji Samu	Saloon	2980	3000	0.8	2384	2400
		Buses	2860	1375		2288	1100
		Pickups	2421	1385		1937	1108
		Heavy articulators	6150	-		4920	-
		Graders	1169	-		935	-
		Motor bike	580	615		464	492
		Total	**16160**	**6375**		**12928**	**5100**
Nkoranza	Alhaji	Saloon	2682	2400	0.8	2146	1920
	Iddrisu	Buses	2002	1375		1602	1100
	Ayiku	Pickups	2600	1108		2080	886
		Heavy articulators	6151	Nil		4921	-
		Graders	2328	Nil		1862	-
		Motor bike	928	855		742	
		Total	**16691**	**5738**		**13353**	**4590**
	Oh Black	Saloon	925	765	0.5	463	383
	Man	Buses	-	-		-	-
		Pickups	708	315		354	158
		Heavy articulators	-	-		-	-
		Graders	-	-		-	-
		Motor bike	1575	1725		788	863
		Total	**3208**	**2805**		**1604**	**1403**

Gaso	Saloon	2370	1630	0.5	1185	815
	Buses	1325	807		663	404
	Pickups	1240	960		620	480
	Heavy articulators	-	-		-	-
	Graders	-	-		-	-
	Motor bike	1440	1070		720	535
	Total	**6375**	**4467**		**3188**	**2234**
Adehyeman	Saloon	880	1105	0.8	704	884
	Buses	520	320		416	256
	Pickups	468	312		374	250
	Heavy articulators	-	-		-	-
	Graders	-	-		-	-
	Motor bike	485	525		388	420
	Total	**2353**	**2262**		**1882**	**1810**
Poku Dum	Saloon	3220	3015	0.8	2576	2412
	Buses	2520	1984		2016	1587
	Pickups	1235	951		988	761
	Heavy articulators	-	-		-	-
	Graders	-	-		-	-
	Motor bike	1455	990		1164	792
	Total	**8430**	**6940**		**6744**	**5552**

Jomo	Saloon	1190	1175	0.5	595	588
Services	Buses	459	320		367	160
	Pickups	446	275		223	138
	Heavy articulators	-	-		-	-
	Graders	-	-		-	-
	Motor bike	1920	1875		960	938
	Total	**4015**	**3645**		**2008**	**1823**
Frimps	Saloon	1360	840	0.8	1088	672
	Buses	1744	1425		1395	1140
	Pickups	1175	640		940	512
	Heavy articulators	1269	-		1015	-
	Graders	1196	-		957	-
	Motor bike	1030	1200		824	960
	Total	**7774**	**4105**		**6219**	**3284**