

**EVALUATING THE EFFECTIVENESS OF ACTIVATED
AND INACTIVATED SUGARCANE BIOCHAR IN
PHYSICOCHEMICAL PURIFICATION OF GREYWATER**

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the Degree of Master of Science in Sanitation of Meru University of Science and
Technology**

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other Institution.

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DEDICATION

This work is dedicated to my family, especially my wife Edna Gakii and my son Shem Mwenda for their unwavering support to my studies.

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ABBREVIATIONS, ACRONYMS, AND SYMBOLS

| | |
|----------------|---|
| AAS | Atomic Absorption Spectrometry |
| Al | Aluminium |
| BOD | Biochemical Oxygen Demand |
| Cd | Cadmium |
| CEC | Cation Exchange Capacity |
| CFU | Colony Forming Units |
| COD | Chemical Oxygen Demand |
| Cr | Chromium |
| Cu | Copper |
| CW | Carwash Wastewater |
| DOC | Dissolved Organic Carbon |
| <i>E. coli</i> | <i>Escherichia coli</i> |
| EC | Electrical Conductivity |
| FC | Faecal Coliforms |
| FTIR | Fourier Transform Infrared Spectroscopy |
| GWT | Grey Water Treatment |
| Hg | Mercury |
| KEBS | Kenya Bureau of Standards |
| KOH | Potassium Hydroxide |
| MBR | Membrane Bioreactors |
| MPN | Most Probable Number |
| N | Nitrogen |
| NEMA | National Environmental Management Authority |
| PAH | Polycyclic Aromatic Hydrocarbons |

| | |
|-------------------|---|
| Pb | Lead |
| pH | Potential of Hydrogen |
| SEM | Scanning Electron Microscopy |
| SDS | Sodium Dodecyl Sulfate |
| SDGs | Sustainable Development Goals |
| TC | Total Coliforms |
| TDS | Total Dissolved Solids |
| TKN | Total Kjeldahl Nitrogen |
| TN | Total Nitrogen |
| TSS | Total Suspended Solids |
| UN | United Nations |
| USEPA | United States Environmental Protection Agency |
| UV | Ultraviolet |
| WHO | World Health Organization |
| XRD | X-ray Diffraction |
| XRF | X-ray Fluorescence |
| ZnCl ₂ | Zinc Chloride |

DEFINITION OF TERMS

- Biochar** is a charcoal-like substance that's made by burning organic material from agricultural and forestry wastes (also called biomass) in a controlled process called pyrolysis (Aly, 2016).
- Greywater** is wastewater generated from households but does not include wastewater from toilets. Example of greywater are kitchen wastewater, bathroom waste water and carwash wastewater.
- Heavy metals** are metallic elements that have a relatively high density and are toxic to living organisms at low concentrations e.g. lead, chromium, copper, silver and cadmium (Al-Gheethi *et al.*, 2016).
- Pyrolysis** is the degradation of organic compounds in the absence of oxygen at temperatures ranging from 500 °C to 800 °C.

ABSTRACT

The study investigated the effectiveness of sugarcane waste biochar as a sustainable material for purifying greywater to address environmental pollution and enhance water recycling. Biochar was produced by heating sugarcane waste at 500°C, with half of it activated using potassium hydroxide to enhance adsorption. X-ray fluorescence, X-ray diffraction and Fourier transform infrared spectroscopy were used to characterize the biochar structure. The structure showed the presence of amorphous carbon with C-H, C-O and COOH functional groups. Greywater samples obtained from the kitchen, bathroom and carwash were purified by filtering 100 mL of samples through 10 g of biochar for 5 minutes. The activated and inactivated biochar achieved 92-96% and 80-87% removal efficiency of lead (II) ions, respectively. Chromium (VI) ions removal ranged from 84-92% and 82-86% with activated and inactivated biochar, respectively. Activated biochar removed 76-77% of oil and grease compared to 51-57% for inactivated biochar. Both biochar increased the pH levels, with activated biochar causing a more rise by 63-73%. Total suspended solids removal efficiencies were 21-34% and 40-54% in inactivated and activated biochar, respectively. Slight decrease in sodium dodecyl sulphate detergent, electrical conductivity and total dissolved solids was observed for both biochar. There was significant difference between the purification efficiency of inactivated and activated biochar shown by the $|t|$ statistic values which were above t_4 critical value of 2.78 ($P = 0.05$). Based on the study findings, activated sugarcane biochar was reliable for greywater treatment, especially the removal of heavy metal pollutants, oil and grease. The study recommends further pilot-scale applications and field testing to validate its long-term performance and integration into decentralized wastewater management systems.

CHAPTER ONE: INTRODUCTION

1.0 Introduction

This chapter contains the background of the study, statement of the problem, justification, objectives, research questions, study limitations and hypothesis.

1.1 Background of the Study

Greywater is wastewater generated from households but does not include wastewater from toilets. Examples of greywater include kitchen wastewater, carwash wastewater and bathroom wastewater (Filali *et al.*, 2022). Biochar is a charcoal-like substance that is made by burning organic material from agricultural and forestry wastes (also called biomass) in a controlled process called pyrolysis (Aly, 2016). Biochar can be used as a filter to remove impurities such as heavy metals (Pb and Cr), detergents, oils and grease from greywater.

Globally, a country like China uses techniques such as ultraviolet (UV) disinfection and sedimentation for greywater treatment because of its advanced technology. In Africa, countries such as South Africa use UV disinfection and flotation, but developing countries like Kenya have limited equipment for UV disinfection and thus rely on other methods like filtration (Nyika & Dinka, 2022).

Adequate sanitation, hygiene and safe water are fundamental to good health and to social and economic development. According to the United Nations (UN Water, 2021), 44% of domestic wastewater is not safely managed. Hospitals in cities and other sectors like small-scale mining and auto repair shops routinely dump extremely harmful chemicals and medical waste into the wastewater system in addition to domestic waste (Edokpayi *et al.*, 2021). All of this takes place despite the local and international standards being set by the Kenya Bureau of Standards (KEBS), National Environmental Management

Authority (NEMA), East African Standard (EAS) and United State Environmental Protection Agency (USEPA) and World Health Organization (WHO).

Due to the lack of fresh water, the untreated and unsafe wastewater is widely used for irrigation in many countries. It is therefore important that wastewater be treated before it is discharged into water bodies. This helps ensure clean, hygienic water and protects the environment from harmful pollutants (Flory *et al.*, 2021).

Wastewater treatment techniques range from primary, to secondary and advanced tertiary methods. Primary treatment involves removal of suspended and floating solids, oils and grease, grit removal by sedimentation. Secondary treatments, which involves biological treatment include activated sludge method, wastewater stabilisation ponds, trickling filters, anaerobic reactors, artificial wetlands, microbial fuel cells and methanogenic reactors (Miruka, 2016).

The final effluent and sludge from the mentioned categories may still contain several types of microbial, chemical and metal contaminants. Tertiary treatment involves the removal of nutrients from wastewater using techniques such as constructed wetlands, aquaculture, chemical precipitation and disinfection (Miruka, 2016), advanced-level ultrasonication, ultraviolet treatment and ozonation (Kesari *et al.*, 2021).

Wastewater stabilization ponds (aerobic, anaerobic, facultative and maturation) are the most widely used technology for wastewater treatment around the world due to their limited technological requirements and low operation and maintenance costs (Desye *et al.*, 2022). Other conventional methods of wastewater treatment require high costs in implementation and high operation and maintenance. Conventional methods suffer challenges, for example increase in wastewater inflows, which is not often accompanied by expansion of infrastructure. Thereby are not able to keep up with the growing demand for lower heavy metal levels in final effluent (Ruxandra *et al.*, 2020). In Kenya most of

the final effluents do not meet the National Environmental Management Authority (NEMA) standards (Flory *et al.*, 2021).

The uncontrolled release of carwash wastewater has been linked to a number of environmental problems, such as the destruction of marine habitats, the loss of biodiversity, aquatic eutrophication, the buildup of metals in the food chain, and changes in the ecological balance. International rules and recommendations have been established to maintain pollutant concentrations in carwash wastewater at the permitted limits because of these detrimental effects on terrestrial and aquatic habitats (Desye *et al.*, 2022).

Chemical coagulation or flocculation, adsorption, electro-Fenton, photo-assisted electrochemical oxidation, ultraviolet-visible oxidation or hydrogen peroxide oxidation, Photo-Fenton, electrocoagulation, electro-flotation, biological-based systems, membrane-based systems, and hybrid processes are among the most widely used technologies for treating carwash wastewater (Misbah Ullah *et al.*, 2024; Zarei & Gholami, 2020).

The treatment of wastewater offers tangible benefits including pollution reduction, human health protection, water security enhancement and bioenergy production. Therefore, there is need to increase public awareness, acceptance, and positive attitudes towards wastewater reuse. These advantages are directly connected to the three pillars of sustainability (environmental, economic, and social aspects), meaning that further research is required to support the 2030 Agenda's sustainable development goals (SDG 6). This agenda is composed of 17 global goals with 169 targets introduced by the United Nations (UN), and seeks to balance the three dimensions of sustainability, especially for low-income countries (Pedersen, 2018).

Sugarcane biochar is used as an alternative material for filtration because it is cheaper than other types of filters, has an abundant supply of carbon materials, and is grown in many areas of the country and waste from sugarcane production is utilised (Goscianska, *et al.*, 2015). Sugarcane waste biochar was used as a filter, for greywater treatment in this study because it contains functional groups and has high porosity which enhance adsorption of impurities such as heavy metals from the greywater.

1.2 Statement of the Problem

Greywater, containing a variety of pollutants including heavy metals, organic matter, nutrients, and pathogens, requires effective treatment before reuse or discharge to prevent environmental degradation and potential health hazards. Conventional approaches such as ultraviolet (UV) disinfection, while effective, are cost-intensive in terms of equipment, electricity and maintenance costs compared to the more affordable sugarcane biochar filtration. For instance, small-scale UV treatment systems cost approximately US \$20 per megaliter, which present a barrier to widespread adoption in low-resource settings (WHO, 2019). The need for innovative, sustainable, and cost-effective solutions to address this challenge is evident (Pedersen, 2018).

Globally, treatment coverage for wastewater remains insufficient. According to UN Water (2021), only 56% of household wastewater flows are safely treated, while more than 80% of wastewater overall is discharged untreated into the environment, contributing to eutrophication, ecological degradation, and public health hazards (WWAP, 2020). Additionally, environmental pollution from untreated greywater discharge exacerbates the degradation of aquatic ecosystems and poses public health risks. Domestic wastewater poses a multifaceted challenge within society, manifesting in various environmental, health, and socioeconomic ramifications.

Recent studies have reported that heavy metal concentrations in greywater, such as lead (Pb), may reach up to 0.099 mg/L, while other contaminants such as chromium (Cr) and copper (Cu) also occur at levels of concern (Gumbo *et al.*, 2022). Contaminants such as pathogens, nutrients, and chemicals from household activities, industries, and agriculture infiltrate water bodies, disrupting ecological balance and endangering biodiversity (Gupta *et al.*, 2021).

Globally, the demand for water is increasing as a result of urbanization, population growth, and industrialization. Freshwater resources are under stress due to this growing demand; hence water recycling techniques must be put in place to alleviate shortages. (Pedersen, 2018). In addition to easing the strain on freshwater supplies, recycling water for applications such as industrial cooling, domestic greywater reuse, and irrigation encourages sustainable water management. Societies can make great strides toward resource conservation and sustainable water usage by using and modifying water recycling techniques.

In the quest for sustainable solutions, there is a growing interest in the utilisation of agricultural waste materials, such as sugarcane bagasse, for resource recovery and pollution mitigation (Gupta *et al.*, 2021). Sugarcane bagasse, a byproduct of the sugar industry, is abundantly available and often underutilized, leading to waste management challenges.

Converting sugarcane bagasse into biochar offers a promising approach to address these issues. Biochar, produced through the pyrolysis of organic waste, has shown potential in various environmental applications, including water purification (Goscianska, *et al.*, 2015). Activated sugarcane biochar is more effective at eliminating heavy metals like lead, chromium, oil and grease compared to inactivated biochar. This study evaluates the suitability of sugarcane biochar as a cheaper alternative material for greywater filtration.

1.3 Justification

Treatment and recycling of wastewater are important components in achieving Sustainable Development Goal 6 (SDG 6) which aims to ensure the availability and sustainable management of water and sanitation for all (Pedersen, 2018). This research will ensure that impurities are removed from greywater before it is disposed or recycled. Many techniques, such as chemical precipitation and electrochemical reduction, are used to remove heavy metals from wastewater (Gupta *et al.* 2021). However, these methods are often costly and less accessible in rural areas when compared with sugarcane biochar filtration.

Adsorption seems to be the most appealing technique out of all of them because it is easy to use, efficient, and cost-effective when it comes to eliminating heavy metals from wastewater. Adsorption using naturally renewable waste materials, like sugarcane waste biochar, provides green chemistry solutions to sustainable water management. This is supported by several facts, including the potential for mass production of sugarcane at a low cost worldwide and the boundless supply of biodegradable carbon raw materials, in contrast to the use of conventional chemical methods (Gupta *et al.*, 2021).

Recycling and reusing greywater help lessen the strain of water pollution on the society (Goscianska, *et al.*, 2015). Furthermore, utilisation of sugarcane waste for making biochar adsorbent could reduce the amount of energy wasted and greenhouse gas emissions from burning such garbage.

1.4 Research questions

- i. How can sugarcane waste biochar be prepared and characterised?
- ii. What are the physicochemical properties of untreated and treated greywater from domestic and carwash effluents?
- iii. How efficient is sugarcane biochar in removing contaminants from greywater?

1.5 Objectives

1.5.1 General objective

To evaluate the effectiveness of activated and inactivated sugarcane biochar in physicochemical purification of greywater.

1.5.2 Specific objectives

- i. To prepare and characterise biochar from sugarcane waste.
- ii. To analyse the physicochemical properties of greywater from domestic and carwash effluents, before and after purification with inactivated and activated biochar.
- iii. To determine the efficiency of inactivated and inactivated sugarcane waste biochar in removing contaminants from greywater.

1.6 Study Limitations

Availability of a well-equipped laboratory was essential for this study. The researcher had to travel to other institutions to assess analytical instruments such as atomic absorption spectrometer (AAS), Fourier transform infrared spectrometer, X-ray Fluorescence and X-ray diffraction spectrometers, which was costly, time consuming and also limited the number of samples analysed.

1.7 Hypothesis

The null hypothesis (H_0) was applied assuming that there was no significant difference in the greywater purification efficiencies between the inactivated and activated biochar.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This chapter contains the history and concepts of grey water, composition of greywater, principles of application of biochar in water purification, preparation of sugarcane biochar, principles of application of biochar in water purification, preparation of sugarcane biochar, properties of sugarcane biochar, characterization of sugarcane biochar, performance of sugarcane biochar in greywater treatment, concepts and principles of treatment of greywater, treatment technologies for greywater, the trend for domestic greywater treatment, water quality parameters, and challenges of greywater treatment.

2.1 History and Concepts of Greywater

Greywater is any wastewater from households that does not include wastewater from the toilet. Greywater is highly contaminated due to its frequent reuse and can resemble untreated sewage in certain ways. In rural areas, greywater is easily assimilated into the ecosystem; however, in highly populated slums, this is typically not the case. Greywater leakage that is not regulated poses a major health risk when there is no sewerage. Residents are forced to dump their dirty water on the ground close to their homes because they have nowhere else to dispose of it (Baykal, 2019).

Greywater collected from cleaning soiled clothes or scrubbing the anal regions in the bathtub or shower may still contain pathogens. Greywater reuse in urban water systems offers significant advantages by lowering the volume of wastewater that needs to be transported and treated as well as the need for fresh and clean water. Among other uses, treated greywater is useful for flushing toilets and irrigation (Edokpayi *et al.*, 2021).

When washing clothes and bodies with water, soap or soap-based products are typically used, which affects the quality of greywater. The number of occupants in a residence, the

users' social and product interests, the geography, and demographics all influence the quantity and quality of these pollutants, which are highly varied (Edokpayi *et al.*, 2021). Water is distributed unevenly in space and time, which affects how it is used in some geographic locations and deprives others of this resource. Only one hundredth of Earth's total water resources is thought to be available for human use. Ninety-seven percent of Earth's total water resources are contained in the oceans (Baykal, 2019).

Biological survival remains one of the primary forces behind water use, alongside its use for household needs, food production, and other developmental requirements. Acute water shortages, excessive resource exploitation that depletes water supplies, and high levels of freshwater pollution brought on by human activity plague many regions of the world. About 800 million people are currently thought to be living in areas where water stress is a threshold at the moment, and by 2025, that figure is predicted to rise to 3 billion (Sati and Vangchhia, 2017).

2.2 Composition of Greywater

Greywater is a mixture of wastewater streams generated from household activities such as bathing, handwashing, laundry, and dishwashing, excluding toilet effluent. Its composition is highly variable and largely depends on the household's water use practices including detergents, and cleaning agents used. Typically, greywater contains suspended solids, fats, oils, surfactants, and nutrients such as nitrogen and phosphorus, which may cause environmental stress if discharged untreated (Li *et al.*, 2023). Additionally, organic matter in greywater contributes to a high biochemical oxygen demand (BOD), making it a potential pollutant when released into natural water systems. Apart from chemical constituents, greywater contains a significant microbial load. Pathogens such as *Escherichia coli* and *Enterococcus spp.* have been detected, mainly originating from skin contact, laundry, and food residues (Ramírez *et al.*, 2022). The

microbial profile makes greywater a public health concern, particularly in areas where untreated wastewater is reused for irrigation or comes into direct contact with humans. The presence of pharmaceuticals, personal care products, and trace heavy metals has also been reported, further complicating its management and treatment (Zhang *et al.*, 2023).

The variability in greywater composition necessitates tailored treatment strategies depending on its intended reuse. For instance, greywater with high detergent concentrations requires processes that remove surfactants and phosphates, while water intended for irrigation must undergo pathogen reduction. Understanding its composition is therefore critical for designing effective treatment systems that ensure both environmental protection and public health safety (Tilley *et al.*, 2022).

2.3 Principles of Application of Biochar in Water Purification

Biochar is a charcoal-like substance that is made by burning organic material from agricultural and forestry wastes (also called biomass) in a controlled process called pyrolysis (Aly, 2016). Biochar has the potential to be a vital tool in the fight against climate change because of its ability to trap carbon. Not all biochar functions in the same manner. It depends on the biomass source, the temperature during pyrolysis, and the size of the final product. Similar to charcoal, biochar is a petroleum-free material. It is created by heating biomass such as animal dung, non-salvageable lumber and slash, or the leftovers of herbaceous or woody crops in a control system (Ahmad *et al.*, 2024).

Carbon sequestration, land reclamation, and water purification are just a few of the numerous possible applications for biochar. Biochar may also be used as a soil amendment for two purposes to improve plant health and to store carbon (Aly, 2016). It is predicted that at least 50% of the carbon in any piece of waste turned into biochar becomes stable, locking away that carbon for a period of several to hundreds of years,

offsetting its contribution as a greenhouse gas in the form of carbon dioxide (USDA 2022).

2.4 Preparation of Sugarcane Biochar

The first step in making sugarcane biochar is gathering sugarcane bagasse, also known as sugarcane stalk leftovers, which are a byproduct of sugar manufacturing. Since too much moisture can interfere with the pyrolysis process, these residues are usually air-dried to remove moisture. Larger sugarcane residues can be chopped or shredded into smaller pieces before drying to ensure uniform size, which aids in a steady pyrolysis process (Wang *et al.*, 2015).

The dried sugarcane residues are subjected to pyrolysis, which involves thermal decomposition under limited or no oxygen conditions. The ideal temperature range for pyrolysis is 300 °C to 700 °C, depending on the desired characteristics of the resulting biochar. Higher temperatures (500 °C to 700 °C) provide biochar with larger surface areas and more stable carbon structures, whereas lower temperatures (300 °C to 400 °C) frequently yield higher biochar yields (Mohanty *et al.*, 2020; Martins *et al.*, 2017).

The residence time and heating rate can be controlled during the pyrolysis process. While a longer residence time can result in the creation of biochar with higher porosity and surface area, a slower heating rate allows for more thorough carbonization. According to research, a residence period of one to four hours is normal, depending on the type of feedstock and the pyrolysis configuration (Santos *et al.*, 2016).

To stop oxidation, the biochar is allowed to cool in an inert atmosphere like nitrogen after pyrolysis. In order to maintain the biochar's structural integrity, cooling is an essential step. To achieve desired particle sizes, the biochar may go through additional processing once it has cooled, such as grinding or sifting. In order to improve sugarcane biochar's adsorption capabilities for contaminants like heavy metals or organic

contaminants, some research has also looked into chemically activating or modifying the material (Mahdi *et al.*, 2022).

The sugarcane bagasse is treated with chemical agents such as zinc chloride (ZnCl_2), potassium hydroxide (KOH), or phosphoric acid (H_3PO_4) either before to or following pyrolysis. Compared to physical activation, chemical activation typically results in larger surface areas and improved pore distribution. The biomass is broken down by the chemical agents, creating microporous structures that are excellent for adsorption (Mohan *et al.*, 2014; Rodrigues *et al.*, 2020).

When compared to non-activated biochar, activated biochar made from sugarcane bagasse usually has a much larger surface area and pore volume. Depending on the activating agent and temperature utilized, studies have indicated that chemical activation can increase the surface area from $200 \text{ m}^2/\text{g}$ to over $1500 \text{ m}^2/\text{g}$ (Ahmad *et al.*, 2024).

Activated sugarcane biochar has been shown to have a greater capacity to remove pollutants from wastewater because of its improved microporous structure and the addition of oxygen-containing functional groups. Additionally, because of its more developed pore structure and increased surface area, it can interact with contaminants more effectively. For example, activated biochar produced with KOH as an activating agent demonstrated significantly higher adsorption of cadmium (Cd^{2+}) and lead (Pb^{2+}) ions (Santos *et al.*, 2017).

The surface chemistry of sugarcane bagasse biochar is also altered by activation. Chemical activation increases the number of oxygen-containing functional groups such as carbonyl, hydroxyl, and carboxyl group in the biochar, improving its ability to bind organic molecules and metal ions. This alteration is essential for enhancing the biochar's interaction with pollutants, which raises the adsorption efficiencies (Machado *et al.*, 2020).

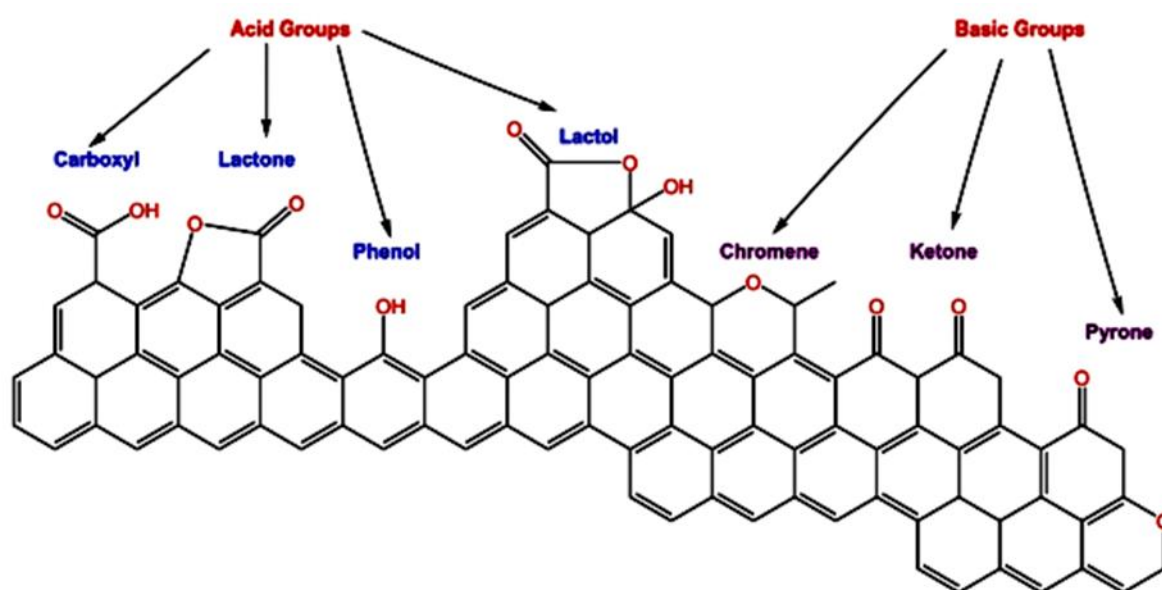
2.5 Properties of Sugarcane Biochar

Sugarcane bagasse is the fibrous waste of sugarcane after juice extraction. It is subjected to pyrolysis, a thermal process that produces sugarcane biochar, a carbon-rich substance. Biochar has gained attention due to its potential applications in agriculture, environmental remediation, and energy production. Its efficacy in adsorption applications, such as soil supplements and water filtration systems, is largely dependent on its large surface area. Sugarcane biochar's physical properties include a large surface area (usually between 100 and 500 m²/g) and high porosity (Chintala *et al.*, 2014).

Like other forms of biochar, the chemical composition of sugarcane biochar is mostly made up of carbonaceous material that is produced when sugarcane biomass is pyrolyzed in low oxygen environments. An aromatic carbon matrix, which makes up the structure, offers excellent stability and breakdown resistance. Sugarcane biochar's hydroxyl (-OH), carboxyl (-COOH), and phenolic groups are important functional groups that support the material's ability to adsorb substances and perform ion exchange (Fidel *et al.*, 2017). The composition may also contain elements such as trace metals, phosphorus, and nitrogen, contingent on the pyrolysis conditions and feedstock. It has been demonstrated that sugarcane bagasse biochar has a high concentration of oxygen-containing functional groups, which are essential for interactions with pollutants in water treatment (Fidel *et al.*, 2017).

Due to its porous structure and vast surface area, biochar is able to absorb a variety of contaminants, such as organic chemicals and heavy metals (Tan *et al.*, 2015). Biochar's chemical composition could vary based on the temperature during pyrolysis. Biochar usually retains more volatile chemicals and functional groups at lower temperatures (300-400 °C), as shown in Figure 2.1, becoming more aromatic and graphitic at higher temperatures (600 °C and above) (Sun *et al.*, 2017).

Figure 2.1



Different functional groups in biochar

Source: (Tan et al., 2024)

Figure 2.1 shows the different functional groups in biochar which helps it to adsorb more impurities from greywater.

2.6 Characterisation Techniques for Sugarcane Waste Biochar

The methods that can be used to characterise sugarcane waste biochar structure include X-ray diffraction (XRD), X-ray fluorescence (XRF), Fourier transform infrared (FTIR) spectroscopy and Scanning electron microscopy (SEM). Characterising biochar involves analysing its physical, chemical, and structural properties to understand its suitability for various applications such as wastewater filtration (Nazbakhsh *et al.*, 2025).

2.6.1 Characterisation using X-ray diffraction (XRD)

The working principle of an X-ray diffraction (XRD) spectrometer is based on the interaction of X-rays with the atomic planes in a crystalline material. The XRD is mainly used to characterize sugarcane biochar by identifying its crystalline and amorphous

phases, which provide information on its structural characteristics (Dharmarathne *et al.*, 2020).

When X-rays are directed at the biochar sample, they are scattered by the atoms in the material. Constructive interference is produced when the path difference between rays scattered by adjacent atomic planes is an integer multiple of the X-ray wavelength, as per Bragg's law ($n\lambda = 2d \sin\theta$) giving a diffraction pattern for the sample. The resulting XRD pattern is used to determine the phases and crystallinity of the material. It is composed of peaks that match the d-spacing, or the distance between the crystal planes (Dharmarathne *et al.*, 2020).

XRD technique is useful in determining the level of carbonisation and the existence of mineral impurities, such as silica and calcium carbonate, in sugarcane biochar that may persist following pyrolysis. Broad, diffuse peaks are suggestive of an amorphous carbon structure, whereas sharp peaks are indicative of crystalline phases (such as quartz or calcite). The analysis of the XRD patterns provides information on the structural organization, which is crucial for understanding the biochar's adsorption capabilities and stability (Bolan *et al.*, 2022).

2.6.2 Characterisation using X-ray fluorescence (XRF)

An X-ray fluorescence (XRF) instrument operation is based on the interaction of high-energy X-rays with atoms in a sample, which produces secondary (fluorescent) X-ray emission. XRF is used in the characterisation of sugarcane biochar to ascertain its elemental composition, especially with regard to the presence of inorganic components such as minerals and metals (Luo *et al.*, 2015).

The biochar's atoms become energized and expel their inner-shell electrons when the sample is exposed to primary X-rays from the XRF instrument. This results in a vacancy that an outer-shell electron fills, releasing energy in the form of distinctive X-rays that

are unique to each element. To determine the element composition of the biochar, the energy and intensity of these X-rays are detected and examined (Luo *et al.*, 2015).

When it comes to determining the trace metals and mineral content of biochar which can contain components like silicon, calcium, magnesium, and iron XRF is very helpful. Because of the characteristics of the biomass feedstock (such as sugarcane bagasse) and the pyrolysis conditions, these components can stay in biochar after pyrolysis. Researchers can determine whether biochar is suitable for a variety of applications, such as soil amendment or pollutant removal, where the performance can be affected by the presence of particular components, by utilising XRF (Han *et al.*, 2016).

2.6.3 Characterisation using Fourier transform infrared (FTIR) spectroscopy

In order to identify functional groups and chemical bonds found in sugarcane biochar, Fourier Transform Infrared (FTIR) spectroscopy is commonly utilised in the material's characterisation. The basis of FTIR's operation is the sample's absorption of infrared (IR) light, which excites chemical bonds through vibration (Rajapaksha *et al.*, 2016).

Certain functional groups (such as hydroxyl, carboxyl, and carbonyl groups) absorb different wavelengths of infrared radiation when it passes through the biochar sample, changing the vibrational energy levels of those groups. These absorption patterns are recorded by the FTIR spectrometer as a spectrum, which is just a plot of absorbance against wavelength (represented by wave numbers, usually in cm^{-1}). It is possible to identify functional groups in the spectrum by looking for distinctive peaks that match the vibrational frequencies of chemical bonds (Rajapaksha *et al.*, 2016).

FTIR is capable of detecting a wide range of surface functional groups in sugarcane biochar, including Hydroxyl, Carboxyl, and Carbonyl groups. The chemical reactivity and adsorption capacity of biochar are significantly influenced by these functional groups (Yang *et al.*, 2019).

The degree of carbonization and the existence of oxygenated functional groups are revealed by the FTIR spectrum, and these details are essential for comprehending the potential uses of biochar in environmental applications such as soil amendment and water filtration. The instrument's Fourier transform feature is crucial since it enables the simultaneous measurement of all wavelengths, boosting the analysis's speed and sensitivity. When it comes to determining alterations in the surface chemistry of biochar following pyrolysis and other functionalisation treatments, FTIR is very helpful (Yang *et al.*, 2019).

2.7 Performance of sugarcane Biochar in Greywater Treatment

Sugarcane biochar has a great deal of potential for treating greywater because of its extraordinary physical and chemical characteristics. The adsorption capability, porosity, and high surface area of this material enable it to effectively remove organic debris, oils, detergents, and trace pollutants from home sources such as washing machines, sinks, and showers from greywater (Chen *et al.*, 2018).

The high surface area and porous structure of sugarcane biochar allow it to efficiently absorb organic pollutants from greywater. Dissolved organic carbon (DOC), which is made up of a variety of organic molecules that pollute water and harm aquatic ecosystems if left untreated, can be eliminated by using biochar, according to studies. Biochar's high carbon content which frequently exceeds 60% improves its capacity to adsorb and retain organic molecules (Ruxandra *et al.*,2020).

The removal of nutrients, especially nitrogen and phosphorus, which can cause eutrophication in water bodies if improperly handled, is one of the most important parts of greywater treatment. Sugarcane biochar is able to effectively retain and immobilise these nutrients because of its high cation exchange capacity (CEC). This characteristic is

especially helpful in limiting the amount of nutrients that leach into the environment, which lowers the chance of algal blooms and preserves water quality (Ahmad, 2024).

Sugarcane biochar is also effective in adsorbing heavy metals and reducing microbial contamination. By interacting with metal ions, its surface functional groups hydroxyl, carboxyl, and carbonyl groups, allow heavy metals like lead, cadmium, and zinc to be removed from greywater. Furthermore, because of its adsorption capability and its antibacterial qualities, biochar can lower pathogen levels, adding an extra degree of security to greywater reuse applications (Lehmann and Joseph, 2015).

Sugarcane biochar's porous nature allows it to hold onto water, increasing its filtration system efficiency. Greywater treatment can be achieved more effectively by using biochar to enhance the hydraulic properties of the filter material in biofilters or built wetlands. Better pollutant removal is made possible by its capacity to hold onto water while allowing for gradual filtration. This ensures that biochar and greywater are in direct contact with one another (Aly, 2016).

2.8 Concepts and Principles of Treatment of Greywater

Septic tanks for collecting grey water, soak away pipes, gravel beds trickling filters, soil beds growing grass or reed, secondary collection tanks for testing, and perforated overflow pipes are examples of techniques for treatment of greywater (Lopez-Serna *et al.*, 2019). Septic tanks and soak pits are integral parts of on-site sanitation systems, especially in rural and suburban areas where centralized sewage systems are not available. The presence of potentially harmful microorganisms is indicated by measuring for the faecal coliform group and more specifically *Escherichia coli* bacteria. These microorganisms indicate the presence of intestinal pathogens such as Salmonella or enteric viruses and are used as a pollution indicator or safety factor (Akinfalabi *et al.*, 2020).

An increased risk of human illness from coming into contact with greywater is indicated by an elevated *E. coli* count in a sample of greywater. However, a low *E. coli* level does not mean that harmful germs are absent. The only indicator microbe used is *E. coli*; other potentially harmful pathogens may still exist but are not detected. Among them are other bacteria, viruses, protozoa, and helminths (parasitic worms). According to some research on household greywater quality, shower water can have faecal coliform levels as high as 6000 colony forming units (CFU) per 100 mL, while bathroom water frequently has up to 3300 most probable number (MPN) (Akinfalabi *et al.*, 2020).

Greywater collected from laundry and bathroom sources often contains hair and lint, despite their low suspended solids content, which may impede treatment procedures. Greywater pH can also be significantly impacted by the use of soaps and detergents that are primarily alkaline. The variety of items used affects pH differently, and this is influenced by the social decisions made in the family. As with the number of dissolved materials, complex treatment is required to manage the high pH. Greywater is therefore typically dumped untreated into gardens or parks, where it is treated by the soil (Lopez-Serna *et al.*, 2019).

Even though greywater quality varies greatly, systems for reusing it must make an effort to prevent, reduce, or mitigate human interaction due to the potential for considerable microbial contamination. The biological treatment options will be restricted by the typically modest nutrient loading (particularly for small systems), and the high dissolved solids content will necessitate a thorough examination of their effects on the soils and environment that receive greywater discharge as well as during the treatment process. Greywater reuse systems that use pumps and drip irrigation systems have issues with suspended solids like hair and lint, which need to be filtered (Akinfalabi *et al.*, 2020).

When greywater quality is compared to wastewater quality, it can be shown that the former has less contaminants and hence requires less treatment. Moreover, the relatively large proportion of generated greywater suggests a substantial opportunity for water conservation via reusing systems. Greywater reuse is mostly utilised for outside applications like irrigation in parks and gardens, as well as indoor usage like laundry and toilet flushing. Household greywater systems must use a treatment process that involves turbidity reduction, disinfection, and the removal of coarse suspended materials if they are to reuse greywater for laundry and toilet flushing (Lopez-Serna *et al.*, 2019).

Greywater is easier to filter and reuse since it frequently has much fewer pathogens than wastewater. Thus, it is typically recommended to keep wastewater and grey water separate for hygienic reasons. Sewage, also called blackwater, is created when greywater and wastewater mix and needs to be treated in a sewage treatment facility. High concentrations of organic compounds are found in greywater from residential and commercial appliances. Ultrafiltration or other filtration methods are required to eliminate these contaminants before releasing the treated grey water into a greywater system. If treatment proves to be too challenging, it may instead be redirected to the sewage system or a nearby sewer (Baykal, 2019).

Greywater treatment techniques include ultraviolet (UV) disinfection, sedimentation, flotation, and pre- and post-filtration. Greywater that you decide to preserve needs to be used within a few days or it will break down due to the organic debris in the water. Although, it is not recommended to drink this kind of recycled greywater, it can be used for cleaning and flushing toilets after undergoing a number of treatment steps. Greywater utilisation is regulated because of the potential for disease to spread both domestically and internationally. Uncontrolled greywater can spread infections if it is stored or used in a way that makes contact with children, pets, or wild animals (El-Ashtoukhy *et al.*, 2015).

Greywater treatment systems are designed to reclaim wastewater efficiently, which preserves freshwater sources and reduces the amount of wastewater entering sewers or treatment plants. This greatly benefits society by playing an important role in conserving quality water in many industries such as industrial facilities, food processing, manufacturing plants, municipals, refineries, mining zones, and hotels (El-Ashtoukhy *et al.*, 2015). Table 2.1 shows comparison of greywater quality results.

Table 2. 1

Comparison of Greywater Quality Results

| Variable | Reported Range | References |
|-------------------------------|-----------------------|---|
| pH | 5.0 - 9.5 | (Oteng-Pepurah <i>et al.</i> , 2018; Filali <i>et al.</i> , 2022; Van de Walle <i>et al.</i> , 2023; Mohan, 2024) |
| Conductivity (μ S/cm) | 14 - 3,000 | (Oteng-Pepurah <i>et al.</i> , 2018; Filali <i>et al.</i> , 2022; Van de Walle <i>et al.</i> , 2023) |
| PO ₄ -P (mg/L) | 0.1 - 57 | (Oteng-Pepurah <i>et al.</i> , 2018; Filali <i>et al.</i> , 2022; Gholami, 2023) |
| COD (mg/L) | <100 - 2,500+ | (Oteng-Pepurah <i>et al.</i> , 2018; Filali <i>et al.</i> , 2022; Mohan, 2024) |
| Suspended solids (mg/L) | 6 - 537 | (Oteng-Pepurah <i>et al.</i> , 2018; Van de Walle <i>et al.</i> , 2023) |
| Oil & Grease | Single digits - 100+ | (Oteng-Pepurah <i>et al.</i> , 2018; Filali <i>et al.</i> , 2022) |
| TKN / Total N (mg/L) | 1 - 50 | (Oteng-Pepurah <i>et al.</i> , 2018; Filali <i>et al.</i> , 2022; Van de Walle <i>et al.</i> , 2023) |
| Ammonia (mg/L) | <1 - 25 | (Oteng-Pepurah <i>et al.</i> , 2018; Filali <i>et al.</i> , 2022; Gholami, 2023) |

Source: Oteng-Peprah et al., (2018); Filali et al., (2022); Van de Walle et al., (2023); Mohan, (2024); Gholami, (2023)

2.9 Treatment Technologies for Greywater

Based on its composition, home wastewater is separated into two categories: greywater and blackwater. Blackwater is the wastewater from toilets, whereas greywater is the wastewater from showers, baths, washing machines, and kitchen sinks. In some places, kitchen greywater is considered as blackwater (Sijimol & Joseph, 2021). Conventional approaches of greywater treatment, while effective, are cost-intensive in terms of equipment, electricity and maintenance costs compared to the more affordable sugarcane biochar filtration.

Nutrient and organic matter must be removed from greywater to avoid eutrophication and algal blooms. Therefore, before being discharged into bodies of water, greywater needs to be properly treated. A previous study on hybrid system with three stages: filter media, a microalgae phytoremediation process and a flocculation process to treat greywater from village dwellings in developing countries, led to the recommendation of the hybrid approach (Wurochekke *et al.*, 2016).

There are several methods for greywater treatment (GWT), each having their own characteristics, forms, pollution loadings, and treatment schedules. The choice of technology is influenced by several factors, including the volume of greywater, the organic content, the planned application, and the acceptance of standards. Globally speaking, there is no standard design for greywater trench systems (GWTs), with the exception of a few countries like Australia and America. GWTs are built with care for the site's features, greywater source, quality, and quantity, as well as alternatives for reuse. Primary, secondary, and preparatory treatment are the three different categories for the greywater treatment process (Al Chalabi, 2024).

It is widely acknowledged that greywater treatment should emphasize on green chemistry approaches using environmentally acceptable methods without the use of hazardous byproducts or chemical additives. Before the treatment procedure, greywater may be stored; however, this should only happen for a brief amount of time to stop microbial growth (Sijimol & Joseph, 2021).

In physicochemical GWT systems, filtration and disinfection techniques are typically employed, whereas biological treatment techniques include membrane bioreactors (MBRs) and aeration. Sequence batch reactors, MBRs, and biologically aerated filters make up the majority of treatment techniques used widely. These technologies have the ability to create greywater with a higher quality than that produced by more conventional processes like primary and secondary processes. Nevertheless, these techniques have a significant initial cost and energy usage (Al Chalabi, 2024).

There are many techniques in use to remove nutrients from greywater, but they are costly and produce large volumes of soft, viscous mud. Microalgae is a possible biological treatment to be used in the removal of nutrients from wastewater. Reusing greywater could have advantages if done correctly, such as lowering household water pollution, preserving freshwater for domestic use, and increasing household income (Wurochekke, *et al.*, 2016).

Consequently, a fundamental problem with treating greywater stems from its erratic nature, including the residents' customs and preferred domestic product types. It should be possible for the system to function at a modest scale without requiring cutting edge technology. Considering the system's maintenance requirement as well, it will be necessary to keep an eye out for clogs in the biodegradability of the influent chemicals. Biomass is expected to require periodic removal from the bioreactor to ensure long-term operation. To meet the standard limits needed for reuse in irrigation, natural material

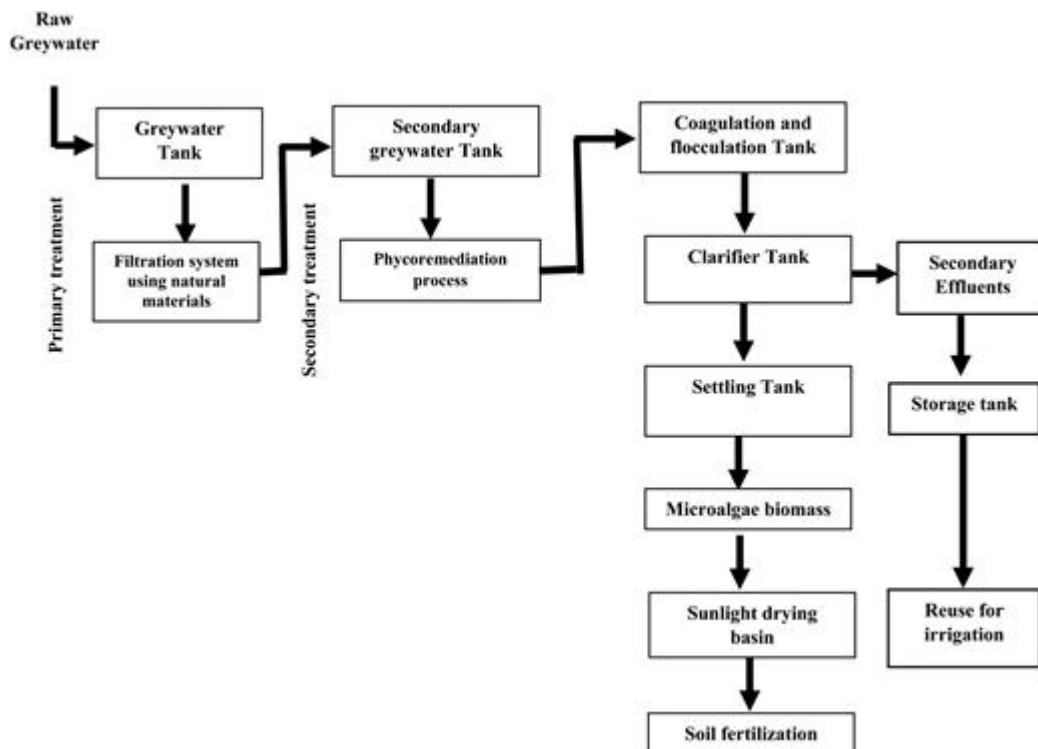
filtration can be used, followed by a phycoremediation process using microalgae (Wurochekke *et al.*, 2016).

2.10 The Trend for Domestic Greywater Treatment Methods

Combining preliminary (physical), primary (chemical), and secondary (biological) systems is a key component of GWT technology. The aforementioned technologies are highlighted because of their low cost, low manpower requirement, ease of handling, and great treatment efficiency. The hybrid system for treatment of household greywater is shown in Figure 2.2.

Figure 2.2

Hybrid System for Treatment of Household Greywater



Source: (Rani *et al.*, 2021)

Figure 2.2 shows a hybrid system for treatment of household greywater consists of a Natural filtration unit, Phycoremediation process, coagulation and flocculation process and microbiological aspects of the hybrid system which are discussed below.

2.10.1 Natural filtration unit

Nature-based filtration systems remain core options for decentralized greywater polishing because they're low-energy, scalable, and cost-effective. Recent reviews show that constructed wetlands (CWs) achieve robust removal of TSS, BOD/COD, nutrients, and surfactants when media and hydraulics are optimized (e.g. vertical flow, amended substrates) (Santos *et al.*, 2024; Biswal *et al.*, 2022).

The predominant method of treatment involves the use of coarse sand and soil filtration. Since the removal of contaminants from greywater can only be partially achieved by the coarse filter alone, it is typically employed in conjunction with soil filtration, a process known as hybrid treatment. In order to create a filter bed in the filtration unit, several natural material types have been mixed, including sand beds, fine particles, coarse size brick beds, charcoal beds, pottery, clamshell, limestone, hardwood sawdust beds, and beds of coconut shell cover (Sgroi *et al.*, 2018).

The utilisation of natural materials as a filtration unit, such as in constructed wetlands, have exhibited high efficiency for removing pollutants, as well as being inexpensive and simple to operate. Filtration system consisting of peat, charcoal and gravel was effective for the treatment of greywater. The filtration system consisted of bark and activated charcoal, which also exhibited efficiency in reducing BODs and total phosphorus by more than 90% (Noutsopoulos *et al.*, (2018).

2.10.2 Phycoremediation process

A green method for treating greywater and lowering pollution is the phycoremediation process. Microalgae are highly capable of absorbing nutrients. domestic greywater is an ideal medium for algal growth because it has high concentrations of carbon, nitrogen, and phosphorus as well as trace elements that are essential to algal growth (El-Khouly *et al.*, 2020).

Phosphorus and nitrogen are the two nutrients that are most significant for greywater. For TN, these nutrients may be found at amounts of 20-40 mg/L and for TP, 50-70 mg/L. Untreated greywater contains phosphorus from household soap and detergent use, nitrogen from blood in meat cleaned in the kitchen sink, and nitrate from diapers washed in the bathroom (Oliveira *et al.*, 2020).

2.10.3 Coagulation and flocculation processes

A crucial stage in the wastewater treatment process is the coagulation and flocculation processes. Both procedures make a substantial contribution to the decrease in turbidity, COD, BOD, and TSS. Furthermore, these procedures are also utilised to harvest microalgal biomass through the mechanism of charge interaction, which occurs between positively charged flocculants and negatively charged functional groups like amine, amide, phosphate, carboxyl, and hydroxyl groups on the walls of microalgal cells, resulting in the flocculation of microalgal biomass (Saleem *et al.*, 2021).

Coagulants and flocculants are made of a variety of chemicals, including ferric sulphate, ferrous sulphate, ferric chloride and ferric chloride. The usage of natural materials, such as *Moringa oleifera* and *Strychnos potatorum* seeds, is becoming more popular, though, as they are inexpensive and devoid of harmful byproducts like carcinogenic chemicals. Literature has documented the effectiveness of natural flocculants in enhancing the properties of water quality and obtaining microalgae biomass (Irfan *et al.*, 2017).

2.10.4 Microbiological aspects of the hybrid treatment system

Compared to sewage, greywater has less suspended solids, but because practical solids in wastewater promote bacterial cell colonisation, greywater has a non-negligible bacterial burden. Total coliforms (TC), faecal coliforms (FC), and *Enterococcus* are among the diverse range of bacteria found in the untreated greywater, with quantities exceeding 104 CFU/100 mL (Al-Gheethi *et al.*, 2016).

There would be little impact of bacteria on the growth of microalgae when the greywater produced by the primary process undergo the phycoremediation process due to its low bacterial load. However, because they are photosynthetic organisms that can take carbon and energy from sunlight, the microalgae in wastewater develop quickly throughout the phycoremediation process (Al-Gheethi *et al.*, 2016).

Bacterial growth then takes place after the microalgae die. This procedure, known as succession, is crucial to the wastewater treatment process. Therefore, using a flocculation procedure and applying phycoremediation for no more than six days may be able to stop the growth of pathogens. Significant contributions to the decrease of bacteria would also come from thermal treatment and solar light (Al-Gheethi *et al.*, 2016).

2.11 Water Quality Parameters

The three main categories of water quality characteristics are physical, chemical, and biological. These qualities are crucial for determining whether water is suitable for drinking, farming, and aquatic ecosystems, among other uses.

Physical attributes such as color, turbidity, and temperature can affect how beautiful and high-quality water is overall. pH, dissolved oxygen, nutrients (phosphates and nitrates, for example), heavy metals, and various pollutants resulting from human activities are examples of chemical factors (Ahmad, 2023).

These features have the potential to have a significant impact on the general biological balance of water bodies as well as the welfare of aquatic organisms. Biological factors include things like the existence of pathogens that can injure people and indicator species like coliform bacteria that can indicate potential faecal contamination (Hu *et al.*, 2022).

2.11.1 Total suspended solids (TSS)

Solid particles suspended in water that cause turbidity and may serve as pathogen carriers are referred to as TSS. Depending on the source, typical TSS concentrations in

greywater range from 23 to 1,140 mg/L, with larger amounts coming from laundry and kitchen operations (Oteng-Peprah *et al.*, 2018). Sand filtering systems and constructed wetlands are frequently used to lower TSS levels. For example, research shows that artificial wetlands can lower TSS to as low as 7 mg/L, allowing the water to be used for irrigation and other non-potable reuse purposes (Oteng-Peprah *et al.*, 2018).

2.11.2 Total dissolved solids (TDS)

The proportion of dissolved organic and inorganic materials, or TDS, affects salinity and the possibility of reusing water. TDS levels in greywater normally range from 140 to 1,300 mg/L, mostly as a result of the use of cleaning products and detergents (National Research Council, 2016). Elevated TDS levels present difficulties for irrigation, because of the possibility of soil salinization. Reverse osmosis and electrocoagulation are two advanced treatment techniques that have shown notable TDS reductions, improving the water's potential for reuse (Parameshwaramurthy *et al.*, 2018).

2.11.3 pH

pH of greywater influences both the effectiveness of disinfection techniques and the chemical reactions occurring during treatment. Greywater pH typically ranges from approximately 6.3 to 10, largely due to the influence of household chemicals like alkaline detergents (El-Fadl *et al.*, 2019). Extreme pH can damage plants or erode infrastructure, therefore maintaining neutral pH levels is crucial for reuse in irrigation and other applications. Biological treatments, such artificial wetlands, have been shown to be successful in stabilizing pH to values that are close to neutral (Oteng-Peprah *et al.*, 2018).

2.11.4 Heavy metals

Lead (Pb), zinc (Zn), and chromium (Cr) are among the heavy metals that frequently enter greywater from industrial and domestic discharges. Because of its porous structure,

large surface area, and the presence of functional groups like hydroxyl and carboxyl, sugarcane bagasse biochar is very effective at adsorbing heavy metals. Modified sugarcane bagasse biochar, particularly when combined with iron oxide, has been shown in studies to improve the removal of heavy metals. For example, because of its improved ion exchange and adsorption capability, biochar treated with iron (III) oxide-hydroxide exhibited high removal efficiencies for Pb, Cu, and Ni (Kumar *et al.*, 2023).

2.11.5 Detergents

The high solubility and stable chemical structure of detergents make them difficult to remove from greywater, which is mostly from laundry and dishwashing. Because sugarcane biochar has adsorption qualities, it may be used to remove detergent. By interacting with detergent molecules, the biochar's large surface area and functional groups lower the amounts of surfactants in treated water. Although there are few studies specifically examining sugarcane biochar's efficacy in removing detergent, overall biochar research indicates that it can reduce surfactants by as much as 80% (García-Segura *et al.*, 2021).

2.11.6 Oil and grease

Grease and oils are frequent pollutants in kitchen greywater and provide problems because they are hydrophobic. The nonpolar surface and large pore volume of sugarcane biochar have demonstrated potential in the adsorption of oils and hydrocarbons. Studies have shown that both treated and untreated sugarcane bagasse biochar can efficiently absorb oil residues, greatly lowering contamination levels (Santos *et al.*, 2022). Biochar is a useful material for dealing with oil and grease in greywater because of its capacity to trap oils within its pores and bind them by van der Waals forces.

2.11.7 Phosphates

Agricultural runoff, industrial effluents (some industries, such as food processing and fertilizer production, can discharge phosphate-rich wastewater), untreated sewage, which releases significant amounts of phosphates contained in detergents, natural sources (phosphate-rich rocks), and soil weathering are some of the main causes of phosphates in water (Abdoli *et al.*, 2024; Ahmad, 2023; UNEP, 2024). Phosphates have a negative impact on human health, impair aesthetic value, and induce eutrophication.

To mitigate phosphate contamination, several preventative measures are essential: regular monitoring of water bodies, effective wastewater treatment at treatment plants, strict enforcement of restrictions on industrial discharges, raising public awareness about phosphate pollution, and promoting the responsible use of fertilizers and detergents (Abdoli *et al.*, 2024; UNEP, 2024).

2.11.8 Nitrates

Nitrates are some of the major nutrients in water. Some of the sources of nitrate in water are infectively treated wastewater, agricultural activities where nitrogen-based fertilizers, like ammonium nitrate and potassium nitrate are major contributors to nitrate contamination in water. Excessive nitrate in water courses eutrophication, Habitat degradation and ground water contamination (Ruxandra *et al.*, 2020).

2.11.9 Biological oxygen demand

The amount of organic matter in water is gauged by its BOD content. Significant organic matter in the water, which could degrade its quality and have an adverse effect on aquatic life, is indicated by high BOD levels. Soil erosion, industrial waste, and decomposing organic matter are some of the primary sources of BOD in water. Depletion of dissolved oxygen in excess BOD causes, foul taste and smell, as well as eutrophication. There are a number of control strategies that can be used to reduce excessive BOD, including waste

management, efficient water treatment, and routine monitoring of BOD levels in water bodies (Flory *et al.*, 2021). Table 2.2 shows the wastewater quality standards

Table 2. 2

Wastewater quality standards

| Parameter | Unit | Typical Standard Limits |
|---------------------------------|--------------|--------------------------------|
| Ph | - | 6.0 – 9.0 |
| Biochemical Oxygen Demand (BOD) | mg/L | ≤ 30 |
| Chemical Oxygen Demand | mg/L | ≤ 250 |
| Total Suspended Solids | mg/L | ≤ 50 |
| Total Dissolved Solids | mg/L | ≤ 2100 |
| Oil and grease | mg/L | ≤ 10 |
| Nitrates (NO ₃) | mg/L | ≤ 10 |
| Ammonia (NH ₃) | mg/L | ≤ 1 |
| Phosphates (PO ₄) | mg/L | ≤ 2 |
| Total Nitrogen (TN) | mg/L | ≤ 10 |
| Heavy Metals | µg/L or mg/L | Varies by metal |
| - Lead (Pb) | µg/L | ≤ 50 |
| - Mercury (Hg) | µg/L | ≤ 2 |
| - Cadmium (Cd) | µg/L | ≤ 10 |
| - Chromium (Cr) | µg/L | ≤ 50 |
| - Zinc (Zn) | µg/L | ≤ 1000 |
| Dissolved Oxygen (DO) | mg/L | ≥ 5 (for receiving waters) |
| Electrical Conductivity | µS/cm | ≤ 1500 |

(EC)

| | | |
|-------------------|------------|-------------|
| Coliform Bacteria | CFU/100 mL | ≤ 1000 |
|-------------------|------------|-------------|

Source: (U.S. Environmental Protection Agency [EPA], 2017)

2.12 Challenges of Grey Water Treatment

Greywater needs to be separated, from the blackwater from urinals and toilets, which calls for more piping (Chen 2016). It will require the construction of a decentralized system. In cases where wastewater normally flows to a centralized wastewater treatment plant, as is common in urban and densely populated areas, a hybrid decentralized and centralized system may be necessary. Greywater is deposited by this dual system into your decentralized system, where it can be recycled locally, while blackwater is deposited into centralized sewage systems.

Some advanced systems are capable of treating both greywater and blackwater, purifying them for specific applications such as toilet flushing. Although recycling blackwater poses significant risks, this approach can still be cost-effective, as it reduces reliance on external water supplies by limiting pumping needs. However, it does require substantial maintenance. Greywater systems remain financially viable despite these challenges (Baliota *et al.* 2020).

CHAPTER THREE: RESEARCH MATERIALS AND METHODS

3.0 Introduction

The chapter discusses the research design, materials used in the experiment, safety protocols for handling biochar, chemicals and greywater, collection of greywater samples, making of sugarcane waste biochar, characterisation of biochar, analysis of greywater, determination of efficiency of sugarcane waste biochar, quality control, data analysis and research license.

3.1 Research Design

The study used an experimental research design. This design is a scientific approach to research, where one or more independent variables are manipulated and applied to one or more dependent variables to measure their effect on the latter. The use of an experimental design provides a structured and controlled framework for investigating the causal relationship between the variables, facilitating a more informed and substantiated conclusion about the interplay between variables. Sampling and analyses were done between May and August 2024.

Through meticulous experimentation and data collection, the researcher aimed to establish the efficiency of sugarcane waste biochar in removing contaminants from grey water. The experiments were primarily conducted in the Chemistry Laboratory at Meru University of Science and Technology. Additional analyses of both greywater and biochar samples were carried out at the Material Testing Laboratory (Ministry of Transport, Infrastructure, Housing and Urban Development), the Geochemistry Laboratory (Ministry of Mining, Blue Economy and Maritime Affairs), and the National Phytotherapeutics Research Centre at Kenyatta University.

3.2 Materials

3.2.1 Instruments and equipment

The following equipment was used: Atomic Absorption Spectrophotometer (AAS), Shimadzu 7000 series; Analytical Balance, Ohaus model CP 318; Multiparameter Water Quality Meter, model MK900-CN; Ultraviolet–Visible (UV–VIS) Spectrometer, model UV-11; X-ray Fluorescence (XRF) Analyzer, S1 Titan model; Fourier Transform Infrared (FTIR) Spectrometer, Shimadzu IRSpirit-T model; and X-ray Diffractometer (XRD), Bruker D6 Phaser model.

3.2.2 Chemicals

The following analytical reagent (AR) chemicals were used: potassium hydroxide (KOH), nitric acid (HNO₃), hydrochloric acid (HCl), lead standard solution, chromium standard solution, and chloroform.

3.3 Safety Protocols for Handling Biochar, Chemicals and Greywater

When handling biochar, safety precautions were observed due to its fine particulate nature and potential fire risks. To minimize this risk inhaling the biochar dust, the researcher wore appropriate respiratory protection such as an N95 mask, along with safety goggles to protect the eyes from dust particles (OSHA, 2020).

A laboratory coat and disposable gloves were worn to prevent skin contact and contamination. Biochar was handled in a well-ventilated area to reduce inhalation hazards. Biochar was stored in sealed, airtight containers away from sources of heat, sparks, or open flames (FAO, 2019).

Chemical handling followed laboratory safety practices because many of the reagents used in greywater purification studies such as hydrochloric acid, petroleum ether, methylene blue, or chloroform posed chemical and health hazards. Researchers wore a

lab coat, chemical-resistant gloves such as nitrile, closed shoes, and protective goggles at all times when handling these substances (CDC, 2016).

Greywater contained pathogens such as bacteria, viruses, and protozoa, making it a potential biohazard. All greywater samples were handled as infectious material (WHO, 2019). Appropriate personal protective equipment, including waterproof laboratory coats or aprons, disposable gloves, protective goggles, and face masks, were worn to reduce the risk of exposure.

3.4 Collection of Greywater Samples

Three different types of greywater samples were carefully collected from the kitchen, bathroom and carwash. Kitchen wastewater was collected from Meru University of science and Technology kitchen and two other kitchens in Meru municipality; bathroom wastewater was collected from three residential houses in Meru municipality and carwash wastewater was collected from three carwashes in Meru municipality.

The sampling method used for collecting water samples from the three households and carwashes in Meru Municipality was purposive sampling, since the households were deliberately selected. The samples were carefully collected in cleaned one-liter polyethylene terephthalate bottles (PET). Bottles were washed thoroughly with tap water and detergent, rinsed thoroughly with tap water, rinsed thoroughly with deionised water and allowed to dry. The bottles were rinsed with the individual water samples thoroughly before filling them with the samples. Three samples were taken in each case for purification and analysis in the laboratory.

3.5 Making Sugarcane Waste Biochar

Sugarcane waste (bagasse) was collected from one of the supermarkets in Meru town where they prepare sugarcane juice. The pieces of sugarcane waste were washed thoroughly with distilled water before being dried out in an oven for 24 hours. The pieces

were then divided into two batches of 50 g each. The first batch of the sugarcane bagasse pieces underwent pyrolysis in a kiln temperature of 500 °C for 3 hours, followed by a 24-hour cooling period in a desiccator. Sugarcane waste was pyrolyzed at 500 °C because this temperature produces biochar with the best trade-off between high surface area, porosity, and retention of active functional groups, making it highly effective for greywater purification and heavy metal removal (Chen *et al.*, 2019).

The second batch was activated using potassium hydroxide (KOH) pellets in a ratio of two to one (Sugarcane pieces: KOH). This was accomplished by soaking in 500 mL of deionised water for four hours and baking dry for 12 hours at 150 °C. The chemically activated sugarcane pieces then underwent pyrolysis in a kiln at 500 °C for 3 hours followed by a 24-hour cooling period in a desiccator. After which regular rinsing in distilled water and 0.1 M hydrochloric acid was done until the washing was free of base medium and the pH fell to 5. Then dried in an oven at 105 °C for 12 hours and crushed using mortar and pestle to powder form (Lingamdinne *et al.*, 2024; Bongosia *et al.*, 2024).

3.6 Characterisation of Biochar

Physical, chemical and structural properties of the biochar were characterised to understand its suitability as an adsorbent. X-ray diffraction (XRD), Bruker D6 Phaser model at the Geochemistry Laboratory (Ministry of Mining, Blue Economy and Maritime Affairs) was used to determine crystallinity of the biochar structure and the presence of salt compounds. X-ray fluorescence (XRF), S1 Titan model at the Geochemistry Laboratory (Ministry of Mining, Blue Economy and Maritime Affairs) was used for the analysis of elemental composition. Organic functional groups were investigated using Fourier transform infrared (FTIR) spectroscopy, Shimadzu model

IRSpirit-t at the National Phytotherapeutics Research Centre (Kenyatta University).

Figure 3.1- 3.3 shows the analytical instruments used for the characterisation.

Figure 3.1



X-ray fluorescence (XRF)

Source: Researcher, (2024)

Figure 3.2

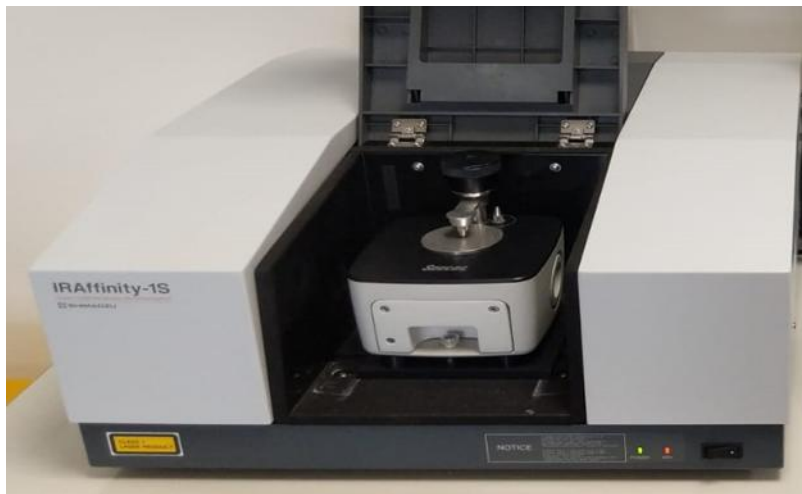


X-ray diffraction (XRD)

Source: Researcher, (2024)

Figure 3.3

Fourier transform infrared (FTIR).



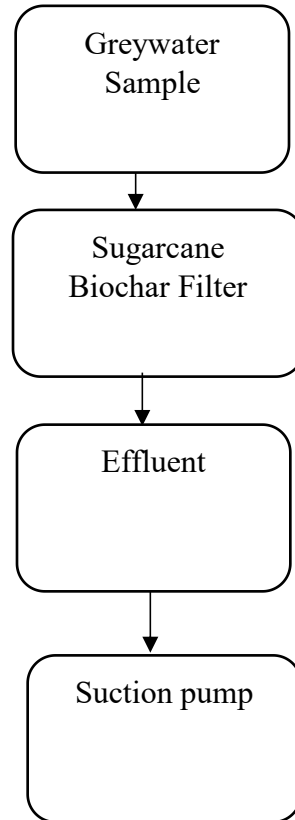
Source: Researcher, (2024)

3.7 Analysis of Greywater

Physical and chemical properties of greywater were analysed prior and after the purification process. Physical properties analysed were total suspended solids (TSS), total dissolved solids (TDS), electrical conductivity (EC) and pH. The chemical properties included heavy metals (chromium and lead), detergents, oil and grease. Figure 3.4 shows the system arrangement used to purify greywater in this study.

Figure 3.4

Greywater Purification System Layout



Source: Researcher, (2024)

All the components were cleaned thoroughly before assembly to ensure that no contaminants were introduced into the system during installation. The assembly was set up as shown in figure 3.4. Through a pipe, the pump extracted the greywater for 5 minutes (approximately 100 mL) from the biochar filter. Biochar from sugarcane filtered detergents, oils, and heavy metals. The cleaned water was released from the system via an outlet pipe after going through the filtering system and analysed.

3.7.1 Determination of total suspended solids (TSS)

Each water sample (100 mL) was passed through 10 g of biochar for 5 minutes at a flow rate of 0.333 mL/second. To determine TSS, 100 mL of greywater was filtered through a

pre-weighed filter paper. The paper was dried and weighed again to determine how many particles were retained on its surface. A clean, pre-dried filter paper was first prepared, and its original mass determined by weighing it using an analytical balance.

A gravity filtration setup was used to filter 100 mL of the greywater sample via the filter paper. After filtration, the filter paper that contained the suspended solids was carefully taken out, dried at 103 to 105 °C in a laboratory oven to maintain a constant weight, and then weighed again. The weight difference between the filter paper before and after filtering volume, was used to determine the TSS concentration (APHA, 2017).

3.7.2 Determination of total dissolved solids (TDS)

Each water sample (100 mL) was passed through 10 g of biochar for 5 minutes at a flow rate of 0.333 mL/second. A pre-weighed, dry, and clean container received a measured volume of the water sample. The volume selected was suitable for the sample's anticipated suspended solids content. The water was evaporated from the sample by placing the container in an oven set at 105 °C for 2 hours. This drove off the water and left behind the suspended solids.

To stop moisture from the atmosphere from absorbing into the container, it was allowed to cool in a desiccator after evaporation. An analytical balance was used to weigh the container containing the dried materials once it had cooled and the constant weight was recorded (Dehghani *et al.*, 2018).

The concentration of TDS was calculated using the following formula:

$$TDS \left(\frac{mg}{L} \right) = \frac{((W_{container} + W_{solid}) - W_{container}) \times 1000}{V_{sample}} \quad (3.1)$$

where:

W_{solid} = Weight of dried solids (mg)

$W_{container}$ = weight of the container (mg)

V_{sample} = volume of the original sample (mL)

All the samples were analysed in triplicate and the mean value and relative standard deviations calculated. Analysis of total dissolved solids (TDS) in the samples was carried out before and after treatment with each sugarcane waste biochar. Fresh 10 g biochar powder was used for each sample. Experiment was done with both inactivated and activated biochar.

3.7.3 Determination of electrical conductivity (EC)

Each water sample (100 mL) was passed through 10 g of biochar for 5 minutes at a flow rate of 0.333 mL/second. The conductivity probe was rinsed with distilled water to ensure there were no contaminants affecting the measurement. Standard conductivity solutions having established values, such as 84 $\mu\text{S}/\text{cm}$, 1413 $\mu\text{S}/\text{cm}$, and 12.88 mS/cm , were prepared before the conductivity meter was calibrated. These solutions operated as reference points for the calibration procedure.

As directed by the manufacturer, the conductivity meter was turned on and given time to stabilize before calibration began. The probe reading for the meter was checked against the value of the standard. The conductivity probe was submerged into the filtered water sample and allowed a few moments for the reading to stabilise. The reading was recorded. To avoid contamination when switching to the next calibration solution, the probe was carefully cleaned with deionized water after every measurement.

All the samples were analysed in triplicate and the mean value and relative standard deviation were calculated. Analysis of electrical conductivity in the samples was carried out before and after treatment with each sugarcane waste biochar. Fresh 10 g biochar powder was used for each sample. Experiment was done with both inactivated and activated biochar.

3.7.4 pH measurement

Each water sample (100 mL) was passed through 10 g of biochar for 5 minutes at a flow rate of 0.333 mL/second. Three representative samples of the filtered water were collected after the filtration process was completed. The pH meter was calibrated using standard buffer solutions of 4.01, 7.0 and 10.0 pH values. Since pH readings varied depending on the temperature, the samples were given time to acclimate to the surrounding air temperature. The pH electrode was immersed into the filtered water sample. Sufficient time was allowed for the pH reading to stabilise, in a few seconds to a minute (Dehghani *et al.*, 2018).

The pH reading displayed on the pH meter was recorded. Analysis of pH in the samples was carried out before and after treatment with each sugarcane waste biochar. Fresh 10 g biochar powder was used for each sample. Experiment was done with both inactivated and activated biochar.

3.7.5 Determination of heavy metals (Cr and Pb)

Three samples were collected in clean polyethylene terephthalate bottles (PET) 500 mL bottles. The samples were filtered and acidified by adding 1 mL of pure concentrated nitric acid. The samples were then digested with pure concentrated nitric acid. The water samples were filtered through a Whatman filter paper No. 42 pore size by vacuum filtration method.

Each filtered water sample (100 mL) was measured and transferred into a clean 250 mL beaker.

Each sample was treated with 5 mL of pure concentrated nitric acid (HNO₃). The samples were placed on a hot plate in a fume cupboard and evaporated to almost dryness. They were allowed to cool and transferred to a clean 100 mL volumetric flask then diluted to the mark.

For the heavy metals determination, the samples were spiked with 5 ppm of chromium (Cr) and lead (Pb) salts. A 100 mL of each water sampled was passed through 10 g of biochar for 5 minutes. Chromium (Cr), and Lead (Pb) ions were determined by Atomic Absorption spectroscopy (AAS) method after instrument calibration with the respective standard salts. The Atomic Absorption Spectroscopy (AAS), Shimadzu 7000 series at the chemistry lab at Ministry of Transport, Infrastructure, Housing and Urban Development instrument used is shown in figure 3.5.

Figure 3.5



AAS Spectrometer.

Source: Researcher, (2024)

The preparation of standards for Pb^{2+} and Cr^{6+} ions for Atomic Absorption Spectroscopy (AAS) analysis began with the preparation of 1000 ppm stock solutions. This was achieved by dissolving 5 ppm of lead salt and 5 ppm of chromium salt separately in one litre of deionized water to obtain the respective Pb^{2+} and Cr^{6+} stock solutions. From each

1000 ppm stock, 10 mL was pipetted into a 100 mL volumetric flask and diluted to the mark with deionized water to obtain a 100 ppm intermediate solution.

Working calibration standards for Pb^{2+} were then prepared by pipetting 10 mL, 20 mL, 30 mL, and 40 mL aliquots of the 100 ppm intermediate solution into separate 100 mL volumetric flasks, topping up with deionized water, and labelling the solutions as 10 ppm, 20 ppm, 30 ppm, and 40 ppm, respectively. Similarly, Cr^{6+} calibration standards were prepared by pipetting 2 mL, 4 mL, 6 mL, 8 mL, and 10 mL of the 100 ppm solution into separate 100 mL volumetric flasks, diluting to the mark, and labelling them as 2 ppm, 4 ppm, 6 ppm, 8 ppm, and 10 ppm, respectively. The standard solutions were run to obtain the absorbances and calibration curve was drawn.

Analysis of heavy metal ions present in kitchen wastewater; carwash wastewater and bathroom wastewater samples were run and absorbances obtained. The respective concentrations were derived from interpolation of absorbances in the calibration curves.

Analysis of heavy metal Cr^{6+} and Pb^{2+} ions present in the samples was carried out before and after treatment with each sugarcane waste biochar. Samples were run in triplicate and mean value and relative standard deviations calculated. Fresh 10 g biochar powder was used for each sample. Experiment was done with both inactivated and activated biochar.

3.7.6 Determination of detergent (sodium dodecyl sulphate)

Kitchen, bath, and carwash greywater samples were collected in 1 L clean plastic (PET) bottles. The samples were filtered through Whatman No. 42 filter paper by vacuum filtration. Three 100 mL of filtered samples were measured into 250 mL glass beakers for each type of greywater. Exactly 5 mg of sodium dodecyl (lauryl) sulphate detergent was added to each sample and stirred to dissolve the salts completely. Each beaker was labelled.

Each water sample (100 mL) was passed through 10 g of biochar for 5 minutes at a flow rate of 0.333 mL/second. Fresh 10 g biochar powder was used for each sample. Experiment was done with both inactivated and activated biochar. Three fresh 100 mL of filtered samples were measured into 250 mL glass beakers for each type of greywater. These samples were not treated with the detergent and biochar (The samples were used as blanks).

A stock solution of 1000 ppm was prepared by dissolving exactly 1 g of sodium dodecyl (lauryl) sulphate standard in 1 L of deionised water. A working solution of 100 ppm was prepared from the stock solutions by serial dilution. Then 0.2, 0.4, 0.6, 0.8 and 1 ppm calibration standard solutions were prepared from the working solutions by serial dilution.

The calibration standards were prepared from the 100 ppm working solution by accurately pipetting 0.2 mL, 0.4 mL, 0.6 mL, 0.8 mL, and 1.0 mL portions into separate 100 mL volumetric flasks, followed by dilution to the mark with deionised water and thorough mixing to ensure homogeneity. Each flask was labelled with the nominal concentration. These 0.2 - 1 ppm solutions are the calibration standards that were used to obtain the UV–VIS is calibration curve.

Each calibration standard solution (20.0 mL) was added into a 50 mL plastic beaker, followed by 10.0 mL of chloroform and 200 μ L of methylene blue solution. Methylene blue acts as a colorimetric reagent that forms a colored complex with the detergent that can be measured spectrophotometrically. The mixture was oscillated for 1 minute. The mixture was left for layering to take place and the upper solution sucked out. The UV-VIS spectrometer was set to zero using chloroform. The absorbance of the bottom extraction solution at 650 nm wavelength was measured to obtain a calibration graph.

Each water sample (20.0 mL) was added into a 50 mL plastic beaker, followed by 10.0 mL of chloroform and 200 μ L of methylene blue solution. The mixture was oscillated for 1 minute. The mixture was left for layering to take place and suck out the upper solution. The instrument was set to zero using chloroform. The absorbance of the bottom extraction solution at 650 nm wavelength was measured.

Concentration of detergent in the samples was established from the calibration curve. The samples were diluted with appropriate dilution factor if the absorbance was higher than that obtained for 10 ppm standard, and multiplied with the concentrations measured with the respective dilution factors. Analysis of detergents present in the samples was carried out before and after treatment with each sugarcane waste biochar. The UV-VIS spectrometer is shown in figure 3.6.

Figure 3.6

Ultraviolet-Visible (UV-VIS) spectrometer



Source: Researcher, (2024)

3.7.7 Determination of oil and grease

Exactly 100 mL of kitchen, bathroom and carwash greywater samples were passed through 10 g of biochar for 5 minutes. Fresh 10 g biochar powder was used for each sample. Experiment was done with both inactivated and activated biochar. The initial weight of dry empty petri-dish was measured.

The greywater sample (100 mL) was measured and poured into a separating funnel, after which 1 mL of dilute hydrochloric acid (1:1) was added to clear any suspended solids. Subsequently, 20 mL of petroleum ether was introduced into the solution. The solution in the separating funnel was shaken to mix properly. The lid was opened for any gas formed to escape. The mixture was allowed to settle for 20 minutes. The water below the oil layer was drained into a beaker. All the oil content was discarded into the petri-dish.

The heating mantle was pre-heated. The petri-dish was placed in the heating mantle to evaporate the water and solvent to be left with the oil content. The petri-dish was allowed to cool down at room temperature. The final weight of the petri-dish was measured and noted. Calculations for concentration of oil and grease;

$$\text{Oil and Grease } \left(\frac{\text{mg}}{\text{L}} \right) = \frac{(\text{W}_{\text{final}} - \text{W}_{\text{initial}}) \times 1000}{V_{\text{sample}}} \quad (3.2)$$

where W_{final} = final weight of the petri-dish containing oil and grease (mg)

$\text{W}_{\text{initial}}$ = weight of empty petri-dish (mg)

V_{sample} = volume of sample (mL)

Fresh 10 g biochar powder was used for each sample. Experiment was done with both inactivated and activated biochar. Analysis of oil and grease present in the samples was carried out before and after treatment with each sugarcane waste biochar.

3.8 Determination of Efficiency of Sugarcane Waste Biochar to Purify Greywater

The effectiveness of sugarcane waste biochar in purifying greywater was evaluated by comparing the performance of inactivated and activated biochar and evaluating its adsorption capabilities. Two forms of biochar were prepared at the beginning of the procedure. Whereas activated biochar underwent chemical activation to improve its adsorption capabilities, inactivated biochar was utilized untreated in its raw state (Ahmed *et al.*, 2016; Tan *et al.*, 2019).

The purifying efficiencies of these two biochars was subsequently assessed by testing. A control group (untreated), a group treated with inactivated biochar, and a group treated with activated biochar were the three groups into which greywater samples were separated after collection. To maintain uniformity, each group used the same amount of greywater. A precise dosage of biochar was added to the greywater, between 2 and 10 g/L.

To ensure that the biochar and greywater had enough time to come into contact, the combination was agitated for a certain amount of time, such as 30 minutes to 2 hours. Following treatment, filtering was used to remove the biochar from the greywater (Zhang *et al.*, 2017). For both the control and treated samples, important water quality metrics were assessed, including pH, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), and the amounts of certain contaminants (such as turbidity or heavy metals). For each parameter, the biochar's efficiency was expressed as a percentage of adsorption, using the formula:

$$\text{Percent Adsorption} = \frac{C_0 - C_t}{C_0} \times 100 \quad (3.3)$$

where C_0 is the initial concentration of a parameter in the greywater and C_t is its final concentration after treatment (Chen *et al.*, 2018).

The percent adsorption data for each parameter was subjected to a paired t-test in order to compare the performance of inactivated and activated biochar. A p-value less than 0.05 indicates that the difference in efficiencies were statistically significant (Ali *et al.*, 2020). The mean adsorption efficiencies of activated and inactivated biochar for each parameter were calculated by analyzing the data.

The total efficiency of sugarcane waste biochar in greywater purification was revealed by the statistical results of the t-test in conjunction with percent adsorption data. This

strategy provided a reliable way to assess the biochar's potential as an environmentally friendly water treatment technology (Kumar *et al.*, 2021; Wang *et al.*, 2023).

3.9 Quality Control

Prior to the sample analysis, the equipment was calibrated using standards of the targeted analytes. Calibration curves with $R^2 > 0.99$ were used for the sample analysis. The samples were mixed with a known quantity of the standards and the percentage of spike recoveries between 5 and 10% were achieved. All the experiments were done in triplicate, then the means and standard deviations were obtained.

3.10 Data Analysis

The statistical and computational analyses were performed using Microsoft Excel. To establish the central trend of the measured physicochemical parameters, the mean values were first calculated for both untreated greywater and biochar-treated samples. The mean values offered a straightforward representation of the average pollutant concentrations, thereby allowing a clear assessment of the extent to which sugarcane biochar reduced contaminants such as pH, total dissolved solids (TDS), total suspended solids (TSS), heavy metals, electrical conductivity (EC), detergents, oil and grease.

To quantify the efficiency of the biochar, the percent adsorption for each parameter was computed using the formula:

$$\text{Percent Adsorption} = \frac{C_0 - C_t}{C_0} \times 100 \quad (3.4)$$

where C_0 is the initial concentration of a pollutant in the greywater, and C_t is the concentration after treatment. This calculation was performed for both inactivated and activated biochar, enabling a direct comparison of their purification capabilities.

This quantitative measure enabled the comparison of adsorption efficiency between inactivated biochar (raw biochar without surface modification) and activated biochar

(biochar treated to enhance surface area and porosity). By applying this formula across multiple parameters, the analysis identified which version of biochar demonstrated superior removal capacity for different classes of pollutants, highlighting the influence of activation on adsorption performance.

To evaluate variability and consistency of results, the standard deviation (SD) was computed for each parameter. The SD values indicated the degree of dispersion of experimental readings around the mean, thereby providing insights into the reliability and reproducibility of the biochar filtration process. A smaller standard deviation suggested more consistent treatment outcomes, while a larger SD indicated fluctuations that might arise from experimental conditions or heterogeneity in greywater composition. To statistically validate the differences between untreated and treated greywater, as well as between inactivated and activated biochar treatments, an independent samples t-test was performed. The t-test determined whether the observed differences in mean pollutant concentrations were statistically significant at a chosen confidence level (commonly $p \leq 0.05$). This inferential analysis added rigor to the study by ensuring that the reported improvements in greywater quality were not due to random variation but rather to the biochar's adsorption properties.

Finally, the results were organized and interpreted through tables, graphs, and charts, which provided visual clarity and facilitated comparative analysis.

3.11 Research License

A research permit for the study was issued on 4th July, 2024 from the National Commission for Science Technology and Innovation (NACOSTI).

CHAPTER FOUR: RESEARCH RESULTS

4.0 Introduction

This chapter contains results, data analysis and interpretation of findings. The study investigated the effectiveness of sugarcane waste biochar in the purification of grey water.

4.1 Making Sugarcane Waste Biochar

Activating agent availability, residence time, heating rate, and pyrolysis temperature are some of the variables that affected the pyrolysis process. These elements had a major impact on the final biochar's physicochemical characteristics, which are essential for its use in water purification and include surface area, porosity, and functional groups.

The biochar's adsorption properties were further improved by the activation procedure. By introducing extra functional groups like hydroxyl or carboxyl groups, chemical activation with agents like Potassium hydroxide (KOH) increased the biochar's attraction for pollutants.

Figure 4.1-4.5 shows the part of the biochar preparation process inside chemistry laboratory at the Meru University of Science and Technology (MUST).

Figure 4.1



Sugarcane Bagasse Oven Drying

Source: Researcher, (2024)

Sugarcane bagasse was dried in an electric oven at 105 °C, to remove all the moisture (Figure 4.1).

Figure 4.2

Pyrolysis in Furnace



Source: Researcher, (2024)

Figure 4.2 demonstrate sugarcane bagasse pyrolysed in an electric furnace at 500 °C for three hours.

Figure 4.3

Sugarcane Bagasse



Source: Researcher, (2024)

Figure 4.3 shows the sugarcane bagasse after drying, before pyrolysis.

Figure 4.4

Activated Biochar



Source: Researcher, (2024)

Figure 4.4 shows activated sugarcane bagasse in an electric oven being dried.

Figure 4.5

Biochar powder in mortar



Source: Researcher, (2024)

Figure 4.5 shows activated biochar being crushed into powder, to increase its surface area for adsorption

4.2 Characterisation of Biochar

The structures of both activated and inactivated sugarcane waste biochar were characterised using X-ray fluorescence (XRF), X-ray diffraction (XRD) and Fourier transform infrared (FTIR) spectroscopy techniques.

4.2.1 X-ray fluorescence (XRF) characterisation of biochar

The elemental composition of inactivated and activated biochar based on X-ray fluorescence (XRF) are presented in Table 4.1 and 4.2, respectively.

Table 4.1

Characterisation of Inactivated Biochar

| Element Name | % Present |
|---------------------|------------------|
| Si | 18.46±0.423 |
| P | 4.46±0.121 |
| S | 1.69±0.052 |
| K | 26.36±0.072 |
| Ti | 0.08±0.008 |
| Cr | 0.01±0.004 |
| Mn | 0.02±0.009 |
| Fe | 0.87±0.013 |
| Ca | 6.16±0.041 |
| Ni | 0.06±0.005 |

| | |
|----|------------|
| Cu | 0.03±0.003 |
| Zn | 0.04±0.002 |
| Rb | 0.07±0.002 |
| Sr | 0.02±0.002 |
| Y | 0.01±0.002 |
| Au | 0.01±0.004 |

Source: Researcher, (2024)

Table 4.2

Characterization of Activated Biochar

| Element Name | % Present |
|---------------------|------------------|
| P | 0.59±0.073 |
| S | 0.41±0.038 |
| Cl | 2.72±0.004 |
| K | 75.70±0.120 |
| Ca | 2.82±0.036 |
| Fe | 0.20±0.007 |
| Mn | 0.06±0.007 |
| Cu | 0.01±0.002 |
| Rb | 0.019±0.002 |

Source: Researcher, (2024)

The amount of potassium is high in activated biochar (Table 4.1) because the biochar was activated using potassium hydroxide. There was no chromium and lead ions present in the activated biochar. According to the XRF results, activation greatly enhances the

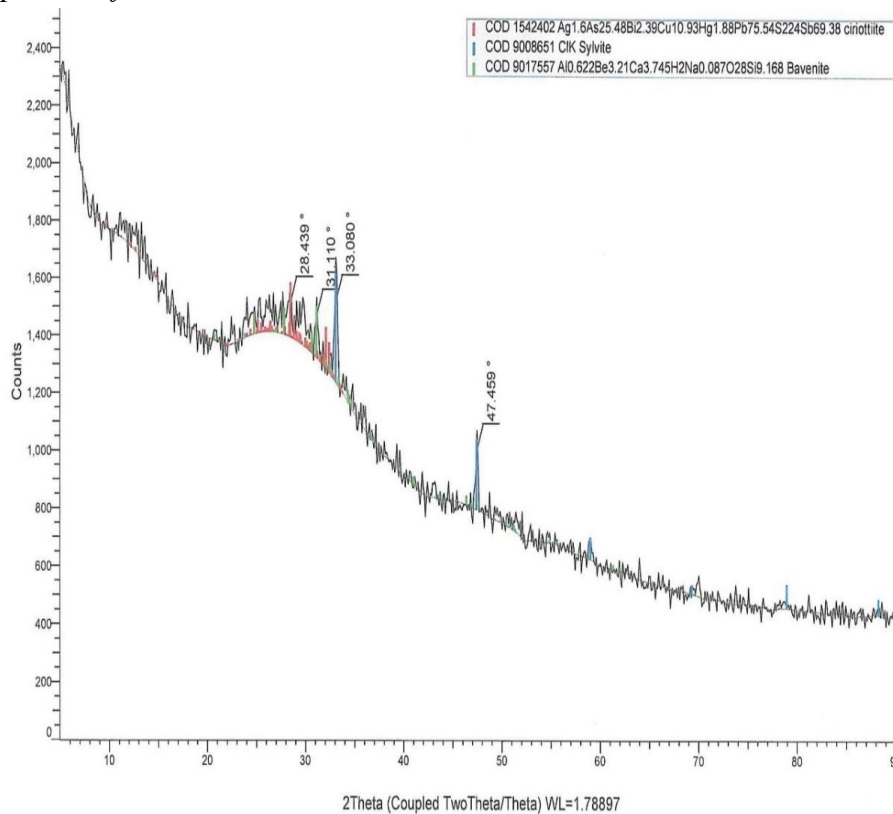
sugarcane waste biochar's elemental composition and adsorption capacity. These results confirm how crucial the activation procedure is to maximizing the effectiveness of biochar made from sugarcane waste.

4.2.2 X-Ray diffraction (XRD) characterisation of biochar

The results from characterization of inactivated biochar, using the XRD instrument are shown figure 4.6. The percentage of the minerals present are shown in Table 4.3.

Figure 4.6

XRD Spectrum for Inactivated Biochar



Source: Researcher, (2024)

Table 4.3*XRD analysis for inactivated Biochar*

| Mineral | Formulae | Percentage |
|------------|---|------------|
| Ciriottite | $\text{Cu}(\text{Cu},\text{Ag})_3\text{Pb}_{19}(\text{Sb},\text{As})_{22}(\text{As})\text{S}$ | 36% |
| Sylvite | KCl | 15.4% |
| Bavenite | $\text{Ca}_4\text{Be}_2\text{Al}_2\text{Si}_9\text{O}_{26}(\text{OH})_2$ | 48.6% |

Source: Researcher, (2024)

The large hump at 20-30° 2θ, which corresponds to disordered carbon, indicates that the inactivated sugarcane waste biochar's XRD pattern is primarily amorphous. Low-temperature pyrolysis is compatible with little graphitization, as evidenced by the lack of prominent peaks for graphitic carbon. Because amorphous carbon and residual mineral phases predominate, these structural features demonstrate the biochar's potential for adsorption applications.

Results for the characterisation of activated biochar, using the XRD method are shown in Figure 4.7. The percentage of the minerals present are shown in Table 4.4

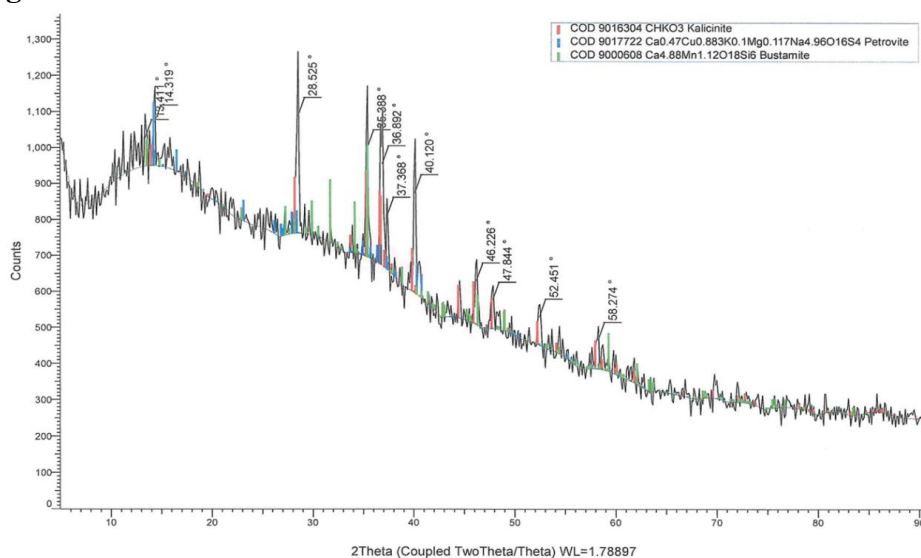
Figure 4.7*Source: Researcher, (2024)*

Table 4.4*XRD Analysis for Activated Biochar*

| Mineral | Formula | Percentage % |
|----------------|--|---------------------|
| Kalicinite | CHKO ₃ | 32.7% |
| Petrovite | Na ₁₀ CaCu ₂ (SO ₄) ₈ | 24.4% |
| Bustamite | CaMnSi ₂ O ₆ | 43% |

Source: Researcher 2024

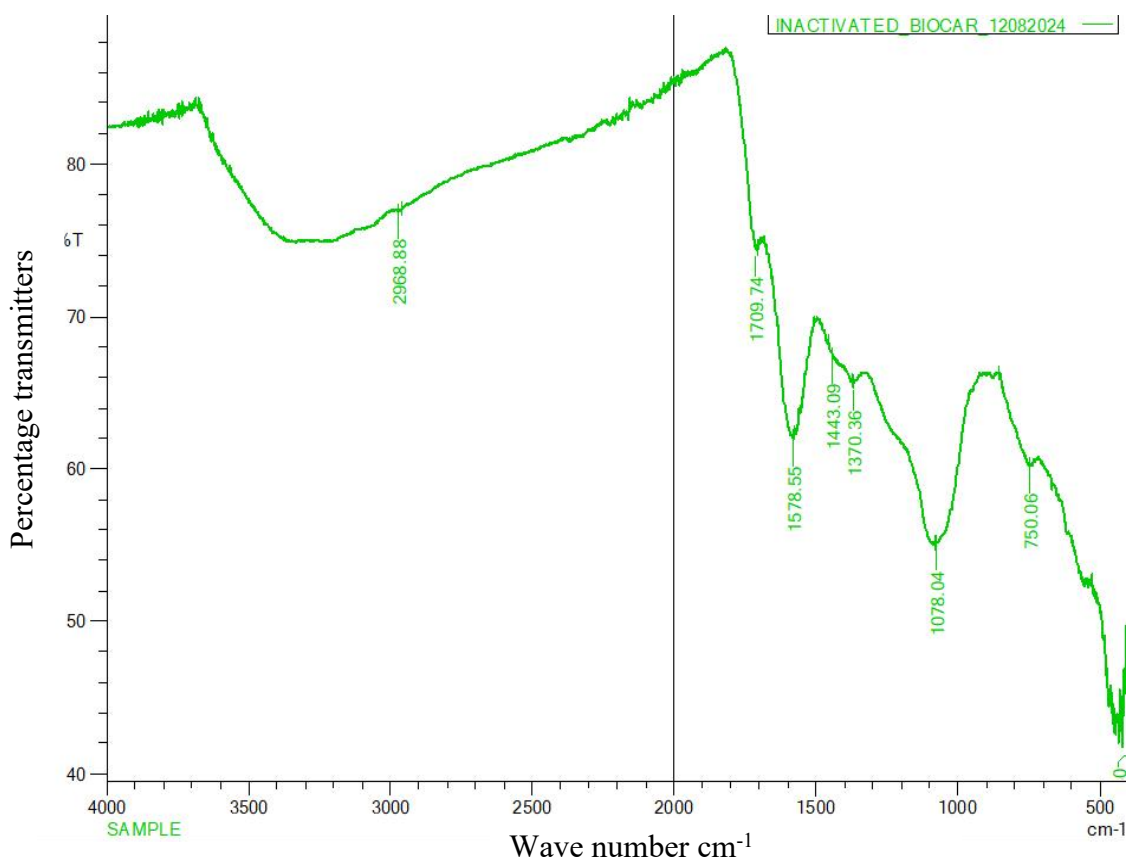
The activated sugarcane waste biochar's XRD pattern shows a mostly amorphous structure with a large hump at around 10-20° 2θ, which is a sign of disordered carbon. Sharper peaks in the activated biochar compared to the inactivated biochar indicate that mineral phases like quartz or leftover salts from chemical activation have been exposed or reorganized. The enhanced potential for adsorption applications and potential improvement of electrochemical properties are highlighted by these structural changes.

4.2.3 Fourier Transform Infrared (FTIR) Spectroscopy Characterisation of Biochar

The results from characterisation of inactivated and activated biochar, using the FTIR spectrometer are shown figure 4.8;

Figure 4.8

Inactivated Biochar FTIR Spectrum



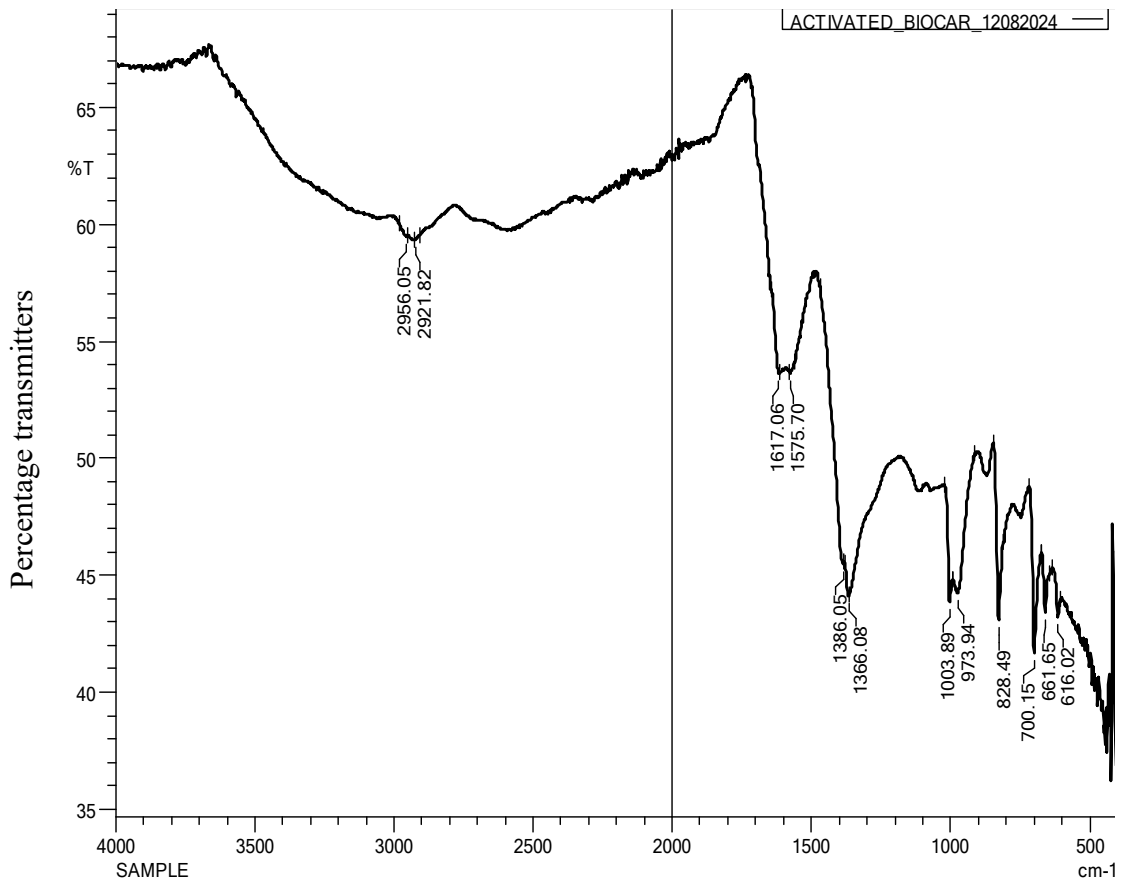
Source: Researcher, (2024)

The following stretching diagnostics peaks are observed: 3500-2500 cm⁻¹ -OH, 2968.88 cm⁻¹ -C-H, 1709.74 cm⁻¹ C=O, 1578.55 cm⁻¹ aromatic C=C and 1078.04 cm⁻¹ C-O.

Results for the characterisation of activated biochar, using the FTIR method are shown in Figure 4.9.

Figure 4.9

Activated Biochar FTIR Spectrum



Source: Researcher, (2024)

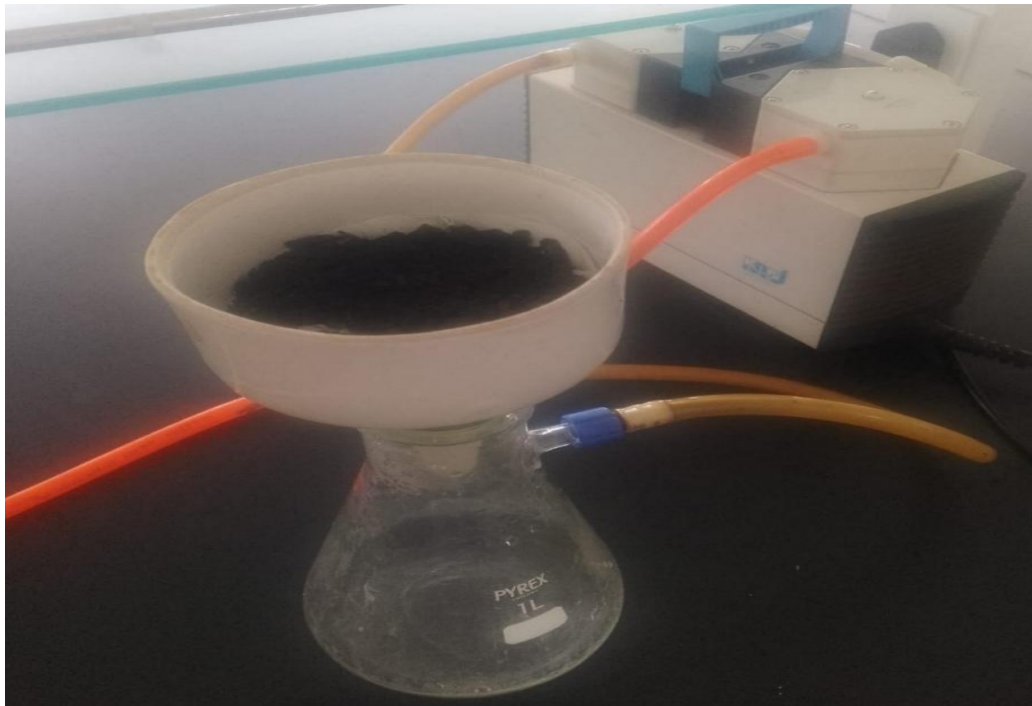
Absorption peaks due to stretching are observed at 2956.05 cm⁻¹ and 2921.82 cm⁻¹ represent -C-H. Peaks at 1617.06 and 1575 cm⁻¹ represents alkene C=C and aromatic C=C, respectively. Bending peaks occur at 1386.05 cm⁻¹ and 1366.08 cm⁻¹ for -C-H and 100.89 cm⁻¹, 973.94cm⁻¹ and 828.49 cm⁻¹ for =C-H (both alkene and aromatic).

4.3 Analysis of Physical Properties in Greywater

The study determined the TSS, TDS, electrical conductivity and pH in the greywater before and after filtration with inactivated biochar and activated biochar. Figure 4.10 shows the experiment setup for greywater filtration at Meru university chemistry laboratory.

Figure 4.10

Experiment Setup for Greywater Filtration



Source: Researcher, (2024)

4.3.1 Analysis of total suspended solids (TSS)

The results are summarized in Table 4.5 for inactivated biochar and Table 4.6 for activated biochar.

Table 4.5

Analysis of TSS in Greywater Filtered with Inactivated Biochar

| Type | of Samples | Initial TSS(A) (mg/L) n=3 | Final TSS (B) (mg/L) n=3 | Decrease in TSS (C = A- B) | Percent (%) Decrease |
|----------|-------------|------------------------------|-----------------------------|----------------------------|-------------------------|
| Bathroom | I | 35 ± 1 | 21± 3 | 14 | 40 |
| | II | 42 ± 1 | 29± 2 | 13 | 30 |
| | III | 45 ± 1 | 32 ± 2 | 13 | 28 |
| | Mean | 41 ± 5 | 27 ± 5 | 14 | 34 ± 6.43 |

| | | | | | |
|---------|-------------|---------------|---------------|-----------|------------------|
| Carwash | I | 64 ± 1 | 50 ± 2 | 14 | 22 |
| | II | 68 ± 1 | 53 ± 2 | 15 | 22 |
| | III | 70 ± 1 | 55 ± 2 | 15 | 21 |
| | Mean | 67 ± 3 | 53 ± 3 | 15 | 21 ± 0.58 |
| Kitchen | I | 39 ± 1 | 25 ± 2 | 14 | 36 |
| | II | 41 ± 1 | 27 ± 2 | 14 | 34 |
| | III | 35 ± 1 | 28 ± 2 | 7 | 20 |
| | Mean | 38 ± 3 | 27 ± 2 | 11 | 29 ± 8.72 |

Source: Researcher, (2024)

Table 4.5 indicates that there was a decrease of 34% in TSS of bathroom water, 21% decrease of TSS in carwash water and 29% decrease of TSS in kitchen water after filtration with inactivated biochar.

Table 4.6

Analysis of TSS in Greywater After Filtered with Activated Biochar

| Type of Greywater | Samples | Initial | Final | Decrease in | Percent (%) |
|-------------------|-------------|----------------------|----------------------|-------------------|------------------|
| | | TSS(A) (mg/L) n=3 | TSS(B) (mg/L) n=3 | TSS (C = A- B) | Decrease |
| Bathroom | I | 35 ± 1 | 17 ± 2 | 18 | 51 |
| | II | 42 ± 1 | 20 ± 1 | 20 | 48 |
| | III | 45 ± 1 | 21 ± 3 | 24 | 53 |
| | Mean | 41 ± 5 | 19 ± 2 | 22 | 51 ± 2.51 |
| Carwash | I | 64 ± 1 | 38 ± 1 | 26 | 40 |
| | II | 68 ± 1 | 40 ± 2 | 28 | 41 |
| | III | 70 ± 1 | 42 ± 1 | 28 | 40 |
| | Mean | 67 ± 3 | 40 ± 3 | 27 | 40 ± 0.58 |

| | | | | | |
|---------|-------------|---------------|---------------|-----------|---------------|
| Kitchen | I | 39 ± 1 | 17 ± 2 | 22 | 56 |
| | II | 41 ± 1 | 19 ± 2 | 22 | 54 |
| | III | 35 ± 1 | 17 ± 2 | 18 | 52 |
| | Mean | 38 ± 3 | 18 ± 1 | 20 | 54 ± 2 |

Source: Researcher, (2024)

Table 4.6 indicates that there was a decrease of 51% in TSS of bathroom water, 40% decrease of TSS in carwash water and 54% decrease of TSS in kitchen water after filtration with activated biochar.

4.3.2 Analysis of total dissolved solids (TDS)

TDS was determined using a multi-parameter meter (MKLAB-900). The results are summarized in Table 4.7 for inactivated biochar and Table 4.8 for activated biochar.

Table 4.7

TDS of Greywater After Filtration with Inactivated Biochar

| Type of Greywater | Samples | Initial TDS(A) (mg/L) n=3 | Final TDS(B) (mg/L) n=3 | Decrease in TDS (C = A-B) | Percent (%) Decrease |
|-------------------|-------------|---------------------------|-------------------------|---------------------------|----------------------|
| Bathroom | I | 39.0 ± 0.200 | 33.4 ± 0.200 | 5.6 | 14 |
| | II | 39.0 ± 0.200 | 34.3 ± 0.200 | 4.7 | 12 |
| | III | 39.2 ± 0.153 | 21.7 ± 0.252 | 17.5 | 13 |
| | Mean | 39.0 ± 0.115 | 34.2 ± 0.850 | 16.5 | 13 ± 1 |
| Carwash | I | 110.1 ± 0.208 | 93.4 ± 0.100 | 16.7 | 15 |
| | II | 111.2 ± 0.153 | 91.8 ± 0.153 | 19.4 | 17 |
| | III | 111.2 ± 0.200 | 91.6 ± 0.100 | 19.6 | 18 |
| | Mean | 110.8 ± 0.635 | 92.3 ± 0.987 | 18.6 | 17 ± 1.53 |
| Kitchen | I | 174.9 ± 0.208 | 156.9 ± 0.200 | 18.0 | 10 |

| | | | | |
|-------------|----------------------|----------------------|-----------|------------------|
| II | 174.9 ± 0.252 | 155.6 ± 0.100 | 19.3 | 11 |
| III | 174.2 ± 0.153 | 154.5 ± 0.152 | 19.7 | 11 |
| Mean | 174.7 ± 0.404 | 155.7 ± 1.201 | 19 | 11 ± 0.58 |

Source: Researcher, (2024)

Table 4.7 indicates that there was a decrease of 13% in TDS of bathroom water, 17% decrease of TDS in carwash water and 11% decrease of TDS in kitchen water after filtration with inactivated biochar.

Table 4.8

Analysis of TDS in Greywater Filtered with Activated Biochar

| Type of Greywater | Samples | Initial TDS(A) (mg/L) n=3 | Final TDS(B) (mg/L) n=3 | Decrease in TDS (C = A- B) | Percent (%) Decrease |
|-------------------|-------------|---------------------------|-------------------------|----------------------------|----------------------|
| Bathroom | I | 39.0 ± 0.200 | 29.6 ± 0.153 | 9.4 | 24 |
| | II | 39.0 ± 0.200 | 30.0 ± 0.153 | 9 | 23 |
| | III | 39.2 ± 0.153 | 29.9 ± 0.200 | 9.1 | 23 |
| | Mean | 39.0 ± 0.115 | 16.7 ± 0.900 | 22.4 | 23 ± 0.58 |
| Carwash | I | 110.1 ± 0.208 | 74.3 ± 0.208 | 35.8 | 32 |
| | II | 111.2 ± 0.153 | 75.7 ± 0.208 | 35.5 | 32 |
| | III | 111.2 ± 0.200 | 73.9 ± 0.115 | 37.3 | 34 |
| | Mean | 110.8 ± 0.635 | 74.6 ± 0.945 | 36.2 | 33 ± 1.15 |

| | | | | | |
|---------|-------------|----------------------|----------------------|-------------|------------------|
| Kitchen | I | 174.9 ± 0.208 | 132.9 ± 0.152 | 42 | 24 |
| | II | 174.9 ± 0.252 | 132.6 ± 0.100 | 42.3 | 24 |
| | III | 174.2 ± 0.153 | 134.5 ± 0.100 | 39.7 | 23 |
| | Mean | 174.7 ± 0.404 | 133.3 ± 1.021 | 41.3 | 24 ± 0.58 |

Source: Researcher, (2024)

Table 4.8 indicates that there was a decrease of 23% in TDS of bathroom water, 33% decrease of TDS in carwash water and 24% decrease of TDS in kitchen water after filtration with activated biochar.

4.3.3 Analysis of pH

The pH of the grey water was measured at a temperature of 25°C. pH was determined using a multi-parameter meter (MK-900). The results are summarised in Table 4.9 for inactivated biochar and Table 4.10 for activated biochar.

Table 4.9

Ph Measurement of Greywater Filtered with Inactivated Biochar

| Type of Greywater | Samples | Initial pH (A) n=3 | Final pH(B) n=3 | Increase in pH (C = B- A) | Percent (%) increase |
|-------------------|-------------|--------------------------|---------------------|---------------------------------|----------------------------|
| Bathroom | I | 6.40 ± 0.006 | 8.81 ± 0.021 | 2.41 | 38 |
| | II | 6.40 ± 0.011 | 8.56 ± 0.306 | 2.16 | 34 |
| | III | 6.41 ± 0.015 | 8.11 ± 0.010 | 1.70 | 27 |
| | Mean | 6.40 ± 0.006 | 8.49 ± 0.355 | 2.09 | 33 ± 5.57 |
| Carwash | I | 6.17 ± 0.040 | 8.78 ± 0.015 | 2.61 | 42 |
| | II | 6.10 ± 0.100 | 8.69 ± 0.049 | 2.59 | 42 |
| | III | 6.10 ± 0.010 | 8.34 ± 0.020 | 2.24 | 37 |
| | Mean | 6.12 ± 0.040 | 8.60 ± 0.232 | 2.48 | 40 ± 2.89 |

| | | | | | |
|---------|-------------|---------------------|---------------------|-------------|------------------|
| Kitchen | I | 6.40 ± 0.017 | 8.87 ± 0.020 | 2.47 | 39 |
| | II | 6.41 ± 0.011 | 8.91 ± 0.015 | 2.50 | 39 |
| | III | 6.43 ± 0.017 | 8.90 ± 0.010 | 2.47 | 38 |
| | Mean | 6.73 ± 0.020 | 8.26 ± 0.295 | 1.54 | 39 ± 0.58 |

Source: Researcher, (2024)

Table 4.9 indicates that there was an increase in pH of 33% in bathroom water, 40% in carwash water and 39% in kitchen water after filtration with inactivated biochar.

Table 4.10

pH measurement of greywater filtered with activated biochar

| Type of Greywater | Samples | Initial pH(A) n=3 | Final pH(B) n=3 | Increase in pH (C) = B-A | Percent (%) increase |
|-------------------|-------------|----------------------|----------------------|-----------------------------|-------------------------|
| Bathroom | I | 6.40 ± 0.006 | 10.71 ± 0.030 | 4.31 | 67 |
| | II | 6.40 ± 0.011 | 10.46 ± 0.032 | 4.06 | 63 |
| | III | 6.41 ± 0.015 | 10.11 ± 0.030 | 3.70 | 58 |
| | Mean | 6.40 ± 0.006 | 10.43 ± 0.301 | 4.02 | 63 ± 4.51 |
| Carwash | I | 6.17 ± 0.040 | 10.78 ± 0.049 | 4.61 | 75 |
| | II | 6.10 ± 0.100 | 10.69 ± 0.059 | 4.59 | 75 |
| | III | 6.10 ± 0.010 | 10.34 ± 0.015 | 4.24 | 70 |
| | Mean | 6.12 ± 0.040 | 10.60 ± 0.232 | 4.48 | 73 ± 2.89 |
| Kitchen | I | 6.45 ± 0.017 | 10.87 ± 0.021 | 4.42 | 69 |
| | II | 6.41 ± 0.011 | 10.91 ± 0.045 | 4.50 | 70 |
| | III | 6.43 ± 0.017 | 10.90 ± 0.252 | 4.47 | 70 |
| | Mean | 6.73 ± 0.020 | 10.26 ± 0.295 | 3.53 | 70 ± 0.58 |

Source: Researcher, (2024)

Table 4.10 indicates that there was an increase in pH of 63% in bathroom water 73% in carwash water and 70% in kitchen water after filtration with activated biochar. The increase of pH is due to the alkaline nature of the biochar.

4.3.4 Analysis of electrical conductivity (EC)

Electrical conductivity was determined using a multi-parameter meter (MKLAB-900). The results are summarized in table 4.11 for inactivated biochar and table 4.12 for activated biochar.

Table 4.11

Electrical Conductivity of Greywater After Filtration with Inactivated Biochar

| Type of Greywater | Samples | Initial EC (A) ($\mu\text{S/cm}$) | Final EC (B) ($\mu\text{S/cm}$) | Decrease in EC (C = A- B) | Percent (%) Decrease |
|-------------------|-------------|---|---|---------------------------------|---------------------------------|
| Bathroom | I | 252 \pm 0.100 | 231 \pm 0.208 | 21 | 8 |
| | II | 254 \pm 0.200 | 233 \pm 0.153 | 21 | 8 |
| | III | 253 \pm 0.153 | 234 \pm 0.152 | 19 | 8 |
| | Mean | 253 \pm 0.361 | 233 \pm 0.435 | 20 | 8 \pm 0 |
| Carwash | I | 222 \pm 1.528 | 198 \pm 1.000 | 24 | 11 |
| | II | 221 \pm 1.000 | 200 \pm 1.528 | 21 | 10 |
| | III | 222 \pm 1.528 | 197 \pm 3.512 | 25 | 11 |
| | Mean | 221 \pm 0.577 | 198 \pm 1.528 | 23 | 11 \pm 0.58 |
| Kitchen | I | 352 \pm 1.000 | 323 \pm 2.082 | 29 | 8 |
| | II | 350 \pm 1.000 | 320 \pm 0.577 | 30 | 9 |
| | III | 352 \pm 1.000 | 322 \pm 1.528 | 30 | 9 |
| | Mean | 351 \pm 1.155 | 321 \pm 1.528 | 30 | 9 \pm 0.58 |

Source: Researcher, (2024)

Table 4.11 indicates that there was a decrease of 8% in electrical conductivity of bathroom water, 11% decrease of electrical conductivity in carwash water and 9% decrease of electrical conductivity in kitchen water after filtration with inactivated biochar.

Table 4.12

Electrical Conductivity of Greywater Filtered with Activated Biochar

| Type of Greywater | Samples | Initial EC (A) ($\mu\text{S/cm}$) n=3 | Final EC (B) ($\mu\text{S/cm}$) n=3 | Decrease in EC (C = A - B) | Percent (%) Decrease |
|-------------------|---------|--|--|----------------------------|---------------------------------|
| Bathroom | I | 252 \pm 0.100 | 200 \pm 0.153 | 52 | 20 |
| | II | 254 \pm 0.200 | 202 \pm 0.208 | 52 | 21 |
| | III | 253 \pm 0.153 | 203 \pm 0.300 | 50 | 20 |
| | Mean | 253 \pm 0.361 | 202 \pm 0.850 | 51 | 20 \pm 0.58 |
| Carwash | I | 222 \pm 1.528 | 171 \pm 1.000 | 51 | 23 |
| | II | 221 \pm 1.000 | 170 \pm 0.577 | 51 | 23 |
| | III | 222 \pm 1.528 | 172 \pm 1.000 | 50 | 23 |
| | Mean | 221 \pm 0.577 | 171 \pm 1.000 | 51 | 23 \pm 0 |
| Kitchen | I | 352 \pm 1.000 | 292 \pm 1.000 | 60 | 17 |
| | II | 350 \pm 1.000 | 291 \pm 1.000 | 59 | 17 |
| | III | 352 \pm 1.000 | 292 \pm 1.000 | 60 | 17 |
| | Mean | 351 \pm 1.155 | 292 \pm 0.577 | 60 | 17 \pm 0 |

Source: Researcher, (2024)

Table 4.12 indicates that there was a decrease of 20% in electrical conductivity of bathroom water, 23% decrease of electrical conductivity in carwash water and 17% decrease of electrical conductivity in kitchen water after filtration with activated biochar.

4.4 Analysis of Chemical Properties in Greywater

The study determined the levels of heavy metals (Lead and Chromium), detergents, oil and grease in the greywater before and after filtration with inactivated biochar and activated biochar.

4.4.1 Determination of lead and chromium

Lead nitrate (50 ppm) and chromium nitrate were added to 100 mL of the samples, which were then analysed using AAS. The results are presented below, and the calibration standards were prepared using lead nitrate as shown in Table 4.13.

Table 4.13

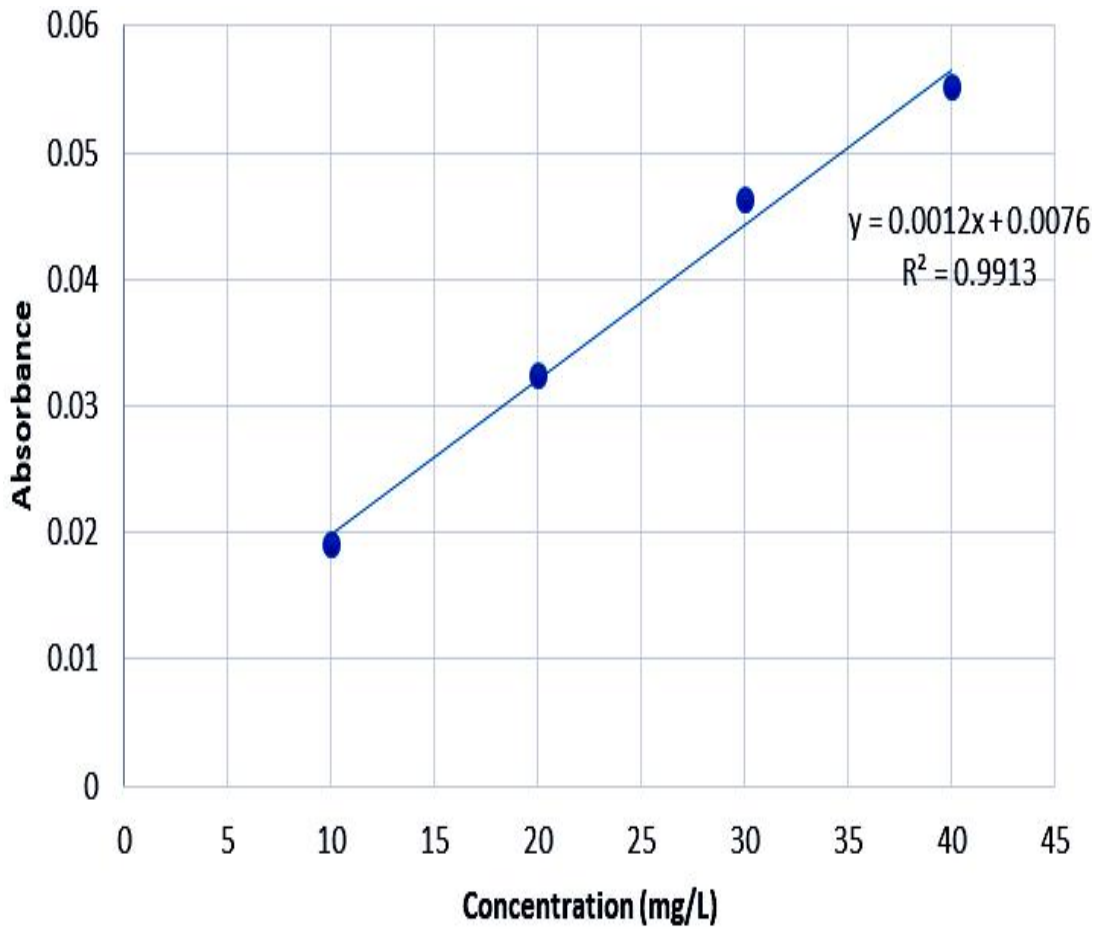
Calibration for Lead

| Pb Concentration (mg/L) | Absorbance |
|--------------------------------|-------------------|
| 10 | 0.0190 |
| 20 | 0.0324 |
| 30 | 0.0463 |
| 40 | 0.0552 |

Source: Researcher, (2024)

The calibration curve regression equation $y = 0.0012x + 0.0076$ and $R^2 = 0.9913$ were as shown in Figure 4.12

Figure 4.11



Calibration curve for Lead

Source: Researcher, (2024)

The calibration curve was used to determine the concentration of the Pb in the greywater samples.

The results for concentration of Pb^{2+} ions are summarised in Table 4.14 for inactivated biochar and Table 4.15 for activated biochar.

Table 4.14*Concentration of Pb²⁺ ions In Greywater Filtered with Inactivated Biochar*

| Type of Greywater | Samples | Pb (mg/L) n = 3 | | | |
|-------------------|-------------|----------------------|-------------|----------------------|------------------------|
| | | Initial (A) | Final (B) | Adsorption (C = A-B) | Percent (%) Adsorption |
| Bathroom | I | 152.53 ± 1.46 | 30.67 ± | 121.86 | 80 |
| | II | 40.46 ± 0.67 | 8.40 | 35.13 | 87 |
| | III | 90.86 ± 12.39 | 5.33 ± 5.70 | 79.28 | 87 |
| | Mean | 94.61 ± 56.12 | 11.58 ± | 78.75 | 85 ± 4.04 |
| Carwash | I | 123.56 ± 3.12 | 11.26 ± | 112.3 | 91 |
| | II | 89.53 ± 3.45 | 1.42 | 60.97 | 68 |
| | III | 56.60 ± 1.73 | 28.56 ± | 46.50 | 82 |
| | Mean | 89.90 ± 33.48 | 6.69 | 73.26 | 80 ± 11.59 |

| | | | | | |
|---------|-------------|----------------------|----------------|--------------|------------------|
| Kitchen | I | 31.46 ± 2.09 | 7.42 ± 3.10 | 24.04 | 76 |
| | II | 122.96 ± 2.20 | 3.65 ± 3.01 | 119.31 | 97 |
| | III | 56.60 ± 1.27 | 7.19 ± 2.92 | 49.41 | 87 |
| | Mean | 70.34 ± 47.27 | 6.086 ± | 64.25 | 87 ± 10.5 |

2.11

Source: Researcher, (2024)

The results in Table 4.14 show that a significant amount of Pb²⁺ ions (>80%) was able to be adsorbed by the inactivated biochar in carwash and kitchen greywater.

Table 4.15

Concentration of Pb²⁺ ions in Greywater Filtered with Activated Biochar.

| Type of | Samples | Pb (ppm) n = 3 | | | |
|-----------|-------------|----------------------|--------------------|-------------------------|---------------------------|
| | | Initial (A) | Final (B) | Adsorption (C = A-B) | Percent (%) adsorption |
| Greywater | I | 152.53 ± 1.46 | 8.39 ± 3.10 | 143.61 | 94 |
| | II | 40.46 ± 0.67 | 3.25 ± 3.38 | 37.21 | 92 |
| | III | 90.86 ± 12.39 | 3.21 ± 3.42 | 87.65 | 96 |
| | Mean | 94.61 ± 56.12 | 4.95 ± 2.98 | 89.49 | 94 ± 2 |
| Carwash | I | 123.56 ± 3.12 | 4.19 ± 1.19 | 119.37 | 97 |
| | II | 89.53 ± 3.45 | 3.71 ± 2.96 | 85.82 | 96 |
| | III | 56.60 ± 1.73 | 2.53 ± 8.30 | 54.07 | 95 |
| | Mean | 89.90 ± 33.48 | 3.48 ± 0.85 | 86.42 | 96 ± 1 |
| Kitchen | I | 31.46 ± 2.09 | 4.17 ± 2.88 | 27.29 | 87 |
| | II | 122.96 ± 2.20 | 3.48 ± 2.29 | 119.48 | 97 |
| | III | 56.60 ± 1.27 | 4.95 ± 6.67 | 51.65 | 91 |

| | | | | |
|-------------|----------------------|-------------------|--------------|------------------|
| Mean | 70.34 ± 47.27 | 4.2 ± 0.74 | 66.14 | 92 ± 5.03 |
|-------------|----------------------|-------------------|--------------|------------------|

Source: *Researcher, (2024)*

The results in Table 4.15 indicate that a significant amount (>90%) of Pb²⁺ ions was able to be adsorbed by the activated biochar.

The calibration standards for Cr were prepared using Chromium nitrate as shown in table 4.16

Table 4.16

Calibration table for Chromium

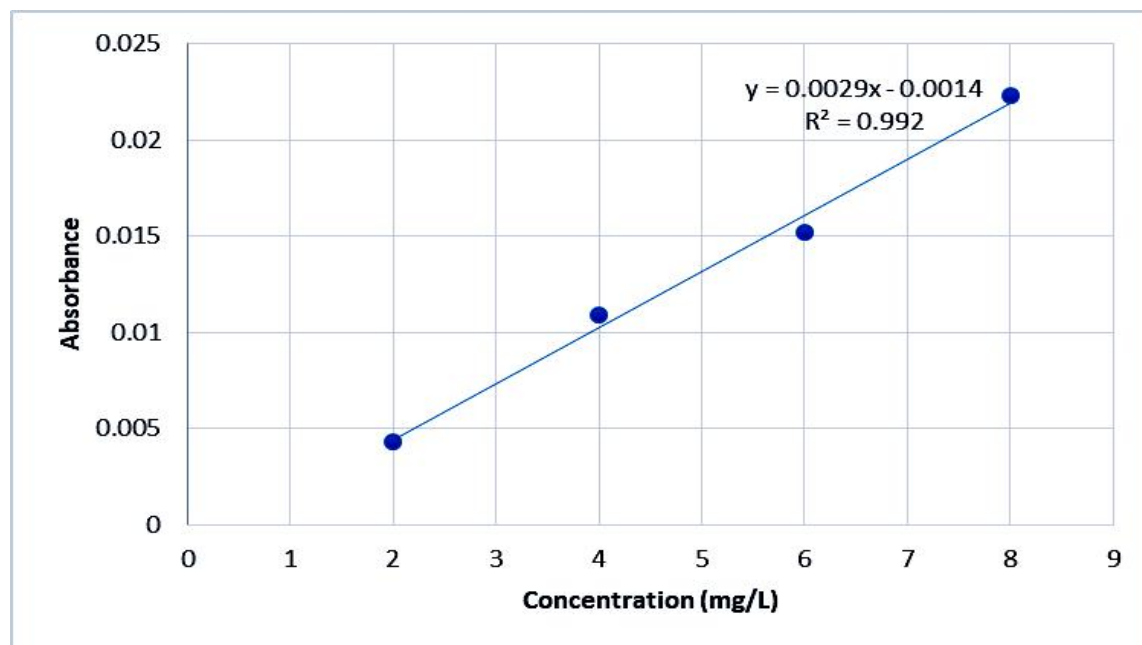
| Cr Concentration (ppm) | Absorbance |
|-------------------------------|-------------------|
| 2 | 0.0043 |
| 4 | 0.0109 |
| 6 | 0.0152 |
| 8 | 0.0223 |

Source: *Researcher, (2024)*

Figure 4.12 shows the calibration curve obtained which had regression equation $y = 0.0029x - 0.0014$ and $R^2 = 0.992$.

Figure 4.12

Calibration Curve for Chromium



Source: Researcher, (2024)

The results are summarised in table 4.17 for inactivated biochar and table 4.18 for activated biochar respectively.

Table 4.17

Concentration of Cr⁶⁺ ions in Greywater Filtered with Inactivated Biochar

| Type of Greywater | Samples | Cr (ppm) n = 3 | | | |
|-------------------|-------------|--------------------|--------------------|----------------------|------------------------|
| | | Initial (A) | Final (B) | Adsorption (C = A-B) | Percent (%) adsorption |
| Bathroom | I | 9.13 ± 1.75 | 1.83 ± 1.46 | 7.30 | 79 |
| | II | 12.03 ± 2.49 | 1.69 ± 0.30 | 10.34 | 85 |
| | III | 7.47 ± 2.68 | 0.39 ± 13.68 | 7.08 | 95 |
| | Mean | 9.54 ± 2.31 | 1.30 ± 4.76 | 8.24 | 86 ± 8.1 |
| Carwash | I | 8.69 ± 2.42 | 1.53 ± 0.80 | 7.16 | 82 |

| | | | | | |
|---------|-------------|--------------------|--------------------|-------------|-----------------|
| | II | 8.60 ± 1.98 | 1.50 ± 1.07 | 7.10 | 82 |
| | III | 8.62 ± 4.32 | 1.05 ± 2.47 | 7.57 | 87 |
| | Mean | 8.63 ± 2.32 | 1.36 ± 2.00 | 7.27 | 84 ± 2.9 |
| Kitchen | I | 8.82 ± 4.30 | 1.19 ± 2.24 | 7.63 | 86 |
| | II | 8.24 ± 2.43 | 1.76 ± 5.64 | 6.48 | 79 |
| | III | 9.16 ± 1.20 | 1.51 ± 2.61 | 7.65 | 83 |
| | Mean | 8.74 ± 1.73 | 1.48 ± 2.38 | 7.25 | 83 ± 3.5 |

Source: Researcher, (2024)

The results in Table 4.17 indicate that a significant amount of Cr⁶⁺ ions was able to be adsorbed by the inactivated biochar in bathroom and kitchen. Results for carwash wastewater varied because the samples were picked from different carwashes.

Table 4.18

Concentration of Cr⁶⁺ ions in Greywater Filtered with Activated Biochar

| Type of Greywater | Samples | Cr (ppm) n = 3 | | | |
|-------------------|-------------|--------------------|--------------------|-------------------------|-----------------------|
| | | Initial (A) | Final (B) | Adsorption (C = A-B) | Percent adsorption |
| Bathroom | I | 9.13 ± 1.75 | 0.81 ± 4.81 | 8.32 | 91 |
| | II | 12.03 ± 2.49 | 0.56 ± 12.50 | 11.47 | 95 |
| | III | 7.47 ± 2.68 | 1.11 ± 10.80 | 6.36 | 85 |
| | Mean | 9.54 ± 2.31 | 0.83 ± 0.27 | 8.72 | 90 ± 5.03 |
| Carwash | I | 8.69 ± 2.42 | 0.78 ± 21.79 | 7.91 | 91 |
| | II | 8.60 ± 1.98 | 0.69 ± 15.94 | 7.91 | 92 |
| | III | 4.62 ± 4.32 | 0.34 ± 26.47 | 4.28 | 93 |
| | Mean | 7.30 ± 2.32 | 0.60 ± 0.23 | 6.70 | 92 ± 1.00 |
| Kitchen | I | 5.82 ± 4.30 | 1.07 ± 11.2 | 4.75 | 82 |

| | | | | |
|-------------|--------------------|--------------------|-------------|------------------|
| II | 8.24 ± 2.43 | 1.11 ± 10.8 | 7.13 | 87 |
| III | 9.16 ± 1.20 | 1.60 ± 1.75 | 7.56 | 83 |
| Mean | 7.74 ± 1.72 | 1.26 ± 0.29 | 6.48 | 84 ± 2.64 |

Source: Researcher, (2024)

The results in Table 4.18 show that significant amount of Cr⁶⁺ ions (84-90%) was able to be adsorbed by the activated biochar.

4.4.2 Determination of detergents

Analysis of sodium dodecyl sulphate detergent was done using UV-VIS spectrometer at 650 nm. The calibration standards were prepared using standard sodium dodecyl sulphate salt as shown in table 4.19.

Table 4.19

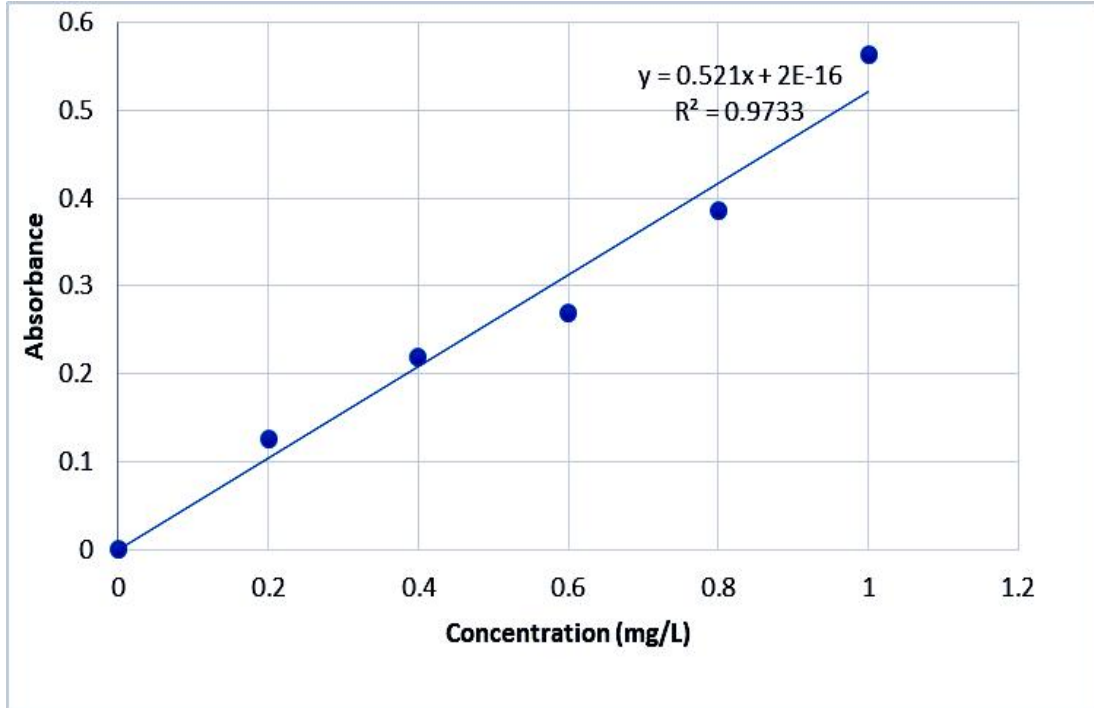
Calibration Standards for Sodium Dodecyl Sulphate.

| Concentration (ppm) | Absorbance |
|----------------------------|-------------------|
| 0 | 0 |
| 0.2 | 0.1254 |
| 0.4 | 0.2194 |
| 0.6 | 0.2694 |
| 0.8 | 0.3854 |
| 1 | 0.5634 |

Source: Researcher, (2024)

Figure 4.13

Calibration curve for sodium dodecyl sulphate detergent



Source: Researcher, (2024)

The calibration curve regression equation $y = 0.521x + 2E-16$ and $R^2 = 0.9733$. A wavelength of 0.650nm was used.

The results are summarised in Table 4.20 for inactivated biochar and Table 4.21 for activated biochar.

Table 4.20

Concentration of detergent (sodium dodecyl sulphate) after filtration with Inactivated biochar

| Type of | Samples | Initial | Final | Adsorption | Percent (%) |
|-----------|-------------|----------------------|----------------|--------------|-------------------|
| Greywater | | (A) | (B) | (C = A-B) | Adsorption |
| Bathroom | I | 77.54 ± 0.691 | 68.91 ± | 8.630 | 11 |
| | II | 92.58 ± 0.296 | 0.195 | 26.97 | 29 |
| | III | 102.88± | 65.61 ± | 33.27 | 32 |
| | Mean | 0.881 | 0.046 | 22.96 | 24 ± 11.36 |
| | | 91.00 ± 12.74 | 69.61 ± | | |
| | | 0.672 | 68.04 ± | | |
| | | | 2.136 | | |
| Carwash | I | 88.48± 0.195 | 65.45 ± | 23.03 | 26 |
| | II | 80.16± 0.115 | 0.508 | 11.00 | 14 |
| | III | 82.53± 0.195 | 69.16 ± | 14.78 | 18 |
| | Mean | 83.72± 4.286 | 0.110 | 16.27 | 19 ± 7.23 |
| | | | 67.75 ± | | |
| | | 0.380 | 67.45 ± | | |
| | | | 1.873 | | |
| Kitchen | I | 78.57± 0.590 | 62.0 ± | 16.57 | 21 |
| | II | 126.68± | 0.691 | 60.66 | 48 |
| | III | 0.960 | 66.02 ± | 34.35 | 35 |
| | Mean | 98.27± 0.190 | 0.882 | 37.19 | 35 ± 7.50 |
| | | | | | |

| | | |
|--|----------------|----------------|
| | 101.17± | 63.92 ± |
| | 24.19 | 0.575 |
| | | 63.98 ± |
| | | 2.011 |

Source: Researcher, (2024)

The results in the table 4.20 show 24%, 19% and 35% adsorption of detergents in bathroom, carwash and kitchen water respectively, after filtration using activated biochar.

Table 4.21

Concentration of Detergent (Sodium Dodecyl Sulphate) After Filtration with Activated Biochar

| Type of | Samples | Initial | Final | Adsorption | Percent (%) |
|-----------|-------------|----------------|----------------|--------------|------------------|
| Greywater | | (A)(ppm) | (B)(ppm) | (C = A-B) | Adsorption |
| Bathroom | I | 77.54 ± | 59.56 ± | 17.98 | 23 |
| | II | 0.691 | 0.110 | 32.06 | 35 |
| | III | 92.58 ± | 60.52 ± | 41.40 | 40 |
| | Mean | 0.296 | 0.110 | 30.48 | 33 ± 8.74 |
| | | 102.88 ± | 61.48 ± | | |
| Carwash | | 0.881 | 0.110 | | |
| | | 91.00 ± | 60.52 ± | | |
| | | 12.74 | 0.960 | | |
| | I | 88.48 ± | 57.58 ± | 30.90 | 35 |
| | II | 0.195 | 0.190 | 20.85 | 26 |
| | III | 80.16 ± | 59.31 ± | 19.32 | 23 |
| | Mean | 0.115 | 0.190 | 23.69 | 28 ± 6.24 |

| | | | | | |
|---------|-------------|-----------------|----------------|--------------|------------------|
| | | 82.53 ± | 63.21 ± | | |
| | | 0.195 | 0.110 | | |
| | | 83.72 ± | 60.03 ± | | |
| | | 4.286 | 2.884 | | |
| Kitchen | I | 78.57 ± | 58.54 ± | 20.03 | 26 |
| | II | 0.590 | 0.770 | 64.37 | 51 |
| | III | 126.68 ± | 62.31 ± | 37.23 | 38 |
| | Mean | 0.960 | 0.867 | 40.54 | 38 ± 7.50 |
| | | 98.27 ± | 61.04 ± | | |
| | | 0.190 | 0.575 | | |
| | | 101.17 ± | 60.63 ± | | |
| | | 24.18 | 1.918 | | |

Source: Researcher, (2024)

The results in the table 4.21 show 33%, 28% and 38% adsorption of detergents in bathroom, carwash and kitchen water respectively, after filtration using inactivated biochar.

4.4.3 Results for Test of oil and grease

The results are summarised in Table 4.22 for inactivated biochar and Table 4.23 for activated biochar.

Table 4.22*Concentration of oil and grease after filtration with Inactivated biochar*

| Type of | Samples | Initial | Final | Adsorption | Percent (%) |
|-----------|-------------|---------------------|--------------------|-------------|------------------|
| Greywater | | (A)(mg/l) | (B)(mg/l) | (C = A-B) | Adsorption |
| Bathroom | I | 1797 ± 0.004 | 843 ± 0.001 | 954 | 53 |
| | II | 1736 ± 0.002 | 859 ± 0.003 | 877 | 51 |
| | III | 1763 ± 0.004 | 889 ± 0.002 | 874 | 50 |
| | Mean | 1765 ± 0.001 | 864 ± 0.001 | 902 | 51 ± 1.52 |
| Carwash | I | 1784 ± 0.005 | 863 ± 0.005 | 921 | 52 |
| | II | 1617 ± 0.002 | 879 ± 0.003 | 738 | 46 |
| | III | 1898 ± 0.006 | 836 ± 0.001 | 1062 | 56 |
| | Mean | 1766 ± 0.002 | 859 ± 0.002 | 907 | 51 ± 5.03 |
| Kitchen | I | 1839 ± 0.007 | 779 ± 0.003 | 1060 | 58 |
| | II | 1881 ± 0.002 | 817 ± 0.003 | 1064 | 57 |
| | III | 1788 ± 0.002 | 795 ± 0.002 | 993 | 56 |
| | Mean | 1836 ± 0.002 | 797 ± 0.001 | 1039 | 57 ± 1 |

Source: Researcher, (2024)

The results in Table 4.22 shows 51%, 51% and 57% adsorption of oil and grease in bathroom, carwash and kitchen water respectively, after filtration using inactivated biochar.

Table 4.23*Concentration of oil and grease after filtration with activated biochar*

| Type of | Samples | Initial | Final | Adsorption | Percent |
|-----------|-------------|---------------------|--------------------|-------------|------------------|
| Greywater | | (A) (mg/l) | (B)(mg/l) | (C = A-B) | (%) |
| | | | | | Adsorption |
| Bathroom | I | 1797 ± 0.004 | 456 ± 0.003 | 1341 | 75 |
| | II | 1736 ± 0.002 | 411 ± 0.002 | 1325 | 76 |
| | III | 1763 ± 0.004 | 417 ± 0.002 | 1346 | 76 |
| | Mean | 1765 ± 0.001 | 428 ± 0.001 | 1337 | 76 ± 0.58 |
| Carwash | I | 1784 ± 0.005 | 437 ± 0.002 | 1347 | 76 |
| | II | 1617 ± 0.002 | 381 ± 0.003 | 1236 | 76 |
| | III | 1898 ± 0.006 | 376 ± 0.002 | 1522 | 80 |
| | Mean | 1766 ± 0.002 | 398 ± 0.001 | 1368 | 77 ± 2.31 |
| Kitchen | I | 1839 ± 0.007 | 453 ± 0.002 | 1386 | 75 |
| | II | 1881 ± 0.002 | 444 ± 0.000 | 1437 | 76 |
| | III | 1788 ± 0.002 | 421 ± 0.002 | 1367 | 76 |
| | Mean | 1836 ± 0.002 | 439 ± 0.001 | 1397 | 76 ± 0.58 |

Source: Researcher, (2024)

The results in the table 4.23 show 76%, 77% and 76% adsorption of oil and grease in bathroom, carwash and kitchen water respectively, after filtration using activated biochar.

4.5 Determination of Greywater Purification Efficiency of Sugarcane Waste Biochar

The results of the efficiency of sugarcane waste biochar in removing contaminants from greywater obtained from the bathroom, carwash and kitchen are summarised in Table 4.24 and Table 4.25.

Table 4.24

Efficiency of Inactivated Biochar

| Physicochemical Parameter | Biochar Efficiency (%) | | |
|--------------------------------------|-------------------------------|----------------|----------------|
| | Bathroom | Carwash | Kitchen |
| Total suspended solids (TSS) | 34 ± 6.43 | 21 ± 0.58 | 29 ± 8.72 |
| Total dissolved solids (TDS) | 13 ± 1 | 17 ± 1.53 | 11 ± 0.58 |
| pH | 33 ± 5.57 | 40 ± 2.89 | 39 ± 0.58 |
| Electrical conductivity (EC) | 8 ± 0 | 11 ± 0.58 | 9 ± 0.58 |
| Chromium | 86 ± 8.1 | 84 ± 2.9 | 83 ± 3.5 |
| Lead | 85 ± 4.04 | 80 ± 11.59 | 87 ± 10.5 |
| Detergent (sodium dodecyl sulphate) | 24 ± 11.36 | 19 ± 7.23 | 35 ± 7.50 |
| Oil and grease | 51 ± 1.52 | 51 ± 5.03 | 57 ± 1 |

Source: Researcher, (2024)

Table 4.25*Efficiency of activated biochar*

| Physicochemical Parameter | Biochar Efficiency (%) | | |
|--------------------------------------|-------------------------------|----------------|----------------|
| | Bathroom | Carwash | Kitchen |
| Total suspended solids (TSS) | 51 ± 2.5 | 40 ± 0.5 | 54 ± 2 |
| Total dissolved solids (TDS) | 23 ± 0.58 | 33 ± 1.15 | 24 ± 0.58 |
| pH | 63 ± 4.51 | 73 ± 2.89 | 70 ± 0.58 |
| Electrical Conductivity (EC) | 20 ± 0.58 | 23 ± 0 | 17 ± 0 |
| Chromium | 90 ± 5.03 | 93 ± 2.60 | 86 ± 2.60 |
| Lead | 94 ± 2 | 96 ± 1 | 92 ± 5.03 |
| Detergent (sodium dodecyl sulphate) | 33 ± 8.74 | 28 ± 6.24 | 38 ± 7.50 |
| Oil and grease | 76 ± 0.58 | 77 ± 2.31 | 76 ± 0.8 |

Source: Researcher, (2024)

The findings in table 4.24 and table 4.25 indicate that the activated biochar had a greater purification efficiency than inactivated biochar for all the parameters. When comparing the effectiveness of activated and inactivated biochar for filtering greywater, a t-test revealed statistically significant differences in the removal of oil and grease, detergents, and heavy metals (Cr and Pb).

The higher performance of activated biochar is confirmed by the lower p-values (<0.05), which show that the observed differences are unlikely to be the result of chance. Its increased surface area and functional groups, which increase adsorption capacity, are probably the cause of this higher efficiency. The efficiency of activation in enhancing pollutant removal from greywater is further supported by the notable mean differences in removal rates between the two biochars.

Further data analysis was done to determine whether there was significant statistical difference between the purification efficiency of inactivated and activated biochar by performing t-test on the means. The t-values are shown in Table 4.26.

Table 4.26

T-Test Comparison of Inactivated and Activated Biochar Efficiency

| Physicochemical | t-values (P = 0.05, two-tailed test) | | |
|-------------------------------------|---|----------------|----------------|
| Parameter | Bathroom | Carwash | Kitchen |
| Total suspended solids (TSS) | 4.52 | 39.60 | 4.65 |
| Total dissolved solids (TDS) | 15.50 | 14.47 | 27.58 |
| pH | 7.17 | 14.00 | 65.76 |
| Electrical Conductivity (EC) | 37.00 | 37.00 | 25.00 |
| Chromium | 0.73* | 2.30* | 0.69* |
| Lead | 3.58 | 2.33* | 0.74* |
| Detergent (sodium dodecyl sulphate) | 1.05* | 1.72* | 0.34* |
| Oil and grease | 25.81 | 8.13 | 28.00 |

Source: Researcher, (2024)

*No significant difference compared with critical value $t_4 = 2.78$ ($P = 0.05$).

The literature critical value $t_4 = 2.78$ ($p = 0.05$). Hence, there is significant difference in the purification efficiency between inactivated and activated biochar over a range of physicochemical parameters as shown by the t-value in table 4.26. The use of activated biochar appears to significantly increase filtering efficiency (Miller, Miller, & Miller, 2018).

CHAPTER FIVE: DISCUSSION

5.0 Introduction

This chapter includes discussions of results for characterization of sugarcane waste biochar, physicochemical properties of greywater after treatment with both inactivated and activated biochar.

5.1 Characterization of Sugarcane Biochar

The characterization of sugarcane biochar was carried out to determine its elemental, mineralogical, and functional properties, which influence its performance in greywater treatment. The analytical techniques employed, namely X-ray Fluorescence (XRF), X-ray Diffraction (XRD), and Fourier Transform Infrared Spectroscopy (FTIR), are discussed in the following section.

5.1.1 Characterization of sugarcane biochar using X-ray fluorescence (XRF)

One method that is frequently used to ascertain the elemental composition of materials is X-ray fluorescence (XRF). This technique made it possible to identify different elements metals and non-metals that were contained in the biochar after pyrolysis. XRF analysis was also done to check whether the biochar contained heavy metals being eliminated from the greywater.

The results revealed that biochar contained significant amounts of elements such as potassium (K), calcium (Ca), magnesium (Mg), phosphorus (P), and silicon (Si). Trace elements like nickel (Ni), copper (Cu), zinc (Zn), chromium (Cr) and iron (Fe) were also found in the biochar. Activated biochar contained a high percentage of potassium since the biochar was activated using potassium hydroxide. This showed that the biochar activation was successful.

According to research by Uchimiya *et al.* (2017), the other elements come from the inherent mineral content of the sugarcane bagasse or from the ash produced during the

pyrolysis process. The capacity of the biochar to adsorb heavy metals from contaminated soils or water is also revealed by XRF analysis.

5.1.2 Characterization of sugarcane biochar using X-ray diffraction (XRD)

Sugarcane biochar's crystalline and amorphous forms was examined using X-ray diffraction (XRD). The following minerals were observed in the inactivated biochar: Ciriottite, Sylvite and Bavenite while for activated biochar were: Kalcinite, Petrovite and Bustanite. Broad peaks, which are a sign of amorphous or disordered carbon in biochar as opposed to well-ordered crystalline carbon, like graphite, were frequently seen in XRD data. Sugarcane biochar is very porous and ideal for adsorption applications due to its amorphous form (Chen *et al.*, 2015).

XRD is useful in identifying the residual mineral phases following pyrolysis. Silicon dioxide (SiO_2) is one of the main crystalline phases in sugarcane biochar because the initial biomass had a high silica content. It is not uncommon to find quartz (SiO_2) in XRD spectra, particularly at higher pyrolysis temperatures (Chen *et al.*, 2015). Depending on the mineral composition of the feedstock, other minerals such calcium compounds (CaO , CaCO_3) and potassium salts (K_2CO_3) are also found (Bai *et al.*, 2015).

5.1.3 Characterization using Fourier transform infrared (FTIR) spectroscopy

Analysis of sugarcane biochar using Fourier Transform Infrared Spectroscopy (FTIR) offers important insights into the functional groups that are present on the surface of the biochar and are crucial to the water filtration performance of the biochar. The following stretching diagnostics peaks were observed for inactivated biochar: $3500\text{-}2500\text{ cm}^{-1}$ COOH, 2968.88 cm^{-1} -C-H, 1709.74 cm^{-1} C=O, 1578.55 cm^{-1} aromatic C=C and 1078.04 cm^{-1} C-O.

Absorption peaks due to stretching were observed for activated biochar at 2956.05 cm^{-1} and 2921.82 cm^{-1} represent -C-H. Peaks at 1617.06 and 1575 cm^{-1} represents alkene C=C

and aromatic C=C, respectively. Bending peaks occur at 1386.05 cm^{-1} and 1366.08 cm^{-1} for -C-H and 100.89 cm^{-1} , 973.94 cm^{-1} and 828.49 cm^{-1} for =C-H (both alkene and aromatic).

The hydroxyl group (-OH) is one of the main functional groups detected by FTIR, it usually manifests as a broad peak in the 3200-3600 cm^{-1} region. These hydroxyl groups are known to improve the adsorption of organic contaminants and heavy metals and are frequently connected to adsorbed water molecules or organic matter on the surface of the biochar. Due to the strong interaction between metal ions and hydroxyl groups via hydrogen bonding and surface complexation, studies have shown that biochar rich in hydroxyl groups effectively eliminates metal ions such as lead (Pb) and cadmium (Cd) from water (Hossain *et al.*, 2015).

Sugarcane biochar's FTIR spectra frequently display absorption peaks in the 2800–3000 cm^{-1} range, which is consistent with aliphatic C-H stretching. These aliphatic groups reflect incomplete carbonization and hint that the biochar may contain unpyrolyzed organic components. But lower aliphatic content biochar, which indicate more thorough pyrolysis, typically have larger surface areas and are better at adsorbing organic contaminants like pesticides and dyes (Manyà *et al.*, 2018). This is important because the more porous structure of well-pyrolyzed biochar increases the surface area available for pollutant adsorption, improving filtration efficiency.

The carbonyl (C=O) group, which ranges from 1600 to 1750 cm^{-1} in the FTIR spectra of sugarcane biochar, is another important functional group found in the sample. Heavy metals and organic contaminants can be adsorbed from water by carbonyl groups, such as carboxyl, aldehyde, and ketone functional groups. It has been shown that carbonyl-rich biochar can create stable complexes with metal ions like copper (Cu) and zinc (Zn), which increases the adsorption capacity of the metal ions (Manyà *et al.*, 2018). Carbonyl-

containing biochar performs better at filtering water because they are especially good at removing metal ions from aqueous solutions.

Aromatic C=C bonds show the presence of persistent aromatic rings created during the pyrolysis of sugarcane biomass. These bonds are often detected in the 1400–1600 cm^{-1} range of FTIR spectra. These aromatic structures are a sign of highly carbonized biochar, which improves the adsorption of hydrophobic organic contaminants like polycyclic aromatic hydrocarbons (PAHs) in addition to offering structural stability. High aromaticity biochar has been demonstrated in studies to be very effective at adsorbing non-polar pollutants from water, which makes it appropriate for use in filtration applications when organic contaminants are present (Joseph *et al.*, 2020).

Due to the higher concentration of functional groups on its surface, sugarcane biochar has been proven in numerous studies to have a significant capacity for adsorbing certain heavy metals. This is especially true when the biochar is formed at high temperatures (Abdelhafez *et al.*, 2016).

5.2 Analysis of Physicochemical Properties of Greywater

The following Physicochemical properties were analyzed: Total suspended solids (TSS), total dissolved solids (TDS), pH, electrical conductivity, heavy metals (Lead and Chromium), detergent (sodium dodecyl sulphate), oil and grease.

5.2.1 Physical properties

There was a decrease of 40% in TSS in bathroom water, a 22% decrease in TSS in carwash water and a 36% decrease in TSS in kitchen water after filtration with inactivated biochar as shown in Table 4.5. There was a decrease of 51% in TSS of bathroom water, a 40% decrease in TSS in carwash water and a 56% decrease in TSS in kitchen water after filtration with activated biochar as shown in Table 4.6.

Filtration with sugarcane biochar effectively reduced TSS levels by capturing and removing suspended solids from water. A study by Chen *et al.* (2018), showed that sugarcane bagasse biochar could effectively reduce TSS in wastewater, highlighting its potential for improving water clarity and quality. This is attributed to its highly porous structure, large surface area, and surface functional groups, which enable it to adsorb and trap particulate matter from wastewater (Ahmad *et al.*, 2024). The biochar acts as a physical filter by intercepting fine suspended particles within its pores, while electrostatic interactions and surface chemistry further enhance particle retention (Singh *et al.*, 2023; Yadav *et al.*, 2024).

There was a decrease of 40% in TDS of bathroom water, a 15% decrease in TDS in carwash water and a 10% decrease in TDS in kitchen water after filtration with inactivated biochar as shown in Table 4.7. There was a decrease of 59% in TDS in bathroom water, a 32% decrease in TDS in carwash water and a 24% decrease in TDS in kitchen water after filtration with activated biochar as shown in Table 4.8.

Filtration with sugarcane biochar reduced TDS levels by adsorbing inorganic salts, metals and organic matter from water. A study by Chen *et al.* (2018), demonstrated that sugarcane bagasse biochar effectively reduced the TDS of contaminated water, with a significant decrease in the concentration of various dissolved ions.

There was an increase in pH from 6.4 to 8.8 in bathroom water, 6.1 to 8.8 in carwash water and 6.8 to 8.0 in kitchen water after filtration with inactivated biochar as shown in Table 4.9. There was an increase in pH from 6.4 to 10.7 in bathroom water from 6.1 to 10.8 in carwash water and from 6.8 to 10.0 in kitchen water after filtration with activated biochar as shown in Table 4.10. A study by Carvalho *et al.* (2016), investigated the effect of sugarcane bagasse biochar on the pH of acidic water. They found that the pH of water

increased from 4.5 to around 7.5 after filtration, demonstrating its effective neutralizing capability.

When greywater passes through the biochar, the pH raises because of the alkaline nature of biochar. Hydroxide (OH^-) ions or carbonate (CO_3^{2-}) ions in the biochar dissolve into the water, raising the pH. Research by Chen *et al.* (2018), on the use of sugarcane biochar for treating acidic leachate showed a significant increase in pH from 3.8 to 7.2, indicating its potential for treating highly acidic effluents. The research has shown that sugarcane biochar can buffer pH changes, maintaining a stable pH level in the filtered water, which is advantageous for various environmental and agricultural applications. Sugarcane biochar when used as a filtration medium can increase the pH of acidic water. This is beneficial for neutralizing acidic wastewater or agricultural runoff.

There was a decrease of 30% in electrical conductivity of bathroom water, a 11% decrease in electrical conductivity in carwash water and an 8% decrease in electrical conductivity of kitchen water after filtration with inactivated biochar as shown in Table 4.11. There was a decrease of 61% in electrical conductivity (EC) of bathroom water, a 23% decrease in electrical conductivity of carwash water and a 17% decrease in electrical conductivity of kitchen water after filtration with activated biochar as shown in Table 4.12.

The electrical conductivity measurement gave an indication of the total dissolved solids (TDS) in the water, which may include salts, minerals, and potentially heavy metals. Higher conductivity levels suggested higher levels of dissolved substances (Igalavithana *et al.*, 2017). Biochar reduces the EC of grey water by adsorbing dissolved salts and ions, thus lowering the overall ionic strength. Research by Lima *et al.* (2018), demonstrated that sugarcane biochar could effectively reduce the EC of saline water, indicating its potential for desalination and remediation of saline soils. Another study by Novak *et al.*

(2016), showed that sugarcane biochar reduced the EC of agricultural runoff, improving water quality for reuse in irrigation.

5.2.2 Chemical properties of greywater

For bathroom waste water, inactivated biochar removed 94% of lead and 25% of chromium, while activated biochar removed 97% of lead and 91% of chromium. For carwash waste water, inactivated biochar removed 91% of lead and 92% of chromium, activated biochar removed 87% of lead and 91% chromium. For kitchen wastewater, inactivated biochar removed a concentration 76% of lead and 84% of chromium, activated biochar removed 94% of lead and 91% of chromium.

The concentration of lead and chromium decreased after filtration because the biochar adsorbed most the ions. Activated biochar adsorbed more of the lead and chromium ions due to the addition of KOH which increased the surface area for adsorption. The initial concentration of lead and chromium ions was slightly high from the carwash water, due to the amounts of heavy metals emitted from the car body parts.

The current study suggested that sugarcane waste biochar exhibits favorable adsorption properties in agreement with previous studies by Nie, *et al.* (2018), which revealed specific interactions that promoted effective heavy metal removal by sugarcane waste-based adsorbents. Research by Inyang *et al.* (2016), indicated that sugarcane biochar effectively removed cadmium (Cd) from water, with a removal efficiency of over 90% under optimal conditions.

There was 24%,19% and 35% adsorption of sodium dodecyl sulphate (anionic detergent) in bathroom, carwash and kitchen water respectively, after filtration using inactivated biochar and 33%, 28% and 38% adsorption of detergents in bathroom, carwash and kitchen water respectively, after filtration using activated biochar.

When compared to other pollutants, sodium dodecyl sulphate adsorption onto biochar surfaces is less effective because it is an anionic surfactant with a hydrophilic sulfate head and a hydrophobic tail. Few functional groups in sugarcane biochar can interact with sodium dodecyl sulphate molecules in an efficient manner (Zhang *et al.*, 2020). Furthermore, at neutral to slightly alkaline pH values, the negative charge on the surfaces of both sodium dodecyl sulphate and biochar may cause electrostatic repulsion, which would further decrease adsorption efficiency. Sodium dodecyl sulphate removal may be limited by the competition for adsorption sites caused by other organic and inorganic components in greywater (Gwenzi *et al.*, 2017).

There was 51%, 51% and 57% adsorption of oil and grease in bathroom, carwash and kitchen water respectively, after filtration using inactivated biochar and 76%, 77% and 76% adsorption of oil and grease in bathroom, carwash and kitchen water respectively, after filtration using activated biochar. Research has shown that using sugarcane bagasse to make biochar can significantly increase the efficiency of oil and grease removal in greywater filtration.

According to Yang *et al.* (2020), sugarcane biochar produced at higher pyrolysis temperatures (500 °C-700 °C) had less oxygen-containing functional groups and more aromatic carbon, which improved its hydrophobicity and ability to absorb oils. This is consistent with earlier research showing that biochar with higher carbonization levels have an advantage when it comes to hydrophobic chemical adsorption (Silva *et al.*, 2021). In research by Chen *et al.* (2018), biochar demonstrated an oil and grease removal efficacy of up to 85% when utilized as a filtering media in greywater treatment. The huge pore capacity and surface area of the biochar, which gave oil molecules plenty of room to get caught and immobilized, were credited by the study for this efficiency. Furthermore, it has been demonstrated that the hydrophobic interactions that biochar's surface

functional groups promote can improve the adsorption of oil droplets and decrease their mobility in water (Silva *et al.*, 2021).

The temperature at which biochar is pyrolyzed, the size of the biochar particle, the duration of contact, and the content of the greywater are some of the variables that affect how well biochar removes oil and grease from greywater. Higher pyrolysis temperatures increase the surface area and micropore volume of biochar, which increases the material's ability to adsorb oils (Okoro *et al.*, 2023).

Biochar made at lower temperatures might hold onto more oxygenated functional groups, which might enhance its ability to sorb other pollutants while marginally lessening its hydrophobicity (Yang *et al.*, 2020). The filtration effectiveness of biochar is also influenced by its particle size. Smaller particles increase the surface area available for adsorption, but they also increase the risk of filtration system blockage. Larger particles, on the other hand, have higher flow rates but may have less surface contact with oil and grease molecules overall (Silva *et al.*, 2021).

5.3 Efficiency of Sugarcane Biochar in Removing Contaminants from Greywater.

The use of activated biochar appears to significantly increase filtering efficiency, as indicated by higher t-values for total suspended solids (TSS) (54%), total dissolved solids (TDS) (33%), pH (73%) and electrical conductivity (EC) (23%). This trend is further supported by notable variations in the removal of oil and grease (77%) and detergent (38%). While there are still differences, lower t-values, such those for lead (1.63) and chromium (1.09), suggest that activation had a less noticeable impact on heavy metal elimination. The varied t-values for each parameter show how biochar activation affects pollutant adsorption differently, having a greater influence on organic pollutants and particles than on heavy metals.

Due to its porous structure and adsorption capacity, sugarcane biochar has been found to have moderate to high removal efficiency for organic contaminants, electrical conductivity (EC), total suspended solids (TSS), and total dissolved solids (TDS) (Gwenzi *et al.*, 2017). However, its effectiveness varies depending on factors such as biochar activation, pyrolysis temperature, and the kind of pollutants present in greywater (Ahmed *et al.*, 2018).

With p-values usually around 0.05, t-test findings frequently show noticeably greater removal rates for activated biochar when compared to inactivated sugarcane biochar, indicating its superior efficacy (Liu *et al.*, 2021). The presence of functional groups that enhance adsorption, improved pore structure, and increased surface area are the main causes of this. Activated biochar showed more efficacy in removing organic pollutants like oil and grease and detergents like sodium dodecyl sulfate (SDS); but, because of electrostatic repulsion effects, SDS removal remained relatively low (Ahmed *et al.*, 2018).

CHAPTER SIX: CONCLUSION, RECOMMENDATIONS AND PUBLICATION

6.0 Introduction

This chapter gives the conclusions and recommendations of the study based on the objectives and findings.

6.1 Conclusion

By meeting all objectives, the study demonstrated that sugarcane biochar, particularly in its activated form, is an effective, low-cost, and sustainable material for greywater purification. This validates its potential as an alternative to conventional wastewater treatment methods, especially in resource-limited settings.

The characterization of the prepared biochar with XRF, indicated that lead (Pb) and chromium (Cr) elements were not found in the activated biochar but 0.067% chromium was present in inactivated biochar. Trace elements like nickel (Ni), copper (Cu), zinc (Zn) and iron (Fe) were also found in the biochar. Characterization using XRD found the following minerals in the inactivated biochar: Ciriottite, Sylvite and Bavenite while for activated biochar were: Kalcinite, Petrovite and Bustanite. Characterization using FTIR of the biochar exhibited functional groups conducive to ion exchange and chemical bonding, particularly with metal ions, which strengthens its effectiveness in pollutant removal.

The treated greywater showed marked improvements in various quality parameters such as decreased amounts of lead and chromium ions. The treated grey water also showed an increase in pH which is beneficial to the soil for agriculture, this is because of the alkaline nature of biochar. There was also a decrease in electrical conductivity because most of the ions for conductivity were filtered out. There was a significant decrease in

TSS, TDS and EC because inorganic salts, metals, and organic matter were filtered from water.

Sugarcane biochar has shown great efficiency in treating greywater, especially in terms of eliminating organic pollutants, heavy metals, total suspended solids (TSS), total dissolved solids (TDS), oil and grease. Because of its increased surface area, porosity, and functional groups that increase adsorption effectiveness, activated biochar performs noticeably better than inactivated biochar, according to studies using statistical analyses like the t-test. Sugarcane biochar is a viable low-cost and sustainable water treatment alternative because of its particularly noteworthy removal efficiencies for oil and grease as well as some organic contaminants. However, a number of variables, including the physicochemical characteristics of the pollutants, biochar activation, and pyrolysis settings, affect its effectiveness. For instance, because of the electrostatic repulsion between the detergent molecules and the negatively charged surface of the biochar, the removal of anionic surfactants such as sodium dodecyl sulfate (SDS) has been comparatively low.

The study found that sugarcane waste biochar with KOH activation could be a viable and eco- friendly solution for remediating greywater for possible reuse. Sugarcane biochar demonstrated significant adsorption capacity for lead and chromium ions meaning that it can be used to remove various metal ions in greywater. Moreover, sugarcane biochar showed high removal efficiency for oil and grease which are major contaminants in greywater.

6.2 Recommendations

Based on the findings presented in the study, the following recommendations are proposed; Raise awareness about the benefits of using sugarcane biochar for greywater treatment among communities. Develop an eco-friendly green technology system for

greywater purification based on sugarcane waste biochar to enhance the effluent reuse for irrigation and other uses. Encourage recycling of sugarcane waste for biochar production particularly in the sugarcane-producing regions to meet the potential greywater purification demand. After greywater filtration, the used biochar should be treated and disposed through an authorized hazardous-waste processor (thermal destruction with emissions control, stabilization/solidification handled by specialist facilities).

6.3 Publication

Mugambi, V., Too, V., & Mungai, G. N. (2025). Evaluating the effectiveness of sugarcane waste biochar in the purification of greywater. *African Journal of Science, Technology and Social Sciences*, 4(2), PAS 81–92.
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APPENDICES

Appendix A : Publication

AFRICAN JOURNAL OF SCIENCE, TECHNOLOGY AND SOCIAL SCIENCES, 4 (2) 2025, PAS 81-92 





Journal website: <https://journals.must.ac.ke>



A publication of Meru University of Science and Technology

Evaluating the effectiveness of sugarcane waste biochar in the purification of greywater

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ARTICLE INFO

ABSTRACT

Keywords

Greywater
Biochar
Heavy metals
Sodium dodecyl sulphate
Oil and grease

The study investigated effectiveness of sugarcane waste biochar as a sustainable material for purifying greywater to address environmental pollution and enhance water recycling. Biochar was produced by heating sugarcane waste at 500°C, with half of it activated using potassium hydroxide to enhance adsorption. X-ray fluorescence, X-ray diffraction and Fourier transform infrared spectroscopy were used to characterise the biochar structure. Greywater samples obtained from the kitchen, bathroom and carwash were purified by filtering 100 mL of samples through 10 g of biochar for 5 minutes. The activated and inactivated biochar achieved 92–96% and 80–87% removal efficiency of lead (II) ions, respectively. Chromium (VI) ions removal ranged from 84–92% and 82–86% with activated and inactivated biochar, respectively. Activated biochar removed 76–77% of oil and grease compared to 51–57% for inactivated biochar. Both biochar increased the pH levels, with activated biochar causing a more rise by 63–73%. Total suspended solids removal efficiencies were 21–34% and 40–54% in inactivated and activated biochar, respectively. Slight decrease in sodium dodecyl sulphate detergent, electrical conductivity and total dissolved solids was observed for both biochar. There was significant difference between the purification efficiency of inactivated and activated biochar shown by the |t| statistic values which were above t4 critical value of 2.78 (P = 0.05). Based on the study findings, activated sugarcane biochar was reliable for greywater treatment, especially the removal of heavy metal pollutants, oil and grease.

Introduction

Greywater is wastewater generated from households but does not include wastewater from toilets. Improper disposal and inadequate treatment of domestic wastewater contribute significantly to water pollution, endangering aquatic ecosystems and human health (Awaleh et al., 2014). Carwashes generate a lot of wastewaters, which contribute to environ-

mental pollution as the wastewater flows into the environment without any control or modifications (Firdaus, 2013). Biochar is a charcoal-like substance made by burning organic material from agricultural wastes in a controlled process called pyrolysis (Aly, 2016). Sugarcane biochar is used as an alternative material for water filtration because it is cheaper than other types of filters, has boundless supply of

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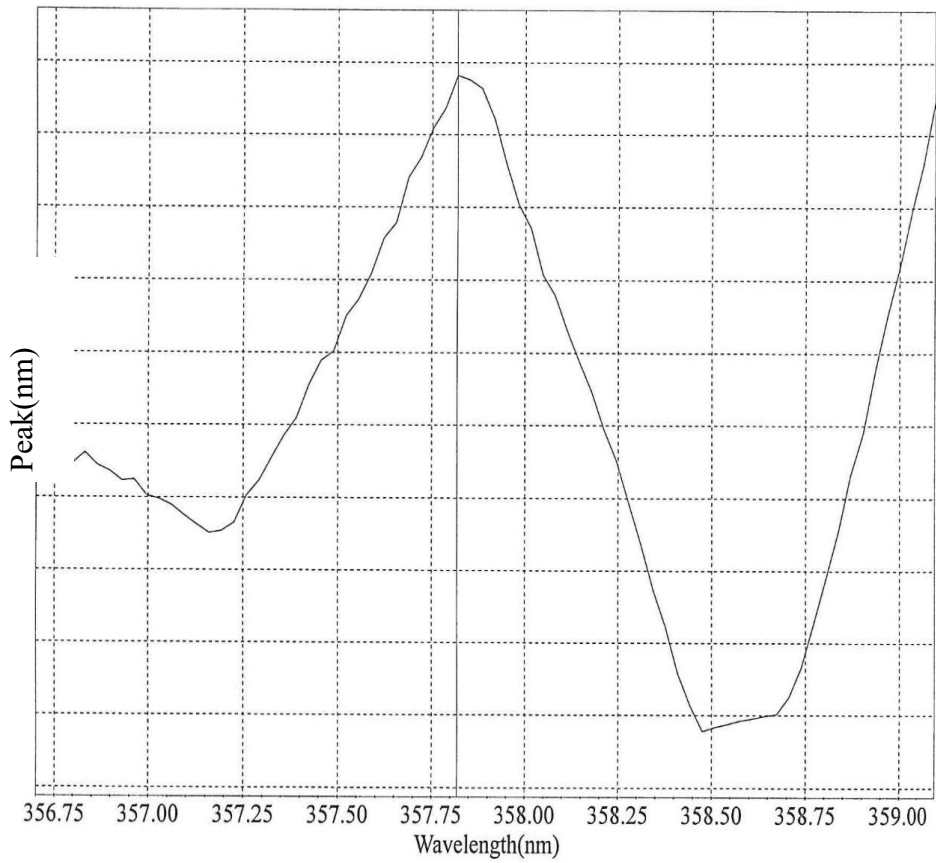
Appendix B: AAS Results for Chromium

Appendix B-1

AAS Results for Chromium

Search

Tuesday, June 18, 2024



| | |
|------------------------|--------|
| Element: | Cr |
| Wavelength (nm): | 357.9 |
| Peak(nm): | 357.82 |
| Lamp Current Low (mA): | 10 |
| Slit Width(nm): | 0.7 |
| Lamp Mode: | BGC-D2 |

| | |
|---------------|----|
| Line Search: | OK |
| Beam Balance: | OK |

Appendix B-2

AAS Results for Chromium

Cr

Tuesday, June 18, 2024 3:35:55 PM

| Action | Sample ID | X | True Value (ppm) | Conc. (ppm) | Abs. | |
|--------|----------------|---|------------------|----------------------|----------------|---------------|
| 1 | BLK-1 | | | | -0.0002 | |
| 2 | BLK-2 | | | | -0.0005 | |
| 3 | BLK-3 | | | | -0.0006 | |
| 4 | BLK-4 | | | | -0.0008 | |
| 5 | BLK-5 | | | | -0.0010 | |
| 6 | BLK-6 | | | | -0.0004 | |
| 7 | BLK-AV | | | | -0.0006 | |
| 8 | STD-1 | X | 2.0000 | 0.0000 | 0.0000 | |
| 9 | STD-2 | X | 2.0000 | 0.0441 | 0.0001 | |
| 10 | STD-3 | X | 2.0000 | 0.0441 | 0.0001 | |
| 11 | STD-4 | | 2.0000 | 1.9682 | 0.0047 | |
| 12 | STD-5 | | 2.0000 | 1.8884 | 0.0045 | |
| 13 | STD-6 | | 2.0000 | 1.6065 | 0.0038 | |
| 14 | STD-AV | | 2.0000 | 1.8082 | 0.0043 | |
| 15 | STD-1 | X | 4.0000 | 1.8483 | 0.0044 | |
| 16 | STD-2 | X | 4.0000 | -0.4470 | -0.0010 | |
| 17 | STD-3 | X | 4.0000 | 0.0881 | 0.0002 | |
| 18 | STD-4 | | 4.0000 | 4.3017 | 0.0109 | |
| 19 | STD-5 | | 4.0000 | 4.1226 | 0.0104 | |
| 20 | STD-6 | | 4.0000 | 4.4794 | 0.0114 | |
| 21 | STD-AV | | 4.0000 | 4.3017 | 0.0109 | |
| 22 | STD-1 | X | 6.0000 | 4.0866 | 0.0103 | |
| 23 | STD-2 | X | 6.0000 | 0.2194 | 0.0005 | |
| 24 | STD-3 | X | 6.0000 | 0.3065 | 0.0007 | |
| 25 | STD-4 | | 6.0000 | 5.7868 | 0.0152 | |
| 26 | STD-5 | | 6.0000 | 5.5852 | 0.0146 | |
| 27 | STD-6 | | 6.0000 | 5.9535 | 0.0157 | |
| 28 | STD-AV | | 6.0000 | 5.7868 | 0.0152 | |
| 29 | STD-1 | X | 8.0000 | 6.4469 | 0.0172 | |
| 30 | STD-2 | X | 8.0000 | 0.4362 | 0.0010 | |
| 31 | STD-3 | X | 8.0000 | 0.2194 | 0.0005 | |
| 32 | STD-4 | | 8.0000 | 8.1770 | 0.0227 | |
| 33 | STD-5 | | 8.0000 | 8.2681 | 0.0230 | |
| 34 | STD-6 | | 8.0000 | 7.7167 | 0.0212 | |
| 35 | STD-AV | | 8.0000 | 8.0551 | 0.0223 | |
| 36 | UNK1-1 | | | carwash blk 2 | 8.4193 | 0.0235 |
| 37 | UNK1-2 | | | carwash blk 2 | 0.3065 | 0.0007 |
| 38 | UNK1-3 | | | carwash blk 2 | 0.3931 | 0.0009 |
| 39 | UNK1-4 | | | carwash blk 2 | 0.3498 | 0.0008 |
| 40 | UNK1-5 | | | carwash blk 2 | 0.3065 | 0.0007 |
| 41 | UNK1-6 | | | carwash blk 2 | 0.1320 | 0.0003 |
| 42 | UNK1-AV | | | carwash blk 2 | 1.8884 | 0.0045 |
| 43 | UNK2-1 | | | carwash blk 1 | 0.2630 | 0.0006 |
| 44 | UNK2-2 | | | carwash blk 1 | 0.0441 | 0.0001 |
| 45 | UNK2-3 | | | carwash blk 1 | 0.3065 | 0.0007 |
| 46 | UNK2-4 | | | carwash blk 1 | 0.0441 | 0.0001 |
| 47 | UNK2-5 | | | carwash blk 1 | 0.0881 | 0.0002 |
| 48 | UNK2-6 | | | carwash blk 1 | 0.0881 | 0.0002 |
| 49 | UNK2-AV | | | carwash blk 1 | 0.1320 | 0.0003 |
| 50 | UNK3-1 | | | carwash blk3 | 0.1320 | 0.0003 |
| 51 | UNK3-2 | | | carwash blk3 | 0.1320 | 0.0003 |
| 52 | UNK3-3 | | | carwash blk3 | 0.1320 | 0.0003 |
| 53 | UNK3-4 | | | carwash blk3 | 0.0881 | 0.0002 |
| 54 | UNK3-5 | | | carwash blk3 | -0.0442 | -0.0001 |
| 55 | UNK3-6 | | | carwash blk3 | -0.0442 | -0.0001 |
| 56 | UNK3-AV | | | carwash blk3 | 0.0881 | 0.0002 |
| 57 | UNK4-1 | | | bathroom spiked 3 | 0.0881 | 0.0002 |
| 58 | UNK4-2 | | | bathroom spiked 3 | -0.0442 | -0.0001 |
| 59 | UNK4-3 | | | bathroom spiked 3 | 1.1967 | 0.0028 |
| 60 | UNK4-4 | | | bathroom spiked 3 | 6.7383 | 0.0181 |

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Appendix B-3

AAS Results for Chromium

Cr

Tuesday, June 18, 2024 3:35:55 PM

| | BG | Pos. | Actual Conc. | Actual Conc. Unit | Date | Time | User Name | Device Name |
|----|----------------|----------|---------------|-------------------|------------------|----------------------|------------------------|-------------|
| 1 | -0.0002 | 1 | | | 18-Jun-24 | 2:17:38 PM(+) | System Administra | AA |
| 2 | -0.0001 | 1 | | | 18-Jun-24 | 2:18:11 PM(+) | System Administra | AA |
| 3 | -0.0001 | 1 | | | 18-Jun-24 | 2:18:21 PM(+) | System Administra | AA |
| 4 | -0.0001 | 1 | | | 18-Jun-24 | 2:18:30 PM(+) | System Administra | AA |
| 5 | 0.0000 | 1 | | | 18-Jun-24 | 2:18:39 PM(+) | System Administra | AA |
| 6 | -0.0005 | 1 | | | 18-Jun-24 | 2:18:48 PM(+) | System Administra | AA |
| 7 | -0.0002 | 1 | | | 18-Jun-24 | 2:17:38 PM(+) | System Administ | AA |
| 8 | -0.0001 | 2 | | | 18-Jun-24 | 2:19:00 PM(+) | System Administr | AA |
| 9 | -0.0001 | 2 | | | 18-Jun-24 | 2:19:33 PM(+) | System Administr | AA |
| 10 | 0.0001 | 2 | | | 18-Jun-24 | 2:19:42 PM(+) | System Administr | AA |
| 11 | 0.0000 | 2 | | | 18-Jun-24 | 2:19:52 PM(+) | System Administra | AA |
| 12 | 0.0002 | 2 | | | 18-Jun-24 | 2:20:01 PM(+) | System Administra | AA |
| 13 | 0.0004 | 2 | | | 18-Jun-24 | 2:20:10 PM(+) | System Administra | AA |
| 14 | 0.0002 | 2 | | | 18-Jun-24 | 2:19:52 PM(+) | System Administ | AA |
| 15 | 0.0001 | 3 | | | 18-Jun-24 | 2:20:22 PM(+) | System Administr | AA |
| 16 | 0.0008 | 3 | | | 18-Jun-24 | 2:20:55 PM(+) | System Administr | AA |
| 17 | -0.0003 | 3 | | | 18-Jun-24 | 2:21:04 PM(+) | System Administr | AA |
| 18 | -0.0004 | 3 | | | 18-Jun-24 | 2:21:13 PM(+) | System Administra | AA |
| 19 | 0.0003 | 3 | | | 18-Jun-24 | 2:21:23 PM(+) | System Administra | AA |
| 20 | -0.0001 | 3 | | | 18-Jun-24 | 2:21:32 PM(+) | System Administra | AA |
| 21 | -0.0001 | 3 | | | 18-Jun-24 | 2:21:13 PM(+) | System Administ | AA |
| 22 | 0.0004 | 4 | | | 18-Jun-24 | 2:21:44 PM(+) | System Administr | AA |
| 23 | -0.0002 | 4 | | | 18-Jun-24 | 2:22:17 PM(+) | System Administr | AA |
| 24 | -0.0004 | 4 | | | 18-Jun-24 | 2:22:26 PM(+) | System Administr | AA |
| 25 | 0.0001 | 4 | | | 18-Jun-24 | 2:22:35 PM(+) | System Administra | AA |
| 26 | 0.0003 | 4 | | | 18-Jun-24 | 2:22:44 PM(+) | System Administra | AA |
| 27 | 0.0004 | 4 | | | 18-Jun-24 | 2:22:54 PM(+) | System Administra | AA |
| 28 | 0.0003 | 4 | | | 18-Jun-24 | 2:22:35 PM(+) | System Administ | AA |
| 29 | -0.0003 | 5 | | | 18-Jun-24 | 2:23:06 PM(+) | System Administr | AA |
| 30 | -0.0002 | 5 | | | 18-Jun-24 | 2:23:39 PM(+) | System Administr | AA |
| 31 | 0.0000 | 5 | | | 18-Jun-24 | 2:23:48 PM(+) | System Administr | AA |
| 32 | 0.0001 | 5 | | | 18-Jun-24 | 2:23:57 PM(+) | System Administra | AA |
| 33 | -0.0002 | 5 | | | 18-Jun-24 | 2:24:06 PM(+) | System Administra | AA |
| 34 | 0.0000 | 5 | | | 18-Jun-24 | 2:24:15 PM(+) | System Administra | AA |
| 35 | 0.0000 | 5 | | | 18-Jun-24 | 2:23:57 PM(+) | System Administ | AA |
| 36 | 0.0000 | 6 | 8.4193 | ppm | 18-Jun-24 | 2:24:28 PM(+) | System Administra | AA |
| 37 | 0.0001 | 6 | 0.3065 | ppm | 18-Jun-24 | 2:25:12 PM(+) | System Administra | AA |
| 38 | -0.0001 | 6 | 0.3931 | ppm | 18-Jun-24 | 2:25:21 PM(+) | System Administra | AA |
| 39 | -0.0002 | 6 | 0.3498 | ppm | 18-Jun-24 | 2:25:30 PM(+) | System Administra | AA |
| 40 | 0.0000 | 6 | 0.3065 | ppm | 18-Jun-24 | 2:25:40 PM(+) | System Administra | AA |
| 41 | 0.0002 | 6 | 0.1320 | ppm | 18-Jun-24 | 2:25:49 PM(+) | System Administra | AA |
| 42 | 0.0000 | 6 | 1.8884 | ppm | 18-Jun-24 | 2:24:28 PM(+) | System Administ | AA |
| 43 | 0.0000 | 7 | 0.2630 | ppm | 18-Jun-24 | 2:26:01 PM(+) | System Administra | AA |
| 44 | 0.0001 | 7 | 0.0441 | ppm | 18-Jun-24 | 2:26:34 PM(+) | System Administra | AA |
| 45 | -0.0002 | 7 | 0.3065 | ppm | 18-Jun-24 | 2:26:43 PM(+) | System Administra | AA |
| 46 | 0.0004 | 7 | 0.0441 | ppm | 18-Jun-24 | 2:26:52 PM(+) | System Administra | AA |
| 47 | 0.0002 | 7 | 0.0881 | ppm | 18-Jun-24 | 2:27:01 PM(+) | System Administra | AA |
| 48 | 0.0003 | 7 | 0.0881 | ppm | 18-Jun-24 | 2:27:11 PM(+) | System Administra | AA |
| 49 | 0.0001 | 7 | 0.1320 | ppm | 18-Jun-24 | 2:26:01 PM(+) | System Administ | AA |
| 50 | 0.0000 | 8 | 0.1320 | ppm | 18-Jun-24 | 2:27:23 PM(+) | System Administra | AA |
| 51 | 0.0002 | 8 | 0.1320 | ppm | 18-Jun-24 | 2:27:56 PM(+) | System Administra | AA |
| 52 | 0.0001 | 8 | 0.1320 | ppm | 18-Jun-24 | 2:28:05 PM(+) | System Administra | AA |
| 53 | 0.0002 | 8 | 0.0881 | ppm | 18-Jun-24 | 2:28:14 PM(+) | System Administra | AA |
| 54 | 0.0002 | 8 | -0.0442 | ppm | 18-Jun-24 | 2:28:24 PM(+) | System Administra | AA |
| 55 | 0.0004 | 8 | -0.0442 | ppm | 18-Jun-24 | 2:28:33 PM(+) | System Administra | AA |
| 56 | 0.0002 | 8 | 0.0881 | ppm | 18-Jun-24 | 2:27:23 PM(+) | System Administ | AA |
| 57 | 0.0002 | 9 | 0.0881 | ppm | 18-Jun-24 | 2:28:45 PM(+) | System Administr | AA |
| 58 | 0.0003 | 9 | -0.0442 | ppm | 18-Jun-24 | 2:29:18 PM(+) | System Administr | AA |
| 59 | 0.0002 | 9 | 1.1967 | ppm | 18-Jun-24 | 2:29:27 PM(+) | System Administr | AA |
| 60 | 0.0000 | 9 | 6.7383 | ppm | 18-Jun-24 | 2:29:36 PM(+) | System Administra | AA |

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Appendix B-4

AAS Results for Chromium

Cr

Tuesday, June 18, 2024 3:35:55 PM

| | Action | Sample ID | X | True Value (ppm) | Conc. (ppm) | Abs. |
|-----|-----------------|--------------------------|---|------------------|---------------|---------------|
| 61 | UNK4-5 | bathroom spiked 3 | | | 6.8026 | 0.0183 |
| 62 | UNK4-6 | bathroom spiked 3 | | | 6.9306 | 0.0187 |
| 63 | UNK4-AV | bathroom spiked 3 | | | 6.8346 | 0.0184 |
| 64 | UNK5-1 | bathroom blk3 | X | | 5.4158 | 0.0141 |
| 65 | UNK5-2 | bathroom blk3 | X | | 0.3065 | 0.0007 |
| 66 | UNK5-3 | bathroom blk3 | X | | 0.3498 | 0.0008 |
| 67 | UNK5-4 | bathroom blk3 | | | 0.2194 | 0.0005 |
| 68 | UNK5-5 | bathroom blk3 | | | 0.3065 | 0.0007 |
| 69 | UNK5-6 | bathroom blk3 | | | 0.0881 | 0.0002 |
| 70 | UNK5-AV | bathroom blk3 | | | 0.2194 | 0.0005 |
| 71 | UNK6-1 | bathroom blk2 | X | | 0.3498 | 0.0008 |
| 72 | UNK6-2 | bathroom blk2 | X | | 0.1757 | 0.0004 |
| 73 | UNK6-3 | bathroom blk2 | X | | 0.1320 | 0.0003 |
| 74 | UNK6-4 | bathroom blk2 | | | 0.3065 | 0.0007 |
| 75 | UNK6-5 | bathroom blk2 | | | 0.1320 | 0.0003 |
| 76 | UNK6-6 | bathroom blk2 | | | 0.2630 | 0.0006 |
| 77 | UNK6-AV | bathroom blk2 | | | 0.2194 | 0.0005 |
| 78 | UNK7-1 | kitchen blk1 | X | | 0.0881 | 0.0002 |
| 79 | UNK7-2 | kitchen blk1 | X | | 0.0881 | 0.0002 |
| 80 | UNK7-3 | kitchen blk1 | X | | 0.2630 | 0.0006 |
| 81 | UNK7-4 | kitchen blk1 | | | 0.0441 | 0.0001 |
| 82 | UNK7-5 | kitchen blk1 | | | 0.2630 | 0.0006 |
| 83 | UNK7-6 | kitchen blk1 | | | 0.2630 | 0.0006 |
| 84 | UNK7-AV | kitchen blk1 | | | 0.1757 | 0.0004 |
| 85 | UNK8-1 | kitchen blk 2 | X | | 0.3498 | 0.0008 |
| 86 | UNK8-2 | kitchen blk 2 | X | | 0.4793 | 0.0011 |
| 87 | UNK8-3 | kitchen blk 2 | X | | 0.2630 | 0.0006 |
| 88 | UNK8-4 | kitchen blk 2 | | | 0.4362 | 0.0010 |
| 89 | UNK8-5 | kitchen blk 2 | | | 0.3065 | 0.0007 |
| 90 | UNK8-6 | kitchen blk 2 | | | 0.4362 | 0.0010 |
| 91 | UNK8-AV | kitchen blk 2 | | | 0.3931 | 0.0009 |
| 92 | UNK9-1 | kitchen blk 3 | X | | 0.4362 | 0.0010 |
| 93 | UNK9-2 | kitchen blk 3 | X | | 0.3065 | 0.0007 |
| 94 | UNK9-3 | kitchen blk 3 | X | | 0.3498 | 0.0008 |
| 95 | UNK9-4 | kitchen blk 3 | | | 0.2194 | 0.0005 |
| 96 | UNK9-5 | kitchen blk 3 | | | 0.2630 | 0.0006 |
| 97 | UNK9-6 | kitchen blk 3 | | | 0.3931 | 0.0009 |
| 98 | UNK9-AV | kitchen blk 3 | | | 0.3065 | 0.0007 |
| 99 | UNK10-1 | carwash spiked 3 | X | | 0.3498 | 0.0008 |
| 100 | UNK10-2 | carwash spiked 3 | X | | 0.3065 | 0.0007 |
| 101 | UNK10-3 | carwash spiked 3 | X | | 1.8082 | 0.0043 |
| 102 | UNK10-4 | carwash spiked 3 | | | 4.7609 | 0.0122 |
| 103 | UNK10-5 | carwash spiked 3 | | | 4.4085 | 0.0112 |
| 104 | UNK10-6 | carwash spiked 3 | | | 4.7259 | 0.0121 |
| 105 | UNK10-AV | carwash spiked 3 | | | 4.6206 | 0.0118 |
| 106 | UNK11-1 | carwash spiked 2 | X | | 3.5025 | 0.0087 |
| 107 | UNK11-2 | carwash spiked 2 | X | | 0.3065 | 0.0007 |
| 108 | UNK11-3 | carwash spiked 2 | X | | 5.2452 | 0.0136 |
| 109 | UNK11-4 | carwash spiked 2 | | | 7.4990 | 0.0205 |
| 110 | UNK11-5 | carwash spiked 2 | | | 7.4052 | 0.0202 |
| 111 | UNK11-6 | carwash spiked 2 | | | 7.5614 | 0.0207 |
| 112 | UNK11-AV | carwash spiked 2 | | | 7.4990 | 0.0205 |
| 113 | UNK12-1 | carwash spiked 1 | X | | 5.6526 | 0.0148 |
| 114 | UNK12-2 | carwash spiked 1 | X | | 0.6079 | 0.0014 |
| 115 | UNK12-3 | carwash spiked 1 | X | | 4.6908 | 0.0120 |
| 116 | UNK12-4 | carwash spiked 1 | | | 8.5396 | 0.0239 |
| 117 | UNK12-5 | carwash spiked 1 | | | 8.5696 | 0.0240 |
| 118 | UNK12-6 | carwash spiked 1 | | | 8.9269 | 0.0252 |
| 119 | UNK12-AV | carwash spiked 1 | | | 8.6892 | 0.0244 |
| 120 | UNK13-1 | bathroom spiked3 | X | | 8.6892 | 0.0244 |

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Appendix B-5

AAS Results for Chromium

Cr

Tuesday, June 18, 2024 3:35:55 PM

| | BG | Pos. | Actual Conc. | Actual Conc. Unit | Date | Time | User Name | Device Name |
|-----|----------------|-----------|---------------|-------------------|------------------|----------------------|------------------------|-------------|
| 61 | 0.0000 | 9 | 6.8026 | ppm | 18-Jun-24 | 2:29:45 PM(+) | System Administra | AA |
| 62 | 0.0000 | 9 | 6.9306 | ppm | 18-Jun-24 | 2:29:55 PM(+) | System Administra | AA |
| 63 | 0.0000 | 9 | 6.8346 | ppm | 18-Jun-24 | 2:29:36 PM(+) | System Administ | AA |
| 64 | 0.0002 | 10 | 5.4158 | ppm | 18-Jun-24 | 2:30:07 PM(+) | System Administr | AA |
| 65 | 0.0004 | 10 | 0.3065 | ppm | 18-Jun-24 | 2:30:40 PM(+) | System Administr | AA |
| 66 | 0.0000 | 10 | 0.3498 | ppm | 18-Jun-24 | 2:30:49 PM(+) | System Administr | AA |
| 67 | 0.0000 | 10 | 0.2194 | ppm | 18-Jun-24 | 2:30:58 PM(+) | System Administra | AA |
| 68 | -0.0001 | 10 | 0.3065 | ppm | 18-Jun-24 | 2:31:07 PM(+) | System Administra | AA |
| 69 | 0.0002 | 10 | 0.0881 | ppm | 18-Jun-24 | 2:31:16 PM(+) | System Administra | AA |
| 70 | 0.0000 | 10 | 0.2194 | ppm | 18-Jun-24 | 2:30:58 PM(+) | System Administ | AA |
| 71 | -0.0001 | 11 | 0.3498 | ppm | 18-Jun-24 | 2:31:29 PM(+) | System Administr | AA |
| 72 | 0.0002 | 11 | 0.1757 | ppm | 18-Jun-24 | 2:32:02 PM(+) | System Administr | AA |
| 73 | 0.0000 | 11 | 0.1320 | ppm | 18-Jun-24 | 2:32:11 PM(+) | System Administr | AA |
| 74 | -0.0001 | 11 | 0.3065 | ppm | 18-Jun-24 | 2:32:20 PM(+) | System Administra | AA |
| 75 | 0.0002 | 11 | 0.1320 | ppm | 18-Jun-24 | 2:32:29 PM(+) | System Administra | AA |
| 76 | -0.0001 | 11 | 0.2630 | ppm | 18-Jun-24 | 2:32:38 PM(+) | System Administra | AA |
| 77 | 0.0000 | 11 | 0.2194 | ppm | 18-Jun-24 | 2:32:20 PM(+) | System Administ | AA |
| 78 | 0.0001 | 12 | 0.0881 | ppm | 18-Jun-24 | 2:32:51 PM(+) | System Administr | AA |
| 79 | 0.0000 | 12 | 0.0881 | ppm | 18-Jun-24 | 2:33:23 PM(+) | System Administr | AA |
| 80 | -0.0003 | 12 | 0.2630 | ppm | 18-Jun-24 | 2:33:32 PM(+) | System Administr | AA |
| 81 | 0.0001 | 12 | 0.0441 | ppm | 18-Jun-24 | 2:33:43 PM(+) | System Administra | AA |
| 82 | -0.0002 | 12 | 0.2630 | ppm | 18-Jun-24 | 2:33:52 PM(+) | System Administra | AA |
| 83 | -0.0001 | 12 | 0.2630 | ppm | 18-Jun-24 | 2:34:01 PM(+) | System Administra | AA |
| 84 | -0.0001 | 12 | 0.1757 | ppm | 18-Jun-24 | 2:33:43 PM(+) | System Administ | AA |
| 85 | -0.0004 | 13 | 0.3498 | ppm | 18-Jun-24 | 2:34:14 PM(+) | System Administr | AA |
| 86 | -0.0004 | 13 | 0.4793 | ppm | 18-Jun-24 | 2:34:46 PM(+) | System Administr | AA |
| 87 | -0.0001 | 13 | 0.2630 | ppm | 18-Jun-24 | 2:34:55 PM(+) | System Administr | AA |
| 88 | -0.0004 | 13 | 0.4362 | ppm | 18-Jun-24 | 2:35:05 PM(+) | System Administra | AA |
| 89 | -0.0001 | 13 | 0.3065 | ppm | 18-Jun-24 | 2:35:14 PM(+) | System Administra | AA |
| 90 | -0.0005 | 13 | 0.4362 | ppm | 18-Jun-24 | 2:35:23 PM(+) | System Administra | AA |
| 91 | -0.0003 | 13 | 0.3931 | ppm | 18-Jun-24 | 2:35:05 PM(+) | System Administ | AA |
| 92 | -0.0003 | 14 | 0.4362 | ppm | 18-Jun-24 | 2:35:35 PM(+) | System Administr | AA |
| 93 | -0.0001 | 14 | 0.3065 | ppm | 18-Jun-24 | 2:36:08 PM(+) | System Administr | AA |
| 94 | -0.0004 | 14 | 0.3498 | ppm | 18-Jun-24 | 2:36:17 PM(+) | System Administr | AA |
| 95 | -0.0001 | 14 | 0.2194 | ppm | 18-Jun-24 | 2:36:26 PM(+) | System Administra | AA |
| 96 | -0.0001 | 14 | 0.2630 | ppm | 18-Jun-24 | 2:36:36 PM(+) | System Administra | AA |
| 97 | -0.0005 | 14 | 0.3931 | ppm | 18-Jun-24 | 2:36:45 PM(+) | System Administra | AA |
| 98 | -0.0002 | 14 | 0.3065 | ppm | 18-Jun-24 | 2:36:26 PM(+) | System Administ | AA |
| 99 | -0.0002 | 15 | 0.3498 | ppm | 18-Jun-24 | 2:36:57 PM(+) | System Administr | AA |
| 100 | 0.0000 | 15 | 0.3065 | ppm | 18-Jun-24 | 2:37:30 PM(+) | System Administr | AA |
| 101 | -0.0004 | 15 | 1.8082 | ppm | 18-Jun-24 | 2:37:39 PM(+) | System Administr | AA |
| 102 | -0.0003 | 15 | 4.7609 | ppm | 18-Jun-24 | 2:37:48 PM(+) | System Administra | AA |
| 103 | 0.0002 | 15 | 4.4085 | ppm | 18-Jun-24 | 2:37:58 PM(+) | System Administra | AA |
| 104 | -0.0002 | 15 | 4.7259 | ppm | 18-Jun-24 | 2:38:07 PM(+) | System Administra | AA |
| 105 | -0.0001 | 15 | 4.6206 | ppm | 18-Jun-24 | 2:37:48 PM(+) | System Administ | AA |
| 106 | -0.0003 | 16 | 3.5025 | ppm | 18-Jun-24 | 2:38:19 PM(+) | System Administr | AA |
| 107 | -0.0002 | 16 | 0.3065 | ppm | 18-Jun-24 | 2:38:52 PM(+) | System Administr | AA |
| 108 | -0.0002 | 16 | 5.2452 | ppm | 18-Jun-24 | 2:39:01 PM(+) | System Administr | AA |
| 109 | -0.0001 | 16 | 7.4990 | ppm | 18-Jun-24 | 2:39:10 PM(+) | System Administra | AA |
| 110 | 0.0002 | 16 | 7.4052 | ppm | 18-Jun-24 | 2:39:19 PM(+) | System Administra | AA |
| 111 | 0.0000 | 16 | 7.5614 | ppm | 18-Jun-24 | 2:39:29 PM(+) | System Administra | AA |
| 112 | 0.0000 | 16 | 7.4990 | ppm | 18-Jun-24 | 2:39:10 PM(+) | System Administ | AA |
| 113 | 0.0002 | 17 | 5.6526 | ppm | 18-Jun-24 | 2:39:41 PM(+) | System Administr | AA |
| 114 | -0.0004 | 17 | 0.6079 | ppm | 18-Jun-24 | 2:40:14 PM(+) | System Administr | AA |
| 115 | 0.0001 | 17 | 4.6908 | ppm | 18-Jun-24 | 2:40:23 PM(+) | System Administr | AA |
| 116 | 0.0002 | 17 | 8.5396 | ppm | 18-Jun-24 | 2:40:32 PM(+) | System Administra | AA |
| 117 | 0.0003 | 17 | 8.5696 | ppm | 18-Jun-24 | 2:40:42 PM(+) | System Administra | AA |
| 118 | 0.0000 | 17 | 8.9269 | ppm | 18-Jun-24 | 2:40:51 PM(+) | System Administra | AA |
| 119 | 0.0002 | 17 | 8.6892 | ppm | 18-Jun-24 | 2:40:32 PM(+) | System Administ | AA |
| 120 | -0.0002 | 18 | 8.6892 | ppm | 18-Jun-24 | 2:41:03 PM(+) | System Administr | AA |

Appendix B-6

AAS Results for Chromium

Cr

Tuesday, June 18, 2024 3:35:55 PM

| | Action | Sample ID | X | True Value (ppm) | Conc. (ppm) | Abs. |
|-----|----------|-------------------|---|------------------|-------------|--------|
| 121 | UNK13-2 | bathroom spiked3 | X | | 0.4793 | 0.0011 |
| 122 | UNK13-3 | bathroom spiked3 | X | | 0.6931 | 0.0016 |
| 123 | UNK13-4 | bathroom spiked3 | | | 0.4362 | 0.0010 |
| 124 | UNK13-5 | bathroom spiked3 | | | 0.3498 | 0.0008 |
| 125 | UNK13-6 | bathroom spiked3 | | | 0.3498 | 0.0008 |
| 126 | UNK13-AV | bathroom spiked3 | | | 0.3931 | 0.0009 |
| 127 | UNK14-1 | bathroom spiked 2 | X | | 0.3498 | 0.0008 |
| 128 | UNK14-2 | bathroom spiked 2 | X | | 0.2630 | 0.0006 |
| 129 | UNK14-3 | bathroom spiked 2 | X | | 5.1079 | 0.0132 |
| 130 | UNK14-4 | bathroom spiked 2 | | | 9.6853 | 0.0278 |
| 131 | UNK14-5 | bathroom spiked 2 | | | 9.7141 | 0.0279 |
| 132 | UNK14-6 | bathroom spiked 2 | | | 9.6565 | 0.0277 |
| 133 | UNK14-AV | bathroom spiked 2 | | | 9.6853 | 0.0278 |
| 134 | UNK15-1 | kitchen spiked 3 | X | | 8.3287 | 0.0232 |
| 135 | UNK15-2 | kitchen spiked 3 | X | | 0.6931 | 0.0016 |
| 136 | UNK15-3 | kitchen spiked 3 | X | | 4.9350 | 0.0127 |
| 137 | UNK15-4 | kitchen spiked 3 | | | 9.0744 | 0.0257 |
| 138 | UNK15-5 | kitchen spiked 3 | | | 9.1625 | 0.0260 |
| 139 | UNK15-6 | kitchen spiked 3 | | | 9.2795 | 0.0264 |
| 140 | UNK15-AV | kitchen spiked 3 | | | 9.1625 | 0.0260 |
| 141 | UNK16-1 | kitchen spiked 2 | X | | 7.8094 | 0.0215 |
| 142 | UNK16-2 | kitchen spiked 2 | X | | 0.6931 | 0.0016 |
| 143 | UNK16-3 | kitchen spiked 2 | X | | 4.0145 | 0.0101 |
| 144 | UNK16-4 | kitchen spiked 2 | | | 8.4494 | 0.0236 |
| 145 | UNK16-5 | kitchen spiked 2 | | | 8.0551 | 0.0223 |
| 146 | UNK16-6 | kitchen spiked 2 | | | 8.1770 | 0.0227 |
| 147 | UNK16-AV | kitchen spiked 2 | | | 8.2378 | 0.0229 |
| 148 | UNK17-1 | kitchen spiked 1 | X | | 7.8402 | 0.0216 |
| 149 | UNK17-2 | kitchen spiked 1 | X | | 0.6931 | 0.0016 |
| 150 | UNK17-3 | kitchen spiked 1 | X | | 2.0080 | 0.0048 |
| 151 | UNK17-4 | kitchen spiked 1 | | | 5.8202 | 0.0153 |
| 152 | UNK17-5 | kitchen spiked 1 | | | 5.5852 | 0.0146 |
| 153 | UNK17-6 | kitchen spiked 1 | | | 6.0861 | 0.0161 |
| 154 | UNK17-AV | kitchen spiked 1 | | | 5.8202 | 0.0153 |
| 155 | UNK18-1 | carwash acti 3 | X | | 2.0477 | 0.0049 |
| 156 | UNK18-2 | carwash acti 3 | X | | 0.9466 | 0.0022 |
| 157 | UNK18-3 | carwash acti 3 | X | | 0.3931 | 0.0009 |
| 158 | UNK18-4 | carwash acti 3 | | | 0.4362 | 0.0010 |
| 159 | UNK18-5 | carwash acti 3 | | | 0.3498 | 0.0008 |
| 160 | UNK18-6 | carwash acti 3 | | | 0.2630 | 0.0006 |
| 161 | UNK18-AV | carwash acti 3 | | | 0.3498 | 0.0008 |
| 162 | UNK19-1 | carwash acti 2 | X | | 0.4793 | 0.0011 |
| 163 | UNK19-2 | carwash acti 2 | X | | 0.5223 | 0.0012 |
| 164 | UNK19-3 | carwash acti 2 | X | | 0.6079 | 0.0014 |
| 165 | UNK19-4 | carwash acti 2 | | | 0.6931 | 0.0016 |
| 166 | UNK19-5 | carwash acti 2 | | | 0.6079 | 0.0014 |
| 167 | UNK19-6 | carwash acti 2 | | | 0.8203 | 0.0019 |
| 168 | UNK19-AV | carwash acti 2 | | | 0.6931 | 0.0016 |
| 169 | UNK20-1 | carwash acti 1 | X | | 0.6079 | 0.0014 |
| 170 | UNK20-2 | carwash acti 1 | X | | 0.4793 | 0.0011 |
| 171 | UNK20-3 | carwash acti 1 | X | | 0.7780 | 0.0018 |
| 172 | UNK20-4 | carwash acti 1 | | | 0.6079 | 0.0014 |
| 173 | UNK20-5 | carwash acti 1 | | | 0.7780 | 0.0018 |
| 174 | UNK20-6 | carwash acti 1 | | | 0.9466 | 0.0022 |
| 175 | UNK20-AV | carwash acti 1 | | | 0.7780 | 0.0018 |
| 176 | UNK21-1 | bathroom acti 2 | X | | 0.9046 | 0.0021 |
| 177 | UNK21-2 | bathroom acti 2 | X | | 0.4793 | 0.0011 |
| 178 | UNK21-3 | bathroom acti 2 | X | | 0.5651 | 0.0013 |
| 179 | UNK21-4 | bathroom acti 2 | | | 0.5651 | 0.0013 |
| 180 | UNK21-5 | bathroom acti 2 | | | 0.5223 | 0.0012 |

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Appendix B-7

AAS Results for Chromium

Cr

Tuesday, June 18, 2024 3:35:55 PM

| | BG | Pos. | Actual Conc. | Actual Conc. Unit | Date | Time | User Name | Device Name |
|-----|----------------|-----------|---------------|-------------------|------------------|----------------------|------------------------|-------------|
| 121 | -0.0001 | 18 | 0.4793 | ppm | 18-Jun-24 | 2:41:37 PM(+) | System Administr | AA |
| 122 | -0.0003 | 18 | 0.6931 | ppm | 18-Jun-24 | 2:41:46 PM(+) | System Administr | AA |
| 123 | -0.0005 | 18 | 0.4362 | ppm | 18-Jun-24 | 2:41:55 PM(+) | System Administra | AA |
| 124 | -0.0001 | 18 | 0.3498 | ppm | 18-Jun-24 | 2:42:04 PM(+) | System Administra | AA |
| 125 | -0.0004 | 18 | 0.3498 | ppm | 18-Jun-24 | 2:42:13 PM(+) | System Administra | AA |
| 126 | -0.0003 | 18 | 0.3931 | ppm | 18-Jun-24 | 2:41:55 PM(+) | System Administ | AA |
| 127 | -0.0002 | 19 | 0.3498 | ppm | 18-Jun-24 | 2:42:26 PM(+) | System Administr | AA |
| 128 | 0.0000 | 19 | 0.2630 | ppm | 18-Jun-24 | 2:42:59 PM(+) | System Administr | AA |
| 129 | -0.0005 | 19 | 5.1079 | ppm | 18-Jun-24 | 2:43:08 PM(+) | System Administr | AA |
| 130 | -0.0006 | 19 | 9.6853 | ppm | 18-Jun-24 | 2:43:17 PM(+) | System Administra | AA |
| 131 | -0.0001 | 19 | 9.7141 | ppm | 18-Jun-24 | 2:43:26 PM(+) | System Administra | AA |
| 132 | -0.0002 | 19 | 9.6565 | ppm | 18-Jun-24 | 2:43:36 PM(+) | System Administra | AA |
| 133 | -0.0003 | 19 | 9.6853 | ppm | 18-Jun-24 | 2:43:17 PM(+) | System Administ | AA |
| 134 | -0.0004 | 20 | 8.3287 | ppm | 18-Jun-24 | 2:43:48 PM(+) | System Administr | AA |
| 135 | -0.0004 | 20 | 0.6931 | ppm | 18-Jun-24 | 2:44:21 PM(+) | System Administr | AA |
| 136 | -0.0002 | 20 | 4.9350 | ppm | 18-Jun-24 | 2:44:30 PM(+) | System Administr | AA |
| 137 | 0.0000 | 20 | 9.0744 | ppm | 18-Jun-24 | 2:44:39 PM(+) | System Administra | AA |
| 138 | -0.0003 | 20 | 9.1625 | ppm | 18-Jun-24 | 2:44:48 PM(+) | System Administra | AA |
| 139 | -0.0002 | 20 | 9.2795 | ppm | 18-Jun-24 | 2:44:57 PM(+) | System Administra | AA |
| 140 | -0.0002 | 20 | 9.1625 | ppm | 18-Jun-24 | 2:44:39 PM(+) | System Administ | AA |
| 141 | -0.0003 | 21 | 7.8094 | ppm | 18-Jun-24 | 2:45:10 PM(+) | System Administr | AA |
| 142 | -0.0004 | 21 | 0.6931 | ppm | 18-Jun-24 | 2:45:43 PM(+) | System Administr | AA |
| 143 | -0.0004 | 21 | 4.0145 | ppm | 18-Jun-24 | 2:45:52 PM(+) | System Administr | AA |
| 144 | -0.0003 | 21 | 8.4494 | ppm | 18-Jun-24 | 2:46:01 PM(+) | System Administra | AA |
| 145 | -0.0001 | 21 | 8.0551 | ppm | 18-Jun-24 | 2:46:10 PM(+) | System Administra | AA |
| 146 | -0.0001 | 21 | 8.1770 | ppm | 18-Jun-24 | 2:46:19 PM(+) | System Administra | AA |
| 147 | -0.0002 | 21 | 8.2378 | ppm | 18-Jun-24 | 2:46:01 PM(+) | System Administ | AA |
| 148 | -0.0002 | 22 | 7.8402 | ppm | 18-Jun-24 | 2:46:32 PM(+) | System Administr | AA |
| 149 | -0.0005 | 22 | 0.6931 | ppm | 18-Jun-24 | 2:47:04 PM(+) | System Administr | AA |
| 150 | -0.0004 | 22 | 2.0080 | ppm | 18-Jun-24 | 2:47:14 PM(+) | System Administr | AA |
| 151 | -0.0003 | 22 | 5.8202 | ppm | 18-Jun-24 | 2:47:23 PM(+) | System Administra | AA |
| 152 | -0.0001 | 22 | 5.5852 | ppm | 18-Jun-24 | 2:47:32 PM(+) | System Administra | AA |
| 153 | -0.0005 | 22 | 6.0861 | ppm | 18-Jun-24 | 2:47:41 PM(+) | System Administra | AA |
| 154 | -0.0003 | 22 | 5.8202 | ppm | 18-Jun-24 | 2:47:23 PM(+) | System Administ | AA |
| 155 | -0.0002 | 23 | 2.0477 | ppm | 18-Jun-24 | 2:48:06 PM(+) | System Administr | AA |
| 156 | -0.0008 | 23 | 0.9466 | ppm | 18-Jun-24 | 2:48:39 PM(+) | System Administr | AA |
| 157 | -0.0003 | 23 | 0.3931 | ppm | 18-Jun-24 | 2:48:48 PM(+) | System Administr | AA |
| 158 | -0.0005 | 23 | 0.4362 | ppm | 18-Jun-24 | 2:48:57 PM(+) | System Administra | AA |
| 159 | -0.0002 | 23 | 0.3498 | ppm | 18-Jun-24 | 2:49:07 PM(+) | System Administra | AA |
| 160 | -0.0002 | 23 | 0.2630 | ppm | 18-Jun-24 | 2:49:16 PM(+) | System Administra | AA |
| 161 | -0.0003 | 23 | 0.3498 | ppm | 18-Jun-24 | 2:48:57 PM(+) | System Administ | AA |
| 162 | -0.0004 | 24 | 0.4793 | ppm | 18-Jun-24 | 2:49:28 PM(+) | System Administr | AA |
| 163 | -0.0005 | 24 | 0.5223 | ppm | 18-Jun-24 | 2:50:01 PM(+) | System Administr | AA |
| 164 | -0.0007 | 24 | 0.6079 | ppm | 18-Jun-24 | 2:50:10 PM(+) | System Administr | AA |
| 165 | -0.0005 | 24 | 0.6931 | ppm | 18-Jun-24 | 2:50:19 PM(+) | System Administra | AA |
| 166 | -0.0005 | 24 | 0.6079 | ppm | 18-Jun-24 | 2:50:29 PM(+) | System Administra | AA |
| 167 | -0.0006 | 24 | 0.8203 | ppm | 18-Jun-24 | 2:50:38 PM(+) | System Administra | AA |
| 168 | -0.0005 | 24 | 0.6931 | ppm | 18-Jun-24 | 2:50:19 PM(+) | System Administ | AA |
| 169 | -0.0007 | 25 | 0.6079 | ppm | 18-Jun-24 | 2:52:31 PM(+) | System Administr | AA |
| 170 | -0.0006 | 25 | 0.4793 | ppm | 18-Jun-24 | 2:53:04 PM(+) | System Administr | AA |
| 171 | -0.0011 | 25 | 0.7780 | ppm | 18-Jun-24 | 2:53:13 PM(+) | System Administr | AA |
| 172 | -0.0007 | 25 | 0.6079 | ppm | 18-Jun-24 | 2:53:22 PM(+) | System Administra | AA |
| 173 | -0.0007 | 25 | 0.7780 | ppm | 18-Jun-24 | 2:53:31 PM(+) | System Administra | AA |
| 174 | -0.0008 | 25 | 0.9466 | ppm | 18-Jun-24 | 2:53:40 PM(+) | System Administra | AA |
| 175 | -0.0007 | 25 | 0.7780 | ppm | 18-Jun-24 | 2:53:22 PM(+) | System Administ | AA |
| 176 | -0.0008 | 26 | 0.9046 | ppm | 18-Jun-24 | 2:53:53 PM(+) | System Administr | AA |
| 177 | -0.0008 | 26 | 0.4793 | ppm | 18-Jun-24 | 2:54:26 PM(+) | System Administr | AA |
| 178 | -0.0006 | 26 | 0.5651 | ppm | 18-Jun-24 | 2:54:35 PM(+) | System Administr | AA |
| 179 | -0.0004 | 26 | 0.5651 | ppm | 18-Jun-24 | 2:54:44 PM(+) | System Administra | AA |
| 180 | -0.0004 | 26 | 0.5223 | ppm | 18-Jun-24 | 2:54:53 PM(+) | System Administra | AA |

Appendix B-8

AAS Results for Chromium

Cr

Tuesday, June 18, 2024 3:35:55 PM

| | BG | Pos. | Actual Conc. | Actual Conc. Unit | Date | Time | User Name | Device Name |
|-----|----------------|-----------|---------------|-------------------|------------------|----------------------|-------------------------|-------------|
| 181 | -0.0006 | 26 | 0.6506 | ppm | 18-Jun-24 | 2:55:02 PM(+) | System Administra | AA |
| 182 | -0.0005 | 26 | 0.5651 | ppm | 18-Jun-24 | 2:54:44 PM(+) | System Administr | AA |
| 183 | -0.0011 | 27 | 0.9466 | ppm | 18-Jun-24 | 2:55:15 PM(+) | System Administra | AA |
| 184 | -0.0009 | 27 | 0.7356 | ppm | 18-Jun-24 | 2:55:47 PM(+) | System Administra | AA |
| 185 | -0.0008 | 27 | 0.7356 | ppm | 18-Jun-24 | 2:55:56 PM(+) | System Administra | AA |
| 186 | -0.0007 | 27 | 1.7278 | ppm | 18-Jun-24 | 2:56:06 PM(+) | System Administra | AA |
| 187 | -0.0007 | 27 | 1.6874 | ppm | 18-Jun-24 | 2:56:15 PM(+) | System Administra | AA |
| 188 | -0.0014 | 27 | 2.3234 | ppm | 18-Jun-24 | 2:56:24 PM(+) | System Administra | AA |
| 189 | -0.0009 | 27 | 1.3616 | ppm | 18-Jun-24 | 2:55:15 PM(+) | System Administr | AA |
| 190 | -0.0010 | 28 | 0.6931 | ppm | 18-Jun-24 | 2:56:36 PM(+) | System Administr | AA |
| 191 | -0.0009 | 28 | 0.6931 | ppm | 18-Jun-24 | 2:57:09 PM(+) | System Administr | AA |
| 192 | -0.0007 | 28 | 0.9885 | ppm | 18-Jun-24 | 2:57:18 PM(+) | System Administr | AA |
| 193 | -0.0009 | 28 | 0.9885 | ppm | 18-Jun-24 | 2:57:27 PM(+) | System Administra | AA |
| 194 | -0.0011 | 28 | 1.1967 | ppm | 18-Jun-24 | 2:57:37 PM(+) | System Administra | AA |
| 195 | -0.0009 | 28 | 1.1967 | ppm | 18-Jun-24 | 2:57:46 PM(+) | System Administra | AA |
| 196 | -0.0010 | 28 | 1.1137 | ppm | 18-Jun-24 | 2:57:27 PM(+) | System Administr | AA |
| 197 | -0.0010 | 29 | 0.9466 | ppm | 18-Jun-24 | 2:57:58 PM(+) | System Administr | AA |
| 198 | -0.0011 | 29 | 0.8203 | ppm | 18-Jun-24 | 2:58:31 PM(+) | System Administr | AA |
| 199 | -0.0009 | 29 | 0.7356 | ppm | 18-Jun-24 | 2:58:40 PM(+) | System Administr | AA |
| 200 | -0.0012 | 29 | 1.1552 | ppm | 18-Jun-24 | 2:58:49 PM(+) | System Administra | AA |
| 201 | -0.0011 | 29 | 1.1552 | ppm | 18-Jun-24 | 2:58:59 PM(+) | System Administra | AA |
| 202 | -0.0007 | 29 | 0.9466 | ppm | 18-Jun-24 | 2:59:08 PM(+) | System Administra | AA |
| 203 | -0.0010 | 29 | 1.0720 | ppm | 18-Jun-24 | 2:58:49 PM(+) | System Administr | AA |
| 204 | -0.0011 | 30 | 0.8203 | ppm | 18-Jun-24 | 2:59:20 PM(+) | System Administr | AA |
| 205 | -0.0011 | 30 | 0.7356 | ppm | 18-Jun-24 | 2:59:53 PM(+) | System Administr | AA |
| 206 | -0.0011 | 30 | 1.0720 | ppm | 18-Jun-24 | 3:00:02 PM(+) | System Administr | AA |
| 207 | -0.0009 | 30 | 0.9885 | ppm | 18-Jun-24 | 3:00:11 PM(+) | System Administra | AA |
| 208 | -0.0014 | 30 | 1.2381 | ppm | 18-Jun-24 | 3:00:20 PM(+) | System Administra | AA |
| 209 | -0.0010 | 30 | 1.0720 | ppm | 18-Jun-24 | 3:00:29 PM(+) | System Administra | AA |
| 210 | -0.0011 | 30 | 1.1137 | ppm | 18-Jun-24 | 3:00:11 PM(+) | System Administr | AA |
| 211 | -0.0014 | 31 | 1.0303 | ppm | 18-Jun-24 | 3:00:42 PM(+) | System Administr | AA |
| 212 | -0.0009 | 31 | 0.7356 | ppm | 18-Jun-24 | 3:01:15 PM(+) | System Administr | AA |
| 213 | -0.0010 | 31 | 1.5659 | ppm | 18-Jun-24 | 3:01:24 PM(+) | System Administr | AA |
| 214 | -0.0013 | 31 | 1.6065 | ppm | 18-Jun-24 | 3:01:33 PM(+) | System Administra | AA |
| 215 | -0.0011 | 31 | 1.6065 | ppm | 18-Jun-24 | 3:01:42 PM(+) | System Administra | AA |
| 216 | -0.0010 | 31 | 1.5659 | ppm | 18-Jun-24 | 3:01:52 PM(+) | System Administra | AA |
| 217 | -0.0011 | 31 | 1.6065 | ppm | 18-Jun-24 | 3:01:33 PM(+) | System Administr | AA |
| 218 | -0.0011 | 32 | 0.7780 | ppm | 18-Jun-24 | 3:02:04 PM(+) | System Administr | AA |
| 219 | -0.0011 | 32 | 0.7780 | ppm | 18-Jun-24 | 3:02:37 PM(+) | System Administr | AA |
| 220 | -0.0012 | 32 | 7.0898 | ppm | 18-Jun-24 | 3:02:46 PM(+) | System Administr | AA |
| 221 | -0.0012 | 32 | 7.4678 | ppm | 18-Jun-24 | 3:02:55 PM(+) | System Administra | AA |
| 222 | -0.0013 | 32 | 7.5925 | ppm | 18-Jun-24 | 3:03:04 PM(+) | System Administra | AA |
| 223 | -0.0010 | 32 | 7.5302 | ppm | 18-Jun-24 | 3:03:14 PM(+) | System Administra | AA |
| 224 | -0.0012 | 32 | 7.5302 | ppm | 18-Jun-24 | 3:02:55 PM(+) | System Administr | AA |
| 225 | -0.0007 | 33 | 0.7356 | ppm | 18-Jun-24 | 3:03:26 PM(+) | System Administr | AA |
| 226 | -0.0012 | 33 | 1.3205 | ppm | 18-Jun-24 | 3:03:59 PM(+) | System Administr | AA |
| 227 | -0.0012 | 33 | 3.9783 | ppm | 18-Jun-24 | 3:04:08 PM(+) | System Administr | AA |
| 228 | -0.0013 | 33 | 4.1586 | ppm | 18-Jun-24 | 3:04:18 PM(+) | System Administra | AA |
| 229 | -0.0011 | 33 | 3.9783 | ppm | 18-Jun-24 | 3:04:27 PM(+) | System Administra | AA |
| 230 | -0.0009 | 33 | 4.0145 | ppm | 18-Jun-24 | 3:04:36 PM(+) | System Administra | AA |
| 231 | -0.0011 | 33 | 4.0506 | ppm | 18-Jun-24 | 3:04:18 PM(+) | System Administr | AA |
| 232 | -0.0012 | 34 | 0.9466 | ppm | 18-Jun-24 | 3:04:48 PM(+) | System Administr | AA |
| 233 | -0.0008 | 34 | 0.9466 | ppm | 18-Jun-24 | 3:05:21 PM(+) | System Administr | AA |
| 234 | -0.0009 | 34 | 8.2681 | ppm | 18-Jun-24 | 3:05:31 PM(+) | System Administr | AA |
| 235 | -0.0011 | 34 | 8.4494 | ppm | 18-Jun-24 | 3:05:40 PM(+) | System Administra | AA |
| 236 | -0.0011 | 34 | 8.5996 | ppm | 18-Jun-24 | 3:05:49 PM(+) | System Administra | AA |
| 237 | -0.0013 | 34 | 8.7786 | ppm | 18-Jun-24 | 3:05:58 PM(+) | System Administra | AA |
| 238 | -0.0012 | 34 | 8.5996 | ppm | 18-Jun-24 | 3:05:40 PM(+) | System Administr | AA |
| 239 | -0.0006 | 35 | 0.6931 | ppm | 18-Jun-24 | 3:06:10 PM(+) | System Administr | AA |
| 240 | -0.0010 | 35 | 0.9885 | ppm | 18-Jun-24 | 3:06:43 PM(+) | System Administr | AA |

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Appendix B-9

AAS Results for Chromium

Cr

Tuesday, June 18, 2024 3:35:55 PM

| Action | Sample ID | X | True Value (ppm) | Conc. (ppm) | Abs. | |
|--------|-----------|---------------------|------------------|-------------|---------|--------|
| 241 | UNK30-3 | bathroom inacti 2 | X | | 11.8989 | 0.0358 |
| 242 | UNK30-4 | bathroom inacti 2 | | | 11.8456 | 0.0356 |
| 243 | UNK30-5 | bathroom inacti 2 | | | 12.3748 | 0.0376 |
| 244 | UNK30-6 | bathroom inacti 2 | | | 11.8722 | 0.0357 |
| 245 | UNK30-AV | bathroom inacti 2 | | | 12.0319 | 0.0363 |
| 246 | UNK31-1 | bathroom inacti 1 | X | | 1.1552 | 0.0027 |
| 247 | UNK31-2 | bathroom inacti 1 | X | | 8.3287 | 0.0232 |
| 248 | UNK31-3 | bathroom inacti 1 | X | | 8.3891 | 0.0234 |
| 249 | UNK31-4 | bathroom inacti 1 | | | 9.2211 | 0.0262 |
| 250 | UNK31-5 | bathroom inacti 1 | | | 9.2503 | 0.0263 |
| 251 | UNK31-6 | bathroom inacti 1 | | | 8.9565 | 0.0253 |
| 252 | UNK31-AV | bathroom inacti 1 | | | 9.1332 | 0.0259 |
| 253 | UNK32-1 | bathroom inacti 3 | X | | 1.1137 | 0.0026 |
| 254 | UNK32-2 | bathroom inacti 3 | X | | 7.3110 | 0.0199 |
| 255 | UNK32-3 | bathroom inacti 3 | X | | 7.4990 | 0.0205 |
| 256 | UNK32-4 | bathroom inacti 3 | | | 7.2480 | 0.0197 |
| 257 | UNK32-5 | bathroom inacti 3 | | | 7.5614 | 0.0207 |
| 258 | UNK32-6 | bathroom inacti 3 | | | 7.6236 | 0.0209 |
| 259 | UNK32-AV | bathroom inacti 3 | | | 7.4678 | 0.0204 |
| 260 | UNK33-1 | kitchen inacti 3 | X | | 1.1552 | 0.0027 |
| 261 | UNK33-2 | kitchen inacti 3 | X | | 0.8625 | 0.0020 |
| 262 | UNK33-3 | kitchen inacti 3 | X | | 5.9203 | 0.0156 |
| 263 | UNK33-4 | kitchen inacti 3 | | | 6.3163 | 0.0168 |
| 264 | UNK33-5 | kitchen inacti 3 | | | 6.6092 | 0.0177 |
| 265 | UNK33-6 | kitchen inacti 3 | | | 6.6416 | 0.0178 |
| 266 | UNK33-AV | kitchen inacti 3 | | | 6.5120 | 0.0174 |
| 267 | UNK34-1 | kitchen inacti 1 | X | | 1.0720 | 0.0025 |
| 268 | UNK34-2 | kitchen inacti 1 | X | | 1.7278 | 0.0041 |
| 269 | UNK34-3 | kitchen inacti 1 | | | 4.3017 | 0.0109 |
| 270 | UNK34-4 | kitchen inacti 1 | | | 4.4794 | 0.0114 |
| 271 | UNK34-5 | kitchen inacti 1 | | | 4.1586 | 0.0105 |
| 272 | UNK34-6 | kitchen inacti 1 | | | 4.1226 | 0.0104 |
| 273 | UNK34-AV | kitchen inacti 1 | | | 4.2660 | 0.0108 |
| 274 | UNK35-1 | kitchen inacti 2 | X | | 1.3205 | 0.0031 |
| 275 | UNK35-2 | kitchen inacti 2 | X | | 1.0303 | 0.0024 |
| 276 | UNK35-3 | kitchen inacti 2 | X | | 1.4844 | 0.0035 |
| 277 | UNK35-4 | kitchen inacti 2 | | | 1.6470 | 0.0039 |
| 278 | UNK35-5 | kitchen inacti 2 | | | 1.7680 | 0.0042 |
| 279 | UNK35-6 | kitchen inacti 2 | | | 1.8483 | 0.0044 |
| 280 | UNK35-AV | kitchen inacti 2 | | | 1.7680 | 0.0042 |
| 281 | UNK36-1 | activated biochar | X | | 1.0303 | 0.0024 |
| 282 | UNK36-2 | activated biochar | X | | 1.2793 | 0.0030 |
| 283 | UNK36-3 | activated biochar | X | | 1.1552 | 0.0027 |
| 284 | UNK36-4 | activated biochar | | | 1.1137 | 0.0026 |
| 285 | UNK36-5 | activated biochar | | | 1.1137 | 0.0026 |
| 286 | UNK36-6 | activated biochar | | | 0.9885 | 0.0023 |
| 287 | UNK36-AV | activated biochar | | | 1.0720 | 0.0025 |
| 288 | UNK37-1 | inactivated biochar | X | | 1.1137 | 0.0026 |
| 289 | UNK37-2 | inactivated biochar | X | | 1.1137 | 0.0026 |
| 290 | UNK37-3 | inactivated biochar | X | | 1.5659 | 0.0037 |
| 291 | UNK37-4 | inactivated biochar | | | 1.8082 | 0.0043 |
| 292 | UNK37-5 | inactivated biochar | | | 1.5659 | 0.0037 |
| 293 | UNK37-6 | inactivated biochar | | | 1.4436 | 0.0034 |
| 294 | UNK37-AV | inactivated biochar | | | 1.6065 | 0.0038 |
| 295 | UNK38-1 | Bathroom soaked | X | | 1.4436 | 0.0034 |
| 296 | UNK38-2 | Bathroom soaked | X | | 1.3205 | 0.0031 |
| 297 | UNK38-3 | Bathroom soaked | X | | 1.4436 | 0.0034 |
| 298 | UNK38-4 | Bathroom soaked | X | | 1.2793 | 0.0030 |
| 299 | UNK38-5 | Bathroom soaked | X | | 1.4844 | 0.0035 |
| 300 | UNK38-6 | Bathroom soaked | X | | 1.0720 | 0.0025 |

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Appendix B-10

AAS Results for Chromiu

Cr

Tuesday, June 18, 2024 3:35:55 PM

| | BG | Pos. | Actual Conc. | Actual Conc. Unit | Date | Time | User Name | Device Name |
|-----|----------------|-----------|----------------|-------------------|------------------|----------------------|------------------------|-------------|
| 241 | -0.0009 | 35 | 11.8989 | ppm | 18-Jun-24 | 3:06:52 PM(+) | System Administr | AA |
| 242 | -0.0007 | 35 | 11.8456 | ppm | 18-Jun-24 | 3:07:02 PM(+) | System Administra | AA |
| 243 | -0.0012 | 35 | 12.3748 | ppm | 18-Jun-24 | 3:07:11 PM(+) | System Administra | AA |
| 244 | -0.0007 | 35 | 11.8722 | ppm | 18-Jun-24 | 3:07:20 PM(+) | System Administra | AA |
| 245 | -0.0009 | 35 | 12.0319 | ppm | 18-Jun-24 | 3:07:02 PM(+) | System Administ | AA |
| 246 | -0.0010 | 36 | 1.1552 | ppm | 18-Jun-24 | 3:07:32 PM(+) | System Administr | AA |
| 247 | -0.0013 | 36 | 8.3287 | ppm | 18-Jun-24 | 3:08:13 PM(+) | System Administr | AA |
| 248 | -0.0011 | 36 | 8.3891 | ppm | 18-Jun-24 | 3:08:22 PM(+) | System Administr | AA |
| 249 | -0.0013 | 36 | 9.2211 | ppm | 18-Jun-24 | 3:09:01 PM(+) | System Administra | AA |
| 250 | -0.0016 | 36 | 9.2503 | ppm | 18-Jun-24 | 3:09:10 PM(+) | System Administra | AA |
| 251 | -0.0010 | 36 | 8.9565 | ppm | 18-Jun-24 | 3:09:20 PM(+) | System Administra | AA |
| 252 | -0.0013 | 36 | 9.1332 | ppm | 18-Jun-24 | 3:09:01 PM(+) | System Administ | AA |
| 253 | -0.0011 | 37 | 1.1137 | ppm | 18-Jun-24 | 3:09:32 PM(+) | System Administr | AA |
| 254 | -0.0010 | 37 | 7.3110 | ppm | 18-Jun-24 | 3:11:47 PM(+) | System Administr | AA |
| 255 | -0.0015 | 37 | 7.4990 | ppm | 18-Jun-24 | 3:11:58 PM(+) | System Administr | AA |
| 256 | -0.0013 | 37 | 7.2480 | ppm | 18-Jun-24 | 3:12:08 PM(+) | System Administra | AA |
| 257 | -0.0013 | 37 | 7.5614 | ppm | 18-Jun-24 | 3:12:17 PM(+) | System Administra | AA |
| 258 | -0.0015 | 37 | 7.6236 | ppm | 18-Jun-24 | 3:12:26 PM(+) | System Administra | AA |
| 259 | -0.0014 | 37 | 7.4678 | ppm | 18-Jun-24 | 3:12:08 PM(+) | System Administ | AA |
| 260 | -0.0014 | 38 | 1.1552 | ppm | 18-Jun-24 | 3:12:41 PM(+) | System Administr | AA |
| 261 | -0.0008 | 38 | 0.8625 | ppm | 18-Jun-24 | 3:13:14 PM(+) | System Administr | AA |
| 262 | -0.0009 | 38 | 5.9203 | ppm | 18-Jun-24 | 3:13:23 PM(+) | System Administr | AA |
| 263 | -0.0012 | 38 | 6.3163 | ppm | 18-Jun-24 | 3:13:32 PM(+) | System Administra | AA |
| 264 | -0.0016 | 38 | 6.6092 | ppm | 18-Jun-24 | 3:13:41 PM(+) | System Administra | AA |
| 265 | -0.0013 | 38 | 6.6416 | ppm | 18-Jun-24 | 3:13:51 PM(+) | System Administra | AA |
| 266 | -0.0014 | 38 | 6.5120 | ppm | 18-Jun-24 | 3:13:32 PM(+) | System Administ | AA |
| 267 | -0.0015 | 39 | 1.0720 | ppm | 18-Jun-24 | 3:14:03 PM(+) | System Administr | AA |
| 268 | -0.0013 | 39 | 1.7278 | ppm | 18-Jun-24 | 3:14:36 PM(+) | System Administr | AA |
| 269 | -0.0014 | 39 | 4.3017 | ppm | 18-Jun-24 | 3:14:46 PM(+) | System Administra | AA |
| 270 | -0.0017 | 39 | 4.4794 | ppm | 18-Jun-24 | 3:14:55 PM(+) | System Administra | AA |
| 271 | -0.0013 | 39 | 4.1586 | ppm | 18-Jun-24 | 3:15:04 PM(+) | System Administra | AA |
| 272 | -0.0011 | 39 | 4.1226 | ppm | 18-Jun-24 | 3:15:13 PM(+) | System Administra | AA |
| 273 | -0.0014 | 39 | 4.2660 | ppm | 18-Jun-24 | 3:14:46 PM(+) | System Administ | AA |
| 274 | -0.0019 | 40 | 1.3205 | ppm | 18-Jun-24 | 3:15:26 PM(+) | System Administr | AA |
| 275 | -0.0013 | 40 | 1.0303 | ppm | 18-Jun-24 | 3:15:59 PM(+) | System Administr | AA |
| 276 | -0.0011 | 40 | 1.4844 | ppm | 18-Jun-24 | 3:16:08 PM(+) | System Administr | AA |
| 277 | -0.0014 | 40 | 1.6470 | ppm | 18-Jun-24 | 3:16:17 PM(+) | System Administra | AA |
| 278 | -0.0016 | 40 | 1.7680 | ppm | 18-Jun-24 | 3:16:26 PM(+) | System Administra | AA |
| 279 | -0.0016 | 40 | 1.8483 | ppm | 18-Jun-24 | 3:16:35 PM(+) | System Administra | AA |
| 280 | -0.0015 | 40 | 1.7680 | ppm | 18-Jun-24 | 3:16:17 PM(+) | System Administ | AA |
| 281 | -0.0014 | 41 | 1.0303 | ppm | 18-Jun-24 | 3:16:48 PM(+) | System Administr | AA |
| 282 | -0.0020 | 41 | 1.2793 | ppm | 18-Jun-24 | 3:17:21 PM(+) | System Administr | AA |
| 283 | -0.0018 | 41 | 1.1552 | ppm | 18-Jun-24 | 3:17:30 PM(+) | System Administr | AA |
| 284 | -0.0016 | 41 | 1.1137 | ppm | 18-Jun-24 | 3:17:39 PM(+) | System Administra | AA |
| 285 | -0.0015 | 41 | 1.1137 | ppm | 18-Jun-24 | 3:17:48 PM(+) | System Administra | AA |
| 286 | -0.0012 | 41 | 0.9885 | ppm | 18-Jun-24 | 3:17:58 PM(+) | System Administra | AA |
| 287 | -0.0014 | 41 | 1.0720 | ppm | 18-Jun-24 | 3:17:39 PM(+) | System Administ | AA |
| 288 | -0.0018 | 42 | 1.1137 | ppm | 18-Jun-24 | 3:18:10 PM(+) | System Administr | AA |
| 289 | -0.0015 | 42 | 1.1137 | ppm | 18-Jun-24 | 3:18:43 PM(+) | System Administr | AA |
| 290 | -0.0016 | 42 | 1.5659 | ppm | 18-Jun-24 | 3:18:52 PM(+) | System Administr | AA |
| 291 | -0.0018 | 42 | 1.8082 | ppm | 18-Jun-24 | 3:19:01 PM(+) | System Administra | AA |
| 292 | -0.0015 | 42 | 1.5659 | ppm | 18-Jun-24 | 3:19:10 PM(+) | System Administra | AA |
| 293 | -0.0012 | 42 | 1.4436 | ppm | 18-Jun-24 | 3:19:20 PM(+) | System Administra | AA |
| 294 | -0.0015 | 42 | 1.6065 | ppm | 18-Jun-24 | 3:19:01 PM(+) | System Administ | AA |
| 295 | -0.0024 | 43 | 1.4436 | ppm | 18-Jun-24 | 3:21:26 PM(+) | System Administr | AA |
| 296 | -0.0020 | 43 | 1.3205 | ppm | 18-Jun-24 | 3:21:59 PM(+) | System Administr | AA |
| 297 | -0.0020 | 43 | 1.4436 | ppm | 18-Jun-24 | 3:22:09 PM(+) | System Administr | AA |
| 298 | -0.0019 | 43 | 1.2793 | ppm | 18-Jun-24 | 3:22:18 PM(+) | System Administr | AA |
| 299 | -0.0025 | 43 | 1.4844 | ppm | 18-Jun-24 | 3:22:27 PM(+) | System Administr | AA |
| 300 | -0.0018 | 43 | 1.0720 | ppm | 18-Jun-24 | 3:22:36 PM(+) | System Administr | AA |

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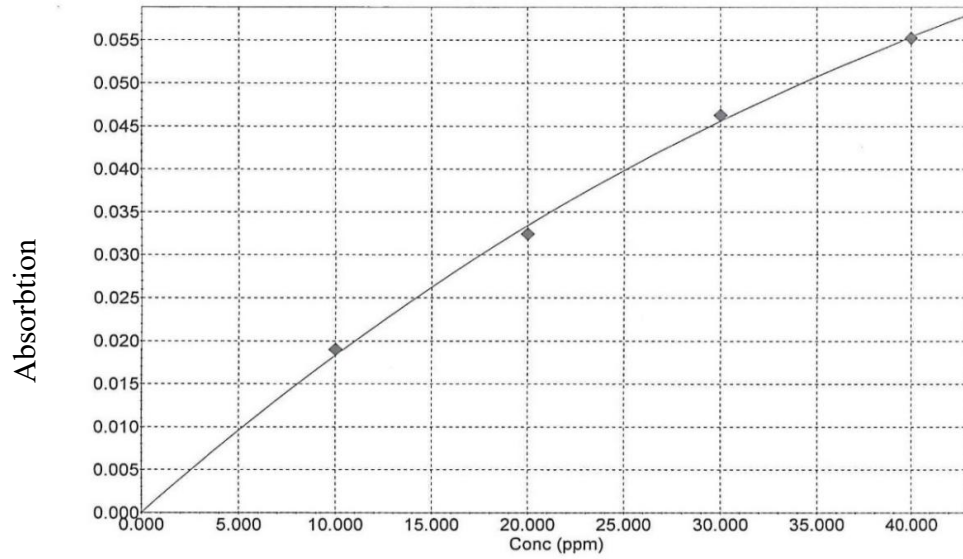
Appendix C: AAS Results for Lead

Appendix C-1

AAS Results for Lead

Tuesday, June 18, 2024

Calibration Curve(Element:Pb:FlameCont C#:01)



$$\text{Abs} = 6.4010\text{e-}008\text{Conc}^3 - 1.8152\text{e-}005\text{Conc}^2 + 0.0020079\text{Conc} + 0.00000 \quad r = 0.9988$$

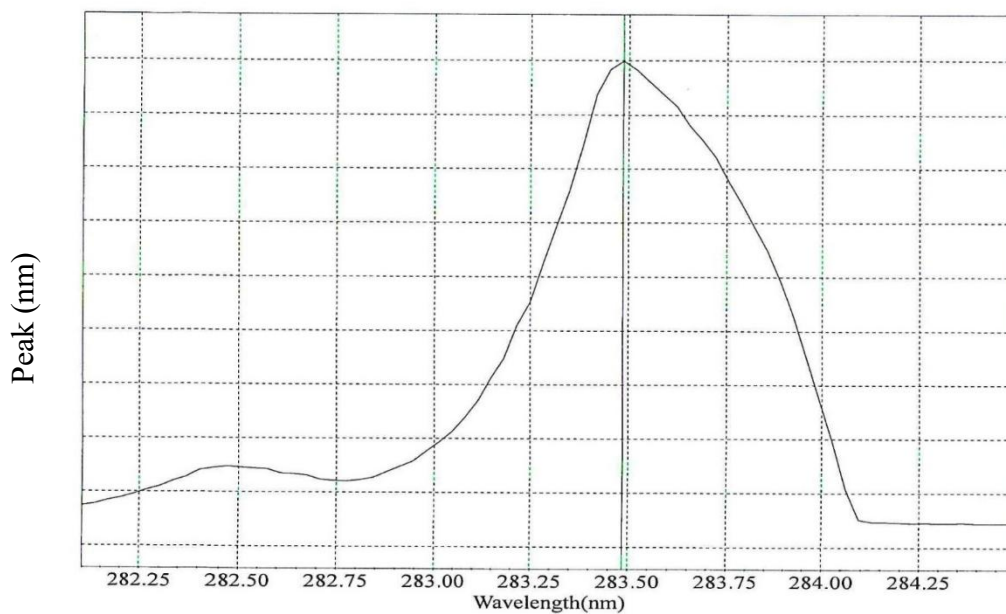
| <u>CONC</u> | <u>ABS</u> |
|-------------|------------|
| 10.0000 | 0.0190 |
| 20.0000 | 0.0324 |
| 30.0000 | 0.0463 |
| 40.0000 | 0.0552 |

Appendix C-2

AAS Results for Lead

Line Search

Tuesday, June 18, 2024



| | |
|-------------------------|--------|
| Element: | Pb |
| Wavelength (nm) : | 283.3 |
| Peak(nm) : | 283.49 |
| Lamp Current Low (mA) : | 10 |
| Slit Width(nm): | 0.7 |
| Lamp Mode : | BGC-D2 |
| Line Search: | OK |
| Beam Balance: | OK |

Appendix C-3

AAS Results for Lead

| | BG | Pos. | Actual Conc. | Actual Conc. Unit | Date | Time | User Name | Device Name |
|----|---------|------|--------------|-------------------|-----------|-------------|-------------------|-------------|
| 1 | 0.0043 | 1 | | | 18-Jun-24 | 11:33:53 AM | System Administra | AA |
| 2 | 0.0042 | 1 | | | 18-Jun-24 | 11:34:25 AM | System Administra | AA |
| 3 | 0.0044 | 1 | | | 18-Jun-24 | 11:34:34 AM | System Administra | AA |
| 4 | 0.0043 | 1 | | | 18-Jun-24 | 11:34:43 AM | System Administra | AA |
| 5 | 0.0042 | 1 | | | 18-Jun-24 | 11:34:53 AM | System Administra | AA |
| 6 | 0.0046 | 1 | | | 18-Jun-24 | 11:35:02 AM | System Administra | AA |
| 7 | 0.0036 | 1 | | | 18-Jun-24 | 11:35:11 AM | System Administra | AA |
| 8 | 0.0035 | 1 | | | 18-Jun-24 | 11:35:20 AM | System Administra | AA |
| 9 | 0.0035 | 1 | | | 18-Jun-24 | 11:35:29 AM | System Administra | AA |
| 10 | 0.0045 | 1 | | | 18-Jun-24 | 11:35:39 AM | System Administra | AA |
| 11 | 0.0041 | 1 | | | 18-Jun-24 | 11:33:53 AM | System Administ | AA |
| 12 | 0.0046 | 2 | | | 18-Jun-24 | 11:35:51 AM | System Administ | AA |
| 13 | 0.0041 | 2 | | | 18-Jun-24 | 11:36:24 AM | System Administ | AA |
| 14 | 0.0030 | 2 | | | 18-Jun-24 | 11:36:33 AM | System Administ | AA |
| 15 | 0.0037 | 2 | | | 18-Jun-24 | 11:36:42 AM | System Administ | AA |
| 16 | 0.0033 | 2 | | | 18-Jun-24 | 11:36:51 AM | System Administ | AA |
| 17 | 0.0037 | 2 | | | 18-Jun-24 | 11:37:00 AM | System Administ | AA |
| 18 | 0.0033 | 2 | | | 18-Jun-24 | 11:37:10 AM | System Administ | AA |
| 19 | 0.0030 | 2 | | | 18-Jun-24 | 11:37:19 AM | System Administ | AA |
| 20 | 0.0042 | 2 | | | 18-Jun-24 | 11:37:28 AM | System Administ | AA |
| 21 | 0.0041 | 2 | | | 18-Jun-24 | 11:37:37 AM | System Administ | AA |
| 22 | | 2 | | | | | System Administ | AA |
| 23 | 0.0039 | 3 | | | 18-Jun-24 | 11:40:03 AM | System Administ | AA |
| 24 | 0.0040 | 3 | | | 18-Jun-24 | 11:40:36 AM | System Administ | AA |
| 25 | 0.0042 | 3 | | | 18-Jun-24 | 11:40:45 AM | System Administ | AA |
| 26 | 0.0039 | 3 | | | 18-Jun-24 | 11:40:54 AM | System Administ | AA |
| 27 | 0.0040 | 3 | | | 18-Jun-24 | 11:41:03 AM | System Administ | AA |
| 28 | 0.0032 | 3 | | | 18-Jun-24 | 11:41:12 AM | System Administ | AA |
| 29 | 0.0035 | 3 | | | 18-Jun-24 | 11:41:22 AM | System Administ | AA |
| 30 | 0.0029 | 3 | | | 18-Jun-24 | 11:41:31 AM | System Administ | AA |
| 31 | 0.0039 | 3 | | | 18-Jun-24 | 11:41:40 AM | System Administ | AA |
| 32 | 0.0033 | 3 | | | 18-Jun-24 | 11:41:49 AM | System Administ | AA |
| 33 | 0.0031 | 3 | | | 18-Jun-24 | 11:41:58 AM | System Administ | AA |
| 34 | 0.0036 | 3 | | | 18-Jun-24 | 11:42:08 AM | System Administ | AA |
| 35 | | 3 | | | | | System Administ | AA |
| 36 | 0.0034 | 4 | | | 18-Jun-24 | 11:42:20 AM | System Administ | AA |
| 37 | 0.0030 | 4 | | | 18-Jun-24 | 11:42:53 AM | System Administ | AA |
| 38 | 0.0032 | 4 | | | 18-Jun-24 | 11:43:02 AM | System Administ | AA |
| 39 | 0.0031 | 4 | | | 18-Jun-24 | 11:43:11 AM | System Administ | AA |
| 40 | 0.0023 | 4 | | | 18-Jun-24 | 11:43:20 AM | System Administ | AA |
| 41 | 0.0023 | 4 | | | 18-Jun-24 | 11:43:29 AM | System Administ | AA |
| 42 | -0.0005 | 4 | | | 18-Jun-24 | 11:43:39 AM | System Administ | AA |
| 43 | 0.0004 | 4 | | | 18-Jun-24 | 11:43:48 AM | System Administ | AA |
| 44 | 0.0031 | 4 | | | 18-Jun-24 | 11:43:57 AM | System Administ | AA |
| 45 | 0.0022 | 4 | | | 18-Jun-24 | 11:44:06 AM | System Administ | AA |
| 46 | 0.0028 | 4 | | | 18-Jun-24 | 11:44:15 AM | System Administ | AA |
| 47 | 0.0007 | 4 | | | 18-Jun-24 | 11:44:25 AM | System Administ | AA |
| 48 | | 4 | | | | | System Administ | AA |
| 49 | 0.0039 | 5 | | | 18-Jun-24 | 11:44:37 AM | System Administ | AA |
| 50 | 0.0033 | 5 | | | 18-Jun-24 | 11:45:10 AM | System Administ | AA |
| 51 | 0.0032 | 5 | | | 18-Jun-24 | 11:45:19 AM | System Administ | AA |
| 52 | 0.0029 | 5 | | | 18-Jun-24 | 11:45:28 AM | System Administ | AA |
| 53 | 0.0032 | 5 | | | 18-Jun-24 | 11:45:37 AM | System Administ | AA |
| 54 | 0.0030 | 5 | | | 18-Jun-24 | 11:45:47 AM | System Administ | AA |
| 55 | 0.0030 | 5 | | | 18-Jun-24 | 11:45:56 AM | System Administ | AA |
| 56 | 0.0035 | 5 | | | 18-Jun-24 | 11:46:13 AM | System Administ | AA |
| 57 | 0.0034 | 5 | | | 18-Jun-24 | 11:46:23 AM | System Administ | AA |
| 58 | 0.0033 | 5 | | | 18-Jun-24 | 11:46:33 AM | System Administ | AA |
| 59 | 0.0032 | 5 | | | 18-Jun-24 | 11:46:43 AM | System Administ | AA |
| 60 | 0.0030 | 5 | | | 18-Jun-24 | 11:46:52 AM | System Administ | AA |

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Appendix C-4

AAS Results for Lead

Pb

Tuesday, June 18, 2024 4:04:21 PM

| Action | Sample ID | X | True Value (ppm) | Conc. (ppm) | Abs. |
|--------|---------------|---|------------------|-------------|----------------|
| 1 | BLK-1 | | | | -0.0014 |
| 2 | BLK-2 | | | | -0.0014 |
| 3 | BLK-3 | | | | -0.0015 |
| 4 | BLK-4 | | | | -0.0013 |
| 5 | BLK-5 | | | | -0.0011 |
| 6 | BLK-6 | | | | -0.0017 |
| 7 | BLK-7 | | | | -0.0007 |
| 8 | BLK-8 | | | | -0.0007 |
| 9 | BLK-9 | | | | -0.0009 |
| 10 | BLK-10 | | | | -0.0014 |
| 11 | BLK-AV | | | | -0.0012 |
| 12 | STD-1 | X | 10.0000 | 0.0000 | 0.0000 |
| 13 | STD-2 | X | 10.0000 | 0.2996 | 0.0006 |
| 14 | STD-3 | X | 10.0000 | 0.4501 | 0.0009 |
| 15 | STD-4 | X | 10.0000 | 0.3999 | 0.0008 |
| 16 | STD-5 | X | 10.0000 | 0.4501 | 0.0009 |
| 17 | STD-6 | X | 10.0000 | 0.1496 | 0.0003 |
| 18 | STD-7 | X | 10.0000 | 0.2496 | 0.0005 |
| 19 | STD-8 | X | 10.0000 | 0.5003 | 0.0010 |
| 20 | STD-9 | X | 10.0000 | 0.0498 | 0.0001 |
| 21 | STD-10 | X | 10.0000 | 4.0294 | 0.0078 |
| 22 | STD-AV | X | 10.0000 | | |
| 23 | STD-1 | X | 20.0000 | 0.2496 | 0.0005 |
| 24 | STD-2 | X | 20.0000 | 0.1996 | 0.0004 |
| 25 | STD-3 | X | 20.0000 | 0.0498 | 0.0001 |
| 26 | STD-4 | X | 20.0000 | 0.1496 | 0.0003 |
| 27 | STD-5 | X | 20.0000 | 0.1996 | 0.0004 |
| 28 | STD-6 | X | 20.0000 | 0.5003 | 0.0010 |
| 29 | STD-7 | X | 20.0000 | 0.4501 | 0.0009 |
| 30 | STD-8 | X | 20.0000 | 0.5506 | 0.0011 |
| 31 | STD-9 | X | 20.0000 | 0.2496 | 0.0005 |
| 32 | STD-10 | X | 20.0000 | 2.4962 | 0.0049 |
| 33 | STD-11 | X | 20.0000 | 6.4428 | 0.0122 |
| 34 | STD-12 | X | 20.0000 | 6.7806 | 0.0128 |
| 35 | STD-AV | X | 20.0000 | | |
| 36 | STD-1 | X | 30.0000 | 6.7806 | 0.0128 |
| 37 | STD-2 | X | 30.0000 | 6.4428 | 0.0122 |
| 38 | STD-3 | X | 30.0000 | 5.9402 | 0.0113 |
| 39 | STD-4 | X | 30.0000 | 5.6077 | 0.0107 |
| 40 | STD-5 | X | 30.0000 | 5.9958 | 0.0114 |
| 41 | STD-6 | X | 30.0000 | 5.6077 | 0.0107 |
| 42 | STD-7 | X | 30.0000 | 9.8035 | 0.0180 |
| 43 | STD-8 | X | 30.0000 | 8.0382 | 0.0150 |
| 44 | STD-9 | X | 30.0000 | 1.9775 | 0.0039 |
| 45 | STD-10 | X | 30.0000 | 0.9545 | 0.0019 |
| 46 | STD-11 | X | 30.0000 | 0.8027 | 0.0016 |
| 47 | STD-12 | X | 30.0000 | 11.2609 | 0.0204 |
| 48 | STD-AV | X | 30.0000 | | |
| 49 | STD-1 | X | 40.0000 | 10.0436 | 0.0184 |
| 50 | STD-2 | X | 40.0000 | 9.4456 | 0.0174 |
| 51 | STD-3 | X | 40.0000 | 7.9803 | 0.0149 |
| 52 | STD-4 | X | 40.0000 | 8.7958 | 0.0163 |
| 53 | STD-5 | X | 40.0000 | 8.5615 | 0.0159 |
| 54 | STD-6 | X | 40.0000 | 7.0638 | 0.0133 |
| 55 | STD-7 | X | 40.0000 | 7.0638 | 0.0133 |
| 56 | STD-8 | X | 40.0000 | 7.7497 | 0.0145 |
| 57 | STD-9 | X | 40.0000 | 2.0808 | 0.0041 |
| 58 | STD-10 | X | 40.0000 | 0.4501 | 0.0009 |
| 59 | STD-11 | X | 40.0000 | 0.5003 | 0.0010 |
| 60 | STD-12 | X | 40.0000 | 6.6114 | 0.0125 |

Appendix C-5

AAS Results for Lead

Pb

Tuesday, June 18, 2024 4:04:21 PM

| | BG | Pos. | Actual Conc. | Actual Conc. Unit | Date | Time | User Name | Device Name |
|-----|---------|------|--------------|-------------------|-----------|-------------|-------------------|-------------|
| 61 | | 5 | | | | | System Administ | AA |
| 62 | 0.0033 | 6 | 15.2329 | ppm | 18-Jun-24 | 11:47:04 AM | System Administr | AA |
| 63 | 0.0011 | 6 | 3.7086 | ppm | 18-Jun-24 | 11:50:52 AM | System Administr | AA |
| 64 | -0.0003 | 6 | 3.8688 | ppm | 18-Jun-24 | 11:51:25 AM | System Administr | AA |
| 65 | 0.0001 | 6 | 3.0200 | ppm | 18-Jun-24 | 11:51:34 AM | System Administr | AA |
| 66 | 0.0000 | 6 | 2.6006 | ppm | 18-Jun-24 | 11:51:43 AM | System Administr | AA |
| 67 | -0.0007 | 6 | 4.8399 | ppm | 18-Jun-24 | 11:51:52 AM | System Administr | AA |
| 68 | 0.0030 | 6 | 2.1326 | ppm | 18-Jun-24 | 11:52:01 AM | System Administra | AA |
| 69 | 0.0035 | 6 | 1.0052 | ppm | 18-Jun-24 | 11:52:11 AM | System Administra | AA |
| 70 | 0.0034 | 6 | 1.1067 | ppm | 18-Jun-24 | 11:52:20 AM | System Administra | AA |
| 71 | 0.0036 | 6 | 1.0052 | ppm | 18-Jun-24 | 11:52:29 AM | System Administra | AA |
| 72 | 0.0042 | 6 | 0.7017 | ppm | 18-Jun-24 | 11:52:38 AM | System Administra | AA |
| 73 | 0.0036 | 6 | 1.0052 | ppm | 18-Jun-24 | 11:52:47 AM | System Administra | AA |
| 74 | 0.0036 | 6 | 1.1576 | ppm | 18-Jun-24 | 11:52:01 AM | System Administ | AA |
| 75 | 0.0035 | 7 | 1.0559 | ppm | 18-Jun-24 | 11:53:00 AM | System Administr | AA |
| 76 | 0.0032 | 7 | 0.9545 | ppm | 18-Jun-24 | 11:53:32 AM | System Administr | AA |
| 77 | 0.0014 | 7 | 1.7713 | ppm | 18-Jun-24 | 11:53:42 AM | System Administr | AA |
| 78 | 0.0031 | 7 | 0.9038 | ppm | 18-Jun-24 | 11:53:51 AM | System Administr | AA |
| 79 | 0.0033 | 7 | 0.9545 | ppm | 18-Jun-24 | 11:54:00 AM | System Administr | AA |
| 80 | 0.0028 | 7 | 0.9038 | ppm | 18-Jun-24 | 11:54:09 AM | System Administr | AA |
| 81 | 0.0018 | 7 | 1.5660 | ppm | 18-Jun-24 | 11:54:18 AM | System Administra | AA |
| 82 | 0.0024 | 7 | 1.1576 | ppm | 18-Jun-24 | 11:54:28 AM | System Administra | AA |
| 83 | 0.0018 | 7 | 1.0559 | ppm | 18-Jun-24 | 11:54:37 AM | System Administra | AA |
| 84 | 0.0033 | 7 | 0.9038 | ppm | 18-Jun-24 | 11:54:46 AM | System Administra | AA |
| 85 | 0.0027 | 7 | 1.0559 | ppm | 18-Jun-24 | 11:54:55 AM | System Administra | AA |
| 86 | 0.0020 | 7 | 1.2594 | ppm | 18-Jun-24 | 11:55:04 AM | System Administra | AA |
| 87 | 0.0023 | 7 | 1.1576 | ppm | 18-Jun-24 | 11:54:18 AM | System Administ | AA |
| 88 | 0.0022 | 8 | 2.7575 | ppm | 18-Jun-24 | 12:12:01 PM | System Administr | AA |
| 89 | 0.0017 | 8 | 3.0200 | ppm | 18-Jun-24 | 12:12:33 PM | System Administr | AA |
| 90 | 0.0020 | 8 | 2.7575 | ppm | 18-Jun-24 | 12:12:42 PM | System Administr | AA |
| 91 | 0.0021 | 8 | 2.6528 | ppm | 18-Jun-24 | 12:12:51 PM | System Administr | AA |
| 92 | 0.0020 | 8 | 2.5484 | ppm | 18-Jun-24 | 12:13:01 PM | System Administr | AA |
| 93 | 0.0028 | 8 | 2.1326 | ppm | 18-Jun-24 | 12:13:10 PM | System Administr | AA |
| 94 | 0.0022 | 8 | 2.4441 | ppm | 18-Jun-24 | 12:13:19 PM | System Administra | AA |
| 95 | 0.0022 | 8 | 2.2362 | ppm | 18-Jun-24 | 12:13:28 PM | System Administra | AA |
| 96 | 0.0019 | 8 | 2.4441 | ppm | 18-Jun-24 | 12:13:38 PM | System Administra | AA |
| 97 | 0.0029 | 8 | 2.0808 | ppm | 18-Jun-24 | 12:13:48 PM | System Administra | AA |
| 98 | 0.0023 | 8 | 2.1844 | ppm | 18-Jun-24 | 12:13:57 PM | System Administra | AA |
| 99 | 0.0023 | 8 | 2.0808 | ppm | 18-Jun-24 | 12:14:06 PM | System Administra | AA |
| 100 | 0.0023 | 8 | 2.2362 | ppm | 18-Jun-24 | 12:13:19 PM | System Administ | AA |
| 101 | 0.0021 | 9 | 2.0808 | ppm | 18-Jun-24 | 12:14:18 PM | System Administr | AA |
| 102 | 0.0026 | 9 | 2.0808 | ppm | 18-Jun-24 | 12:14:51 PM | System Administr | AA |
| 103 | 0.0026 | 9 | 1.9775 | ppm | 18-Jun-24 | 12:15:00 PM | System Administr | AA |
| 104 | 0.0020 | 9 | 33.0074 | ppm | 18-Jun-24 | 12:15:09 PM | System Administr | AA |
| 105 | 0.0027 | 9 | 33.1057 | ppm | 18-Jun-24 | 12:15:19 PM | System Administr | AA |
| 106 | 0.0024 | 9 | 33.0074 | ppm | 18-Jun-24 | 12:15:28 PM | System Administra | AA |
| 107 | 0.0020 | 9 | 33.5010 | ppm | 18-Jun-24 | 12:15:37 PM | System Administra | AA |
| 108 | 0.0021 | 9 | 33.6004 | ppm | 18-Jun-24 | 12:15:46 PM | System Administra | AA |
| 109 | 0.0031 | 9 | 31.4647 | ppm | 18-Jun-24 | 12:15:55 PM | System Administra | AA |
| 110 | 0.0033 | 9 | 30.8066 | ppm | 18-Jun-24 | 12:16:05 PM | System Administra | AA |
| 111 | 0.0024 | 9 | 32.1329 | ppm | 18-Jun-24 | 12:16:14 PM | System Administra | AA |
| 112 | 0.0023 | 9 | 33.0074 | ppm | 18-Jun-24 | 12:16:23 PM | System Administra | AA |
| 113 | 0.0025 | 9 | 32.5194 | ppm | 18-Jun-24 | 12:15:28 PM | System Administ | AA |
| 114 | 0.0027 | 10 | 30.7134 | ppm | 18-Jun-24 | 12:16:35 PM | System Administr | AA |
| 115 | 0.0024 | 10 | 17.5547 | ppm | 18-Jun-24 | 12:17:08 PM | System Administr | AA |
| 116 | 0.0022 | 10 | 2.8099 | ppm | 18-Jun-24 | 12:17:17 PM | System Administr | AA |
| 117 | 0.0025 | 10 | 2.6006 | ppm | 18-Jun-24 | 12:17:26 PM | System Administr | AA |
| 118 | 0.0026 | 10 | 1.8743 | ppm | 18-Jun-24 | 12:17:36 PM | System Administr | AA |
| 119 | 0.0020 | 10 | 2.2881 | ppm | 18-Jun-24 | 12:17:45 PM | System Administr | AA |
| 120 | 0.0032 | 10 | 1.6172 | ppm | 18-Jun-24 | 12:17:54 PM | System Administr | AA |

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Appendix C-6

AAS Results for Lead

Pb Tuesday, June 18, 2024 4:04:21 PM

| Action | Sample ID | X | True Value (ppm) | Conc. (ppm) | Abs. |
|--------|----------------|---------------------------------|------------------|----------------|---------------|
| 61 | STD-AV | | 40.0000 | | |
| 62 | UNK1-1 | car wash blk 2 | | 15.2329 | 0.0266 |
| 63 | UNK1-2 | car wash blk 2 | | 3.7086 | 0.0072 |
| 64 | UNK1-3 | car wash blk 2 | | 3.8688 | 0.0075 |
| 65 | UNK1-4 | car wash blk 2 | | 3.0200 | 0.0059 |
| 66 | UNK1-5 | car wash blk 2 | | 2.6006 | 0.0051 |
| 67 | UNK1-6 | car wash blk 2 | | 4.8399 | 0.0093 |
| 68 | UNK1-7 | car wash blk 2 | | 2.1326 | 0.0042 |
| 69 | UNK1-8 | car wash blk 2 | | 1.0052 | 0.0020 |
| 70 | UNK1-9 | car wash blk 2 | | 1.1067 | 0.0022 |
| 71 | UNK1-10 | car wash blk 2 | | 1.0052 | 0.0020 |
| 72 | UNK1-11 | car wash blk 2 | | 0.7017 | 0.0014 |
| 73 | UNK1-12 | car wash blk 2 | | 1.0052 | 0.0020 |
| 74 | UNK1-AV | car wash blk 2 | | 1.1576 | 0.0023 |
| 75 | UNK2-1 | carwash blk digested | | 1.0559 | 0.0021 |
| 76 | UNK2-2 | carwash blk digested | | 0.9545 | 0.0019 |
| 77 | UNK2-3 | carwash blk digested | | 1.7713 | 0.0035 |
| 78 | UNK2-4 | carwash blk digested | | 0.9038 | 0.0018 |
| 79 | UNK2-5 | carwash blk digested | | 0.9545 | 0.0019 |
| 80 | UNK2-6 | carwash blk digested | | 0.9038 | 0.0018 |
| 81 | UNK2-7 | carwash blk digested | | 1.5660 | 0.0031 |
| 82 | UNK2-8 | carwash blk digested | | 1.1576 | 0.0023 |
| 83 | UNK2-9 | carwash blk digested | | 1.0559 | 0.0021 |
| 84 | UNK2-10 | carwash blk digested | | 0.9038 | 0.0018 |
| 85 | UNK2-11 | carwash blk digested | | 1.0559 | 0.0021 |
| 86 | UNK2-12 | carwash blk digested | | 1.2594 | 0.0025 |
| 87 | UNK2-AV | carwash blk digested | | 1.1576 | 0.0023 |
| 88 | UNK3-1 | carwash blk 3 | | 2.7575 | 0.0054 |
| 89 | UNK3-2 | carwash blk 3 | | 3.0200 | 0.0059 |
| 90 | UNK3-3 | carwash blk 3 | | 2.7575 | 0.0054 |
| 91 | UNK3-4 | carwash blk 3 | | 2.6528 | 0.0052 |
| 92 | UNK3-5 | carwash blk 3 | | 2.5484 | 0.0050 |
| 93 | UNK3-6 | carwash blk 3 | | 2.1326 | 0.0042 |
| 94 | UNK3-7 | carwash blk 3 | | 2.4441 | 0.0048 |
| 95 | UNK3-8 | carwash blk 3 | | 2.2362 | 0.0044 |
| 96 | UNK3-9 | carwash blk 3 | | 2.4441 | 0.0048 |
| 97 | UNK3-10 | carwash blk 3 | | 2.0808 | 0.0041 |
| 98 | UNK3-11 | carwash blk 3 | | 2.1844 | 0.0043 |
| 99 | UNK3-12 | carwash blk 3 | | 2.0808 | 0.0041 |
| 100 | UNK3-AV | carwash blk 3 | | 2.2362 | 0.0044 |
| 101 | UNK4-1 | kitchen spiked untreated | | 2.0808 | 0.0041 |
| 102 | UNK4-2 | kitchen spiked untreated | | 2.0808 | 0.0041 |
| 103 | UNK4-3 | kitchen spiked untreated | | 1.9775 | 0.0039 |
| 104 | UNK4-4 | kitchen spiked untreated | | 33.0074 | 0.0488 |
| 105 | UNK4-5 | kitchen spiked untreated | | 33.1057 | 0.0489 |
| 106 | UNK4-6 | kitchen spiked untreated | | 33.0074 | 0.0488 |
| 107 | UNK4-7 | kitchen spiked untreated | | 33.5010 | 0.0493 |
| 108 | UNK4-8 | kitchen spiked untreated | | 33.6004 | 0.0494 |
| 109 | UNK4-9 | kitchen spiked untreated | | 31.4647 | 0.0472 |
| 110 | UNK4-10 | kitchen spiked untreated | | 30.8066 | 0.0465 |
| 111 | UNK4-11 | kitchen spiked untreated | | 32.1329 | 0.0479 |
| 112 | UNK4-12 | kitchen spiked untreated | | 33.0074 | 0.0488 |
| 113 | UNK4-AV | kitchen spiked untreated | | 32.5194 | 0.0483 |
| 114 | UNK5-1 | bathroom blk 3 | | 30.7134 | 0.0464 |
| 115 | UNK5-2 | bathroom blk 3 | | 17.5547 | 0.0300 |
| 116 | UNK5-3 | bathroom blk 3 | | 2.8099 | 0.0055 |
| 117 | UNK5-4 | bathroom blk 3 | | 2.6006 | 0.0051 |
| 118 | UNK5-5 | bathroom blk 3 | | 1.8743 | 0.0037 |
| 119 | UNK5-6 | bathroom blk 3 | | 2.2881 | 0.0045 |
| 120 | UNK5-7 | bathroom blk 3 | | 1.6172 | 0.0032 |

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Appendix C-7

AAS Results for Lead

Pb

Tuesday, June 18, 2024 4:04:21 PM

| | BG | Pos. | Actual Conc. | Actual Conc. Unit | Date | Time | User Name | Device Name |
|-----|--------|------|--------------|-------------------|-----------|-------------|-------------------|-------------|
| 121 | 0.0025 | 10 | 1.9775 | ppm | 18-Jun-24 | 12:18:03 PM | System Administr | AA |
| 122 | 0.0021 | 10 | 2.3401 | ppm | 18-Jun-24 | 12:18:12 PM | System Administr | AA |
| 123 | 0.0028 | 10 | 1.9259 | ppm | 18-Jun-24 | 12:18:22 PM | System Administr | AA |
| 124 | 0.0030 | 10 | 1.8743 | ppm | 18-Jun-24 | 12:18:31 PM | System Administr | AA |
| 125 | 0.0028 | 10 | 1.8228 | ppm | 18-Jun-24 | 12:18:40 PM | System Administr | AA |
| 126 | | 10 | | ppm | | | System Administ | AA |
| 127 | 0.0028 | 11 | 1.6686 | ppm | 18-Jun-24 | 12:18:52 PM | System Administr | AA |
| 128 | 0.0023 | 11 | 1.7199 | ppm | 18-Jun-24 | 12:19:27 PM | System Administr | AA |
| 129 | 0.0027 | 11 | 1.8228 | ppm | 18-Jun-24 | 12:19:36 PM | System Administra | AA |
| 130 | 0.0029 | 11 | 1.8743 | ppm | 18-Jun-24 | 12:19:45 PM | System Administra | AA |
| 131 | 0.0022 | 11 | 2.2881 | ppm | 18-Jun-24 | 12:19:54 PM | System Administra | AA |
| 132 | 0.0021 | 11 | 2.2881 | ppm | 18-Jun-24 | 12:20:03 PM | System Administra | AA |
| 133 | 0.0024 | 11 | 2.1844 | ppm | 18-Jun-24 | 12:20:13 PM | System Administra | AA |
| 134 | 0.0023 | 11 | 2.0808 | ppm | 18-Jun-24 | 12:20:22 PM | System Administra | AA |
| 135 | 0.0023 | 11 | 1.9259 | ppm | 18-Jun-24 | 12:20:31 PM | System Administra | AA |
| 136 | 0.0027 | 11 | 1.9775 | ppm | 18-Jun-24 | 12:20:40 PM | System Administra | AA |
| 137 | 0.0027 | 11 | 1.9259 | ppm | 18-Jun-24 | 12:20:49 PM | System Administra | AA |
| 138 | 0.0024 | 11 | 2.1844 | ppm | 18-Jun-24 | 12:20:59 PM | System Administra | AA |
| 139 | 0.0025 | 11 | 2.0291 | ppm | 18-Jun-24 | 12:19:36 PM | System Administ | AA |
| 140 | 0.0021 | 12 | 2.0291 | ppm | 18-Jun-24 | 12:21:11 PM | System Administr | AA |
| 141 | 0.0024 | 12 | 1.9259 | ppm | 18-Jun-24 | 12:21:44 PM | System Administr | AA |
| 142 | 0.0021 | 12 | 2.1326 | ppm | 18-Jun-24 | 12:21:53 PM | System Administr | AA |
| 143 | 0.0020 | 12 | 2.0291 | ppm | 18-Jun-24 | 12:22:02 PM | System Administr | AA |
| 144 | 0.0024 | 12 | 2.0291 | ppm | 18-Jun-24 | 12:22:11 PM | System Administra | AA |
| 145 | 0.0027 | 12 | 1.9775 | ppm | 18-Jun-24 | 12:22:20 PM | System Administra | AA |
| 146 | 0.0027 | 12 | 1.9259 | ppm | 18-Jun-24 | 12:22:30 PM | System Administra | AA |
| 147 | 0.0023 | 12 | 2.0291 | ppm | 18-Jun-24 | 12:22:39 PM | System Administra | AA |
| 148 | 0.0029 | 12 | 1.9259 | ppm | 18-Jun-24 | 12:22:48 PM | System Administra | AA |
| 149 | 0.0022 | 12 | 2.2362 | ppm | 18-Jun-24 | 12:22:57 PM | System Administra | AA |
| 150 | 0.0029 | 12 | 1.7713 | ppm | 18-Jun-24 | 12:23:06 PM | System Administra | AA |
| 151 | 0.0029 | 12 | 1.9775 | ppm | 18-Jun-24 | 12:23:16 PM | System Administra | AA |
| 152 | 0.0026 | 12 | 1.9775 | ppm | 18-Jun-24 | 12:22:11 PM | System Administ | AA |
| 153 | 0.0027 | 13 | 2.1326 | ppm | 18-Jun-24 | 12:23:28 PM | System Administr | AA |
| 154 | 0.0020 | 13 | 2.2362 | ppm | 18-Jun-24 | 12:24:01 PM | System Administr | AA |
| 155 | 0.0024 | 13 | 2.0291 | ppm | 18-Jun-24 | 12:24:10 PM | System Administr | AA |
| 156 | 0.0025 | 13 | 2.0808 | ppm | 18-Jun-24 | 12:24:19 PM | System Administr | AA |
| 157 | 0.0022 | 13 | 2.1844 | ppm | 18-Jun-24 | 12:24:28 PM | System Administr | AA |
| 158 | 0.0030 | 13 | 1.8743 | ppm | 18-Jun-24 | 12:24:38 PM | System Administra | AA |
| 159 | 0.0029 | 13 | 1.7713 | ppm | 18-Jun-24 | 12:24:47 PM | System Administra | AA |
| 160 | 0.0032 | 13 | 1.6172 | ppm | 18-Jun-24 | 12:24:56 PM | System Administra | AA |
| 161 | 0.0033 | 13 | 1.6686 | ppm | 18-Jun-24 | 12:25:05 PM | System Administra | AA |
| 162 | 0.0028 | 13 | 1.9775 | ppm | 18-Jun-24 | 12:25:14 PM | System Administra | AA |
| 163 | 0.0038 | 13 | 1.6172 | ppm | 18-Jun-24 | 12:25:24 PM | System Administra | AA |
| 164 | 0.0030 | 13 | 1.9259 | ppm | 18-Jun-24 | 12:25:33 PM | System Administra | AA |
| 165 | 0.0031 | 13 | 1.7713 | ppm | 18-Jun-24 | 12:24:38 PM | System Administ | AA |
| 166 | 0.0035 | 14 | 1.6172 | ppm | 18-Jun-24 | 12:25:45 PM | System Administr | AA |
| 167 | 0.0029 | 14 | 2.0808 | ppm | 18-Jun-24 | 12:26:18 PM | System Administr | AA |
| 168 | 0.0032 | 14 | 2.0808 | ppm | 18-Jun-24 | 12:26:27 PM | System Administr | AA |
| 169 | 0.0023 | 14 | 2.2881 | ppm | 18-Jun-24 | 12:26:38 PM | System Administr | AA |
| 170 | 0.0041 | 14 | 1.6172 | ppm | 18-Jun-24 | 12:26:47 PM | System Administr | AA |
| 171 | 0.0042 | 14 | 1.9259 | ppm | 18-Jun-24 | 12:29:59 PM | System Administra | AA |
| 172 | 0.0045 | 14 | 1.8228 | ppm | 18-Jun-24 | 12:30:31 PM | System Administra | AA |
| 173 | 0.0036 | 14 | 2.1326 | ppm | 18-Jun-24 | 12:30:43 PM | System Administra | AA |
| 174 | 0.0034 | 14 | 2.0291 | ppm | 18-Jun-24 | 12:30:52 PM | System Administra | AA |
| 175 | 0.0027 | 14 | 2.1844 | ppm | 18-Jun-24 | 12:32:26 PM | System Administra | AA |
| 176 | 0.0037 | 14 | 2.0291 | ppm | 18-Jun-24 | 12:29:59 PM | System Administ | AA |
| 177 | 0.0026 | 15 | 2.1326 | ppm | 18-Jun-24 | 12:33:02 PM | System Administr | AA |
| 178 | 0.0024 | 15 | 2.3401 | ppm | 18-Jun-24 | 12:33:34 PM | System Administr | AA |
| 179 | 0.0040 | 15 | 49.2425 | ppm | 18-Jun-24 | 12:33:43 PM | System Administr | AA |
| 180 | 0.0031 | 15 | 55.5574 | ppm | 18-Jun-24 | 12:33:53 PM | System Administra | AA |

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Appendix C-8

AAS Results for Lead

Pb

Tuesday, June 18, 2024 4:04:21 PM

| Action | Sample ID | X | True Value (ppm) | Conc. (ppm) | Abs. |
|-------------|-----------------------|---|------------------|-------------|--------|
| 121 UNK5-8 | bathroom blk 3 | X | | 1.9775 | 0.0039 |
| 122 UNK5-9 | bathroom blk 3 | X | | 2.3401 | 0.0046 |
| 123 UNK5-10 | bathroom blk 3 | X | | 1.9259 | 0.0038 |
| 124 UNK5-11 | bathroom blk 3 | X | | 1.8743 | 0.0037 |
| 125 UNK5-12 | bathroom blk 3 | X | | 1.8228 | 0.0036 |
| 126 UNK5-AV | bathroom blk 3 | | | | |
| 127 UNK6-1 | bathroom blk 2 | X | | 1.6686 | 0.0033 |
| 128 UNK6-2 | bathroom blk 2 | X | | 1.7199 | 0.0034 |
| 129 UNK6-3 | bathroom blk 2 | | | 1.8228 | 0.0036 |
| 130 UNK6-4 | bathroom blk 2 | | | 1.8743 | 0.0037 |
| 131 UNK6-5 | bathroom blk 2 | | | 2.2881 | 0.0045 |
| 132 UNK6-6 | bathroom blk 2 | | | 2.2881 | 0.0045 |
| 133 UNK6-7 | bathroom blk 2 | | | 2.1844 | 0.0043 |
| 134 UNK6-8 | bathroom blk 2 | | | 2.0808 | 0.0041 |
| 135 UNK6-9 | bathroom blk 2 | | | 1.9259 | 0.0038 |
| 136 UNK6-10 | bathroom blk 2 | | | 1.9775 | 0.0039 |
| 137 UNK6-11 | bathroom blk 2 | | | 1.9259 | 0.0038 |
| 138 UNK6-12 | bathroom blk 2 | | | 2.1844 | 0.0043 |
| 139 UNK6-AV | bathroom blk 2 | | | 2.0291 | 0.0040 |
| 140 UNK7-1 | kitchen blk3 | X | | 2.0291 | 0.0040 |
| 141 UNK7-2 | kitchen blk3 | X | | 1.9259 | 0.0038 |
| 142 UNK7-3 | kitchen blk3 | X | | 2.1326 | 0.0042 |
| 143 UNK7-4 | kitchen blk3 | X | | 2.0291 | 0.0040 |
| 144 UNK7-5 | kitchen blk3 | | | 2.0291 | 0.0040 |
| 145 UNK7-6 | kitchen blk3 | | | 1.9775 | 0.0039 |
| 146 UNK7-7 | kitchen blk3 | | | 1.9259 | 0.0038 |
| 147 UNK7-8 | kitchen blk3 | | | 2.0291 | 0.0040 |
| 148 UNK7-9 | kitchen blk3 | | | 1.9259 | 0.0038 |
| 149 UNK7-10 | kitchen blk3 | | | 2.2362 | 0.0044 |
| 150 UNK7-11 | kitchen blk3 | | | 1.7713 | 0.0035 |
| 151 UNK7-12 | kitchen blk3 | | | 1.9775 | 0.0039 |
| 152 UNK7-AV | kitchen blk3 | | | 1.9775 | 0.0039 |
| 153 UNK8-1 | kitchen blk2 | X | | 2.1326 | 0.0042 |
| 154 UNK8-2 | kitchen blk2 | X | | 2.2362 | 0.0044 |
| 155 UNK8-3 | kitchen blk2 | X | | 2.0291 | 0.0040 |
| 156 UNK8-4 | kitchen blk2 | X | | 2.0808 | 0.0041 |
| 157 UNK8-5 | kitchen blk2 | X | | 2.1844 | 0.0043 |
| 158 UNK8-6 | kitchen blk2 | | | 1.8743 | 0.0037 |
| 159 UNK8-7 | kitchen blk2 | | | 1.7713 | 0.0035 |
| 160 UNK8-8 | kitchen blk2 | | | 1.6172 | 0.0032 |
| 161 UNK8-9 | kitchen blk2 | | | 1.6686 | 0.0033 |
| 162 UNK8-10 | kitchen blk2 | | | 1.9775 | 0.0039 |
| 163 UNK8-11 | kitchen blk2 | | | 1.6172 | 0.0032 |
| 164 UNK8-12 | kitchen blk2 | | | 1.9259 | 0.0038 |
| 165 UNK8-AV | kitchen blk2 | | | 1.7713 | 0.0035 |
| 166 UNK9-1 | kitchen blk 3 | X | | 1.6172 | 0.0032 |
| 167 UNK9-2 | kitchen blk 3 | X | | 2.0808 | 0.0041 |
| 168 UNK9-3 | kitchen blk 3 | X | | 2.0808 | 0.0041 |
| 169 UNK9-4 | kitchen blk 3 | X | | 2.2881 | 0.0045 |
| 170 UNK9-5 | kitchen blk 3 | X | | 1.6172 | 0.0032 |
| 171 UNK9-6 | kitchen blk 3 | | | 1.9259 | 0.0038 |
| 172 UNK9-7 | kitchen blk 3 | | | 1.8228 | 0.0036 |
| 173 UNK9-8 | kitchen blk 3 | | | 2.1326 | 0.0042 |
| 174 UNK9-9 | kitchen blk 3 | | | 2.0291 | 0.0040 |
| 175 UNK9-10 | kitchen blk 3 | | | 2.1844 | 0.0043 |
| 176 UNK9-AV | kitchen blk 3 | | | 2.0291 | 0.0040 |
| 177 UNK10-1 | carwash spiked 3 | X | | 2.1326 | 0.0042 |
| 178 UNK10-2 | carwash spiked 3 | X | | 2.3401 | 0.0046 |
| 179 UNK10-3 | carwash spiked 3 | X | | 49.2425 | 0.0625 |
| 180 UNK10-4 | carwash spiked 3 | | | 55.5574 | 0.0665 |

Appendix C-9

AAS Results for Lead

Pb

Tuesday, June 18, 2024 4:04:21 PM

| Action | Sample ID | X | True Value (ppm) | Conc. (ppm) | Abs. |
|--------------|-------------------|---|------------------|-------------|--------|
| 181 UNK10-5 | carwash spiked 3 | | | 57.4892 | 0.0676 |
| 182 UNK10-6 | carwash spiked 3 | | | 56.7756 | 0.0672 |
| 183 UNK10-AV | carwash spiked 3 | | | 56.5992 | 0.0671 |
| 184 UNK11-1 | carwash spiked 2 | X | | 3.1254 | 0.0061 |
| 185 UNK11-2 | carwash spiked 2 | X | | 5.6630 | 0.0108 |
| 186 UNK11-3 | carwash spiked 2 | X | | 76.7028 | 0.0761 |
| 187 UNK11-4 | carwash spiked 2 | | | 86.8620 | 0.0794 |
| 188 UNK11-5 | carwash spiked 2 | | | 88.8581 | 0.0800 |
| 189 UNK11-6 | carwash spiked 2 | | | 92.9289 | 0.0812 |
| 190 UNK11-AV | carwash spiked 2 | | | 89.5305 | 0.0802 |
| 191 UNK12-1 | carwash spiked 1 | X | | 2.9148 | 0.0057 |
| 192 UNK12-2 | carwash spiked 1 | X | | 13.1435 | 0.0234 |
| 193 UNK12-3 | carwash spiked 1 | | | 120.5668 | 0.0904 |
| 194 UNK12-4 | carwash spiked 1 | | | 122.1929 | 0.0911 |
| 195 UNK12-5 | carwash spiked 1 | | | 128.3129 | 0.0940 |
| 196 UNK12-6 | carwash spiked 1 | | | 127.9197 | 0.0938 |
| 197 UNK12-AV | carwash spiked 1 | | | 124.8392 | 0.0923 |
| 198 UNK13-1 | bathroom spiked 3 | X | | 2.2362 | 0.0044 |
| 199 UNK13-2 | bathroom spiked 3 | X | | 2.2881 | 0.0045 |
| 200 UNK13-3 | bathroom spiked 3 | | | 77.8484 | 0.0765 |
| 201 UNK13-4 | bathroom spiked 3 | | | 97.3753 | 0.0825 |
| 202 UNK13-5 | bathroom spiked 3 | | | 98.7340 | 0.0829 |
| 203 UNK13-6 | bathroom spiked 3 | | | 97.3753 | 0.0825 |
| 204 UNK13-AV | bathroom spiked 3 | | | 92.5871 | 0.0811 |
| 205 UNK14-1 | bathroom spiked 1 | X | | 3.0200 | 0.0059 |
| 206 UNK14-2 | bathroom spiked 1 | X | | 23.6070 | 0.0380 |
| 207 UNK14-3 | bathroom spiked 1 | | | 150.0115 | 0.1088 |
| 208 UNK14-4 | bathroom spiked 1 | | | 154.2097 | 0.1127 |
| 209 UNK14-5 | bathroom spiked 1 | | | 153.3819 | 0.1119 |
| 210 UNK14-6 | bathroom spiked 1 | | | 157.6539 | 0.1162 |
| 211 UNK14-AV | bathroom spiked 1 | | | 153.9012 | 0.1124 |
| 212 UNK15-1 | kitchen spiked 2 | X | | 3.4958 | 0.0068 |
| 213 UNK15-2 | kitchen spiked 2 | X | | 11.9430 | 0.0215 |
| 214 UNK15-3 | kitchen spiked 2 | | | 40.6210 | 0.0559 |
| 215 UNK15-4 | kitchen spiked 2 | | | 40.6210 | 0.0559 |
| 216 UNK15-5 | kitchen spiked 2 | | | 41.8147 | 0.0569 |
| 217 UNK15-6 | kitchen spiked 2 | | | 40.1531 | 0.0555 |
| 218 UNK15-AV | kitchen spiked 2 | | | 40.7388 | 0.0560 |
| 219 UNK16-1 | kitchen spiked 3 | X | | 2.8099 | 0.0055 |
| 220 UNK16-2 | kitchen spiked 3 | X | | 5.9402 | 0.0113 |
| 221 UNK16-3 | kitchen spiked 3 | X | | 51.6477 | 0.0641 |
| 222 UNK16-4 | kitchen spiked 3 | | | 57.3096 | 0.0675 |
| 223 UNK16-5 | kitchen spiked 3 | | | 55.9016 | 0.0667 |
| 224 UNK16-6 | kitchen spiked 3 | | | 56.7756 | 0.0672 |
| 225 UNK16-AV | kitchen spiked 3 | | | 56.5992 | 0.0671 |
| 226 UNK17-1 | kitchen spiked un | X | | 2.8623 | 0.0056 |
| 227 UNK17-2 | kitchen spiked un | X | | 12.6345 | 0.0226 |
| 228 UNK17-3 | kitchen spiked un | | | 119.8501 | 0.0901 |
| 229 UNK17-4 | kitchen spiked un | | | 124.8392 | 0.0923 |
| 230 UNK17-5 | kitchen spiked un | | | 127.5225 | 0.0936 |
| 231 UNK17-6 | kitchen spiked un | | | 124.1936 | 0.0920 |
| 232 UNK17-AV | kitchen spiked un | | | 124.1936 | 0.0920 |
| 233 UNK18-1 | carwash 3 acti | X | | 2.6528 | 0.0052 |
| 234 UNK18-2 | carwash 3 acti | X | | 2.6528 | 0.0052 |
| 235 UNK18-3 | carwash 3 acti | | | 3.0727 | 0.0060 |
| 236 UNK18-4 | carwash 3 acti | | | 2.7575 | 0.0054 |
| 237 UNK18-5 | carwash 3 acti | | | 2.4962 | 0.0049 |
| 238 UNK18-6 | carwash 3 acti | | | 2.3401 | 0.0046 |
| 239 UNK18-AV | carwash 3 acti | | | 2.6528 | 0.0052 |
| 240 UNK19-1 | carwash activated | X | | 2.6006 | 0.0051 |

C:\Users\user\Desktop\kibetpb in water VICTOR MERU UN1.aa

Appendix C-10

AAS Results for Lead

Pb

Tuesday, June 18, 2024 4:04:21 PM

| | BG | Pos. | Actual Conc. | Actual Conc. Unit | Date | Time | User Name | Device Name |
|-----|---------------|-----------|-----------------|-------------------|------------------|--------------------|------------------------|-------------|
| 181 | 0.0030 | 15 | 57.4892 | ppm | 18-Jun-24 | 12:34:02 PM | System Administra | AA |
| 182 | 0.0028 | 15 | 56.7756 | ppm | 18-Jun-24 | 12:34:11 PM | System Administra | AA |
| 183 | 0.0030 | 15 | 56.5992 | ppm | 18-Jun-24 | 12:33:53 PM | System Administ | AA |
| 184 | 0.0023 | 16 | 3.1254 | ppm | 18-Jun-24 | 12:34:23 PM | System Administr | AA |
| 185 | 0.0017 | 16 | 5.6630 | ppm | 18-Jun-24 | 12:34:56 PM | System Administr | AA |
| 186 | 0.0031 | 16 | 76.7028 | ppm | 18-Jun-24 | 12:35:05 PM | System Administr | AA |
| 187 | 0.0031 | 16 | 86.8620 | ppm | 18-Jun-24 | 12:35:15 PM | System Administra | AA |
| 188 | 0.0029 | 16 | 88.8581 | ppm | 18-Jun-24 | 12:35:24 PM | System Administra | AA |
| 189 | 0.0032 | 16 | 92.9289 | ppm | 18-Jun-24 | 12:35:33 PM | System Administra | AA |
| 190 | 0.0031 | 16 | 89.5305 | ppm | 18-Jun-24 | 12:35:15 PM | System Administ | AA |
| 191 | 0.0026 | 17 | 2.9148 | ppm | 18-Jun-24 | 12:35:45 PM | System Administr | AA |
| 192 | 0.0029 | 17 | 13.1435 | ppm | 18-Jun-24 | 12:36:18 PM | System Administr | AA |
| 193 | 0.0032 | 17 | 120.5668 | ppm | 18-Jun-24 | 12:36:27 PM | System Administra | AA |
| 194 | 0.0035 | 17 | 122.1929 | ppm | 18-Jun-24 | 12:36:36 PM | System Administra | AA |
| 195 | 0.0034 | 17 | 128.3129 | ppm | 18-Jun-24 | 12:36:46 PM | System Administra | AA |
| 196 | 0.0030 | 17 | 127.9197 | ppm | 18-Jun-24 | 12:36:55 PM | System Administra | AA |
| 197 | 0.0033 | 17 | 124.8392 | ppm | 18-Jun-24 | 12:36:27 PM | System Administ | AA |
| 198 | 0.0029 | 18 | 2.2362 | ppm | 18-Jun-24 | 12:39:57 PM | System Administr | AA |
| 199 | 0.0027 | 18 | 2.2881 | ppm | 18-Jun-24 | 12:40:29 PM | System Administr | AA |
| 200 | 0.0033 | 18 | 77.8484 | ppm | 18-Jun-24 | 12:40:38 PM | System Administra | AA |
| 201 | 0.0028 | 18 | 97.3753 | ppm | 18-Jun-24 | 12:40:47 PM | System Administra | AA |
| 202 | 0.0033 | 18 | 98.7340 | ppm | 18-Jun-24 | 12:40:58 PM | System Administra | AA |
| 203 | 0.0034 | 18 | 97.3753 | ppm | 18-Jun-24 | 12:41:07 PM | System Administra | AA |
| 204 | 0.0032 | 18 | 92.5871 | ppm | 18-Jun-24 | 12:40:38 PM | System Administ | AA |
| 205 | 0.0032 | 19 | 3.0200 | ppm | 18-Jun-24 | 12:41:19 PM | System Administr | AA |
| 206 | 0.0031 | 19 | 23.5070 | ppm | 18-Jun-24 | 12:41:52 PM | System Administr | AA |
| 207 | 0.0032 | 19 | 150.0115 | ppm | 18-Jun-24 | 12:42:01 PM | System Administra | AA |
| 208 | 0.0032 | 19 | 154.2097 | ppm | 18-Jun-24 | 12:42:10 PM | System Administra | AA |
| 209 | 0.0038 | 19 | 153.3819 | ppm | 18-Jun-24 | 12:42:19 PM | System Administra | AA |
| 210 | 0.0031 | 19 | 157.6539 | ppm | 18-Jun-24 | 12:42:28 PM | System Administra | AA |
| 211 | 0.0033 | 19 | 153.9012 | ppm | 18-Jun-24 | 12:42:01 PM | System Administ | AA |
| 212 | 0.0027 | 20 | 3.4958 | ppm | 18-Jun-24 | 12:42:41 PM | System Administr | AA |
| 213 | 0.0042 | 20 | 11.9430 | ppm | 18-Jun-24 | 12:43:14 PM | System Administr | AA |
| 214 | 0.0033 | 20 | 40.6210 | ppm | 18-Jun-24 | 12:43:26 PM | System Administra | AA |
| 215 | 0.0035 | 20 | 40.6210 | ppm | 18-Jun-24 | 12:43:35 PM | System Administra | AA |
| 216 | 0.0038 | 20 | 41.8147 | ppm | 18-Jun-24 | 12:43:44 PM | System Administra | AA |
| 217 | 0.0040 | 20 | 40.1531 | ppm | 18-Jun-24 | 12:43:53 PM | System Administra | AA |
| 218 | 0.0036 | 20 | 40.7388 | ppm | 18-Jun-24 | 12:43:26 PM | System Administ | AA |
| 219 | 0.0028 | 21 | 2.8099 | ppm | 18-Jun-24 | 12:44:06 PM | System Administr | AA |
| 220 | 0.0039 | 21 | 5.9402 | ppm | 18-Jun-24 | 12:44:38 PM | System Administr | AA |
| 221 | 0.0037 | 21 | 51.6477 | ppm | 18-Jun-24 | 12:44:47 PM | System Administr | AA |
| 222 | 0.0034 | 21 | 57.3096 | ppm | 18-Jun-24 | 12:44:57 PM | System Administra | AA |
| 223 | 0.0033 | 21 | 55.9016 | ppm | 18-Jun-24 | 12:45:06 PM | System Administra | AA |
| 224 | 0.0032 | 21 | 56.7756 | ppm | 18-Jun-24 | 12:45:15 PM | System Administra | AA |
| 225 | 0.0033 | 21 | 56.5992 | ppm | 18-Jun-24 | 12:44:57 PM | System Administ | AA |
| 226 | 0.0033 | 22 | 2.8623 | ppm | 18-Jun-24 | 12:45:27 PM | System Administr | AA |
| 227 | 0.0032 | 22 | 12.6345 | ppm | 18-Jun-24 | 12:46:00 PM | System Administr | AA |
| 228 | 0.0034 | 22 | 119.8501 | ppm | 18-Jun-24 | 12:46:09 PM | System Administra | AA |
| 229 | 0.0030 | 22 | 124.8392 | ppm | 18-Jun-24 | 12:46:19 PM | System Administra | AA |
| 230 | 0.0027 | 22 | 127.5225 | ppm | 18-Jun-24 | 12:46:28 PM | System Administra | AA |
| 231 | 0.0031 | 22 | 124.1936 | ppm | 18-Jun-24 | 12:46:37 PM | System Administra | AA |
| 232 | 0.0030 | 22 | 124.1936 | ppm | 18-Jun-24 | 12:46:09 PM | System Administ | AA |
| 233 | 0.0024 | 23 | 2.6528 | ppm | 18-Jun-24 | 12:49:21 PM | System Administr | AA |
| 234 | 0.0025 | 23 | 2.6528 | ppm | 18-Jun-24 | 12:50:02 PM | System Administr | AA |
| 235 | 0.0020 | 23 | 3.0727 | ppm | 18-Jun-24 | 12:50:11 PM | System Administra | AA |
| 236 | 0.0022 | 23 | 2.7575 | ppm | 18-Jun-24 | 12:50:20 PM | System Administra | AA |
| 237 | 0.0029 | 23 | 2.4962 | ppm | 18-Jun-24 | 12:50:30 PM | System Administra | AA |
| 238 | 0.0034 | 23 | 2.3401 | ppm | 18-Jun-24 | 12:50:39 PM | System Administra | AA |
| 239 | 0.0026 | 23 | 2.6528 | ppm | 18-Jun-24 | 12:50:11 PM | System Administ | AA |
| 240 | 0.0025 | 24 | 2.6006 | ppm | 18-Jun-24 | 12:50:53 PM | System Administr | AA |

Appendix C-11

AAS Results for Lead

Pb

Tuesday, June 18, 2024 4:04:21 PM

| | BG | Pos. | Actual Conc. | Actual Conc. Unit | Date | Time | User Name | Device Name |
|-----|---------------|-----------|---------------|-------------------|------------------|----------------------|------------------------|-------------|
| 241 | 0.0026 | 24 | 3.0727 | ppm | 18-Jun-24 | 12:51:25 PM(| System Administr | AA |
| 242 | 0.0023 | 24 | 3.8153 | ppm | 18-Jun-24 | 12:51:35 PM(| System Administra | AA |
| 243 | 0.0023 | 24 | 3.7086 | ppm | 18-Jun-24 | 12:51:44 PM(| System Administra | AA |
| 244 | 0.0025 | 24 | 3.6021 | ppm | 18-Jun-24 | 12:51:53 PM(| System Administra | AA |
| 245 | 0.0024 | 24 | 3.8153 | ppm | 18-Jun-24 | 12:52:02 PM(| System Administra | AA |
| 246 | 0.0024 | 24 | 3.7086 | ppm | 18-Jun-24 | 12:51:35 PM(| System Administ | AA |
| 247 | 0.0021 | 25 | 2.8099 | ppm | 18-Jun-24 | 12:52:15 PM(| System Administr | AA |
| 248 | 0.0021 | 25 | 2.6528 | ppm | 18-Jun-24 | 12:52:47 PM(| System Administr | AA |
| 249 | 0.0020 | 25 | 4.1905 | ppm | 18-Jun-24 | 12:52:57 PM(| System Administra | AA |
| 250 | 0.0021 | 25 | 4.2443 | ppm | 18-Jun-24 | 12:53:06 PM(| System Administra | AA |
| 251 | 0.0022 | 25 | 4.1368 | ppm | 18-Jun-24 | 12:53:15 PM(| System Administra | AA |
| 252 | 0.0014 | 25 | 4.5684 | ppm | 18-Jun-24 | 12:53:24 PM(| System Administra | AA |
| 253 | 0.0019 | 25 | 4.2982 | ppm | 18-Jun-24 | 12:52:57 PM(| System Administ | AA |
| 254 | 0.0012 | 26 | 3.2309 | ppm | 18-Jun-24 | 12:53:37 PM(| System Administr | AA |
| 255 | 0.0020 | 26 | 2.9148 | ppm | 18-Jun-24 | 12:54:09 PM(| System Administr | AA |
| 256 | 0.0014 | 26 | 3.3367 | ppm | 18-Jun-24 | 12:54:19 PM(| System Administra | AA |
| 257 | 0.0020 | 26 | 3.1254 | ppm | 18-Jun-24 | 12:54:28 PM(| System Administra | AA |
| 258 | 0.0017 | 26 | 3.1781 | ppm | 18-Jun-24 | 12:54:37 PM(| System Administra | AA |
| 259 | 0.0018 | 26 | 3.3367 | ppm | 18-Jun-24 | 12:54:46 PM(| System Administra | AA |
| 260 | 0.0017 | 26 | 3.2309 | ppm | 18-Jun-24 | 12:54:19 PM(| System Administ | AA |
| 261 | 0.0018 | 27 | 3.0200 | ppm | 18-Jun-24 | 12:54:59 PM(| System Administr | AA |
| 262 | 0.0014 | 27 | 4.2443 | ppm | 18-Jun-24 | 12:55:31 PM(| System Administr | AA |
| 263 | 0.0015 | 27 | 8.6199 | ppm | 18-Jun-24 | 12:55:41 PM(| System Administra | AA |
| 264 | 0.0014 | 27 | 8.7371 | ppm | 18-Jun-24 | 12:55:50 PM(| System Administra | AA |
| 265 | 0.0022 | 27 | 8.0960 | ppm | 18-Jun-24 | 12:55:59 PM(| System Administra | AA |
| 266 | 0.0021 | 27 | 8.4447 | ppm | 18-Jun-24 | 12:56:08 PM(| System Administra | AA |
| 267 | 0.0018 | 27 | 8.5031 | ppm | 18-Jun-24 | 12:55:41 PM(| System Administ | AA |
| 268 | 0.0018 | 28 | 3.0200 | ppm | 18-Jun-24 | 12:56:21 PM(| System Administr | AA |
| 269 | 0.0020 | 28 | 3.1781 | ppm | 18-Jun-24 | 12:57:00 PM(| System Administr | AA |
| 270 | 0.0022 | 28 | 3.1254 | ppm | 18-Jun-24 | 12:57:09 PM(| System Administra | AA |
| 271 | 0.0018 | 28 | 3.4427 | ppm | 18-Jun-24 | 12:57:18 PM(| System Administra | AA |
| 272 | 0.0019 | 28 | 3.2838 | ppm | 18-Jun-24 | 12:57:27 PM(| System Administra | AA |
| 273 | 0.0019 | 28 | 3.3367 | ppm | 18-Jun-24 | 12:57:37 PM(| System Administra | AA |
| 274 | 0.0020 | 28 | 3.2838 | ppm | 18-Jun-24 | 12:57:09 PM(| System Administ | AA |
| 275 | 0.0022 | 29 | 2.6006 | ppm | 18-Jun-24 | 12:57:49 PM(| System Administr | AA |
| 276 | 0.0018 | 29 | 2.8623 | ppm | 18-Jun-24 | 12:58:28 PM(| System Administr | AA |
| 277 | 0.0019 | 29 | 4.2982 | ppm | 18-Jun-24 | 12:58:37 PM(| System Administr | AA |
| 278 | 0.0020 | 29 | 4.5684 | ppm | 18-Jun-24 | 12:58:46 PM(| System Administra | AA |
| 279 | 0.0018 | 29 | 5.0035 | ppm | 18-Jun-24 | 12:58:55 PM(| System Administra | AA |
| 280 | 0.0017 | 29 | 5.2224 | ppm | 18-Jun-24 | 12:59:05 PM(| System Administra | AA |
| 281 | 0.0018 | 29 | 4.9489 | ppm | 18-Jun-24 | 12:58:46 PM(| System Administ | AA |
| 282 | 0.0015 | 30 | 3.1781 | ppm | 18-Jun-24 | 12:59:17 PM(| System Administr | AA |
| 283 | 0.0012 | 30 | 3.0200 | ppm | 18-Jun-24 | 12:59:50 PM(| System Administr | AA |
| 284 | 0.0019 | 30 | 3.5489 | ppm | 18-Jun-24 | 12:59:59 PM(| System Administra | AA |
| 285 | 0.0018 | 30 | 3.4958 | ppm | 18-Jun-24 | 1:00:08 PM(+) | System Administra | AA |
| 286 | 0.0019 | 30 | 3.3897 | ppm | 18-Jun-24 | 1:00:17 PM(+) | System Administra | AA |
| 287 | 0.0014 | 30 | 3.8688 | ppm | 18-Jun-24 | 1:00:26 PM(+) | System Administra | AA |
| 288 | 0.0018 | 30 | 3.6021 | ppm | 18-Jun-24 | 12:59:59 PM(| System Administ | AA |
| 289 | 0.0019 | 31 | 3.0200 | ppm | 18-Jun-24 | 1:00:39 PM(+) | System Administr | AA |
| 290 | 0.0013 | 31 | 3.1781 | ppm | 18-Jun-24 | 1:01:12 PM(+) | System Administr | AA |
| 291 | 0.0012 | 31 | 4.2443 | ppm | 18-Jun-24 | 1:01:21 PM(+) | System Administra | AA |
| 292 | 0.0016 | 31 | 4.0294 | ppm | 18-Jun-24 | 1:01:30 PM(+) | System Administra | AA |
| 293 | 0.0011 | 31 | 4.2443 | ppm | 18-Jun-24 | 1:01:39 PM(+) | System Administra | AA |
| 294 | 0.0012 | 31 | 4.2982 | ppm | 18-Jun-24 | 1:01:48 PM(+) | System Administra | AA |
| 295 | 0.0013 | 31 | 4.1905 | ppm | 18-Jun-24 | 1:01:21 PM(+) | System Administ | AA |
| 296 | 0.0011 | 32 | 3.4958 | ppm | 18-Jun-24 | 1:02:01 PM(+) | System Administr | AA |
| 297 | 0.0018 | 32 | 3.0727 | ppm | 18-Jun-24 | 1:02:34 PM(+) | System Administr | AA |
| 298 | 0.0013 | 32 | 11.0764 | ppm | 18-Jun-24 | 1:02:43 PM(+) | System Administra | AA |
| 299 | 0.0013 | 32 | 11.8806 | ppm | 18-Jun-24 | 1:02:52 PM(+) | System Administra | AA |
| 300 | 0.0022 | 32 | 11.3225 | ppm | 18-Jun-24 | 1:03:01 PM(+) | System Administra | AA |

C:\Users\user\Desktop\kibet\pb in water VICTOR MERU UNI.a

Appendix C-12

AAS Results for Lead

Pb

Tuesday, June 18, 2024 4:04:21 PM

| | Action | Sample ID | X | True Value (ppm) | Conc. (ppm) | Abs. |
|-----|-----------------|-----------------------------|---|------------------|---------------|---------------|
| 241 | UNK19-2 | carwash activated | X | | 3.0727 | 0.0060 |
| 242 | UNK19-3 | carwash activated | | | 3.8153 | 0.0074 |
| 243 | UNK19-4 | carwash activated | | | 3.7086 | 0.0072 |
| 244 | UNK19-5 | carwash activated | | | 3.6021 | 0.0070 |
| 245 | UNK19-6 | carwash activated | | | 3.8153 | 0.0074 |
| 246 | UNK19-AV | carwash activated | | | 3.7086 | 0.0072 |
| 247 | UNK20-1 | carwash activated 1 | X | | 2.8099 | 0.0055 |
| 248 | UNK20-2 | carwash activated 1 | X | | 2.6528 | 0.0052 |
| 249 | UNK20-3 | carwash activated 1 | | | 4.1905 | 0.0081 |
| 250 | UNK20-4 | carwash activated 1 | | | 4.2443 | 0.0082 |
| 251 | UNK20-5 | carwash activated 1 | | | 4.1368 | 0.0080 |
| 252 | UNK20-6 | carwash activated 1 | | | 4.5684 | 0.0088 |
| 253 | UNK20-AV | carwash activated 1 | | | 4.2982 | 0.0083 |
| 254 | UNK21-1 | bathroom activated 3 | X | | 3.2309 | 0.0063 |
| 255 | UNK21-2 | bathroom activated 3 | X | | 2.9148 | 0.0057 |
| 256 | UNK21-3 | bathroom activated 3 | | | 3.3367 | 0.0065 |
| 257 | UNK21-4 | bathroom activated 3 | | | 3.1254 | 0.0061 |
| 258 | UNK21-5 | bathroom activated 3 | | | 3.1781 | 0.0062 |
| 259 | UNK21-6 | bathroom activated 3 | | | 3.3367 | 0.0065 |
| 260 | UNK21-AV | bathroom activated 3 | | | 3.2309 | 0.0063 |
| 261 | UNK22-1 | bathroom activated 1 | X | | 3.0200 | 0.0059 |
| 262 | UNK22-2 | bathroom activated 1 | X | | 4.2443 | 0.0082 |
| 263 | UNK22-3 | bathroom activated 1 | | | 8.6199 | 0.0160 |
| 264 | UNK22-4 | bathroom activated 1 | | | 8.7371 | 0.0162 |
| 265 | UNK22-5 | bathroom activated 1 | | | 8.0960 | 0.0151 |
| 266 | UNK22-6 | bathroom activated 1 | | | 8.4447 | 0.0157 |
| 267 | UNK22-AV | bathroom activated 1 | | | 8.5031 | 0.0158 |
| 268 | UNK23-1 | bathroom activated | X | | 3.0200 | 0.0059 |
| 269 | UNK23-2 | bathroom activated | X | | 3.1781 | 0.0062 |
| 270 | UNK23-3 | bathroom activated | | | 3.1254 | 0.0061 |
| 271 | UNK23-4 | bathroom activated | | | 3.4427 | 0.0067 |
| 272 | UNK23-5 | bathroom activated | | | 3.2838 | 0.0064 |
| 273 | UNK23-6 | bathroom activated | | | 3.3367 | 0.0065 |
| 274 | UNK23-AV | bathroom activated | | | 3.2838 | 0.0064 |
| 275 | UNK24-1 | kitchen acti 3 | X | | 2.6006 | 0.0051 |
| 276 | UNK24-2 | kitchen acti 3 | X | | 2.8623 | 0.0056 |
| 277 | UNK24-3 | kitchen acti 3 | X | | 4.2982 | 0.0083 |
| 278 | UNK24-4 | kitchen acti 3 | | | 4.5684 | 0.0088 |
| 279 | UNK24-5 | kitchen acti 3 | | | 5.0035 | 0.0096 |
| 280 | UNK24-6 | kitchen acti 3 | | | 5.2224 | 0.0100 |
| 281 | UNK24-AV | kitchen acti 3 | | | 4.9489 | 0.0095 |
| 282 | UNK25-1 | kitchen acti 2 | X | | 3.1781 | 0.0062 |
| 283 | UNK25-2 | kitchen acti 2 | X | | 3.0200 | 0.0059 |
| 284 | UNK25-3 | kitchen acti 2 | | | 3.5489 | 0.0069 |
| 285 | UNK25-4 | kitchen acti 2 | | | 3.4958 | 0.0068 |
| 286 | UNK25-5 | kitchen acti 2 | | | 3.3897 | 0.0066 |
| 287 | UNK25-6 | kitchen acti 2 | | | 3.8688 | 0.0075 |
| 288 | UNK25-AV | kitchen acti 2 | | | 3.6021 | 0.0070 |
| 289 | UNK26-1 | kitchen act 1 | X | | 3.0200 | 0.0059 |
| 290 | UNK26-2 | kitchen act 1 | X | | 3.1781 | 0.0062 |
| 291 | UNK26-3 | kitchen act 1 | | | 4.2443 | 0.0082 |
| 292 | UNK26-4 | kitchen act 1 | | | 4.0294 | 0.0078 |
| 293 | UNK26-5 | kitchen act 1 | | | 4.2443 | 0.0082 |
| 294 | UNK26-6 | kitchen act 1 | | | 4.2982 | 0.0083 |
| 295 | UNK26-AV | kitchen act 1 | | | 4.1905 | 0.0081 |
| 296 | UNK27-1 | carwash in acti 1 | X | | 3.4958 | 0.0068 |
| 297 | UNK27-2 | carwash in acti 1 | X | | 3.0727 | 0.0060 |
| 298 | UNK27-3 | carwash in acti 1 | | | 11.0764 | 0.0201 |
| 299 | UNK27-4 | carwash in acti 1 | | | 11.8806 | 0.0214 |
| 300 | UNK27-5 | carwash in acti 1 | | | 11.3225 | 0.0205 |

Appendix C-13

AAS Results for Lead

Pb

Tuesday, June 18, 2024 4:04:21 PM

| | BG | Pos. | Actual Conc. | Actual Conc. Unit | Date | Time | User Name | Device Name |
|-----|---------------|-----------|-----------------|-------------------|------------------|----------------------|------------------------|-------------|
| 301 | 0.0018 | 32 | 11.3842 | ppm | 18-Jun-24 | 1:03:11 PM(+) | System Administra | AA |
| 302 | 0.0016 | 32 | 11.3842 | ppm | 18-Jun-24 | 1:02:43 PM(+) | System Administ | AA |
| 303 | 0.0017 | 33 | 3.7619 | ppm | 18-Jun-24 | 1:03:23 PM(+) | System Administr | AA |
| 304 | 0.0020 | 33 | 3.2309 | ppm | 18-Jun-24 | 1:03:56 PM(+) | System Administr | AA |
| 305 | 0.0016 | 33 | 9.8035 | ppm | 18-Jun-24 | 1:04:05 PM(+) | System Administra | AA |
| 306 | 0.0013 | 33 | 10.7705 | ppm | 18-Jun-24 | 1:04:14 PM(+) | System Administra | AA |
| 307 | 0.0011 | 33 | 11.2609 | ppm | 18-Jun-24 | 1:04:24 PM(+) | System Administra | AA |
| 308 | 0.0026 | 33 | 9.7437 | ppm | 18-Jun-24 | 1:04:33 PM(+) | System Administra | AA |
| 309 | 0.0016 | 33 | 10.4057 | ppm | 18-Jun-24 | 1:04:05 PM(+) | System Administ | AA |
| 310 | 0.0014 | 34 | 4.7311 | ppm | 18-Jun-24 | 1:04:45 PM(+) | System Administr | AA |
| 311 | 0.0021 | 34 | 3.1781 | ppm | 18-Jun-24 | 1:05:18 PM(+) | System Administr | AA |
| 312 | 0.0023 | 34 | 26.5402 | ppm | 18-Jun-24 | 1:05:27 PM(+) | System Administra | AA |
| 313 | 0.0031 | 34 | 28.8003 | ppm | 18-Jun-24 | 1:05:37 PM(+) | System Administra | AA |
| 314 | 0.0024 | 34 | 30.3425 | ppm | 18-Jun-24 | 1:05:46 PM(+) | System Administra | AA |
| 315 | 0.0020 | 34 | 31.0875 | ppm | 18-Jun-24 | 1:05:55 PM(+) | System Administra | AA |
| 316 | 0.0024 | 34 | 29.1583 | ppm | 18-Jun-24 | 1:05:27 PM(+) | System Administ | AA |
| 317 | 0.0015 | 35 | 5.9402 | ppm | 18-Jun-24 | 1:06:07 PM(+) | System Administr | AA |
| 318 | 0.0013 | 35 | 3.5489 | ppm | 18-Jun-24 | 1:06:40 PM(+) | System Administr | AA |
| 319 | 0.0022 | 35 | 124.1936 | ppm | 18-Jun-24 | 1:06:50 PM(+) | System Administra | AA |
| 320 | 0.0024 | 35 | 138.8778 | ppm | 18-Jun-24 | 1:06:59 PM(+) | System Administra | AA |
| 321 | 0.0021 | 35 | 147.0787 | ppm | 18-Jun-24 | 1:07:08 PM(+) | System Administra | AA |
| 322 | 0.0021 | 35 | 146.9569 | ppm | 18-Jun-24 | 1:07:17 PM(+) | System Administra | AA |
| 323 | 0.0022 | 35 | 140.3434 | ppm | 18-Jun-24 | 1:06:50 PM(+) | System Administ | AA |
| 324 | 0.0018 | 36 | 13.2075 | ppm | 18-Jun-24 | 1:07:30 PM(+) | System Administr | AA |
| 325 | 0.0013 | 36 | 4.5142 | ppm | 18-Jun-24 | 1:08:03 PM(+) | System Administr | AA |
| 326 | 0.0012 | 36 | 23.2696 | ppm | 18-Jun-24 | 1:08:12 PM(+) | System Administra | AA |
| 327 | 0.0014 | 36 | 22.0237 | ppm | 18-Jun-24 | 1:08:21 PM(+) | System Administra | AA |
| 328 | 0.0014 | 36 | 24.7940 | ppm | 18-Jun-24 | 1:08:30 PM(+) | System Administra | AA |
| 329 | 0.0011 | 36 | 24.7125 | ppm | 18-Jun-24 | 1:08:39 PM(+) | System Administra | AA |
| 330 | 0.0013 | 36 | 23.6659 | ppm | 18-Jun-24 | 1:08:12 PM(+) | System Administ | AA |
| 331 | 0.0020 | 37 | 8.6199 | ppm | 18-Jun-24 | 1:08:52 PM(+) | System Administr | AA |
| 332 | 0.0013 | 37 | 3.8153 | ppm | 18-Jun-24 | 1:09:25 PM(+) | System Administr | AA |
| 333 | 0.0018 | 37 | 57.1308 | ppm | 18-Jun-24 | 1:09:34 PM(+) | System Administra | AA |
| 334 | 0.0017 | 37 | 60.6763 | ppm | 18-Jun-24 | 1:09:43 PM(+) | System Administra | AA |
| 335 | 0.0018 | 37 | 63.9312 | ppm | 18-Jun-24 | 1:09:52 PM(+) | System Administra | AA |
| 336 | 0.0014 | 37 | 64.7882 | ppm | 18-Jun-24 | 1:10:02 PM(+) | System Administra | AA |
| 337 | 0.0017 | 37 | 61.4653 | ppm | 18-Jun-24 | 1:09:34 PM(+) | System Administ | AA |
| 338 | 0.0020 | 38 | 9.3268 | ppm | 18-Jun-24 | 1:10:14 PM(+) | System Administr | AA |
| 339 | 0.0012 | 38 | 4.2982 | ppm | 18-Jun-24 | 1:10:47 PM(+) | System Administr | AA |
| 340 | 0.0018 | 38 | 6.9503 | ppm | 18-Jun-24 | 1:10:57 PM(+) | System Administra | AA |
| 341 | 0.0011 | 38 | 7.5774 | ppm | 18-Jun-24 | 1:11:06 PM(+) | System Administra | AA |
| 342 | 0.0018 | 38 | 7.2914 | ppm | 18-Jun-24 | 1:11:15 PM(+) | System Administra | AA |
| 343 | 0.0015 | 38 | 7.3485 | ppm | 18-Jun-24 | 1:11:25 PM(+) | System Administra | AA |
| 344 | 0.0016 | 38 | 7.2914 | ppm | 18-Jun-24 | 1:10:57 PM(+) | System Administ | AA |
| 345 | 0.0018 | 39 | 4.2982 | ppm | 18-Jun-24 | 1:11:37 PM(+) | System Administr | AA |
| 346 | 0.0012 | 39 | 3.7086 | ppm | 18-Jun-24 | 1:12:10 PM(+) | System Administr | AA |
| 347 | 0.0019 | 39 | 7.1775 | ppm | 18-Jun-24 | 1:12:19 PM(+) | System Administra | AA |
| 348 | 0.0016 | 39 | 7.6347 | ppm | 18-Jun-24 | 1:12:28 PM(+) | System Administra | AA |
| 349 | 0.0019 | 39 | 7.4628 | ppm | 18-Jun-24 | 1:12:38 PM(+) | System Administra | AA |
| 350 | 0.0020 | 39 | 7.5774 | ppm | 18-Jun-24 | 1:12:47 PM(+) | System Administra | AA |
| 351 | 0.0018 | 39 | 7.4628 | ppm | 18-Jun-24 | 1:12:19 PM(+) | System Administ | AA |
| 352 | 0.0016 | 40 | 4.6768 | ppm | 18-Jun-24 | 1:12:59 PM(+) | System Administra | AA |
| 353 | 0.0018 | 40 | 3.2838 | ppm | 18-Jun-24 | 1:13:32 PM(+) | System Administra | AA |
| 354 | 0.0013 | 40 | 3.9223 | ppm | 18-Jun-24 | 1:13:41 PM(+) | System Administra | AA |
| 355 | 0.0012 | 40 | 3.9223 | ppm | 18-Jun-24 | 1:13:51 PM(+) | System Administra | AA |
| 356 | 0.0018 | 40 | 3.7619 | ppm | 18-Jun-24 | 1:14:00 PM(+) | System Administra | AA |
| 357 | 0.0012 | 40 | 3.9758 | ppm | 18-Jun-24 | 1:14:09 PM(+) | System Administra | AA |
| 358 | 0.0015 | 40 | 3.9223 | ppm | 18-Jun-24 | 1:12:59 PM(+) | System Administ | AA |
| 359 | 0.0015 | 2 | | | 18-Jun-24 | 1:16:52 PM(+) | System Administr | AA |
| 360 | 0.0021 | 2 | | | 18-Jun-24 | 1:17:26 PM(+) | System Administr | AA |

Appendix C-14

AAS Results for Lead

Pb

Tuesday, June 18, 2024 4:04:21 PM

| Action | Sample ID | X | True Value (ppm) | Conc. (ppm) | Abs. |
|--------------|-------------------|---|------------------|-------------|--------|
| 301 UNK27-6 | carwash in acti 1 | | | 11.3842 | 0.0206 |
| 302 UNK27-AV | carwash in acti 1 | | | 11.3842 | 0.0206 |
| 303 UNK28-1 | carwash inacti 3 | X | | 3.7619 | 0.0073 |
| 304 UNK28-2 | carwash inacti 3 | X | | 3.2309 | 0.0063 |
| 305 UNK28-3 | carwash inacti 3 | | | 9.8035 | 0.0180 |
| 306 UNK28-4 | carwash inacti 3 | | | 10.7705 | 0.0196 |
| 307 UNK28-5 | carwash inacti 3 | | | 11.2609 | 0.0204 |
| 308 UNK28-6 | carwash inacti 3 | | | 9.7437 | 0.0179 |
| 309 UNK28-AV | carwash inacti 3 | | | 10.4057 | 0.0190 |
| 310 UNK29-1 | carwash inacti 2 | X | | 4.7311 | 0.0091 |
| 311 UNK29-2 | carwash inacti 2 | X | | 3.1781 | 0.0062 |
| 312 UNK29-3 | carwash inacti 2 | | | 26.5402 | 0.0417 |
| 313 UNK29-4 | carwash inacti 2 | | | 28.8003 | 0.0443 |
| 314 UNK29-5 | carwash inacti 2 | | | 30.3425 | 0.0460 |
| 315 UNK29-6 | carwash inacti 2 | | | 31.0875 | 0.0468 |
| 316 UNK29-AV | carwash inacti 2 | | | 29.1583 | 0.0447 |
| 317 UNK30-1 | bathroom inacti 2 | X | | 5.9402 | 0.0113 |
| 318 UNK30-2 | bathroom inacti 2 | X | | 3.5489 | 0.0069 |
| 319 UNK30-3 | bathroom inacti 2 | | | 124.1936 | 0.0920 |
| 320 UNK30-4 | bathroom inacti 2 | | | 138.8778 | 0.1002 |
| 321 UNK30-5 | bathroom inacti 2 | | | 147.0787 | 0.1063 |
| 322 UNK30-6 | bathroom inacti 2 | | | 146.9569 | 0.1062 |
| 323 UNK30-AV | bathroom inacti 2 | | | 140.3434 | 0.1012 |
| 324 UNK31-1 | bathroom inacti 1 | X | | 13.2075 | 0.0235 |
| 325 UNK31-2 | bathroom inacti 1 | X | | 4.5142 | 0.0087 |
| 326 UNK31-3 | bathroom inacti 1 | | | 23.2696 | 0.0377 |
| 327 UNK31-4 | bathroom inacti 1 | | | 22.0237 | 0.0361 |
| 328 UNK31-5 | bathroom inacti 1 | | | 24.7940 | 0.0396 |
| 329 UNK31-6 | bathroom inacti 1 | | | 24.7125 | 0.0395 |
| 330 UNK31-AV | bathroom inacti 1 | | | 23.6659 | 0.0382 |
| 331 UNK32-1 | bathroom inacti3 | X | | 8.6199 | 0.0160 |
| 332 UNK32-2 | bathroom inacti3 | X | | 3.8153 | 0.0074 |
| 333 UNK32-3 | bathroom inacti3 | | | 57.1308 | 0.0674 |
| 334 UNK32-4 | bathroom inacti3 | | | 60.6763 | 0.0693 |
| 335 UNK32-5 | bathroom inacti3 | | | 63.9312 | 0.0709 |
| 336 UNK32-6 | bathroom inacti3 | | | 64.7882 | 0.0713 |
| 337 UNK32-AV | bathroom inacti3 | | | 61.4653 | 0.0697 |
| 338 UNK33-1 | kitchen inacti3 | X | | 9.3268 | 0.0172 |
| 339 UNK33-2 | kitchen inacti3 | X | | 4.2982 | 0.0083 |
| 340 UNK33-3 | kitchen inacti3 | | | 6.9503 | 0.0131 |
| 341 UNK33-4 | kitchen inacti3 | | | 7.5774 | 0.0142 |
| 342 UNK33-5 | kitchen inacti3 | | | 7.2914 | 0.0137 |
| 343 UNK33-6 | kitchen inacti3 | | | 7.3485 | 0.0138 |
| 344 UNK33-AV | kitchen inacti3 | | | 7.2914 | 0.0137 |
| 345 UNK34-1 | kitchen inacti 1 | X | | 4.2982 | 0.0083 |
| 346 UNK34-2 | kitchen inacti 1 | X | | 3.7086 | 0.0072 |
| 347 UNK34-3 | kitchen inacti 1 | | | 7.1775 | 0.0135 |
| 348 UNK34-4 | kitchen inacti 1 | | | 7.6347 | 0.0143 |
| 349 UNK34-5 | kitchen inacti 1 | | | 7.4628 | 0.0140 |
| 350 UNK34-6 | kitchen inacti 1 | | | 7.5774 | 0.0142 |
| 351 UNK34-AV | kitchen inacti 1 | | | 7.4628 | 0.0140 |
| 352 UNK35-1 | kitchen inacti 3 | | | 4.6768 | 0.0090 |
| 353 UNK35-2 | kitchen inacti 3 | | | 3.2838 | 0.0064 |
| 354 UNK35-3 | kitchen inacti 3 | | | 3.9223 | 0.0076 |
| 355 UNK35-4 | kitchen inacti 3 | | | 3.9223 | 0.0076 |
| 356 UNK35-5 | kitchen inacti 3 | | | 3.7619 | 0.0073 |
| 357 UNK35-6 | kitchen inacti 3 | | | 3.9758 | 0.0077 |
| 358 UNK35-AV | kitchen inacti 3 | | | 3.9223 | 0.0076 |
| 359 STD-1 | | X | 10.0000 | 3.6553 | 0.0071 |
| 360 STD-2 | | X | 10.0000 | 3.2309 | 0.0063 |

C:\Users\user\Desktop\kibet\pb in water VICTOR MERU UNL.aa

Appendix D: Characterization of Biochar

Appendix D-1

Characterization of Activated Biochar

| | | |
|-----------------------|--------------------------------|------------------|
| 01266- GeoChem.pdz | AssayTime: 18/06/2024 16:30:58 | Elapsed Time: 50 |
|-----------------------|--------------------------------|------------------|

| | | | |
|---------------|------------|-------------|--------|
| Field | SUPERVISOR | SAMPLE TYPE | POWDER |
| Info OPERATOR | | | |
| SENDER NAME | VICTOR | LAB No | |
| SENDER REF | ACTIVATED | | |

| Element Name | Min | % | Max | +/- [*3] |
|--------------------------------|-----|--------|-----|----------|
| MgO | 0 | 0.000 | 0 | 1.328 |
| Al ₂ O ₃ | 0 | 21.842 | 0 | 0.256 |
| SiO ₂ | 0 | 0.000 | 0 | 0.157 |
| P ₂ O ₅ | 0 | 7.370 | 0 | 0.050 |
| S | 0 | 0.000 | 0 | 0.043 |
| Cl | 0 | 52.643 | 0 | 0.001 |
| K ₂ O | 0 | 0.000 | 0 | 0.011 |
| CaO | 0 | 0.000 | 0 | 0.012 |
| Ti | 0 | 1.035 | 0 | 0.008 |
| V | 0 | 0.000 | 0 | 0.007 |
| Cr | 0 | 0.000 | 0 | 0.005 |
| Mn | 0 | 0.000 | 0 | 0.004 |

| | | | | |
|----|---|-------|---|-------|
| Fe | 0 | 4.473 | 0 | 0.006 |
| Co | 0 | 0.000 | 0 | 0.003 |
| Ni | 0 | 0.038 | 0 | 0.004 |
| Cu | 0 | 0.000 | 0 | 0.003 |
| Zn | 0 | 0.000 | 0 | 0.001 |
| As | 0 | 0.000 | 0 | 0.002 |
| Se | 0 | 0.000 | 0 | 0.002 |
| Rb | 0 | 0.013 | 0 | 0.002 |
| Sr | 0 | 0.000 | 0 | 0.003 |
| Y | 0 | 0.000 | 0 | 0.002 |
| Zr | 0 | 0.000 | 0 | 0.002 |
| Nb | 0 | 0.000 | 0 | 0.004 |
| Mo | 0 | 0.000 | 0 | 0.004 |

Appendix D-2

Characterisation of Activated Biochar

| | | |
|-------------------|--------------------------------|------------------|
| 01266-GeoChem.pdz | AssayTime: 18/06/2024 16:30:58 | Elapsed Time: 50 |
|-------------------|--------------------------------|------------------|

| | | | |
|---------------------|------------|-------------|--------|
| Field Info OPERATOR | SUPERVISOR | SAMPLE TYPE | POWDER |
| SENDER NAME | VICTOR | LAB No | |
| SENDER REF | ACTIVATED | | |






| Element Name | Min | % | Max | +/- [*3] |
|--------------|-----|--------|-----|----------|
| Rh | 0 | 0.000 | 0 | 0.002 |
| Pd | 0 | 0.000 | 0 | 0.004 |
| Ag | 0 | 0.000 | 0 | 0.004 |
| Cd | 0 | 0.000 | 0 | 0.009 |
| Sn | 0 | 0.000 | 0 | 0.055 |
| Sb | 0 | 0.000 | 0 | 0.011 |
| Ba | 0 | 0.000 | 0 | 0.032 |
| La | 0 | 0.000 | 0 | 0.102 |
| Ce | 0 | 12.586 | 0 | 0.049 |
| Hf | 0 | 0.000 | 0 | 0.005 |
| Ta | 0 | 0.000 | 0 | 0.004 |
| W | 0 | 0.000 | 0 | 0.003 |
| Pt | 0 | 0.000 | 0 | 0.002 |
| Hg | 0 | 0.000 | 0 | 0.000 |
| Tl | 0 | 0.000 | 0 | 0.000 |
| Pb | 0 | 0.000 | 0 | 0.009 |
| Bi | 0 | 0.000 | 0 | 0.008 |
| Th | 0 | 0.000 | 0 | 0.009 |

Appendix D-3

Characterisation of Inactivated Biochar

| Element Name | Min | % | Max | +/- [*2] |
|---------------------|------------|----------|------------|-----------------|
| Si | 1.75 | 6.292 | 2.25 | 0.466 |
| P | 0 | 0.014 | 0.03 | 0.037 |
| S | 0 | 0.397 | 0.03 | 0.078 |
| V | 0 | 0.000 | 0.35 | 0.064 |
| Cr | 0 | 0.067 | 0.35 | 0.057 |
| Mn | 0.6 | 0.591 | 1 | 0.081 |
| Fe | 89 | 83.947 | 98 | 0.666 |
| Mo | 0.2 | 0.000 | 1.35 | 0.011 |
| Mg | 0 | 0.000 | 0 | 0.989 |
| Al | 0 | 1.248 | 0 | 0.437 |
| Ti | 0 | 4.972 | 0 | 0.297 |
| Co | 0 | 1.513 | 0 | 0.154 |
| Ni | 0 | 0.000 | 0 | 0.035 |
| Cu | 0 | 0.000 | 0 | 0.013 |
| Zn | 0 | 0.504 | 0 | 0.036 |
| As | 0 | 0.000 | 0 | 0.062 |
| Y | 0 | 0.000 | 0 | 0.014 |
| Zr | 0 | 0.000 | 0 | 0.014 |
| Nb | 0 | 0.000 | 0 | 0.013 |
| Pd | 0 | 0.000 | 0 | 0.098 |
| Ag | 0 | 0.000 | 0 | 0.077 |
| Cd | 0 | 0.000 | 0 | 0.097 |
| Sn | 0 | 0.000 | 0 | 0.195 |
| Sb | 0 | 0.000 | 0 | 0.279 |

Appendix E : Research Permit

| | |
|--|--|
|  REPUBLIC OF KENYA |  NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION |
| Ref No: 777807 | Date of Issue: 04/July/2024 |
| RESEARCH LICENSE | |
|  | |
| <p>This is to Certify that Mr. VICTOR MUGAMBI of Meru University of Science and Technology, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Meru on the topic: EFFECTIVENESS OF SUGARCANE WASTE BIOCHAR IN THE PURIFICATION OF GREYWATER for the period ending : 04/July/2025.</p> | |
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Appendix F: Plagiarism Report

