

**PERFORMANCE OF GREEN SILVER NANO PARTICLES USING
Psidium guajava LEAVES FOR ADSORPTION OF LEAD FROM WATER**

BY

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DECLARATION

I, Josephine Kihumuro, hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person, institution and organization nor material which has been accepted for the award of any other degree of the University or other institution of higher learning, except where due acknowledgement has been made in the text and reference list.

Signed: Date:

APPROVAL

The undersigned approve that they have read and hereby recommend for submission to the Directorate of Research and Graduate Training of Kyambogo University, a dissertation titled: “Performance of green silver nano particles using *Psidium guajava* leaves for adsorption of lead from water” in partial fulfilment of the requirements for the award of Master of Science in Water and Sanitation Engineering Degree of Kyambogo University

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DEDICATION

I dedicate this dissertation to my loving husband, Mr. Eng. Asimwe Arnold and to our children Devine, Justice, Chloe and Cruz.

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I wish to extend my genuine appreciation to God for the grace, knowledge and wisdom He provided during this research. Secondly, I appreciate Dr. Charles Onyutha, whose ability, mentorship, and resolute consolation have been critical in shaping this study. I am likewise profoundly appreciative to Dr. Hellen Aluku for her helpful suggestions and insightful feedback that significantly enhanced the dissertation content.

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LIST OF ACRONOMYS, ABBREVIATIONS/ SYMBOLS

| | |
|---------|--|
| AgNPs | Silver Nano particles |
| BET | Brunauer-Emmett-Teller |
| BOD | Biochemical Oxygen Demand |
| COD | Chemical Oxygen Demand |
| DPPH | 2,2-Diphenyl-1-picrylhydrazyl |
| EPA | Environmental Protection Agency |
| FTIR | Fourier Transform Infrared Spectroscopy |
| GC-MS | Gas Chromatography-Mass Spectrometry |
| HM | Heavy Metal |
| HPLC | High-Performance Liquid Chromatography |
| ICP-OES | Inductively Coupled Plasma Optical Emission Spectroscopy |
| ISO | International Organization for Standardization |
| MIC | Minimum Inhibitory Concentration |
| MoLH&UD | Ministry of Lands, Housing and Urban Development |
| SDA | Sabouraud Dextrose Agar |
| SEM | Scanning Electron Microscopy |
| TDS | Total Dissolved Solids |

| | |
|-----|----------------------------------|
| TEM | Transmission Electron Microscopy |
| WHO | World Health Organization |
| WTP | Water Treatment Plant |
| XRD | X-ray Diffraction |

ABSTRACT

This research examined the effectiveness of green silver nanoparticles (AgNPs) produced from aqueous extracts of three varieties of *Psidium guajava* leaves (white, orange, and red fruit mesocarp) in adsorbing lead (Pb^{2+}) ions from contaminated water. The study assessed antioxidant activity, characterised nanoparticles, and analysed adsorption performance across different dosages (0.1–1.0 g) and contact durations (5–25 minutes). White guava extract demonstrated the highest antioxidant activity, achieving 83.85% 2,2-Diphenyl-1-picrylhydrazyl (DPPH) scavenging. Additionally, AgNPs from all varieties displayed spherical morphology as observed through Scanning Electron Microscope (SEM), with white guava derived AgNPs exhibiting uniform distribution of the NPs in the matrix. Adsorption experiments demonstrated a maximum Pb^{2+} removal efficiency of 83.16% at a dosage of 0.6 g and a contact time of 20 minutes for white guava AgNPs, while orange and red had 81.53 and 78.35 % respectively. Clay filters infused with AgNPs demonstrated a Pb^{2+} removal efficiency of 99.59% (composite filter), surpassing the performance of unmodified clay, which achieved 91.62% removal. The research findings indicate that white guava derived AgNPs possess significant antioxidant capacity and adsorption affinity, presenting a viable approach for heavy metal remediation, with prospective applications in point-of-use water treatment technologies. It is recommended to optimise the ratios of hybrid nanoparticles and conduct field validation in real-world conditions.

Key words: Lead ions removal; silver nanoparticles; guava genotypes.

CHAPTER ONE

INTRODUCTION

1.1 Background

Heavy metal (HM) water contamination is a global human health risk. The availability and quality of water resources have been profoundly dependant on the human activities and the world faces water supply problems and drinking water quality problems (Fernández-luqueño *et al.*, 2013). Drinking water contaminated with heavy metals like arsenic, cadmium, nickel, mercury, chromium, zinc, and lead are becoming a major public health concern because they non-biodegradable and accumulates in living tissues and causes various disorders and diseases through food chain (Fernández-luqueño *et al.*, 2013). Occupational exposure for heavy metals is through utilization of these metals in various industrial processes (Rehman *et al.*, 2018). There is also evidence of heavy metals in drinking water causing adverse effect on human health through food chain contamination (Sankhla *et al.*, 2016) a problem that should be addressed.

The Uganda Geological Survey and the Ministry of Energy and Mineral Development have identified various minerals throughout the country, including heavy metals such as gold, lead, and mercury (Nagudi, 2011). These metals are present in various ores of copper, tin, cobalt, and limestone. Presently, numerous legal and illegal mines are distributed throughout the country (Moono, 2021)

Mining in Uganda dates back to the pre-colonial era. Most traditional communities used to mine, process and smelt mineral ore for example iron ore, kaolin and clay

(MEMD, 2018). Typical mines containing heavy metals include tin in Kabale and gold in Busia, Karamoja, and Mubende (Omara *et al.* , 2019). Abraham and his colleagues discovered that the toenails of residents near Kilembe mine exhibited concentrations of copper (Cu), cobalt (Co), and nickel (Ni) that were significantly higher than the average Cu levels found in the toenails of individuals living outside the Kilembe mine vicinity, indicating exposure to these toxic metals (Abraham & Susan, 2017). There are inadequate methods for managing waste from various mines. Mining waste contaminates arable agricultural land and multiple water sources (Hajam *et al.* , 2023)

Individuals residing near mines tend to be exposed to heavy metals via the utilisation of contaminated surface and groundwater sources for domestic purposes, including drinking, cooking, and washing (Geremias & Masuhara, 2025). The extensive pollution of water resources with heavy metals like lead (Pb) and cadmium (Cd) constitutes an escalating environmental crisis, presenting considerable threats to human health and ecosystem integrity (Jagaba *et al.* , 2024).

The establishment of factories and industries is on the increase in the various parts of Uganda (MoLH&UD, 2022). Certain byproducts from factories and industries contain heavy metals (Swain, 2024). Industrial and factory effluents in urban areas contaminate water bodies, including streams, rivers, lakes, and swamps. The effluent is identified to contain heavy metals including lead (Pb), mercury (Hg), cadmium (Cd), and Copper (Cu) (Walakira & Okot-Okumu, 2011).

Consequently, it is important to treat contaminated water to enhance its quality before drinking and usage. This is in line with the United Nations Sustainable

Development Goals (SDGs), specifically SDG 6, which highlights the necessity for clean water and sanitation, and SDG 15, which concentrates on the sustainable utilisation of terrestrial ecosystems (Services *et al.* , 2022).

Plant extracts have been utilised in the synthesis of silver nanoparticles (Mashwani *et al.* , 2015) attributed to the presence of antioxidant phytochemicals in the extracts .The presence and concentration of these substances in plants differ by species and geographical location (Singh *et al.* , 2016).

The studies (Jagaba *et al.* , 2024) highlight Guava leaves have effective and eco-friendly adsorbent for heavy metals in water, showcasing their potential to address environmental challenges associated with metal pollution. *Psidium guajava* leaves were used because of their phytochemical substances (Mohapatra *et al.* , 2024) that is flavonoids, phenolics and terpenoids that act as stabilisers and reducing agents (Albadawi *et al.* , 2024) in the formation of nanoparticles. Despite the advancements in green nanotechnology and specifically use of guava leaves in the synthesis green silver nanoparticles (AgNPs), there is a knowledge gap in the performance of different varieties of *Psidium guajava* for the synthesis of silver nanoparticles (AgNPs) and their ability to eliminate heavy metals. Consequently, the study aimed at addressing this knowledge gap by investigating lead adsorption in contaminated water by green silver Nanoparticles using *Psidium guajava* leaves synthesized from and has not been utilised for the synthesis of silver nanoparticles (Mohapatra *et al.* , 2024). To confirm nanomaterials, techniques such as X-Ray Diffraction (XRD), Scanning Electron Microscope (SEM), and Fourier Transform Infrared Spectroscopy (FTIR) are employed (Abood & TYAl-Abdullah, 2022),

(Al-Senani & Al-Kadhi, 2020) and thus utilised in the characterisation of the nanoparticles employing green silver nanoparticles derived from *Psidium leaves*.

1.2 Statement of the problem

Heavy metals in water present a potential threat to environmental integrity and human health via the ingestion and use of contaminated water. New visions of 8th March 2024 reported that 28% of Ugandan drinking water points are contaminated with lead. Exposure to lead, even at minimal concentrations, results in various health issues, including cognitive impairment, neurological disorders, and organ damage.

There are various methods for lead removal from water including chemical precipitation, ion exchange, adsorption, membrane filtration, and electrochemical phytoremediation and bio adsorption methods. Most of these methods especially the chemical, ion exchange, membrane and electrochemical methods are expensive, result into secondary pollution as well as require a lot of chemicals. Adsorption is gaining attention due to low costs and environmental friendliness of this method; however, it is faced with low efficiency compared to other methods which are efficient though expensive, energy-consuming, and produce hazardous byproducts that may lead to secondary contamination of water sources. To address issues of lead contamination at domestic level of communities in Uganda, the study sought to synthesis green silver nanoparticles (AgNPs) from various guava leaf genotypes and investigate the effect of embedding AgNPs the clay filter for removal of lead in water.

1.3 Objectives of the study

1.3.1 Main objective

To investigate the removal of lead from contaminated water using green silver nanoparticles synthesized from selected varieties of Guava leaf extracts.

1.3.2 Specific objectives

The specific objectives included:

- i. To determine the anti-oxidant activity of aqueous extracts of the identified guava leaves.
- ii. To evaluate the crystal, morphological and chemical composition of the AgNPs synthesized using aqueous guava leaf extracts and silver nitrate precursor.
- iii. To optimise the performance of the synthesized AgNPs on removal of lead from water.
- iv. To analyse the effect of incorporating AgNPs in clay filters in the removal of lead from water.

1.4 Research questions

- i. What is the total oxidant activity of the identified guava varieties?
- ii. What is the crystal, morphological and chemical characteristics of the synthesized AgNPs?
- iii. What is the optimal lead removal efficiency of AgNPs?
- iv. How does incorporation of AgNPs in clay filters affect removal of lead in water?

1.5 Justification

Access to safe and clean water constitutes a fundamental human right and is essential for sustainable development. This study was in line with various essential frameworks, including the United Nations Sustainable Development Goals (SDGs) (Camp, 2025), Uganda Vision 2040, the National Development Plan IV (NDP IV) (Ber, 2025), and the African Union Agenda 2063 (Moono, 2021), all of which emphasise water quality and environmental sustainability.

Plant extracts have been used in the synthesis nanoparticles of silver (Logeswari *et al.*, 2015; Ahmed *et al.*, 2016 and Vanlalveni *et al.*, 2021) and this is linked to the presence of anti-oxidant Phyto substrates in the extracts (Mohapatra *et al.*, 2024). The quantity of these substances can vary among varieties of a particular plant. An example of such a plant is *Psidium guajava*.

This study used lead (Pb (II)) as the model pollutant because of its global danger to public health and aquatic ecosystems. Lead is hazardous, non-biodegradable, and accumulating even at low doses (WHO, 2022). It is mostly found in water sources from old plumbing, battery production and smelting effluents, and landfill leachate (U.S. EPA, 2023) which are very common in most Ugandan local communities. Lead ingestion damages the nervous system, causing developmental delays, learning difficulties, and reduced intellectual capacity in children (World Bank, 2021). Additionally, it causes cardiovascular and renal disorders in adults. Due to these hazards, the World Health Organisation (WHO) limits drinking water at 0.01 mg/L, which many regions with inadequate water treatment infrastructure exceed (WHO, 2022). Thus, producing effective and economical lead adsorbents

like green-synthesized silver nanoparticles is not just academic research but an essential effort to mitigate a major environmental health catastrophe.

Green silver nanoparticles synthesised with aid of *Moringa oleifera* leaf extract have been used for removal of chromium (Ali *et al.* , 2022). Narkhede and her colleagues have studied the removal of arsenic (As) from water using green AgNPs (Narkhede *et al.* , 2024) however, they have not been studied for removal of lead, which is among toxic heavy metals with a very low permissible limit.

This study of lead removal from water using green silver nanoparticles synthesized from *Psidium guajava* was significant due to its eco-friendly, cost-effective, and efficient approach to addressing heavy metal contamination. Traditional methods for lead removal, such as chemical precipitation and ion exchange, often involve high costs, secondary pollution, and energy-intensive processes (Fu & Wang, 2011). In contrast, biogenic AgNPs derived from *P. guajava* leaf extract offer a sustainable alternative, leveraging the plant's rich phytochemicals (e.g., flavonoids, polyphenols, and terpenoids) as reducing and stabilizing agents, thus eliminating the need for toxic chemical reagents (Shi *et al.* , 2013). Research indicates that green-synthesized AgNPs exhibit high surface-area-to-volume ratios and strong adsorption capacities, enhancing their affinity for heavy metals like lead (Pb^{2+}) through mechanisms such as electrostatic attraction and complexation (Tamburini *et al.* , 2021). Additionally, *P. guajava*-mediated AgNPs have demonstrated antimicrobial properties, which could simultaneously mitigate microbial contaminants in water (Vijay Kumar *et al.* , 2014).

Given the severe health risks of lead exposure including neurological damage and developmental disorders in children (Schettler, 2001). The study of Lead removal from contaminated water aligns with global Sustainable Development Goals (SDG 6) (Monroy-Licht *et al.* , 2024) for clean water. Furthermore, the scalability and biodegradability of plant-based nanoparticles make them a viable solution for large-scale water treatment in developing regions (Njagi *et al.* , 2011). Thus, investigating *Psidium guajava*-synthesized AgNPs for lead removal not only advances green nanotechnology but also offers a practical, sustainable strategy for water purification.

Further, the performance of clay filters impregnated with AgNPs has not been investigated. This study intended to close the gap and pave the way for the commercialization of silver nanoparticles as broad-spectrum heavy metal remediation in wastewater.

1.6 Scope of the study

1.6.1 Content scope

The study concentrated on the synthesis of nanoparticles utilising extracts from various guava leaf varieties and their corresponding antioxidant activity based on (DPPH) radical scavenging assay. Post-synthesis, the nanoparticles was characterised for size, shape, surface properties, and composition of the AgNPs.

1.6.2 Geographical scope

The guava leaves were sourced from within Kyambogo University and identified by a technician in the department of biological science at Kyambogo University. The synthesis and sorption experiments were conducted at the chemistry laboratory

of Kyambogo University, while the characterisation of AgNPs occurred at College of Engineering, Design, Art and Technology (CEDAT), Makerere University.

1.6.3 Time scope

This study ran for 12 months, started from May 2024 to August 2025.

1.7 Significance of the study

The importance of this study resides in its diverse contributions to public health safeguarding, environmental sustainability, and technological advancement in mitigating lead contamination in water sources. The study reduces environmental impact and reliance on synthetic chemicals by synthesizing green silver nanoparticles from guava leaves, thus advocating for eco-friendly and resource-efficient methods for lead remediation.

The initiative fosters collaboration across disciplines to advance nanotechnology and sustainable materials research, offering viable solutions for environmental remediation and water purification globally.

The research findings not only safeguard public health but also promote innovation and knowledge dissemination, underscoring the project's global importance in tackling the enduring issues related to lead contamination in water systems.

1.8 Conceptual framework

The independent variable, guava genotypes, was modified to generate silver nanoparticles. The dependent variable, lead removal efficiency, was assessed to evaluate their efficacy (Figure 1.1). The intervening variables, such as the synthesis

process and experimental conditions, substantially affected the characteristics of the synthesised nanoparticles and their effectiveness in lead ion removal.

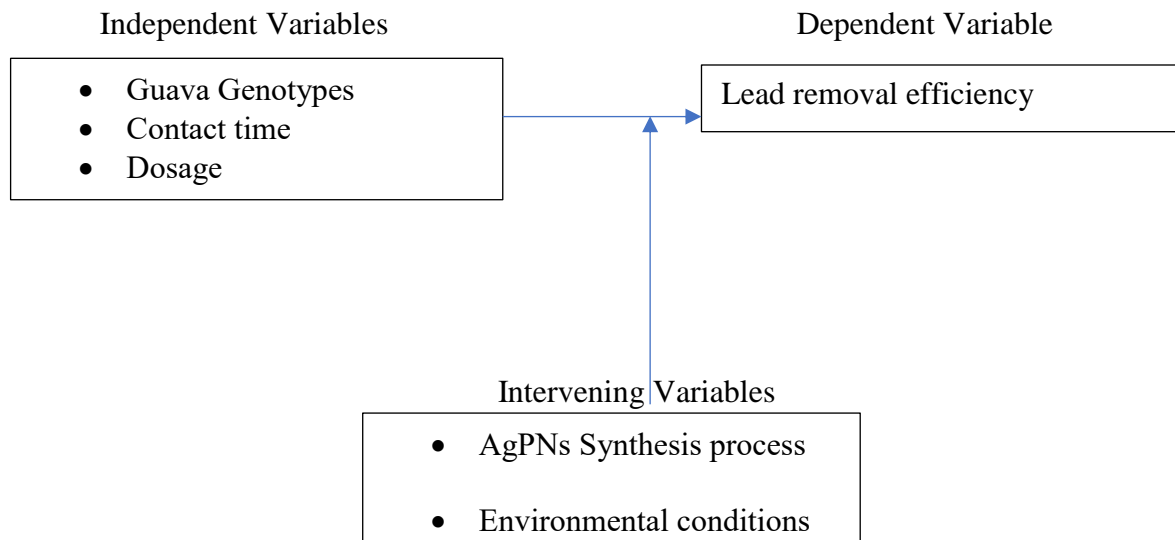


Figure 1.1: Conceptual framework of the study

The synthesis process, varying according to the guava genotype utilised, can affect the size, morphology, and surface chemistry of the nanoparticles. Additionally, experimental variables including pH, contact duration, dosage, and temperature can affect the effectiveness of lead removal.

1.9 Chapter summary

This chapter presents an overview of a technique for the remediation of lead in contaminated water. It highlights the gaps regarding treatment of water contaminated with lead. Four research questions were posed in this study. To answer these questions, the study was delimited to three guava species. The synthesis of AgNPs was limited to the leaf aqueous extracts of the selected guava varieties. The chapter elaborates on the independent and dependent variables for the study. Also outlined the intervening variables.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter focusses on a review of literature relevant for this study. This was done while aligning the literature with the various specific objectives, gaps in knowledge regarding the study were identified.

2.2. The guava varieties in Uganda

Guava, referred to as "mupeera" in Luganda in Uganda, is a prevalent fruit tree in many African households. Its origin is in South America, likely Brazil (Asiimwe *et al.* , 2022). In Uganda, it is cultivated in all regions of the country, including the North Eastern region, where it is found near water sources around Mt. Kadam (Nakalembe *et al.* , 2017). In Uganda, the plant serves as firewood, charcoal, poles, tool handles, and food (fruit) (Monroy-Licht *et al.* , 2024; Dagne *et al.* , 1999).

There are three common guava varieties in Uganda namely; apple, pineapples and strawberry guava (Table 2.1). *Psidium guajava* var. *pyriformis*, commonly referred to as Apple Guava, is the primary guava variety in Uganda (Bekele-Tesemma and Tengnas, 2009)., The plant produces substantial elliptical fruits that display a light green to yellow colouration upon full maturation(Dagne *et al.* , 1999).The fruit's flesh is distinguished by its white or cream hue, firm consistency, and a delicately sweet flavour. Apple guava is celebrated for its high vitamin C content and is typically consumed fresh or processed into juice, jams, and jellies(Of *et al.* , 2022).

The Strawberry Guava (*Psidium cattleianum*) is distinguished by its small, spherical fruits that display a vivid crimson colour upon full maturation. The fruit's flesh is crimson, displaying a supple texture akin to that of apple guava. Furthermore, it exhibits an increased sweetness and a more distinct flavour profile (Pasupuleti & Kulkarni, 2014). Strawberry guava is a nutrient-dense fruit abundant in vitamins A and C. It is highly appreciated for its refreshing flavour.

Table 2.1: Comparison of the three common guava types in Uganda

| Feature | Apple Guava | Pineapple Guava | Strawberry Guava |
|--------------|--------------------------------|--------------------------------|--------------------------------|
| Fruit size | Large | Small | Small |
| Fruit shape | Round to pear-shaped | Round, ribbed | Round, ribbed |
| Skin color | Green or yellow | Bright red or yellow | Bright red |
| Flesh flavor | Sweet, slightly tart | Sweet, pineapple-like | Sweet, strawberry-like |
| Growth habit | Shrub or small tree (30-40 ft) | Shrub or small tree (15-20 ft) | Shrub or small tree (15-20 ft) |

Source: (Bekele-Tesemma and Tengnas, 2009)

The Pineapple Guava (*Psidium littorale*) is a rare cultivar with unique and remarkable characteristics. Pineapple guava thrives in temperate climates within tropical regions and produces fruits with yellow skin that exude an aroma akin to pineapple. The fruit's flesh is either white or yellow, noted for its juiciness and a flavour that is simultaneously sweet and acidic (Parra-Coronado *et al.* , 2015).

2.3. Antioxidant activity of guava leaf extracts

Guava leaves, rich in bioactive compounds, have been extensively studied for their antioxidant properties (Adamu, 2021; Oncho *et al.* , 2021). While studies on the

antioxidant properties of apple, pineapple, and strawberry guava leaf extracts may vary, general trends and factors influencing antioxidant activity can be analysed.

The primary antioxidant constituents in guava leaves include polyphenols, ascorbic acid (Vitamin C), and carotenoids (Oncho *et al.* , 2021). These compounds can neutralise harmful free radicals, protecting cells from damage. The concentrations and varieties of antioxidants can vary according to the guava cultivar, agricultural practices, extraction methods, and storage conditions (Iravani, 2011).

While direct comparisons of antioxidant activity among apple, pineapple, and strawberry guava leaf extracts are limited, some research suggests that all three varieties possess antioxidant properties (Medina and Herrero, 2015). However, the specific concentrations and types of antioxidants may differ. The variety, cultivation conditions, and extraction technique are deemed to influence the overall antioxidant capacity of the extracts.

The antioxidant properties of guava leaf extracts make them suitable for various applications (Mohapatra *et al.*, 2024). They function as natural food preservatives to extend the shelf life of food items and prevent oxidative deterioration. Guava leaf extracts contain antioxidant compounds such as phenolics that may provide therapeutic advantages for conditions linked to oxidative stress, such as cardiovascular disease and cancer (Lok *et al.*, 2023). Furthermore, guava leaf extract may be incorporated into skincare products to protect the skin from environmental damage and promote healthy ageing (Mohapatra *et al.*, 2024).

Further research is necessary to investigate the differences in antioxidant activity among apple, pineapple, and strawberry guava leaf extracts, as well as to explore their potential for water treatment. Understanding of the factors influencing antioxidant activity could improve the extraction and utilisation of guava leaf extracts for maximum effectiveness.

2.4 Water pollution with heavy metals

Heavy metal comprises a category of metals and metalloids characterised by an atomic density exceeding 4000 kgm^{-3} (Edelstein & Ben-Hur, 2018). Heavy metals are inherently toxic, resulting in severe health issues for humans and animals, even at minimal concentrations (Govind & Madhuri, 2014).

The presence of heavy metals like lead and cadmium in water sources compromises water quality and jeopardises aquatic life (Glicklich *et al .*, 2024). Humanity, alongside other food crops, relies on aquatic life; however, the ingestion of water contaminated with heavy metals, including fish, heightens the risk of heavy metal accumulation in human health via the food chain (Chaudhari *et al .*, 2024). Excessive intake of water contaminated with heavy metals is associated with significant health problems, including renal impairment, bone fractures, cognitive deficits in children, and multiple cancer types (Kafayat Kehinde Lawal *et al .*, 2021)

Lead is acknowledged as a highly toxic heavy metal (Balali-Mood *et al .*, 2021). Its significant toxicity and tendency to bioaccumulate in organisms lead to various health issues (Garai *et al .*, 2021). Lead exposure is associated with neurological

disorders, renal dysfunction, cardiovascular complications, and an elevated risk of cancer (Chowdhury *et al.* , 2022). Conventional techniques for the extraction of heavy metals from water encompass chemical precipitation, ion exchange, and membrane filtration (Abdullayev *et al.* , 2024). Although effective, these methods frequently incur substantial operational costs (Chowdhury *et al.* , 2022; Gorde & Jadhav, 2013), considerable energy requirements, and produce secondary pollutants, including trihalomethanes (THMs), haloacetic acids (HAAs), haloacetonitriles (HANs), halonitromethanes (HNMs), haloketones (HKs), haloacetamides (HAcAms), and haloaldehydes (HAs), which can exacerbate environmental contamination of land and water sources (Ayach *et al.* , 2024) . To mitigate the detrimental impacts of heavy metal pollution, various approaches, including biological synthesis utilising nanoparticles like silver, have been proposed as alternatives for addressing heavy metal water contamination (Maqsood *et al.* , 2022).

Biological synthesis utilises plant extracts as safe and environmentally friendly alternatives to traditional physical and chemical methods for nanomaterial production (Adeyemi *et al.* , 2022). Studies have emphasised the formation of nanoparticles via green synthesis, utilising plant extracts for the fabrication of nanoparticles aimed at the extraction of heavy metals from water(Oyanedel-Craver & Smith, 2008)through ecofriendly methods (Albadawi *et al.* , 2024).

Recent studies by researchers (Albadawi *et al.* , 2024) investigated the green synthesis of silver nanoparticles utilising guava leaf extracts. The efficacy of various species, including Tropical White, Mexican Cream, China White, Sweet

White Indonesian, Giant Vietnamese, Cas/Costa Rican, White Indian, Apple Seedless, Egyptian Yellow, Allahabad Safeda, and Lucknow 49, remains undetermined (Gangappa *et al.* , 2022).

The escalation of human activity and industrial processes, including plating and electroplating, battery production, pesticide application, mining, rayon manufacturing, tanning, fluidised bed bioreactors, textiles, metal smelting, petrochemicals, paper production, and electrolysis, has resulted in a significant increase in the prevalence and concentration of heavy metals in wastewater (Graber *et al.* , 2010; Okafor *et al.* , 2023). Contaminated wastewater containing heavy metals infiltrates the environment, jeopardising ecological systems and human health. Due to their non-biodegradable nature (Thanigaivel *et al.* , 2024) and potential carcinogenic effects, elevated concentrations of heavy metals in water can significantly harm the health of living organisms (Govind & Madhuri, 2014)

2.5. Heavy metal in water remediation technologies

Heavy metals infiltrate human food chains via a process termed bioaccumulation (Mitra *et al.* , 2022; Ray and Vashishth, 2024). Ultimately, this results in an elevated concentration of metal ions, posing a threat to biological systems (Jaishankar *et al.* , 2014). Due to domestic, commercial, agricultural runoff, and industrial wastewater, these heavy metals can easily enter the aquatic system (Ray and Vashishth, 2024). The diverse treatment methodologies (Figure 2.1) employed to eliminate deleterious heavy metals from water or wastewater encompass membrane filtration, ion exchange, chemical precipitation, chemical coagulation

and flocculation, electrochemical techniques, bioremediation, and adsorption (Ayach *et al.*, 2024)

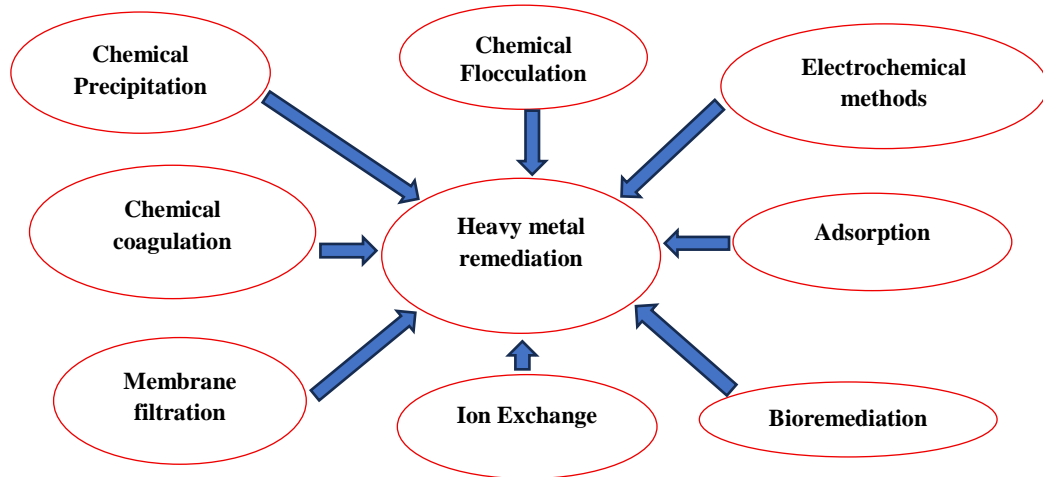


Figure 2.1: Treatment methods for the removal of heavy metals from wastewater source (Qasem *et al.*, 2021)

2.6 Adsorption and heavy metal remediation technique

Adsorption is a dynamic equilibrium process characterised by the adherence of adsorbates to a solid surface or interface via van der Waals forces or electrostatic interactions (Ray and Vashishth, 2024). Adsorbates adhere to surfaces or interfaces through physisorption or chemisorption mechanisms during the adsorption process (Tao and Rappe, 2014).

Physisorption is found to be ubiquitous owing to a wide range of van der Waals weak attractive forces between adsorbates and adsorbents. Currently, the adsorption process is regarded as the most practical, efficient, and selective method for the removal of heavy metals from wastewater (Mahmood Aljamali *et al.*, 2021). Physisorption provides complete recovery of heavy metals from wastewater

with operational and design flexibility. Adsorption is a solid-liquid mass transfer process wherein heavy metals (adsorbates) are transferred from wastewater to an adsorbent, a solid surface, where they chemically or physically adhere to form a bond (Gahrouei *et al.* , 2024). Physical adsorption is induced by weak Van der Waals forces of attraction, while chemical adsorption results from the robust covalent bond between the adsorbent and adsorbate (Saleh, 2022). The adsorption of heavy metals may sometimes be reversible, enabling the adsorbent to be regenerated using suitable desorption methods (Gahrouei *et al.* , 2024).

Activated carbon (AC) is a widely employed adsorbent for the removal of heavy metals from wastewater, attributed to its extensive surface area and high affinity for these contaminants (Wang *et al.* , 2023). The water treatment sector has utilised various types of activated carbon (AC), including granular activated carbon (GAC), powdered activated carbon (PAC), and woven carbon (Ajmal *et al.* , 1998)

Carbon, modified to the nanoscale, has also been utilised for the removal of heavy metals from water. The carbon nanomaterials encompass carbon nanotubes (CNTs), fullerenes, graphene, and their derivatives. Various nanomaterials and nano strategies are capable of removing emerging contaminants and heavy metals (Iravani, 2021). Different nanoparticles, have been thoroughly investigated for the remediation of heavy metals in wastewater. Nanotechnology has already been integrated into numerous every day and industrial applications, while many significant applications remain in the research and development phase. It is accurate to assert that Nanotechnology has significantly impacted the technological landscape.

2.7 Adsorption of heavy metals

Heavy metal removal studies using green methods have demonstrated that guava tree leaves possess the capability to remove heavy metals from aqueous solutions (Challab, 2024; Chowdhury *et al.*, 2022; Khan *et al.*, 2023; Narkhede *et al.*, 2024; Sekabira; *et al.*, 2010; Tagesse, 2021). In 2020, El-Sesy and Mahran conducted a study to evaluate the effectiveness of guava leaf extract in wastewater treatment (El-Sesy & Mahran, 2020). Researchers discovered that the extract demonstrated coagulant properties, specifically attracting and binding metal ions such as chromium to its surface (Benalia *et al.*, 2024). A study by (Andal *et al.*, 2022) demonstrated that powdered guava leaves can effectively absorb lead, rendering them appropriate for lead remediation.

Additionally, (Andal *et al.*, 2022) performed a study on the application of guava leaf extracts for the adsorption of Chromium, Manganese, Selenium, Nickel, Cobalt, and Iron from aqueous acidic solutions in batch processes. Their findings illustrated the significant efficacy of these leaves in adsorbing diverse heavy metals. These studies underscore the ability of guava leaves to accumulate specific heavy metals.

The exact mechanism by which guava leaves chelate heavy metals remains under investigation, though it is probable that various constituents operate in a synergistic manner (Ruksiriwanich *et al.*, 2022). The leaf surface comprises functional groups including carboxylate anions, hydroxyl groups, and amine groups, which can

interact with metal ions through electrostatic attraction, complexation, or ion exchange (Kamelnia *et al.* , 2023).

Furthermore, the biomolecules present in guava leaves may improve adsorption through chelation or physical entanglement. The specific interaction between guava leaves and different heavy metals likely involves a combination of these mechanisms (Huynh *et al.* , 2025). Further research is necessary to thoroughly understand the interaction between these components and improve the adsorption process.

2.8. Nanomaterials

Nanotechnology is defined as the science of nanoscale objects, which range in size from one to one hundred nanometres. Nanomaterials are substances of this scale that exhibit enhanced properties and functions (Harish *et al.* , 2022). The efficacy of nanoparticles (NPs) as adsorbents for pollutants, heavy metals, and gases is profoundly influenced by their physical dimensions, which include size, surface area, and shape. Unlike bulk materials, the properties of nanomaterials are dominated by surface phenomena, making their dimensional characteristics a primary determinant of their adsorption capacity and kinetics. The relationship is fundamentally governed by the increase in specific surface area (surface area per unit mass) as particle size decreases, but it extends into more complex geometric and electronic effects that dictate how adsorbates interact with the nanomaterial surface (Auffan *et al.*, 2009). Nanomaterials are classified based on their dimensions and intrinsic properties. They are categorised by dimension into zero,

one, two, and three-dimensional nanomaterials. Conversely, there are four categories based on the characteristics of the nanomaterials (Alkaç *et al.* , 2021).

Carbon-based nanomaterials primarily consist of carbon and are available in various geometries, including spheres, ellipsoids, and tubes. Graphene and its derivatives, fullerenes, carbon nanotubes (CNTs), graphene oxide, nano-diamonds, and carbon-based quantum dots are included; graphene has received the most research attention in the past decade (S. Jain *et al.* , 2023; Mahor *et al.* , 2021).

The second category comprises inorganic nanomaterials, including nanoscale materials and metal and metal oxide nanoparticles. Examples of inorganic-based nanomaterials include metal nanoparticles, quantum dots, superparamagnetic iron oxide nanoparticles, and paramagnetic lanthanide ions (Ma *et al.* , 2023). The synthesis processes employed include precipitation, electrospinning, sol-gel techniques, template-assisted spinning, chemical vapour deposition (CVD), and environmentally friendly synthesis methods utilising Phyto antioxidants like phenolics to reduce metal salts to their elemental form or metal oxides at the nanoscale (Ma *et al.* , 2023).

The third category comprises organic-based nanomaterials, which, in contrast to carbon- or inorganic-based nanoparticles, are predominantly constituted of organic matter (Ma *et al.* , 2023). Included are liposomes, dendrimers, micelles, and ferritin. The composite-based nanoparticles are the final category. These are multifaceted structures in which one phase exists at the nanoscale, integrating

nanoparticles with other nanoparticles linked to larger materials or forming more complex nanocomposites with an intricate architecture (Singh *et al.* , 2021).

Nanomaterials have facilitated the elimination of heavy metals from wastewater and the detection of environmental pollutants, among other contributions. Silver nanoparticles have been investigated for the removal of iron (Fe), chromium (Cr), cobalt (Co) and lead (Pb) (ŞAhiN *et al.* , 2023) and naphthalene (Abbas *et al.* , 2020). Silver possesses high thermal and electrical conductivity and is a rare, malleable, white, and lustrous element found in nature. Silver nanoparticles, characterised by dimensions under 100 nm in at least one axis, represent a distinctive form of metallic silver with a high surface area to volume ratio (Attatsi & Nsiah, 2020).

2.9. Silver nanoparticles synthesis

Silver nanoparticles can be synthesised through various methods, including physical and chemical processes, each possessing distinct advantages and disadvantages concerning process complexity, particle size distribution, stability, applications, and cost (Jain *et al.* , 2024).

The green method has been extensively researched. Some researchers have successfully utilised live organisms or specific plant extracts as reducing agents instead of artificial chemicals. The creation of silver nanoparticles through chemical reduction utilising plant extract is commonly termed biological reduction, eco-friendly, or green manufacturing (Vega-Baudrit *et al.* , 2019). The production techniques are summarised in Figure 2.2.

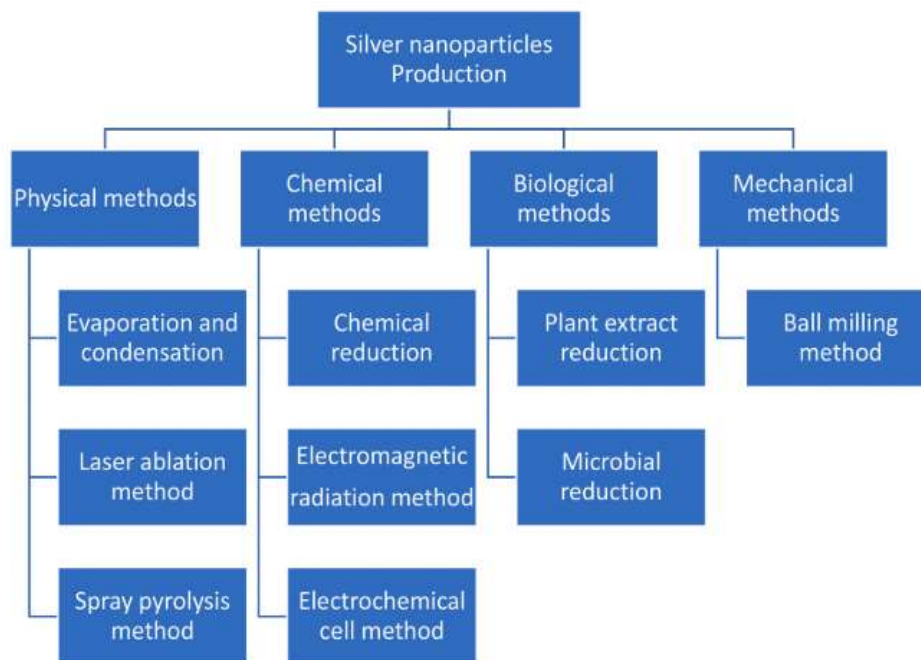


Figure 2.2: Silver Nanoparticles synthesis techniques

Source (Islam *et al.* , 2021)

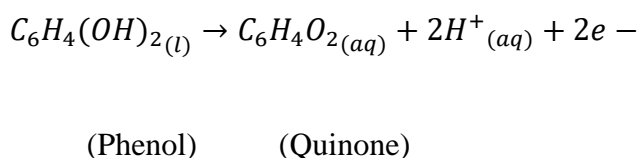
2.10 Mechanism of green synthesis of silver nanoparticles using plant extracts.

A comprehensive review of the literature demonstrates that the green synthesis mechanism is a multi-stage process predominantly facilitated by several phytochemicals and microbial metabolites functioning as reducing, capping, and stabilising agents.

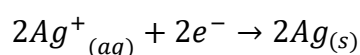
The primary and most essential phase in the green synthesis of AgNPs is the reduction of Ag^+ to Ag^0 , a process primarily facilitated by various bioactive chemicals found in biological extracts. In plant-mediated synthesis, the most extensively researched method, water-soluble metabolites including flavonoids, alkaloids, terpenoids, and phenolic acids are recognised as the principal reducing agents (Asgary *et al.*, 2016).

The procedure entails the transfer of electrons from these biomolecules to the silver ions. For example, the hydroxyl (-OH) and carbonyl (-C=O) groups in polyphenols can be oxidised to quinones while concurrently contributing electrons to reduce Ag^+ to Ag^0 (Ahmed *et al.*, 2016). The enol form of flavonoids can similarly be transformed into the keto form, facilitating the release of electrons for reduction. The redox reaction is visually validated by the colour shift of the reaction mixture to yellowish-brown, signifying the synthesis of AgNPs as a result of their surface plasmon resonance (SPR).

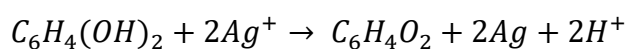
Polyphenols contain hydroxyl groups (-OH) attached to an aromatic ring. These groups can be oxidized to carbonyl groups (C=O), specifically quinones, while donating electrons to reduce silver ions. The general half-reaction for the oxidation of a phenol to a quinone is:



The reduction of the silver ion is:

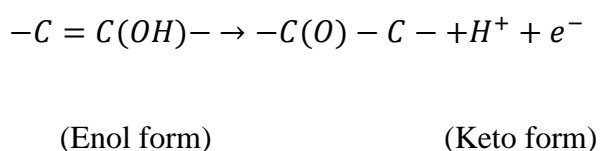


Combining these for a diol (like catechol, commonly found in plant extracts) to reduce two silver ions, the overall reaction becomes:

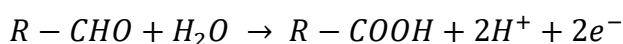


This reaction shows the formation of the silver atom (Ag) and the release of protons (H⁺), which often leads to a slight change in the pH of the reaction mixture.

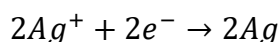
Flavonoids are a large class of polyphenols with a specific C6-C3-C6 structure. A key functional group in many flavonoids for reduction is the enol group (-C=C-OH), which can tautomerize to a keto group (-C=O) and release electrons. The tautomerization and reduction mechanism can be represented as follows:



Terpenoids, another major class of phytochemicals, often contain aldehyde groups (-CHO). Aldehydes can be oxidized to the corresponding carboxylic acids (-COOH), serving as an electron source. The half-reaction for the oxidation of an aldehyde is:



The corresponding reduction of two silver ions is:



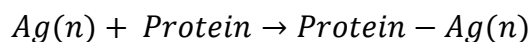
Therefore, the overall reaction is:



Subsequent to nucleation, the newly formed AgNPs exhibit high reactivity and are susceptible to aggregation and Ostwald ripening, resulting in the development of bigger, unstable particles. To avert this, the identical biological extracts serve a secondary essential function: capping and stabilisation. Biomolecules functioning

as reducing agents frequently also act as capping agents. Proteins and polysaccharides in the extract adhere to the surfaces of the freshly synthesised nanoparticles, establishing a protective coating that induces electrostatic repulsion or steric hindrance among individual particles, thus inhibiting coalescence (V. Kumar & Yadav, 2009).

While not a reduction mechanism, the stabilization of the formed nanoparticles is crucial. Proteins and amino acids present in the extract bind to the nanoparticle surface via their functional groups. This can be represented as a complexation reaction, where "Protein" represents a molecule with lone pairs on nitrogen or oxygen atoms (e.g., from amine or carboxylate groups). This capping action provides electrostatic or steric stabilization, preventing the nanoparticles from aggregating.



(Nascent nanoparticle) (Capped/stabilized nanoparticle)

Fourier-transform infrared (FTIR) spectroscopy is a widely employed analytical method for identifying capping agents, with distinctive peaks often associated with amide bonds from proteins and O-H/N-H stretches from various polyphenols and polysaccharides (Logeswari *et al.*, 2015). This bio-cap not only stabilises the colloidal suspension but also often enhances the biological activity and functional features of the nanoparticles. The characteristics and composition of this capping layer are directly determined by the biological source employed, which

subsequently governs the ultimate size, shape, and stability of the synthesised AgNPs.

2.11 Mechanism of adsorption of lead ions by silver nanoparticles

The adsorption of Pb (II) ions onto AgNPs is not a simple physisorption process but a complex interplay of several mechanisms influenced by the nanoparticle's surface chemistry, the surrounding environment, and the nature of the Pb (II) ion. A review of the literature reveals that the primary mechanisms governing this process include electrostatic interaction, complexation with surface functional groups, ion exchange, and chemical reduction, with the dominant mechanism often dictated by the capping agents on the AgNPs.

The surface charge of AgNPs, which is a function of the solution pH and the nanoparticles' zeta potential, plays a pivotal role in the initial adsorption of Pb (II) ions through electrostatic attraction. The surface of AgNPs, especially those synthesized via green methods, is typically functionalized with organic capping agents like proteins, polyphenols, or carboxylic acids derived from the biological extract (Molnár *et al.*, 2018). The ionization states of these functional groups are highly pH-dependent. At low pH, high concentrations of H⁺ ions protonate these groups, creating a positively charged nanoparticle surface that electrostatically repels the positively charged Pb (II) ions, leading to low adsorption efficiency. As the pH increases, the functional groups (e.g., -COOH, -OH) deprotonate, imparting a negative charge to the AgNP surface, which strongly attracts and facilitates the adsorption of cationic Pb (II) species (e.g., Pb²⁺, Pb(OH)⁺) (Pan *et al.*, 2019). This

electrostatic-driven mechanism is often the first and most rapid step in the adsorption process, as confirmed by studies showing a dramatic increase in Pb (II) uptake with increasing pH until precipitation begins to dominate.

Beyond simple electrostatic forces, the specific chemical interaction between Pb (II) ions and the functional groups on the AgNP surface, known as complexation or coordination, is a critical mechanism. This chemisorption involves the sharing of electron pairs between the Pb (II) ion and donor atoms on the adsorbent surface. For instance, the oxygen atoms in carbonyl (-C=O) and hydroxyl (-OH) groups, and nitrogen atoms in amine (-NH₂) groups from capping agents, can act as Lewis bases, forming stable complexes with the Lewis acidic Pb (II) ion (Mishra *et al.*, 2019). This mechanism is strongly supported by spectroscopic evidence. Fourier-Transform Infrared (FTIR) spectroscopy analyses conducted before and after Pb (II) adsorption often show shifts or decreases in the intensity of peaks corresponding to these functional groups, indicating their direct involvement in metal binding (Tripathy *et al.*, 2024). This inner-sphere complexation is less reversible than electrostatic attraction and is responsible for the high specificity and stability of the adsorbed Pb (II).

In certain scenarios, more complex mechanisms beyond adsorption can occur. For AgNPs synthesized with reducing agents that are not strongly capping, or under specific conditions, a redox reaction can take place. Silver has a lower reduction potential ($E^\circ \text{Ag}^+/\text{Ag} = 0.80 \text{ V}$) compared to lead ($E^\circ \text{Pb}^{2+}/\text{Pb} = -0.13 \text{ V}$).

Thermodynamically, this suggests Pb (II) cannot reduce Ag⁰. However, the system is more complex at the nanoscale. The adsorption of Pb (II) onto the AgNP surface

can facilitate the formation of bimetallic structures or lead to slight oxidative dissolution of silver, altering the local chemical environment (Zhang *et al.*, 2016). Furthermore, for AgNPs capped with polysaccharides or other biomolecules, an ion-exchange mechanism has been proposed. In this process, light metal ions (e.g., Na⁺, K⁺, Ca²⁺, H⁺) associated with the capping layer are released into the solution and replaced by the heavier Pb (II) ions to maintain charge neutrality (Logeswari *et al.*, 2015). The contribution of this mechanism is often inferred from the detection of these lighter ions in the solution post-adsorption.

In summary, the adsorption of Pb (II) ions onto silver nanoparticles is a multifaceted process governed by a combination of physical and chemical mechanisms. Electrostatic attraction serves as the initial, pH-dependent driver for bringing Pb (II) ions to the nanoparticle surface. This is followed by stronger, more specific chemisorption through complexation with oxygen- and nitrogen-containing functional groups from the capping agents, which is largely responsible for the high adsorption capacity. In specific cases, ion-exchange and complex redox-driven interactions may also contribute. The predominance of any single mechanism is not universal but is intrinsically linked to the surface chemistry of the AgNPs, which is determined by their synthesis route. Future research should focus on engineering AgNPs with tailored surface functionalities to enhance selectivity and capacity for Pb (II) and other toxic heavy metals, paving the way for their application in targeted water purification technologies.

2.12. Characteristics of nanomaterials

Nanoparticles are ultrafine entities often measuring between 1 to 100 nanometres (nm), displaying distinct physical, chemical, and biological characteristics attributable to their elevated surface-area-to-volume ratio (Jeevanandam *et al.* , 2018). At this scale, quantum effects become prominent, resulting in modified optical, electrical, and magnetic properties relative to bulk materials. For example, gold nanoparticles exhibit red or purple hues instead of gold due to surface plasmon resonance, phenomena not present in bigger particles (Astruc *et al.* , 2004). Their diminutive size further amplifies reactivity, rendering them advantageous in catalysis, pharmaceutical delivery, and environmental cleanup. Nanomaterials exhibit unique physicochemical properties that make them highly effective for adsorption applications in environmental remediation, catalysis, and biomedical fields.

The elevated surface-area-to-volume ratio of nanoparticles markedly affects their mechanical and thermal characteristics (Pokropivny & Skorokhod, 2007). This attribute enhances their interaction with adjacent molecules, hence augmenting adsorption and catalytic efficacy. Titanium dioxide (TiO₂) nanoparticles exhibit superior efficacy in photocatalysis compared to their bulk forms, attributable to their increased surface reactivity (Ahmad *et al.* , 2023). Moreover, their thermal conductivity can significantly differ from that of bulk materials, with certain nanoparticles displaying reduced melting points, which is beneficial in sintering and nanomanufacturing operations.

The surface properties of nanomaterials can be modified through functionalization, allowing for selective adsorption of target molecules (Qu *et al.* , 2013). Introducing functional groups such as carboxyl (–COOH), hydroxyl (–OH), or amine (–NH₂), nanomaterials can be tailored to adsorb specific ions or organic compounds. For instance, magnetic iron oxide nanoparticles (Fe₃O₄) functionalized with thiol groups exhibit high affinity for mercury (Hg²⁺) adsorption due to strong Hg–S interactions (Yantasee *et al.* , 2007).

Nanomaterials often exhibit enhanced reactivity due to quantum confinement effects and unsaturated surface atoms (Auffan *et al.* , 2009). For example, zero-valent iron nanoparticles (nZVI) effectively adsorb and reduce toxic Cr(VI) to less harmful Cr(III) due to their strong redox activity (Li *et al.* , 2006). Similarly, titanium dioxide (TiO₂) nanoparticles demonstrate high affinity for organic dyes through photocatalytic degradation coupled with adsorption (Hoffmann *et al.* , 1995).

The optical characteristics of nanoparticles are significantly influenced by their size, a characteristic utilised in biological imaging and photonic applications (Murphy *et al.* , 2005). Quantum dots, semiconductor nanoparticles, emit distinct wavelengths of light upon excitation, with the emission colours varying according to particle size smaller dots emit blue light, whereas larger ones emit red. This tunability is utilised in fluorescence labelling and solar cell technology. Likewise, silver nanoparticles demonstrate potent antibacterial properties resulting from their interaction with light and the subsequent liberation of silver ions (Marambio-Jones & Hoek, 2010).

Magnetic nanoparticles, including iron oxide (Fe_3O_4), exhibit superparamagnetic properties, a characteristic that allows them to magnetise solely in the presence of an external magnetic field. Magnetic nanomaterials, such as Fe_3O_4 and CoFe_2O_4 nanoparticles, enable easy separation and regeneration after adsorption (Wu *et al* ., 2015). Their superparamagnetic behaviour allows for rapid recovery using an external magnetic field, reducing operational costs and minimizing secondary pollution. Studies show that magnetic graphene-based nanocomposites can be reused multiple times without significant loss in adsorption efficiency (Kyzas & Matis, 2015).

Their colloidal stability and biocompatibility augment their use in nanomedicine. Nevertheless, concerns of aggregation and oxidation must be alleviated through surface coatings such as polyethylene glycol (PEG) or dextran (Ockwig *et al* ., 2010).

The toxicity and environmental ramifications of nanoparticles are considerable issues owing to their elevated reactivity and capacity for cellular infiltration (Nel *et al* ., 2006). Research indicates that specific nanoparticles, such as carbon nanotubes, may provoke inflammatory reactions upon inhalation, whereas others, such silica nanoparticles, can generate oxidative stress. Regulatory bodies underscore the necessity of stringent toxicity assessments prior to commercial or medical application. Notwithstanding these obstacles, progress in surface functionalisation and biocompatible materials persists in broadening nanoparticle uses while reducing dangers (Oberdörster *et al* ., 2005).

2.13. Performance of AgNPs impregnated clay filter in the removal of lead

Nanotechnology is an advanced method that is currently used in the developing of new material and water treatment devices and it is extensively invested in water purification. Silver is a noble metal that is resistant to severe conditions and have unique properties when produced at nanoscale ranging from 1nm to 100 nm with good electrical, optical and thermal properties, good conductivity and are chemically stable (Rus *et al .*, 2017).

Point-of-use technologies (POU) (Senanu *et al .*, 2023) are methods of water treatment that are available for individual use while treating drinking water. The technologies include; Ceramic pot filtration, chlorination, Boiling, Cloth filtration, Solar disinfection, sand Filtration, Coagulation (natural or chemical), Pasteurization and others. The technologies treat mostly the turbidity and microbial load in the contaminated water but not removal of heavy metal (Senanu *et al .*, 2023) .These technologies are installed at the point of use and the research studied the extra lead ions removed by the filters that were impregnated with AgNPs in comparison to the traditional clay filters.

Clay filters have been widely used in water purification due to their low cost, natural abundance, and inherent adsorption properties. However, their efficiency in removing contaminants such as heavy metals, pathogens, and organic pollutants is often limited. To enhance their performance, researchers have incorporated nanoparticles (NPs) into clay matrices, creating composite filters with superior adsorption and antimicrobial capabilities (Bhattacharyya & Gupta, 2008). The impregnation of nanoparticles, such as silver (Ag), titanium dioxide (TiO₂), iron

oxide (Fe_3O_4), and carbon nanotubes (CNTs), significantly improves contaminant removal by increasing surface reactivity and introducing new functional groups (Oyanedel-Craver & Smith, 2008). Studies have demonstrated that nanoparticle-enhanced clay filters exhibit higher flow rates and prolonged lifespans compared to traditional ceramic filters, making them a sustainable solution for decentralized water treatment (Kumar *et al.* , 2014).

One of the key advantages of nanoparticle-impregnated clay filters is their enhanced adsorption capacity for heavy metals such as lead (Pb^{2+}), arsenic (As^{3+}), and cadmium (Cd^{2+}). The high surface area and reactivity of nanoparticles enable stronger electrostatic interactions and chemisorption with metal ions (Bhattacharyya & Gupta, 2008). For example, iron oxide (Fe_3O_4)-modified clay filters have shown over 90% removal efficiency for arsenic due to the formation of stable Fe–As complexes (Sheng *et al.* , 2016). Similarly, titanium dioxide (TiO_2) nanoparticles embedded in clay matrices facilitate photocatalytic degradation of organic pollutants, further improving water quality (Ahmed *et al.* , 2011). These modifications allow clay filters to meet stringent drinking water standards while maintaining cost-effectiveness for large-scale applications.

In addition to heavy metal removal, nanoparticle-impregnated clay filters exhibit strong antimicrobial properties, making them effective against waterborne pathogens. Silver nanoparticles (Ag NPs) are particularly effective due to their ability to disrupt bacterial cell membranes and inhibit DNA replication (Vijay Kumar *et al.* , 2014). Studies have shown that clay filters doped with Ag NPs achieve >99% bacterial (*E. coli*) removal, significantly outperforming

conventional ceramic filters (Oyanedel-Craver & Smith, 2008). Furthermore, the slow release of silver ions ensures long-term disinfection without requiring frequent replacement (Dao *et al.* , 2013). This makes them ideal for use in low-resource settings where access to clean water is limited.

AgNP is one of the most popular nanoparticles due to its many applications and relatively low manufacturing costs. Traditionally the industrial processes generate by-products which become waste materials that have potential in contaminating the environment and human life as well. The effect of lead is well documented by other researchers (Brooks *et al.* , 2010)

Despite their advantages, challenges remain in optimizing nanoparticle-clay composites for real-world applications. Issues such as nanoparticle leaching, long-term stability, and scalability must be addressed to ensure environmental safety and economic feasibility (Kumar *et al.* , 2014). Future research should focus on developing sustainable synthesis methods, improving nanoparticle immobilization techniques, and conducting field trials to assess long-term performance (Sheng *et al.* , 2016). Overall, nanoparticle-impregnated clay filters represent a promising advancement in water purification, combining the affordability of clay with the high efficiency of nanotechnology.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Introduction

This chapter contains information on the study area, study materials' preparation, instrumentation analysis and research timeline.

3.2. Study area

The samples were collected purposively from site with orange, red and white varieties around Kyambogo University. The locations include ITEK, Upper Estate and UPK as clearly located on the map as shown in Figure 3.1.

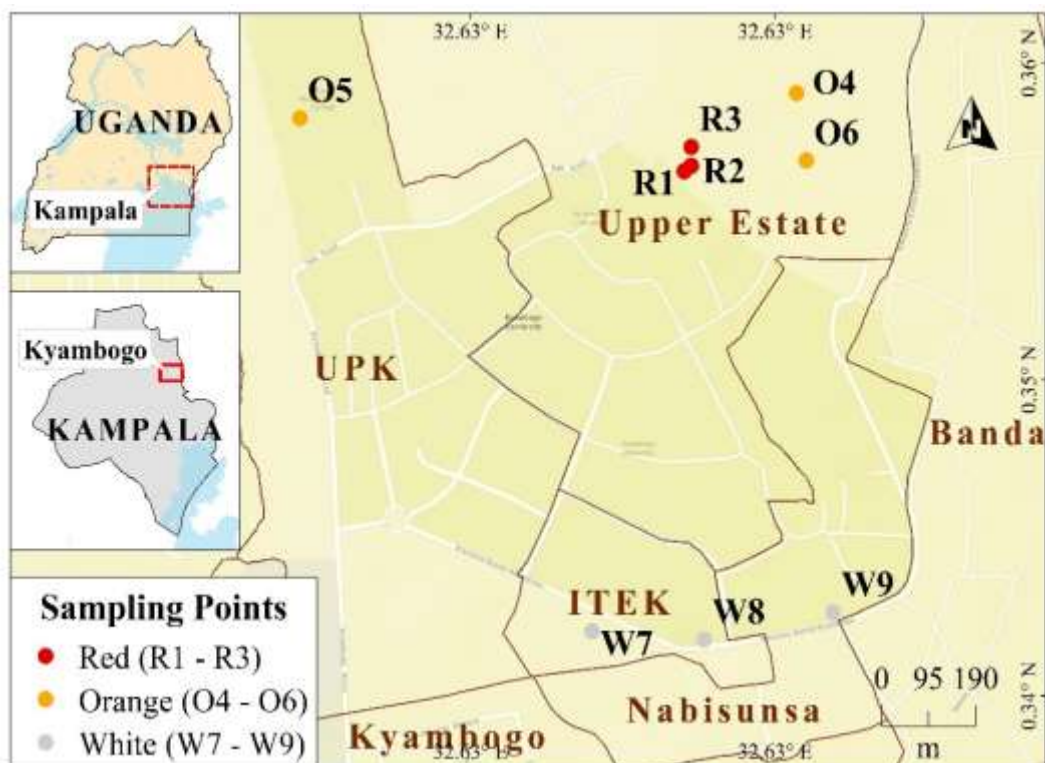


Figure 3.1: Map showing the location of the sample collection area

Three guava varieties were used in the study area. These were noted from their leaves and the fruits as illustrated in Table 3.1. The plant study was done at Kyambogo University at Biology Laboratory. All the fruits for these varieties had diameter sizes ranging between 4 and 5 centimetres with circular or oval shapes.










Table 3.1: Characteristics of guava varieties

| Guava variety | Red | Yellow | White |
|----------------------------|------------|---------------|--------------|
| Leaves -Descriptors | | | |
| Leave texture | Smooth | Smooth | Rough |
| Leave size (cm) | 10 - 12 | 10 - 12 | 10 - 12 |
| Leaf shape | Ovate | Ovate | Obovate |
| Green colour | Deep Green | Green | Green |
| Shape of leave base | Acute | Acute | Apiculate |
| Shape of leave tip | Obtuse | Rounded | Rounded |
| Blade venation curvature | Medium | Medium | Strong |
| Fruit Descriptors | | | |
| Fruit size (cm) | 4-5 | 4-5 | 4-5 |
| Fruit texture/ surface | Rough | Smooth | Smooth |
| Fruit colour | Dark Green | Green | Pale Yellow |
| Number of seed | Many | Many | Medium |
| Epicarp size (mm) | 2-4 | 2-4 | 2-5 |
| Fruit mesocarp size (mm) | 5-6 | 5-6 | 5-6 |
| Flesh colouring | Red | Yellow | White |
| Stem -Descriptors | | | |
| Stem texture | Rough | Rough | Smooth |
| Trunk size (cm) | 50 | 50 | 30 |

They all had many seeds in the range of 400 to 600 seeds. The stem barks were pale grey rough, with layers of dead bark peeling off when dry. Three plants (W₇, W₈ and W₉) were found behind the Mandela Hall of Residence, the staff quarter's residence just in front of the university medical centre gate and near the university gate next to Banda Mosque respectively. They had fruits with yellow skin when ripe and white flesh inside. The leaves were found to be harder/rough with bigger

veins compared with leaves for the other varieties. The leaves were longer with an average size of 12–13.5 cm.

Table 3.2: The morphological characteristics of white, red and orange fruit guava variety.

| Guava variety | White | Orange | Red |
|---------------|---|--|---|
| Leaves |  |  |  |
| Fruit |  |  |  |
| Fruit |  |  |  |

One (O₅) guava plant was found in the university farm, it had leaves with deep green, fruits with rough texture on the skin, and they were yellow when ripe with red flesh inside when ripe. Five (O₄, O₆, R₁, R₂ and R₃) guava plants were found in the university farm and one near the faculty of science block. These plants had green fruits, with smooth skin texture, yellow when ripe, and with orange or light

pink flesh as shown in Table 3.2. The leaf size was ranging from 10 to 12 centimetres. The leaf density was moderate which emerges from opposite points on the stem which gave the plant a heavy leaf canopy.

3.3.Materials

The silver nitrate (AgNO₃) was used as a precursor for Silver Nanoparticles, 1,1-diphenyl-2-picryl hydrazyl (DPPH) was used to determine the anti-oxidant properties of the extracts from different guava genotypes, absolute ethanol (99% purity) ThermoScientific (Genesys 10s) UV/Vis spectrophotometer (200-1000 nm wavelength) with Quartz cuvettes (1 cm path length), ICP-OES, distilled water and Whatman filter paper (qualitative) were used.

3.4.Extraction of the phytochemicals from guava leaves

The guava leaf extracts were acquired through a modified hot aqueous extraction method (Nafiu *et al.*, 2013). The fresh leaves were thoroughly washed, ground in an electric grinder, and combined with 1000 mL of double-distilled deionised water in a glass beaker containing 400 g of biomass. This mixture was heated to 70°C on a heating mantle with periodic agitation for uniform mixing and extraction over a duration of 3 hours to ensure thorough extraction.

The crude extract was allowed to cool, then sieved thorough cotton, and subsequently filtered using Whatman No. 1 filter paper. The filtrate was preserved in a 500 mL glass sample bottle, enveloped in aluminium foil, and maintained at 4°C to prevent oxidative reactions (Ssekatawa *et al.* , 2021).

3.5. Determination of anti-oxidant activity of the fresh dilute leaf extracts

Anti-oxidant activity was carried out to establish the anti-oxidant potential which directly provides insights on the concentration of anti-oxidants which play major role in green synthesis of nanoparticles. High anti-oxidant activity corresponds to high concentration of anti-oxidants in the extract, these phytochemicals include flavonoids like quercetin, kaempferol, and catechin; phenolic acids such as gallic acid, ellagic acid, and ferulic acid; and carotenoids like lycopene and beta-carotene. Other important compounds include tannins, terpenoids, and ascorbic acid. Whereas quantifying these substances is possible with aid of advanced techniques such as high-performance thin layer chromatography and high-performance liquid chromatography, there is need for standards of each phytochemical which makes analysis very expensive. It is important to note that the characteristics of the nanoparticles are influenced by presence of these chemicals in the extract which necessitated need to ensure their presence. Without specification, anti-oxidant test, allows quantification of the potential of the extract to reduce the silver ion to elemental silver which is a role played by all the antioxidants present in the extract.

To provide insights on the level of anti-oxidants in the leaf extracts, free Radical Scavenging Activity (RSA) of the dilute guava leaf extract was assessed using the DPPH method as outlined by Baliyan *et al.* (2022). 24 mg of DPPH was dissolved in 100 mL of absolute ethanol to prepare the stock solution. The solution was passed through Whatman No. 1 filter paper, and the absorbance of the filtrate was measured using a Genesys 10S UV spectrophotometer at 517 nm. The solution was

diluted until the absorbance falls below 1.0 A. In a test tube, 3 mL of DPPH working solution was mixed with 50 μ L of diluted leaf extract. Three millilitres of a solution containing DPPH in 50 μ L of absolute ethanol was used as the standard. The tubes were incubated in total darkness for 30 minutes. The absorbances were measured at 517 nm as described by Valko and co-workers (2007). The percentage of antioxidant activity was calculated using Equation 3.1.

$$\text{Percent Antioxidant activity (\%)} = \left[\frac{(A_c - A_s)}{A_c} \right] \times 100 \quad (3.1)$$

where: A_c is the control reaction absorbance; A_s is the testing specimen absorbance. The anti-oxidant activity based on radical scavenging activity (RSA) was calculated using Equation 3.1, where the absorbance was 1.9125 Au and 2.9810 Au for the blank.

$$\text{Percentage Antioxidant activity} = \frac{2.9820 - 1.9125}{2.9820} \times 100 \% = 35.87 \%$$

3.6. Synthesis of silver nanoparticles

To prepare 1000 ml of 1 mM silver ion solution, 0.68 g of silver acetate was weighed and transferred into a 1000 mL volumetric flask. Subsequently, 1 mL of 1 M nitric acid was added to dissolve the silver acetate, and the solution was diluted to the 1000 mL mark with distilled water. The resultant solution was designated as a 1 mM silver nitrate solution. The silver nanoparticles were synthesised according to the method outlined by Devanesan and Alsalhi (2021).

To prepare AgNPs, 5 mL of 1 M AgNO_3 and 10 mL of 1 M NaOH are combined with 10 mL of guava leaf extracts, followed by continuous stirring with glass rod for 15 minutes and heating to 50°C to ensure the complete formation and stability

of AgNPs. The solution will swiftly alter its colour from red to grey, signifying the direct synthesis of silver nanoparticles (Abbas *et al.* , 2020). The solution was placed into sterilized 15 mL centrifuge tubes, and AgNPs was harvested by centrifugation at 6000 rpm for 10 minutes. The AgNPs was collected, rinsed thrice with double distilled deionised water, and dried at 105°C in a digital oven for six hours.

The percentage yield of the synthesized nanoparticles was calculated using the experimental yield and theoretical yield with the aid of Equation 3.2. For example, replicate of white guava-based silver nanoparticles produced 1.6702 g of silver nanoparticles while the theoretical yield is 2.6967 g. The yield was calculated as follows:

$$\text{Percent yield} = \frac{\text{Actual yeild (g)}}{\text{Theoretical yeild (g)}} \times 100 \quad (3.2)$$

$$\text{Perecent yield (\%)} = \frac{1.6702}{2.6967} \times 100 = 61.93 \%$$

3.7. Characterization of the silver nanoparticles

The optical absorption and bio reduction of AgNO₃ in an aqueous solution of synthesised AgNPs was examined using a UV-Vis-NIR spectrophotometer (Genesys 10S) within the wavelength range of 200–800 nm. The mineral composition and structure of the extract was analysed using X-ray diffraction (XRD) with Cu-K α radiation ($\lambda = 1.5406 \text{ \AA}$) to confirm the crystallinity of AgNPs at room temperature.

For purposes of high resolution, the SEM slides were precoated with chromium with aid of High Vacuum Desk Sputter Coater (QUORUM Q150 ES Plus). A Scanning Electron Microscope (SEM) (ZEISS, Gemini 1) coupled with energy dispersive X-ray (EDX) (SMART EDX) was employed to examine the surface morphology of AgNPs and their chemical composition.

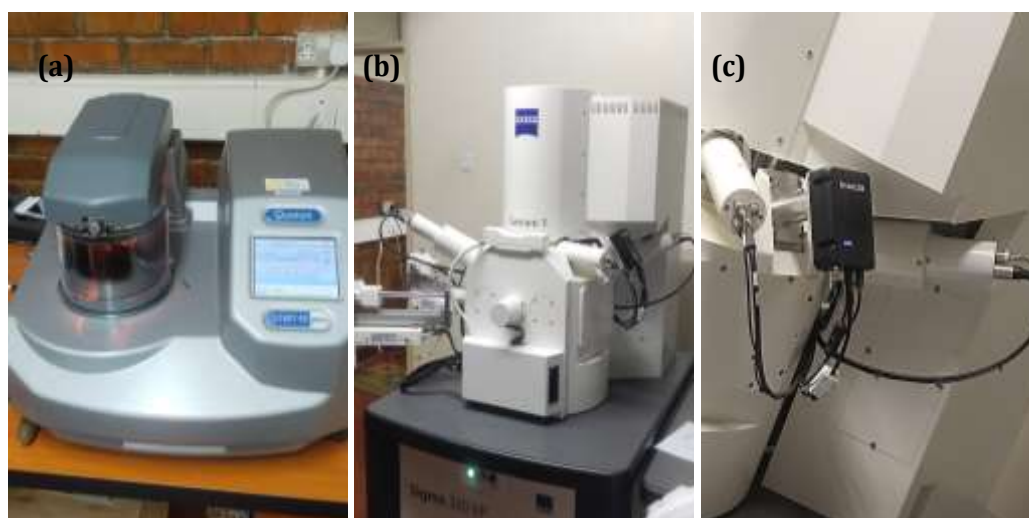


Figure 3.2: Instruments for SEM micrographs collection. (a) Chromium coater, (b) SEM and (c) EDX.

3.8 Lead sorption experiments

A 50 mL volume of a 250 mg/L lead (II) ions solution was combined with a specified quantity of AgNPs, as indicated in Table 3.3. Subsequently centrifuged at 3000 rpm for a designated duration at room temperature. The supernatant was collected, and the concentration of lead ions was quantified using inductively coupled plasma optical emission spectroscopy (ICP-OES). The quantity of lead ions adsorbed per unit mass of adsorbent (mg/g) at time t (q_t) and the removal percentage (R%) was calculated using equations 3.3 and 3.4 respectively (Elessawy *et al.*, 2020). The contact time study range was selected to be 5-25 for ensure that adsorption efficiencies that give result in meaningful discussions are obtained.

Higher contact times would result into 100 % removal efficiencies even for lower dosages. This is same for dosage. Higher dosages could give 100 % removal efficiencies which makes analysis hard.

Each experiment was conducted in triplicate, and the average performance was reported.

$$\text{Adsorption capacity (mgg}^{-1} \text{ at time t)} = \left[\frac{C_0 - C_t}{w} \right] \times 100 \quad (3.3)$$

$$\text{Removal efficiency (\%)} = \left[\frac{C_0 - C_t}{C_0} \right] \times 100 \quad (3.4)$$

Table 3.3: Adsorption study research experiment design

| Dosage (g) | Contact time (minutes) | | | | |
|------------|------------------------|----|----|----|----|
| | 5 | 10 | 15 | 20 | 25 |
| 0.1 | | | | | |
| 0.2 | | | | | |
| 0.4 | | | | | |
| 0.6 | | | | | |
| 0.8 | | | | | |
| 1.0 | | | | | |

3.9. Preparation of AgNPs impregnated clay filter

To prepare models of the ceramic filter, sieved clay and saw dust (in a 1:4 ratio) was manually mixed together to obtain homogenous mix. This was then divided into 5 portions of 2 kg.



Figure 3.3: Clay filter preparation process

To each of the 3 portions, 3 g of silver nanoparticle powder was added. In the fourth portion was added 3 g mixture of silver nanoparticles in a blend of 1:1:1 from the three guava types while and the fifth portion was left without any nanoparticles. The mixtures were each mixed by wedging and rolling for 30 minutes to ensure uniform distribution of the nanoparticles within the clay matrix.

The clay was then transferred to the porters' wheel where the blocked clay mixtures were moulded into frustum shape as shown in Figure 3.3. The prepared filter models had a 10.0 cm top diameter, 15.0 cm height, 5.0 cm bottom diameter, and 1.10 cm wall thickness.



Figure 3.4: AgNPs impregnated clay filter Models

The shaped filters models were allowed to sun dry for about two weeks. Once the filters are completely dried, they were sintered in muffle furnace at 900°C for a period of 6 hours gradually starting from room temperature with an intermediate stay time 1hr at 500°C for combustible material removal in the initial heat treatment. Afterward, the filters were left to cool gradually until the temperature reached room temperature.

3.10. Evaluation of AgNPs impregnated clay filter for the removal of lead

Once cooled, the filters models were soaked in water for 24 hours as shown in Figure 3.4, and tested for their clean water flux. The selected filters were washed with distilled water, dried in an oven, packed properly in plastic bags to protect them from any contamination and made ready for the lead removal tests in batch studies.

The filtrate was collected, and the concentration of lead ions was quantified using ICP-OES. The removal percentage (R %) was calculated using equations 3.5.



Figure 3.5: Experimental Set up of Lead Removal

3.11. Expected data and analysis

The antioxidant potential data expected were absorbance values and were analysed to determine the antioxidant activity of the extract using the Equation 3.1 (Baliyan *et al.* , 2022; Valko *et al.* , 2007). The silver nanoparticles yield was determined by weighing the amount of the dried nanoparticles while the conversion was determined by Equation 3.2. The XRD data was converted into readable data using PowDLL software and the XRD pattern drawn using OriginPro 2018 and the peaks assigned. The crystal sizes was determined by Scherrer Equation (Monshi *et al.* , 2012) as shown in Equation 3.3. The expected SEM/EDX data are micrographs and elemental mappings respectively. The micrographs were used for describing the morphology of the particles (shape and connectivity) while the EDX maps give information in the elemental composition of the nanoparticles.

To determine the amount of lead ions adsorbed per unit mass of adsorbent (mg/g) at time t (q_t), and the removal percentage (R %) equations (3.4) and (3.5) were used respectively. Varieties with higher adsorption and removal efficiency were

taken as the best form remediation of lead in the solution. The removal of Lead ions that remained in the treated water was quantified.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1. Introduction

This section contains results from various specific objectives. Findings of a given specific objective are described, interpreted and discussed under separate sub-headings.

4.2. Synthesis of silver nanoparticles

All the guava trees that were studied were mature trees that had fruited for more than four seasons; the average stem size was between 30 and 50 cm. The average tree height was 6-8 meters tall for all the trees studied.

4.3. Antioxidant activity of aqueous extracts

White guava extract demonstrated the highest RSA ($83.85 \pm 0.54\%$), followed by the red guava extract ($35.30 \pm 0.79\%$), and the orange guava extract ($26.33 \pm 5.78\%$) as summarized in Figure 4.1. The results indicated significant differences ($p \leq 0.05$) (Table 4.1) in the percentage radical scavenging activity (RSA) among the three guava varieties (red, orange, and white) tested using the DPPH method.

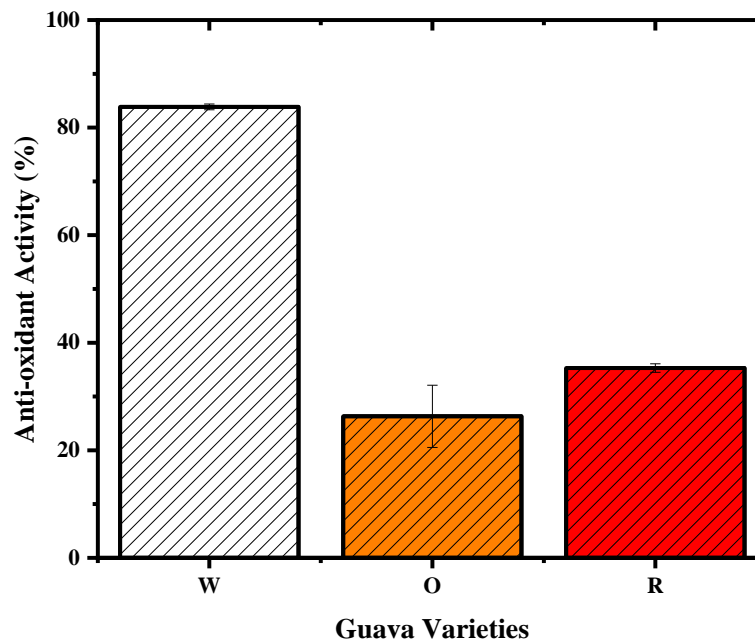


Figure 4.1: Variation of anti-oxidant activity in different guava varieties

The relatively high RSA of white guava extract suggests it contains a high concentration of antioxidant compounds, such as phenolics, flavonoids, or ascorbic acid, which are known to neutralize free radicals effectively (Tachakittirungrad *et al.*, 2007). However, this finding aligns with studies that have reported white-fleshed guava varieties to exhibit superior antioxidant properties (58.7%) compared to other varieties (Jiménez-Escrig *et al.*, 2001).

Meanwhile, this study disagrees with findings by Mazumder *et al.*, (2023), who reported antioxidant activity of 33.08 ± 1.13 , 35.79 ± 0.12 , and $39.85 \pm 0.58\%$ by microwave-assisted, ultrasound-assisted, and solvent extraction respectively based on DPPH for aqueous leaf extract of *Psidium guajava* of pink (red) fruit variety. The moderate RSA of red guava extract (35.30 %) may be attributed to its lower concentration of antioxidant compounds compared to white guava. But, still it demonstrates significant antioxidant potential, which is consistent with previous

studies highlighting the presence of lycopene and other bioactive compounds in red guava varieties by Nwaichi *et al.* , (2015) and 42.8 % following a study by Lella *et al.* , (2024).

Table 4.1: ANOVA results for antioxidant activity of various guava varieties leaf extracts

Anova: Single Factor
SUMMARY

| Groups | Count | Sum | Average | Variance |
|--------|-------|----------|---------|----------|
| Red | 3 | 105.8853 | 35.2951 | 0.9466 |
| Orange | 3 | 62.7431 | 20.9143 | 50.0930 |
| White | 3 | 251.5425 | 83.8475 | 0.42995 |

ANOVA

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---------------------|-----------|----|-----------|----------|-----------|--------|
| Between Varieties | 6524.7253 | 2 | 3262.3627 | 190.1528 | 3.747E-06 | 5.1432 |
| Within varieties | 102.9391 | 6 | 17.1565 | | | |
| Total | 6627.6644 | 8 | | | | |

The lowest RSA observed in orange guava extract (26.33 %), coupled with the highest variability, suggests that this variety may have a less stable antioxidant profile. This could be due to differences in ripeness, environmental factors, or genetic variability within the orange guava variety (Flores *et al.*, 2015).

The RSA value of 24.3% was observed for orange only, and for red was reported as 35.30%. White guava extracts were found to exhibit higher antioxidant activity compared to red and yellow varieties, which supports the trend observed in this study (Thaipong *et al.* , 2006). Similarly, guava varieties with lighter flesh colours tended to have high antioxidant capacities due to their high phenolic content (Jiménez-Escrig *et al.* , 2001). However, Ribeiro *et al.*, (2007) noted that red guava varieties, rich in lycopene, also exhibited antioxidant activity, which aligns with the moderate RSA observed for red guava in this study.

The lower RSA observed in the red and orange guava extracts in this study may be attributed to differences in the concentration of bioactive compounds, such as polyphenols and flavonoids, which are known to contribute to antioxidant activity (Lella *et al.* , 2024). The wide range of standard deviation in the orange guava extract may be attributed to the high variability in the concentration of the bioactive compounds.

4.4. Silver nanoparticles synthesis and characterisation

4.4.1. Silver nanoparticles synthesis

The percent yield of 61.93% was calculated for the white variety. The average percent yield for all varieties are shown in Figure 4.2 The yield increased in the order of red, white and orange with average percent yields of 55.94 ± 2.99 , 57.76 ± 3.97 and $57.99 \pm 4.50\%$, respectively. All varieties were able to produce sufficient quantity of nanoparticles for the study.

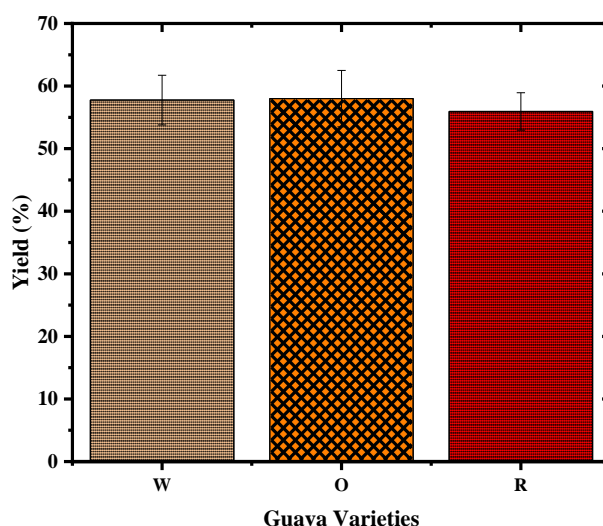


Figure 4.2: Variation of Ag-NPs yield for different guava varieties extracts.

The ANOVA results as shown in Table 4.2, suggest that there is no statistically significant variations in Ag NPs yields among the three guava types (white: 57.76

± 3.25 ; orange: 57.99 ± 3.79 ; red: 55.94 ± 2.49), as seen by the elevated p -value (0.630) and an F-statistic (0.486) that falls below the threshold F-value (4.256). This indicated that the reduction capabilities of the three extracts are analogous.

Table 4.2: ANOVA results for yield of synthesized silver nanoparticles

| Anova: Single Factor | | | | | | |
|----------------------------|--------------|------------|----------------|-----------------|----------------|---------------|
| SUMMARY | | | | | | |
| <i>Guava variety</i> | <i>Count</i> | <i>Sum</i> | <i>Average</i> | <i>Variance</i> | | |
| White | 4 | 231.0455 | 57.7614 | 10.5687 | | |
| Orange | 4 | 231.9752 | 57.9938 | 14.3710 | | |
| Red | 4 | 223.7675 | 55.9418 | 6.21736 | | |
| ANOVA | | | | | | |
| <i>Source of Variation</i> | <i>SS</i> | <i>df</i> | <i>MS</i> | <i>F</i> | <i>P-value</i> | <i>F crit</i> |
| Between varieties | 10.1000 | 2 | 5.0500 | 0.4862 | 0.6302 | 4.2564 |
| Within varieties | 93.4716 | 9 | 10.3857 | | | |
| Total | 103.5717 | 11 | | | | |

The silver ion concentration exceeded the extracts' reducing capacity, masking variability (Kumar *et al.* , 2020) and ascorbic acid (common in all guava varieties) may drive reduction uniformly, while secondary antioxidants (e.g., lycopene in red guava) play negligible roles (He *et al.* , 2019). This study aligns with studies by Ghidan and Antary (2020) who observed that plant extracts with similar total phenolic content yielded AgNPs of comparable amounts of silver nanoparticles. Additionally, Jadhav *et al.* . (2021) noted that subtle antioxidant differences for instance $\pm 5\%$ Total Phenolic Content (TPC) rarely translate to significant yield changes, echoing these results. On the other hand, studies using extracts with divergent antioxidant mechanisms (e.g., phenolic-rich vs. flavonoid-dominated) reported yield differences (Mallikarjuna *et al.* , 2021). The guava varieties' similar phytochemical compositions may explain the absence of such differences.

4.4.2. Nanoparticles characterisation

According to the SEM micrograph (Figure 4.3), the nanoparticles appeared with spherical shape, a typical morphology for green-synthesized AgNPs given the isotropic growth circumstances supplied by the guava plant extract. The particles showed a consistent and well-dispersed distribution suggesting efficient stabilisation by the phytochemicals in the guava leaf extract. There was observable degree of aggregation which was decreasing in the order of red, orange, and distinct nanoparticles for white variety. Minimal aggregation was recorded in white variety as indicated by the synthesis technique that effectively avoids too strong particle clustering. Clustering is caused by availability of limited anti-oxidant to promote synthesis and subsequent stabilisation of the NPs (Ying *et al.*, 2022). Therefore, this is a typical of biologically produced AgNPs, where biomolecules serve as capping agents, the surface of the nanoparticles seems smooth.

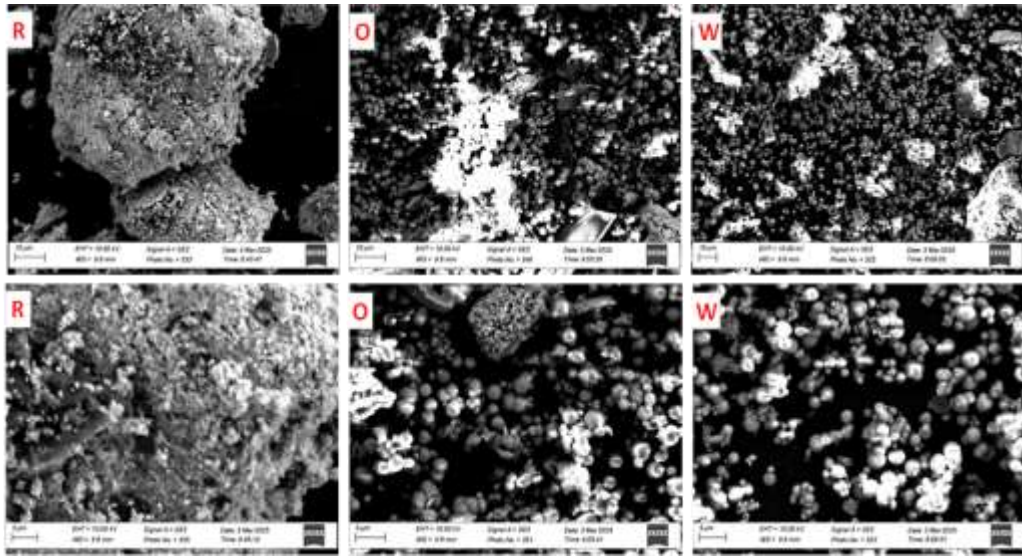


Figure 4.3: Silver NPs characterisation; SEM micrographs for Ag NPs.

The micrographs are for Ag NPs synthesized using guava leaf extracts of the three varieties at 5 and 10 μm resolution. R, O and W are silver nanoparticles synthesised using red, orange and white guava leaf extracts respectively.

At these resolutions, there is clear difference within the nanoparticles. At 5 μm , the morphology of Ag NPs in white were more define compared to those from orange and red. Both from white and Orange are seen as distinct particles with interparticle spaces higher in white than orange while for red, they are completely clustered into a single big lump. The diameter distribution of the nanoparticle was 4.857 ± 1.339 , 4.651 ± 1.013 and 3.603 ± 2.018 μm for white, orange and red guava fruit derived green silver nanoparticles. The spherical shapes of the NPs was in agreement with studies by (Asgary *et al.*, 2016; Dhasarathan *et al.*, 2018)

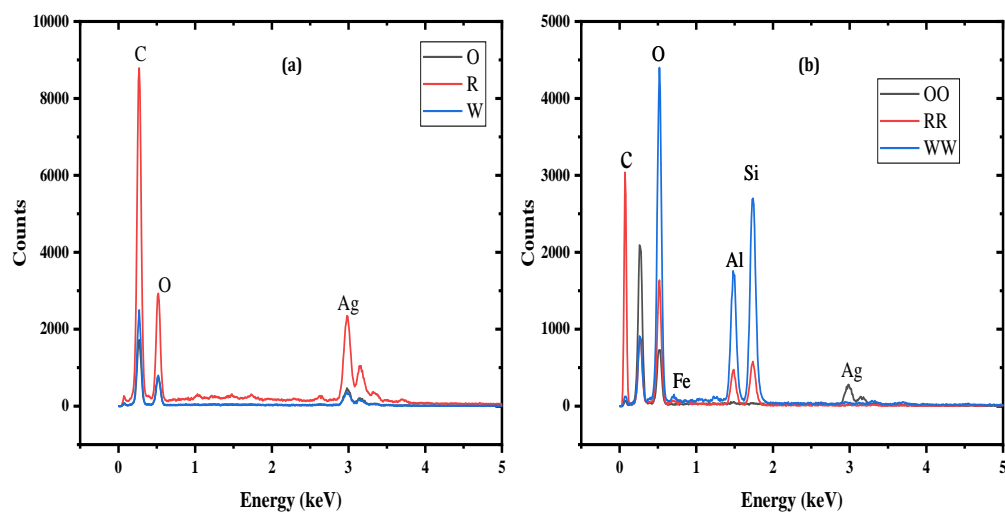


Figure 4.4: (a) Silver NPs composition (b) EDS mappings for Ag NPs

The EDS elemental mapping (Figure 4.4) revealed the presence of silver and oxygen in the nanoparticles from all the three varieties of guava plants with orange varieties having the highest atomic composition of silver than orange and white varieties as shown in Figure 4.4: (a). Orange and white varieties produced nearly the same atomic composition.

Table 4.3: Elemental atomic composition of the nanoparticles, fired clay and clay-NPs composite filter

| Sample ID | Atomic Composition (%) | | | | |
|-----------|------------------------|-----------|---------|------|--------|
| | Oxygen | Aluminium | Silicon | Iron | Silver |
| R | 74.73 | - | - | - | 25.27 |
| O | 79.92 | - | - | - | 20.08 |
| W | 84.16 | - | - | - | 15.84 |
| RR | 73.47 | 6.17 | 18.23 | 1.67 | 0.47 |
| OO | 84.95 | - | - | - | 15.05 |
| WW | 59.81 | 14.26 | 24.97 | 0.62 | 0.35 |
| C | 69.99 | 12.93 | 15.7 | 1.38 | - |

Where; R, O and W are separate silver nanoparticles synthesised using red, orange and white guava leaf extracts while RR, OO and WW are fired clay-silver

nanoparticles composites and finally, C is pure clay without nanoparticles (Nyakairu *et al.*, 2002).

For the EDS mapping for the fired clay filter mixed with Ag NPs, the EDS pattern revealed presence of iron, aluminium and silicon in addition to silver and oxygen. It should be noted that, the relative abundancy of oxygen increased for all samples this comes from organic material in the reducing guava leaf extract. This is due to that fact that the peaks from the oxides of iron, aluminium and silicon, respectively. The carbon revealed by EDS is the background carbon on the SEM slide. This carbon was revealed in all the ESD mapping.

For the clay composite with AgNPs from orange guava (OO), the Energy-Dispersive X-ray Spectroscopy (EDS) data shows no Al, Si, or Fe signals. This is typical of a thick or dense surface coating, which attenuates the substrate's X-ray signal. Low-energy X-rays from lighter elements like Al and Si are easily absorbed by overlaying material in EDS analysis due to a limited interaction volume near the sample surface. Due to silver's high atomic number (Z), a dense layer of AgNPs and their phytochemical capping agents synthesised from orange guava extract absorbs the clay's soft X-rays (Al, Si, Fe) and prevents them from reaching the detector (Goldstein *et al.*, 2018). This effect is well-documented in core-shell nanoparticles and composite materials with heavy elements on lighter substrates. This only occurs in the OO sample, not the RR or WW composites, strongly suggesting that the AgNPs produced using orange guava extract have a uniquely thick organic capping layer or formed a more uniform and denser biofilm on the clay surface, as indicated by its significantly higher oxygen content (84.95%),

which is representative of the organic matrix. The EDS spectrum for OO mostly shows the surface layer (Ag and organic cap), making the clay "invisible."

4.4.3. Comparison of elemental composition

All fired samples had higher oxygen composition compared to other elements, followed by silver, silicon, aluminium and iron respectively. The higher oxygen content is due to reduction of all elements to their stable oxide forms.

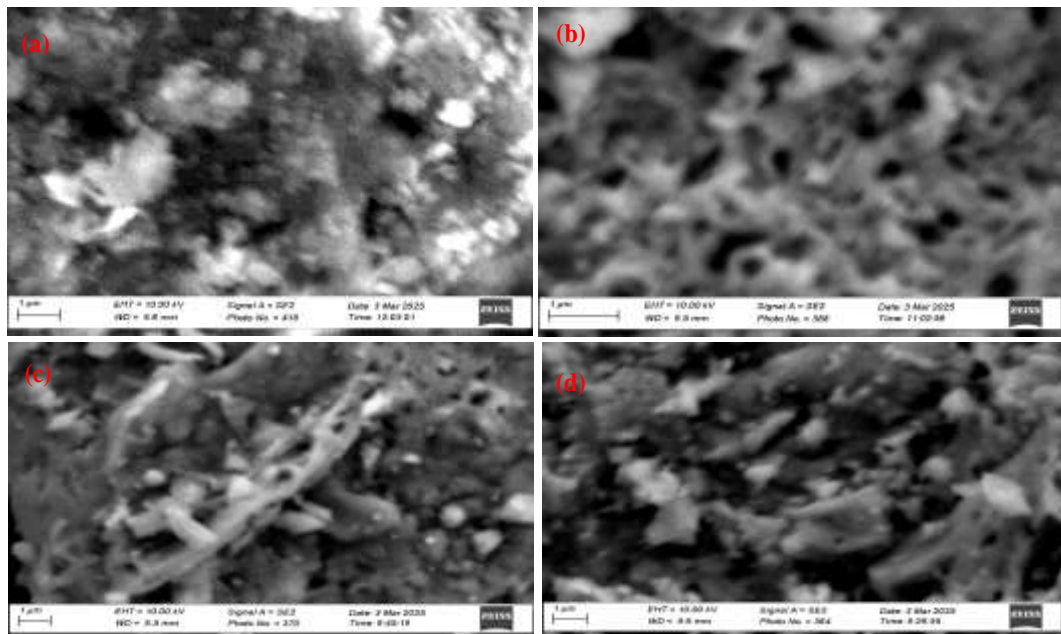


Figure 4.5: Clay filter characterisation; SEM micrographs of fired clay and Ag-NPs clay composite filter at 1 μ m.

Where (a), (b), (c) and (d) are fired clay, Ag NPs composite from Orange, Red and White guava extracts respectively. At these resolutions, the fired clay is seen to be continuous while clay Ag NPs composites are observed to have distinct pores. The pores are less distributed and are bigger in (O) and (R) while they are smaller in (W).

The micrographs in Figure 4.6 show the microstructure of fired clay. With some uneven, plate-like shapes, the clay (a) particles showed an angular to sub-rounded morphology. After burning, this is typical of kaolinite or illite-based clays (Bergaya *et al.* , 2006). Indicating exposure to high temperatures usually 800–1100°C the particles seem sintered with clear fusion sites. This is consistent with (Cultrone *et al.* , 2004) findings, who observed that burning causes particle coalescence and densification due to loss of ignitable and combustible components..

Common in mid-range firing temperatures (1150 to 1260°C), the microstructure revealed inter-particle gaps indicating poor densification (Mamun & Bindiganavile, 2014). Even after thermal treatment, Bergaya *et al.* , (2006) found that burned clay particles kept angularity because of the ongoing silicate layers. According to Cultrone *et al.* , (2004), sintering preserves certain structural irregularity while rounding edges to fit the morphology shown in (a). While this sample keeps roughness, which supports the firing temperatures of 1100 °C utilised in this work, some studies such as (Mamun and Bindiganavile, 2014) show that greater firing temperatures (>1200°C) generate smoother, more spherical particles.

In the composite, the silver nanoparticles looked like sparkling, spherical deposits clinging to clay surfaces instead of creating distinct big clusters. This implies effective heterogeneous nucleation on clay (Pradhan *et al.* , 2019). Phytochemicals in the guava extract such as polyphenols could serve as bridge ligands attaching Ag-NPs to clay surfaces (Mallikarjuna *et al.* , 2021). Unlike in (a), the composite

showed no signs of Ag-NPs melting, suggesting lower-temperature processing or protecting organic layers.

Zhang *et al.* , (2020) found similar Ag NP-clay composites in which nanoparticles preferentially attached to clay edges, hence improving antibacterial qualities. According to Suleman *et al.* , (2021), natural surfactants cause plant-extract-synthesized AgNPs to have closer clay adherence, hence matching the uniform coating in composite. Some investigations, such as Ganuza *et al.* , (2019), found AgNPs clustering into bigger groups on clays; here, however, dispersion is very consistent, maybe owing to the stabilising properties of guava extract.

4.4.4 Crystal structure of the clay, AgNPs, and clay-NPs composites

The X-ray diffraction (XRD) pattern provided essential insights into the crystalline structure and successful synthesis of silver nanoparticles (AgNPs) utilising aqueous leaf extracts from various *Psidium guajava* (guava) varieties, along with their subsequent incorporation into a clay matrix. The examination of these peaks validated the creation of metallic silver and substantiated the composite's structure.

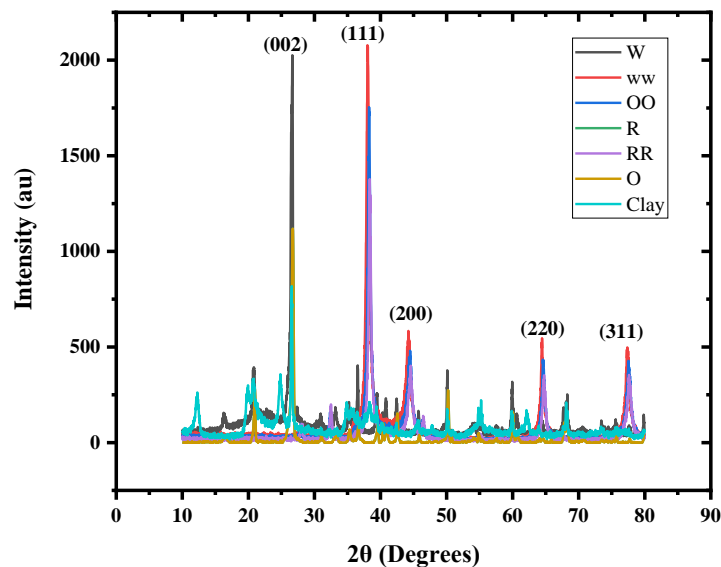


Figure 4.6: Crystalline pattern of the AgNPs, clay and clay NPs composite

The diffraction patterns for the green-synthesized AgNPs (Figure 4.7.) (W, O, R) exhibited definite peaks, characteristic of a crystalline substance. The principal peaks for the AgNPs are noted at 2θ values of roughly 38.1° , 44.3° , 64.4° , and 77.4° . These relate to the (111), (200), (220), and (311) crystallographic planes of face-centered cubic (FCC) silver, respectively (JCPDS file No. 04-0783). The existence of these distinct, pronounced peaks validates the conversion of ionic silver (Ag^+) to crystalline metallic silver (Ag^0) facilitated by the phytochemicals in guava leaf extracts (Ntoumba *et al.*, 2020).

The (111) plane consistently exhibits the highest intensity peak among all three samples (W, O, R), signifying that this is the primary orientation of crystal formation. The (111) plane is frequently observed in the green synthesis of AgNPs, as it is typically the most thermodynamically stable facet. The minor differences in peak intensity and width among the W, O, and R samples indicate that the phytochemical composition of the various guava leaf extracts may affect the

nucleation and growth kinetics, potentially resulting in variations in nanoparticle size or crystallinity (Ameen *et al.*, 2019). The lack of further conspicuous peaks further signifies the great purity of the synthesised AgNPs, indicating no substantial crystalline by-products from the plant extract.

The profile of the pure clay exhibited a distinctly different pattern, characterised by wider, less pronounced peaks at lower 2θ angles. This is characteristic of clay minerals such as montmorillonite or kaolinite, which possess layered silicate structures and frequently demonstrate reduced crystallinity in comparison to metals (Bergaya *et al.*, 2006). The prominent bulge in the clay's pattern reveals its amorphous composition. The most persuasive evidence for successful composite production is shown in the patterns designated WW, OO, and RR (Figure 4.7), which illustrate the clay combined with the corresponding AgNPs. These composite patterns are not simply the aggregation of the individual clay and AgNPs patterns.

On the other hand, they exhibited a superposition in which the distinctive broad characteristics of the clay are evident, while the sharp, pronounced peaks of FCC silver, particularly the powerful (111) peak at around 38.1° , are now distinctly observable against the clay's backdrop. This indicated that the crystalline structure of the AgNPs was maintained during their integration into the clay matrix. The effective incorporation of AgNPs onto clay is a noteworthy discovery, since clay functions as an exceptional support material to inhibit nanoparticle aggregation, thus enhancing the accessible surface area for applications like adsorption or catalysis (Vanlalveni *et al.*, 2021). The uniformity of the silver peaks in WW, OO,

and RR composites further validates that the synthesis approach is reliable across several guava cultivars, yielding AgNPs with an identical core crystalline structure for efficient composite production.

4.5. Lead adsorption

The data presented in Tables 4.4 demonstrate the lead ion removal efficiency (%) of green silver nanoparticles synthesized using white, orange, and red *Psidium guajava* aqueous leaf extracts with an average final concentration of 179.00398 and initial lead ion concentration of 250.01361 mg/L in 0.1 g dosage at 5 minutes contact time, respectively. This was obtained by using Equation 3.5. For all the three types of AgNPs (white, orange, and red), the lead removal efficiency increases with an increase in nanoparticle dosage from 0.1 g to 0.6 g. This is attributed to the greater availability of active adsorption sites on the nanoparticle surface at higher dosages, which enhances the interaction between Pb^{2+} ions and the nanoparticles (Kumar *et al.* , 2019).

Table 4.4: Lead adsorption efficiency

| AgNPs prepared using White <i>Psidium guajava</i> , n=3 | | | | | |
|--|------------------------|--------------|--------------|--------------|--------------|
| Dosage (g) | Contact time (minutes) | | | | |
| | 5 | 10 | 15 | 20 | 25 |
| 0.1 | 28.402±1.268 | 31.214±0.715 | 32.897±1.111 | 33.377±1.505 | 35.174±1.133 |
| 0.2 | 43.327±1.229 | 45.878±0.563 | 48.199±0.857 | 49.027±0.151 | 47.590±0.916 |
| 0.4 | 55.180±0.794 | 57.620±0.441 | 60.297±0.657 | 61.583±0.868 | 63.327±0.785 |
| 0.6 | 72.998±0.1478 | 77.919±0.281 | 81.018±0.314 | 82.683±0.391 | 81.187±0.329 |
| 0.8 | 72.136±0.604 | 74.417±0.326 | 78.181±0.361 | 80.061±0.540 | 78.716±0.455 |
| 1 | 67.176±0.581 | 69.504±0.388 | 73.549±0.438 | 75.712±0.549 | 73.928±0.456 |
| AgNPs prepared using Orange <i>Psidium guajava</i> , n=3 | | | | | |
| 0.1 | 27.602±1.983 | 29.655±2.049 | 31.614±2.105 | 32.566±2.144 | 33.874±2.319 |
| 0.2 | 42.581±1.882 | 44.478±1.966 | 46.908±2.073 | 48.061±2.124 | 46.584±2.059 |
| 0.4 | 54.187±1.889 | 56.104±1.956 | 58.840±2.051 | 60.343±2.103 | 61.874±2.157 |
| 0.6 | 69.221±3.310 | 76.220±1.880 | 79.289±1.956 | 81.011±1.998 | 79.540±1.962 |
| 0.8 | 70.969±1.621 | 72.909±1.665 | 76.632±1.751 | 78.581±1.795 | 77.246±1.765 |
| 1 | 64.873±3.079 | 66.773±3.169 | 70.706±3.356 | 72.911±3.460 | 71.183±3.378 |
| AgNPs prepared using Red <i>Psidium guajava</i> , n=3 | | | | | |
| 0.1 | 23.435±1.356 | 26.125±0.941 | 27.639±1.198 | 27.978±1.993 | 29.354±1.234 |
| 0.2 | 38.650±1.086 | 41.039±0.613 | 43.069±0.942 | 43.729±1.271 | 42.469±1.005 |
| 0.4 | 50.505±0.876 | 52.825±0.491 | 55.243±0.741 | 56.357±0.986 | 57.985±0.734 |
| 0.6 | 64.839±0.623 | 73.324±0.277 | 76.213±0.394 | 77.735±0.502 | 76.342±0.413 |
| 0.8 | 68.098±0.565 | 70.307±0.309 | 73.839±0.433 | 75.573±0.552 | 74.317±0.550 |
| 1 | 59.709±0.713 | 61.890±0.485 | 65.444±0.572 | 67.287±0.739 | 65.728±0.599 |

Beyond 0.6 g, the removal efficiency either plateaus or slightly decreases. This trend is likely due to particle aggregation at higher dosages, which reduces the effective surface area available for adsorption (Khan *et al.* , 2020). The lead removal efficiency increases with contact time for all dosages and guava varieties. This is because a longer contact time allows for greater diffusion of Pb²⁺ ions to the active sites on the nanoparticle surface (Rafique *et al.* , 2020). The most significant improvements in efficiency occurred within the first 15–20 minutes,

after which the rate of adsorption slows down, indicating near-saturation of adsorption sites.

From the Figure 4.7, at lower dosages (0.1-0.2 g), the removal efficiency is relatively low, ranging from 25.26% to 44.68% across the three guava varieties. This is because the limited number of nanoparticles provides fewer active sites for Pb^{2+} ion adsorption. The surface area available for interaction is insufficient to achieve high removal rates (Kumar *et al.* , 2019).

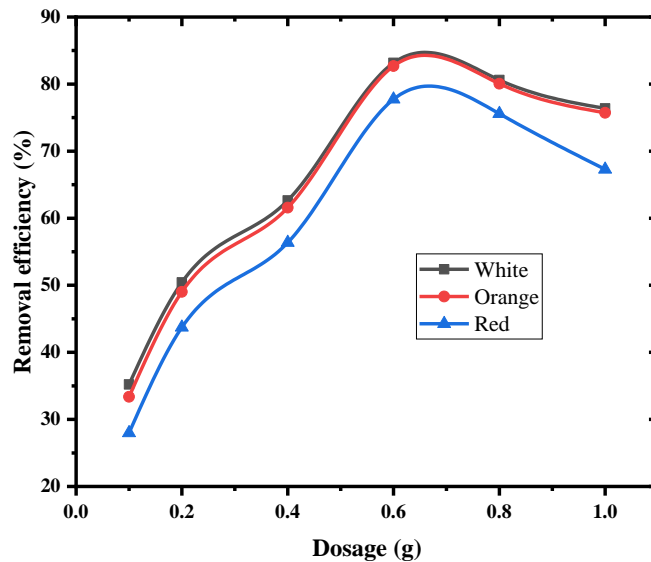


Figure 4.7: Plot of lead removal efficiency against contact time at 0.6 g dosage.

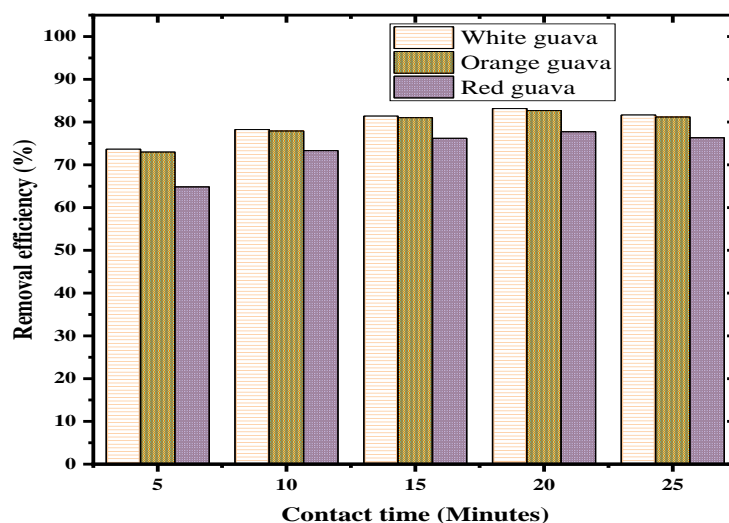
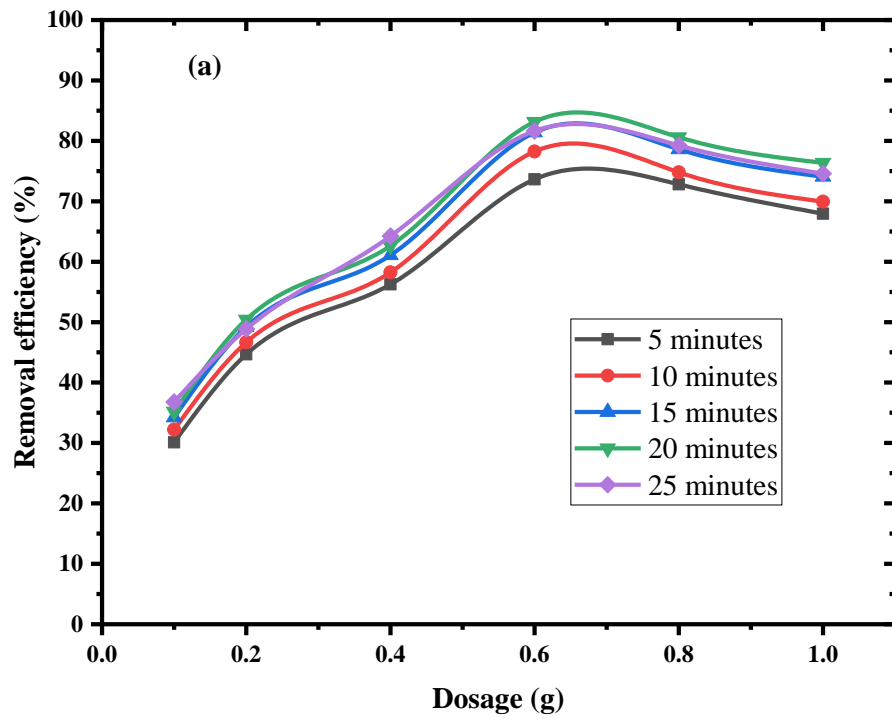


Figure 4.8: Plot of efficiency against dosage at 20 minutes of contact time

For instance, at 0.6 g, the efficiency reaches 83.16% for white guava AgNPs, 81.53% for orange guava AgNPs, and 78.35% for red guava AgNPs. This is due to the increased availability of adsorption sites and greater surface area for Pb^{2+} ions to bind (Khan *et al.* , 2020).

As the dosage increases (0.4 to 0.6), the removal efficiency improves significantly. Beyond 0.6g, the removal efficiency either plateaus or slightly decreases. This phenomenon is attributed to nanoparticle aggregation at higher concentrations, which reduces the effective surface area and accessibility of active sites. Additionally, overcrowding of nanoparticles may lead to overlapping adsorption sites, diminishing their overall efficiency (Rafique *et al.* , 2020).

At shorter contact times (5-10 minutes), the removal efficiency is relatively low, as the Pb^{2+} ions have insufficient time to diffuse and bind to the active sites on the nanoparticle surface. For example, at 5 minutes, the efficiency ranges from 25.26% (red guava Ag NPs) to 30.112% (white guava Ag NPs).



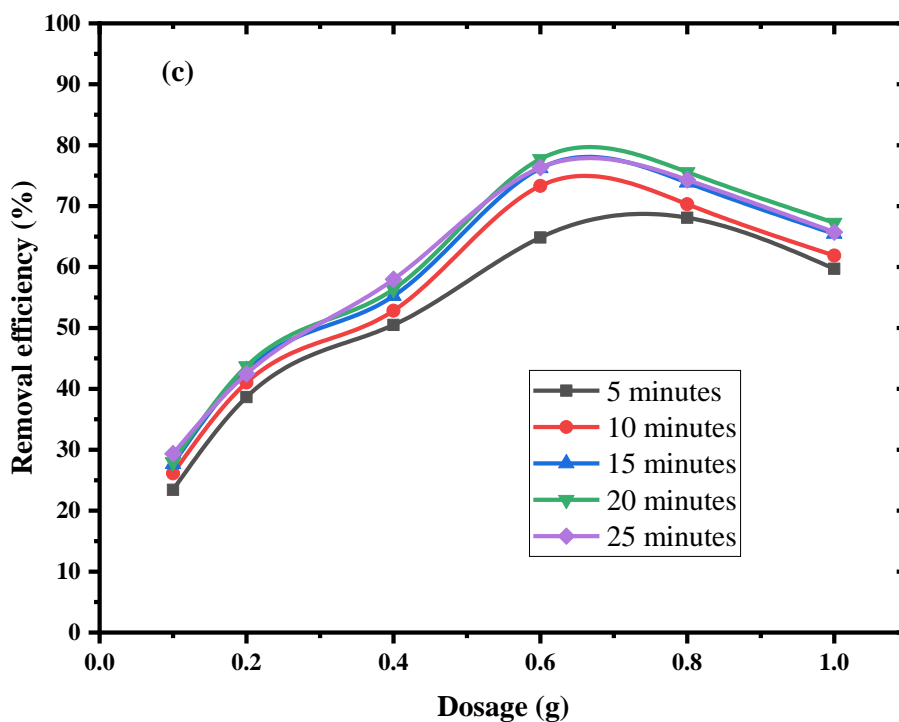
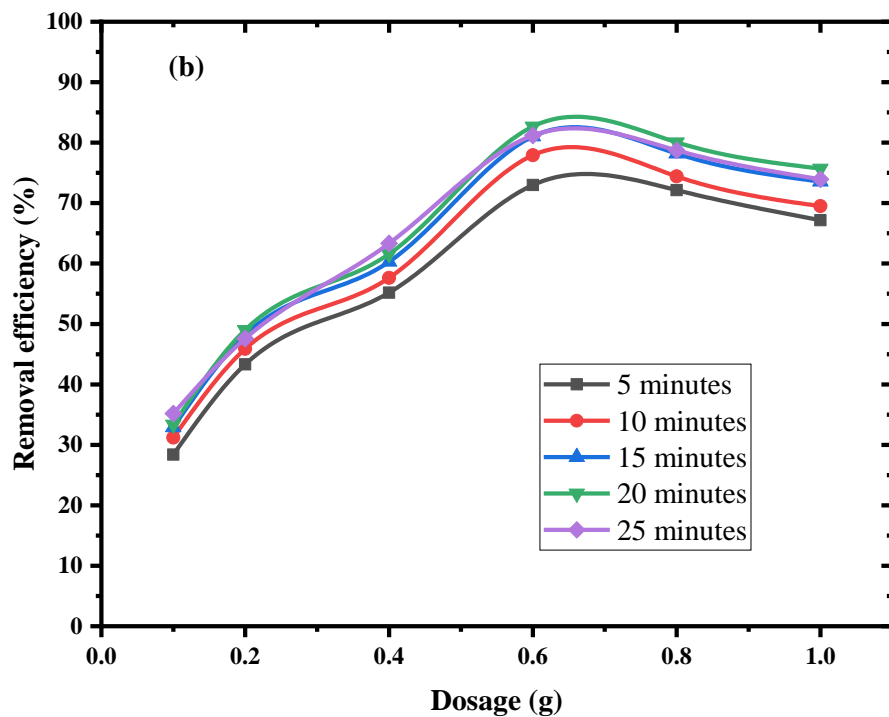


Figure 4.9: Plot of removal efficiency against dosage for derived silver nanoparticles. Where; (a), (b), (c) variation of lead ion removal at various Ag NPs dosage for white, orange and red respectively. The maximum removal efficiency is at 0.6g as

dosage and 20 minutes as contact time. The maximum removal efficiency is 83.16, 81.53 and 78.35% for white, orange and red guava fruit derived silver nanoparticles respectively.

The removal efficiency increases significantly as the contact time extends to 15–20 minutes. This is because the Pb^{2+} ions have more time to diffuse and interact with the nanoparticles. For instance, at 20 minutes, the efficiency reaches 83.16 % for white guava AgNPs, 81.53 % for orange guava AgNPs, and 78.35% for red guava AgNPs. Beyond 20 minutes, the rate of adsorption slows down, and the efficiency either stabilizes or slightly decreases. This indicates that the adsorption process approaches equilibrium, with most active sites already occupied by Pb^{2+} ions (Mittal *et al.* , 2013).

The nanoparticles from white guava exhibited the highest lead removal efficiency across all dosages and contact times. For example, at 0.6 g and 20 minutes, the efficiency reaches 83.16 %. This superior performance is likely due to the high antioxidant activity (83.85 ± 0.53 %) of white guava extract, which facilitates the synthesis of smaller, more stable, and highly reactive AgNPs with a greater number of active sites (Thaipong *et al.* , 2006). At this optimum contact time, there is linear relationship between contact time and removal efficiency and there is no difference among the varieties ($p \geq 0.05$) as shown in ANOVA results illustrated in Table 4.7

Table 4.5: ANOVA results for lead removal efficiency

| Anova: Single Factor | | | | | | |
|----------------------------|--------------|------------|----------------|-----------------|----------------|---------------|
| SUMMARY | | | | | | |
| <i>Groups</i> | <i>Count</i> | <i>Sum</i> | <i>Average</i> | <i>Variance</i> | | |
| White | 6 | 388.43 | 64.73833 | 361.57 | | |
| Orange | 6 | 382.44277 | 63.74046 | 382.3237 | | |
| Red | 6 | 348.65864 | 58.10977 | 378.4349 | | |
| ANOVA | | | | | | |
| <i>Source of Variation</i> | <i>SS</i> | <i>df</i> | <i>MS</i> | <i>F</i> | <i>P-value</i> | <i>F crit</i> |
| Between Varieties | 153.2764 | 2 | 76.63822 | 0.204855 | 0.817007 | 3.68232 |
| Within Varieties | 5611.643 | 15 | 374.1095 | | | |
| Total | 5764.919 | 17 | | | | |

ANOVA analysis is for removal efficiency at 29 minutes contact time. This time was chosen as all nanoparticles from the three varieties showed their highest removal efficiency.

The nanoparticles from orange guava showed an intermediate performance, with a maximum efficiency of 81.53% at 0.6 g and 20 minutes. The variability in antioxidant activity ($26.33 \pm 6.47\%$) of orange guava extract may result in less uniform Ag-NPs, contributing to slightly lower and less consistent performance. Lastly, the nanoparticles from red guava exhibited the lowest lead removal efficiency, with a maximum of 78.35% at 0.6 g and 20 minutes. The moderate antioxidant activity ($35.30 \pm 0.80\%$) of red guava extract may lead to the formation of Ag-NPs with fewer active sites or less stability, reducing their adsorption capacity.

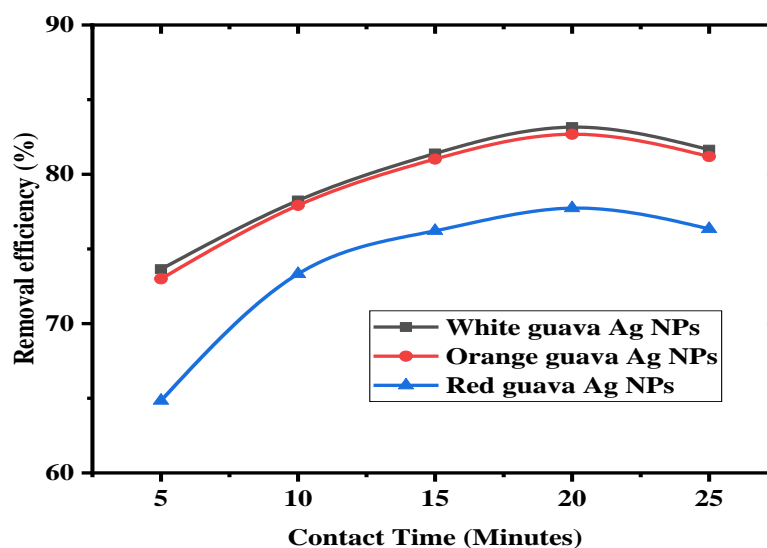


Figure 4.10: Variation removal efficiency against contact of lead ion from water using silver nanoparticles at dosage of 0.6 g.

From Figure 4.8, the optimal conditions for lead removal appear to be a dosage of 0.6 g and a contact time of 20 minutes for all three nanoparticle types (Figure 4.9). At these conditions, the removal efficiency reaches its peak, with white guava nanoparticles achieving up to 83.16% efficiency (Figure 4.10). This aligns with findings from other studies, where moderate dosages and longer contact times were identified as optimal for maximizing heavy metal adsorption using biogenic nanoparticles (Singh *et al.* , 2022).

The antioxidant activity of the guava extracts is a key determinant of the performance of the synthesized Ag-NPs. Higher antioxidant activity correlates with better lead removal efficiency, as seen in the case of white guava Ag-NPs. This is because antioxidants, such as phenolics and flavonoids, not only act as reducing agents during nanoparticle synthesis but also stabilize the nanoparticles, enhancing their adsorption capacity (Mittal *et al.* , 2013). The white guava extract,

with its high RSA, likely facilitates the formation of smaller, more uniform, and highly reactive Ag-NPs, which explains their superior performance in lead removal.

The findings of this study are consistent with previous research on the use of biogenic nanoparticles for heavy metal removal. For example, Kumar *et al.* (2021) reported that silver nanoparticles synthesized using plant extracts exhibited high efficiency in removing lead ions, with optimal performance achieved at moderate dosages and longer contact times. Similarly, Sharma *et al.* (2020) observed that the adsorption capacity of biogenic nanoparticles increased with contact time due to enhanced interaction between metal ions and nanoparticle surfaces.

However, the superior performance of white guava nanoparticles in this study contrasts with some earlier findings. For instance, Rajendran *et al.* (2019) found that nanoparticles synthesized using different plant extracts exhibited comparable efficiency, with minor variations attributed to differences in phytochemical composition. The higher efficiency of white guava nanoparticles in the current study may be due to the unique composition of the extract, which could enhance the adsorption properties of the nanoparticles.

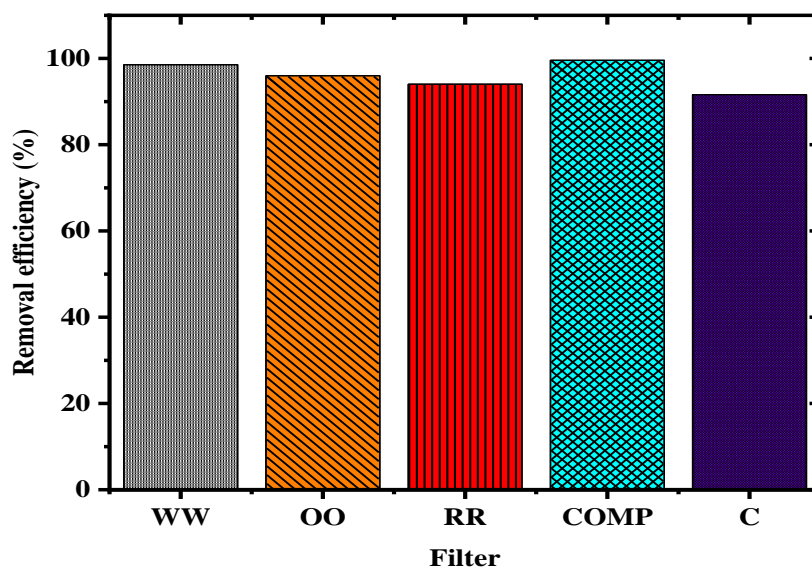


Figure 4.11: Comparison of lead ion removal for fired pure, impregnated and composite clay filters.

Where; RR, OO, WW and COMP are fired clay-silver nanoparticles composites with nanoparticles from respective guava varieties, all integrated nanoparticles and finally, C is pure clay without nanoparticles.

4.6. Performance of the fabricated clay filters

The removal efficiency of lead (Pb^{2+}) ions by various clay filters models that were constructed with distinct green silver nanoparticles (AgNPs) generated from white (WW), orange (OO), and red (RR) guava leaf extracts, are displayed in Figure 4.12. The performance of the filters was evaluated in comparison to bare clay (C) and a composite filter (COMP) comprising a 1:1:1 mixture of the three AgNPs.

The composite filter surpassed all others, attaining nearly total Pb^{2+} elimination. The synergistic impact arises from the collective strengths of the three AgNPs: the

high affinity of white guava AgNPs, the physisorption capability of orange guava AgNPs, and the robust initial binding of red guava AgNPs (Mallikarjuna *et al.* , 2021). The outcome highlights the promise of hybrid nanoparticle systems for water purification applications.

The unadulterated clay filter exhibited considerable intrinsic Pb²⁺ removal efficacy, presumably because to its inherent ion-exchange capacity and surface functional groups (He *et al.* , 2019). This closely agrees with what is reported by Sdiri *et al.* (2016) who reports 95 % removal capacities. Nonetheless, its efficiency was significantly inferior to that of AgNPs enhanced filters, underscoring the importance of nanoparticle modification in enhancing adsorption performance.

4.7. Economic viability and cost analysis

A preliminary economic analysis was conducted to evaluate the cost-effectiveness of producing AgNPs and the composite clay filters, a critical consideration for their potential application in decentralized water treatment. The cost estimation was based on local market prices in Uganda for the primary materials: Silver nitrate (AgNO₃) precursor at 120,000 UGX per 25 g, and clay at 200,000 UGX per tonne. Guava leaves were considered zero-cost, given their local abundance and availability.

For the synthesis of AgNPs, the reaction used 0.68 g of AgNO₃ to produce 1.67g of AgNPs (as per the 61.93% yield calculation for white guava in Section 3.6).

- Cost of AgNO₃ per gram: $120,000 \text{ UGX} / 25 \text{ g} = 4,800 \text{ UGX/g}$
- Cost of AgNO₃ per batch: $0.68 \text{ g} * 4,800 \text{ UGX/g} = 3,264 \text{ UGX}$

- This yields a material cost of approximately 1,955 UGX per gram of AgNPs (3,264 UGX / 1.67 g), solely from the silver precursor.

The fabrication of a single AgNPs-composite clay filter (as described in Section 3.9) required 2 kg of clay-sawdust mixture and 3g of AgNPs.

- Cost of Clay (for 2 kg): $(2 \text{ kg} / 1000 \text{ kg}) * 200,000 \text{ UGX} = 400 \text{ UGX}$
- Cost of AgNPs (for 3 g): $3 \text{ g} * 1,955 \text{ UGX/g} = 5,865 \text{ UGX}$
- Total Estimated Material Cost per Filter: ~6,265 UGX (approximately 1.69 USD using an approximate exchange rate of 1 USD = 3,700 UGX).

This cost is significantly dominated by the silver precursor. It is crucial to note that this is a direct material cost estimate and does not include operational expenditures such as labour, energy for extraction and sintering, transportation, or equipment depreciation. Scaling up the synthesis and sourcing reagents in bulk could substantially reduce the unit cost of AgNO_3 .

When compared with existing literature, the high cost of silver-based nanomaterials is a known challenge. However, the value proposition lies in their exceptional performance and the green synthesis method. The composite filter achieved a Pb^{2+} removal efficiency of 99.59 %, surpassing the 91.62 % efficiency of the pure clay filter.

This represents a significant enhancement in water treatment capability. (Oyanedel-Craver & Smith, 2008), who pioneered silver-infused ceramic filters, argued that despite higher material costs, the long-term public health benefits and

effectiveness against both microbial and chemical contaminants can make such technologies cost-effective solutions for point-of-use water treatment.

The only identified maintenance need for clay filters is regeneration through refiring at 450 °C for one hour as recommended by (Shivaraju *et al.*, 2018). For a kiln rated 13 A and 240 V, 3.12 kWh is required for regeneration firing with a unit assumed to cost 756.3 UGX according to (UEDCL, 2025) brings energy cost of maintaining the filter to 2359.66 UGX.

Furthermore, the use of *Psidium guajava* leaf extract eliminates the need for expensive and toxic chemical reducing agents (e.g., sodium borohydride), which reduces environmental impact and aligns with green chemistry principles (Vanlalveni *et al.*, 2021). Future research should focus on optimizing the AgNPs dosage in the filter to find a balance between cost and performance, and on recovering and reusing silver from spent filters to improve lifecycle economics.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

This study effectively classified guava varieties significantly differentiated by the fruit mesocarp as white, orange, and red fruit, extracted aqueous leaf extracts with significant difference in the anti-oxidant activity ($p > 0.05$) while there was no significant difference in silver nanoparticles yield, hence there is no significant influence of anti-oxidant activity on the yield of the nanoparticles. However, there was significant difference in the lead removal efficiency of the silver nanoparticles synthesised using aqueous extracts from the three varieties with white topping with 83.16% followed by 81.53% and 78.35% for orange and red guava derived AgNPs respectively.

The lead (Pb^{2+}) removal efficiency of nanoparticles and clay filters augmented with green silver nanoparticles derived from the leaf extracts of white, orange, and red guava, alongside a composite filter and virgin clay. The findings indicated that AgNPs modification markedly ($p > 0.05$) enhanced Pb^{2+} adsorption relative to unmodified clay, with removal efficiencies ordered as follows: composite (99.59 %) > white (98.54 %) > orange (95.99 %) > red (94.03 %) > clay (91.62 %).

The exceptional performance of the white filter corresponds with its elevated Langmuir affinity ($L = 242.33 \text{ atm}^{-1}$) and advantageous Freundlich heterogeneity ($n = 4.22$), affirming the pivotal influence of nanoparticle surface chemistry on adsorption efficacy. The composite filter's outstanding performance underscores

the synergistic capabilities of hybrid nanoparticle systems; wherein complementary adsorption mechanisms collectively improve pollutant removal.

5.2. Recommendations

5.2.1. To optimise cost-efficiency and performance, future studies should examine the optimal mixing ratios of white (WW), orange (OO), and red (RR) guava-derived AgNPs in composite filters. The 1:1:1 ratio achieved 99.59 % clearance; however other ratios may work at lower nanoparticle loadings. Multifunctional filters that remove organic pollutants and heavy metals could be made by adding nanomaterials like iron oxides or activated carbon. This optimisation should account hybrid filter adsorption capacity and mechanical stability.

5.2.2. Analysing nanoparticle-clay composites using FTIR, XPS, and TEM-EDX is crucial to identify functional groups (e.g., -OH, -COOH) responsible for Pb^{2+} binding. Characterisation would show why white guava AgNPs performed better and how the composite filter synergises. Long-term stability studies should include assess filter capacity retention and nanoparticle leaching after several adsorption-desorption cycles. These tests should replicate real-world pH and flow rates.

5.2.3. Validate filters with contaminated water samples including competing ions (Ca^{2+} , Mg^{2+}) and organic debris. Single-metal solution lab studies don't simulate natural water system competitive adsorption. Continuous flow column studies might better predict field performance. Water chemistry characteristics (pH, ionic strength) that affect nanoparticle stability and adsorption efficiency in diverse geological environments should be considered.

5.2.4. Filters' effectiveness in removing Pb^{2+} should be assessed with additional pollutants such as cadmium (Cd^{2+}), arsenic (As^{3+}), and mercury (Hg^{2+}). Different guava-derived AgNPs may have metal selectivity due to their surface chemistries. This discovery could lead to regional contamination-specific filters. Ecotoxicological research must also evaluate nanoparticle release during filter use or disposal.

REFERENCES

- Abbas, S., Nasreen, S., Haroon, A., & Ashraf, M. A. (2020). Synthesis of Silver and Copper Nanoparticles from Plants and Application as Adsorbents for Naphthalene decontamination. *Saudi Journal of Biological Sciences*, 27(4), 1016–1023. <https://doi.org/10.1016/j.sjbs.2020.02.011>
- Abdullayev, E., Vakili, A. H., Abu Amr, S. S., Karaağaç, S. U., & Alazaiza, M. Y. D. (2024). Navigating heavy metal removal: Insights into advanced treatment technologies for wastewater: A review. *Global Nest Journal*, 26(6). <https://doi.org/10.30955/gnj.06247>
- Abood, M. I., & TYAl-Abdullah, Z. (2022). Synthesis of Ag-Nanoparticles and their Application in Treatment of Waste Water. *AIP Conference Proceedings*, 2398. <https://doi.org/10.1063/5.0093970>
- Abraham, M. R., & Susan, T. B. (2017). Water contamination with heavy metals and trace elements from Kilembe copper mine and tailing sites in Western Uganda; implications for domestic water quality. *Chemosphere*, 169, 281–287. <https://doi.org/10.1016/j.chemosphere.2016.11.077>
- Adeyemi, J. O., Oriola, A. O., Onwudiwe, D. C., & Oyedeji, A. O. (2022). Plant Extracts Mediated Metal-Based Nanoparticles: Synthesis and Biological Applications. *Biomolecules*, 12(5). <https://doi.org/10.3390/biom12050627>
- Ahmad, W., Singh, A., Mishrwan, V. S., Joshi, S., & Rawat, A. (2023). Titanium Dioxide Nanomaterials: Synthesis and Applications. *Asian Journal of Chemistry*, 35(8), 1770–1774. <https://doi.org/10.14233/ajchem.2023.27287>

- Ahmed, S., Ahmad, M., Swami, B. L., & Ikram, S. (2016). A review on plants extract mediated synthesis of silver nanoparticles for antimicrobial applications: A green expertise. *Journal of Advanced Research*, 7(1), 17–28. <https://doi.org/10.1016/j.jare.2015.02.007>
- Ahmed, S., Rasul, M. G., Martens, W. N., Brown, R., & Hashib, M. A. (2011). Advances in heterogeneous photocatalytic degradation of phenols and dyes in wastewater: A review. *Water, Air, and Soil Pollution*, 215(1–4), 3–29. <https://doi.org/10.1007/s11270-010-0456-3>
- Ajmal, M., Hussain Khan, A., Ahmad, S., & Ahmad, A. (1998). Role of sawdust in the removal of copper(II) from industrial wastes. *Water Research*, 32(10), 3085–3091. [https://doi.org/10.1016/S0043-1354\(98\)00067-0](https://doi.org/10.1016/S0043-1354(98)00067-0)
- Al-Senani, G. M., & Al-Kadhi, N. (2020). The synthesis and effect of silver nanoparticles on the adsorption of Cu²⁺ from aqueous solutions. *Applied Sciences (Switzerland)*, 10(14). <https://doi.org/10.3390/app10144840>
- Albadawi, E. A., Musa, E. N. A., Ghaban, H. M., Ebrahim, N. A., Albadrani, M. S., & El-Tokhy, A. I. (2024). Eco-friendly green synthesis of silver nanoparticles from guajava leaves extract for controlling organophosphorus pesticides hazards, characterization, and in-vivo toxicity assessment. *BMC Pharmacology and Toxicology*, 25(1). <https://doi.org/10.1186/s40360-024-00826-7>
- Ali, A. E., Mustafa, A. A., Eledkawy, M. A., Ahmed, A. M., Alnaggar, G. A., Elmelegy, E., & Kolkaila, S. A. (2022). Removal of Cadmium (II) from Water

by Adsorption on Natural Compound. *Dormaj.Org*, 2022(2), 164–169.

Alkaç, İ. M., Çerçi, B., Timuralp, C., & Şen, F. (2021). Nanomaterials and their classification. In *Nanomaterials for Direct Alcohol Fuel Cells: Characterization, Design, and Electrocatalysis* (pp. 17–33). <https://doi.org/10.1016/B978-0-12-821713-9.00011-1>

Ameen, F., Srinivasan, P., Selvankumar, T., Kamala-Kannan, S., Al Nadhari, S., Almansob, A., Dawoud, T., & Govarthan, M. (2019). Phytosynthesis of silver nanoparticles using *Mangifera indica* flower extract as bioreductant and their broad-spectrum antibacterial activity. *Bioorganic Chemistry*, 88(May), 102970. <https://doi.org/10.1016/j.bioorg.2019.102970>

Andal, V., Kannan, K., Selvaraj, V., & Suba, K. (2022). Plant-Derived Nanoparticles for Heavy Metal Remediation. In *Phytonanotechnology* (pp. 59–76). https://doi.org/10.1007/978-981-19-4811-4_3

Asgary, V., Shoari, A., Baghbani-Arani, F., Shandiz, S. A. S., Khosravy, M. S., Janani, A., Bigdeli, R., Bashar, R., & Cohan, R. A. (2016). Green synthesis and evaluation of silver nanoparticles as adjuvant in rabies veterinary vaccine. *International Journal of Nanomedicine*, 11, 3597–3605. <https://doi.org/10.2147/IJN.S109098>

Asiimwe, J. B., Atukunda, E. C., Nagendrappa, P. P., Sarki, A. M., Alonga, L. S. M., Kahwa, I., Ajayi, C. O., Iqbal, S., Nambozi, G., Edward, K., Tolo, C. U., Ogwang, P. E., & Kamatenesi, M. M. (2022). Medicinal Plants Used by Traditional Medicine Practitioners in the Management of Patients with Cancer

in Selected Districts of Uganda. *SSRN Electronic Journal*.
<https://doi.org/10.2139/ssrn.4250760>

Astruc, D., Daniel, M. C., & Ruiz, J. (2004). Dendrimers and gold nanoparticles as exo-receptors sensing biologically important anions. In *Chemical Communications* (Issue 23, pp. 2637–2649).
<https://doi.org/10.1039/b410399h>

Attatsi, I. K., & Nsiah, F. (2020). Application of silver nanoparticles toward Co(II) and Pb(II) ions contaminant removal in groundwater. *Applied Water Science*, *10*(6), 1–13. <https://doi.org/10.1007/s13201-020-01240-0>

Auffan, M., Rose, J., Bottero, J. Y., Lowry, G. V., Jolivet, J. P., & Wiesner, M. R. (2009). Towards a definition of inorganic nanoparticles from an environmental, health and safety perspective. *Nature Nanotechnology*, *4*(10), 634–641. <https://doi.org/10.1038/nnano.2009.242>

Ayach, J., El Malti, W., Duma, L., Lalevée, J., Al Ajami, M., Hamad, H., & Hijazi, A. (2024). Comparing Conventional and Advanced Approaches for Heavy Metal Removal in Wastewater Treatment: An In-Depth Review Emphasizing Filter-Based Strategies. *Polymers*, *16*(14). <https://doi.org/10.3390/polym16141959>

Balali-Mood, M., Naseri, K., Tahergorabi, Z., Khazdair, M. R., & Sadeghi, M. (2021). Toxic Mechanisms of Five Heavy Metals: Mercury, Lead, Chromium, Cadmium, and Arsenic. *Frontiers in Pharmacology*, *12*(April), 1–19. <https://doi.org/10.3389/fphar.2021.643972>

- Baliyan, S., Mukherjee, R., Priyadarshini, A., Vibhuti, A., Gupta, A., Pandey, R. P., & Chang, C. M. (2022). Determination of Antioxidants by DPPH Radical Scavenging Activity and Quantitative Phytochemical Analysis of *Ficus religiosa*. *Molecules*, 27(4). <https://doi.org/10.3390/molecules27041326>
- Bekele-Tesemma, A., & Tengnas, with A. B. and B. (2009). *Psidium guajava* Myrtaceae L. *Regional Soil Conservation Unit, 0*(World Agroforestry Centre, Kenya.), 1–5. http://www.worldagroforestry.org/treedb/AFTPDFS/Psidium_guajava.PDF
- Benalia, A., Derbal, K., Amrouci, Z., Baatache, O., Khalfaoui, A., & Pizzi, A. (2024). Application of Plant-Based Coagulants and Their Mechanisms in Water Treatment: A Review. *Journal of Renewable Materials*, 12(4), 667–698. <https://doi.org/10.32604/jrm.2024.048306>
- Ber, D. (2025). *Fourth national development plan (ndpiv) 2025/26 - 2029/30*.
- Bergaya, F., Theng, B. K. G., & Lagaly, G. (2006). Handbook of Clay Science. In *Developments in Clay Science* (Vol. 1, Issue 2). [https://doi.org/10.1016/S1572-4352\(05\)01039-1](https://doi.org/10.1016/S1572-4352(05)01039-1)
- Bhattacharyya, K. G., & Gupta, S. Sen. (2008). Adsorption of a few heavy metals on natural and modified kaolinite and montmorillonite: A review. *Advances in Colloid and Interface Science*, 140(2), 114–131. <https://doi.org/10.1016/j.cis.2007.12.008>
- Brooks, R. M., Bahadory, M., Tovia, F., & Rostami, H. (2010). Removal of lead from contaminated water. *International Journal of Soil, Sediment and Water*,

3(2), 14.

Challab, M. K. (2024). *Removal of Pb (II) and Cu (II) From Water Using Silver Nanoparticles Prepared using Extract Plant*. 29(1).

Chaudhari, M., Chotaliya, R., Ali, G. H., Pandya, A., & Shrivastav, P. (2024). Assessment of heavy metal contamination in the groundwater of Gujarat, India using the Heavy Metal Pollution Index. *Environmental Research and Technology*, 7(3), 471–488. <https://doi.org/10.35208/ert.1433696>

Chowdhury, I. R., Chowdhury, S., Mazumder, M. A. J., & Al-Ahmed, A. (2022). Removal of lead ions (Pb²⁺) from water and wastewater: a review on the low-cost adsorbents. In *Applied Water Science* (Vol. 12, Issue 8). Springer International Publishing. <https://doi.org/10.1007/s13201-022-01703-6>

Cultrone, G., Sebastián, E., Elert, K., de la Torre, M. J., Cazalla, O., & Rodriguez-Navarro, C. (2004). Influence of mineralogy and firing temperature on the porosity of bricks. *Journal of the European Ceramic Society*, 24(3), 547–564. [https://doi.org/10.1016/S0955-2219\(03\)00249-8](https://doi.org/10.1016/S0955-2219(03)00249-8)

Dagne, E., Bekele, T., Bisrat, D., Alemayehu, M., Worku, T., & Elokaokich, J. P. (1999). Essential oils of resins from three *Pinus* species growing in Ethiopia and Uganda. In *SINET: Ethiopian Journal of Science* (Vol. 22, Issue 2). <https://doi.org/10.4314/sinet.v22i2.18146>

Dao, T. D., Mericq, J. P., Laborie, S., & Cabassud, C. (2013). A new method for permeability measurement of hydrophobic membranes in Vacuum Membrane Distillation process. *Water Research*, 47(6), 2096–2104.

<https://doi.org/10.1016/j.watres.2013.01.040>

Dhasarathan, P., Devi, N. R., Sangeetha, P., Navaraj, S. M. G., Ranjitsingh, A. J. A., & Padmalatha, C. (2018). Utilisation of Green Synthesised Silver Nanoparticles for Water Quality Management. *Advances in Nanoparticles*, 07(04), 77–84. <https://doi.org/10.4236/anp.2018.74007>

Edelstein, M., & Ben-Hur, M. (2018). Heavy metals and metalloids: Sources, risks and strategies to reduce their accumulation in horticultural crops. *Scientia Horticulturae*, 234(December), 431–444. <https://doi.org/10.1016/j.scienta.2017.12.039>

El-Sesy, M. E., & Mahran, B. N. A. (2020). The Antibacterial and Coagulant Activity of Psidium Guajava Leaves Extracts in Purification of Wastewater. *Biosciences, Biotechnology Research Asia*, 17(1), 191–203. <https://doi.org/10.13005/bbra/2823>

ELECTRICITY RETAIL TARIFFS FOR THE THIRD QUARTER (JULY TO SEPTEMBER) OF 2025. (2025). 360.

Elessawy, N. A., Gouda, M. H., Elkady, M. F., Ali, S. M., Gouda, M., & Mohy Eldin, M. S. (2020). Ultra-fast removal of cadmium and lead from wastewater using high-efficient adsorbent derived from plastic waste: Statistical modeling kinetic and isotherm studies. *Desalination and Water Treatment*, 173, 394–408. <https://doi.org/10.5004/dwt.2020.24809>

Fernández-luqueño, F., López-valdez, F., Gamero-melo, P., Luna-, S., Aguilera-gonzález, E. N., Martínez, A. I., García-, M. S., Hernández-martínez, G.,

- Herrera-mendoza, R., & Álvarez-, M. A. (2013). *Heavy metal pollution in drinking water - a global risk for human health : A review*. 7(July), 567–584.
<https://doi.org/10.5897/AJEST12.197>
- Fu, F., & Wang, Q. (2011). Removal of heavy metal ions from wastewaters: A review. *Journal of Environmental Management*, 92(3), 407–418.
<https://doi.org/10.1016/j.jenvman.2010.11.011>
- Gahrouei, A. E., Rezapour, A., Pirooz, M., & Pourebrahimi, S. (2024). From classic to cutting-edge solutions: A comprehensive review of materials and methods for heavy metal removal from water environments. *Desalination and Water Treatment*, 319(April), 100446.
<https://doi.org/10.1016/j.dwt.2024.100446>
- Gangappa, N. D., Singh, C., Verma, M. K., Thakre, M., Sevanthi, A. M., Singh, R., Srivastav, M., Raghunandan, K., Anusha, C., Yadav, V., & Nagaraja, A. (2022). Assessing the genetic diversity of guava germplasm characterized by morpho-biochemical traits. *Frontiers in Nutrition*, 9.
<https://doi.org/10.3389/fnut.2022.1017680>
- Ganuja, M., Pastor, N., Boccolini, M., Erazo, J., Palacios, S., Oddino, C., Reynoso, M. M., Rovera, M., & Torres, A. M. (2019). Evaluating the impact of the biocontrol agent *Trichoderma harzianum* ITEM 3636 on indigenous microbial communities from field soils. *Journal of Applied Microbiology*, 126(2), 608–623. <https://doi.org/10.1111/jam.14147>
- Garai, P., Banerjee, P., Mondal, P., & Saha, N. C. (2021). Effect of Heavy Metals

on Fishes: Toxicity and Bioaccumulation. *Journal of Clinical Toxicology*, 11, 1.

Geremias, R., & Masuhara, N. (2025). Water–Energy–Land–Food Nexus to Assess the Environmental Impacts from Coal Mining. *Land*, 14(7). <https://doi.org/10.3390/land14071360>

Glicklich, D., Mustafa, M., & Wolfe, K. (2024). Toxic effects of heavy metal exposure in solid organ transplant recipients. *Transplantation Reports*, 9(2), 100151. <https://doi.org/10.1016/j.tpr.2024.100151>

Gorde, S. P., & Jadhav, M. V. (2013). Assessment of Water Quality Parameters : A Review. *International Journal of Engineering Research and Applications*, 3(6), 2029–2035.

Govind, P., & Madhuri, S. (2014). Heavy metals causing toxicity in humans, animals and environment. *Research Journal of Animal, Veterinary and Fishery Sciences*, 2(2), 17–23.

Graber, L. K., Asher, D., Anandaraja, N., Bopp, R. F., Merrill, K., Cullen, M. R., Luboga, S., & Trasande, L. (2010). Childhood lead exposure after the phaseout of leaded gasoline: An ecological study of school-age children in Kampala, Uganda. *Environmental Health Perspectives*, 118(6), 884–889. <https://doi.org/10.1289/ehp.0901768>

Harish, V., Tewari, D., Gaur, M., Yadav, A. B., Swaroop, S., Bechelany, M., & Barhoum, A. (2022). Review on Nanoparticles and Nanostructured Materials: Bioimaging, Biosensing, Drug Delivery, Tissue Engineering, Antimicrobial,

and Agro-Food Applications. *Nanomaterials*, 12(3).
<https://doi.org/10.3390/nano12030457>

Hoffmann, M. R., Martin, S. T., Choi, W., & Bahnemann, D. W. (1995). Environmental Applications of Semiconductor Photocatalysis. *Chemical Reviews*, 95(1), 69–96. <https://doi.org/10.1021/cr00033a004>

Huynh, H. D., Nargotra, P., Wang, H. M. D., Shieh, C. J., Liu, Y. C., & Kuo, C. H. (2025). Bioactive Compounds from Guava Leaves (*Psidium guajava* L.): Characterization, Biological Activity, Synergistic Effects, and Technological Applications. *Molecules*, 30(6). <https://doi.org/10.3390/molecules30061278>

Iravani, S. (2021). Nanomaterials and nanotechnology for water treatment: recent advances. In *Inorganic and Nano-Metal Chemistry* (Vol. 51, Issue 12, pp. 1615–1645). <https://doi.org/10.1080/24701556.2020.1852253>

Islam, M. A., Jacob, M. V., & Antunes, E. (2021). A critical review on silver nanoparticles: From synthesis and applications to its mitigation through low-cost adsorption by biochar. *Journal of Environmental Management*, 281(July 2020), 111918. <https://doi.org/10.1016/j.jenvman.2020.111918>

Jagaba, A. H., Lawal, I. M., Birniwa, A. H., Affam, A. C., Usman, A. K., Soja, U. B., Saleh, D., Hussaini, A., Noor, A., & Aliyu Yaro, N. S. (2024). Sources of Water Contamination by Heavy Metals. *Membrane Technologies for Heavy Metal Removal from Water*, 3–27. <https://doi.org/10.1201/9781003326281-2>

Jain, K., Takuli, A., Gupta, T. K., & Gupta, D. (2024). Rethinking Nanoparticle Synthesis: A Sustainable Approach vs. Traditional Methods. In *Chemistry -*

An Asian Journal (Vol. 19, Issue 21). <https://doi.org/10.1002/asia.202400701>

Jain, S., Kumar, N., Tahir, M., & Garg, S. (2023). Chapter 2 - Nanoparticle synthesis, characterization and applications. In N. S. Chauhan & S. S. Gill (Eds.), *The Impact of Nanoparticles on Agriculture and Soil* (pp. 13–40). Academic Press. <https://doi.org/10.1016/B978-0-323-91703-2.00007-5>

Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B. B., & Beeregowda, K. N. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary Toxicology*, 7(2), 60–72. <https://doi.org/10.2478/intox-2014-0009>

Jeevanandam, J., Barhoum, A., Chan, Y. S., Dufresne, A., & Danquah, M. K. (2018). Review on nanoparticles and nanostructured materials: History, sources, toxicity and regulations. *Beilstein Journal of Nanotechnology*, 9(1), 1050–1074. <https://doi.org/10.3762/bjnano.9.98>

Jiménez-Escrig, A., Rincón, M., Pulido, R., & Saura-Calixto, F. (2001). Guava fruit (*Psidium guajava* L.) as a new source of antioxidant dietary fiber. *Journal of Agricultural and Food Chemistry*, 49(11), 5489–5493. <https://doi.org/10.1021/jf010147p>

Kafayat Kehinde Lawal, Ike Kenneth Ekeleme, Chinemerem Martin Onuigbo, Victor Okezie Ikpeazu, & Smart Obumneme Obiekezie. (2021). A review on the public health implications of heavy metals. *World Journal of Advanced Research and Reviews*, 10(3), 255–265.

<https://doi.org/10.30574/wjarr.2021.10.3.0249>

Kamelnia, E., Mohebbati, R., Kamelnia, R., El-Seedi, H. R., & Boskabady, M. H. (2023). Anti-inflammatory, immunomodulatory and anti-oxidant effects of *Ocimum basilicum* L. and its main constituents: A review. *Iranian Journal of Basic Medical Sciences*, 26(6), 617–627.

<https://doi.org/10.22038/IJBMS.2023.67466.14783>

Khan, S., Ajmal, S., Hussain, T., & Rahman, M. U. (2023). Clay-based materials for enhanced water treatment: adsorption mechanisms, challenges, and future directions. *Journal of Umm Al-Qura University for Applied Sciences*, 0123456789. <https://doi.org/10.1007/s43994-023-00083-0>

Kumar, S., Ahlawat, W., Bhanjana, G., Heydarifard, S., Nazhad, M. M., & Dilbaghi, N. (2014). Nanotechnology-based water treatment strategies. *Journal of Nanoscience and Nanotechnology*, 14(2), 1838–1858.

<https://doi.org/10.1166/jnn.2014.9050>

Kumar, V., & Yadav, S. K. (2009). Plant-mediated synthesis of silver and gold nanoparticles and their applications. *Journal of Chemical Technology and Biotechnology*, 84(2), 151–157. <https://doi.org/10.1002/jctb.2023>

Kyzas, G. Z., & Matis, K. A. (2015). Nanoadsorbents for pollutants removal: A review. *Journal of Molecular Liquids*, 203, 159–168.

<https://doi.org/10.1016/j.molliq.2015.01.004>

Lella, T., Vishnupriya, G., Brigida, S., Elizabeth, A. A., & Soujanya Singh, G. (2024). Evaluation of Synergistic Antioxidant Activity of *Psidium Guajava*

and Raw Honey-An Invitro study. *Texila International Journal of Public Health*, 12(3). <https://doi.org/10.21522/TIJPH.2013.12.03.Art020>

Li, X. Q., Elliott, D. W., & Zhang, W. X. (2006). Zero-valent iron nanoparticles for abatement of environmental pollutants: Materials and engineering aspects. *Critical Reviews in Solid State and Materials Sciences*, 31(4), 111–122. <https://doi.org/10.1080/10408430601057611>

Logeswari, P., Silambarasan, S., & Abraham, J. (2015). Synthesis of silver nanoparticles using plants extract and analysis of their antimicrobial property. *Journal of Saudi Chemical Society*, 19(3), 311–317. <https://doi.org/10.1016/j.jscs.2012.04.007>

Ma, X., Luan, Z., & Li, J. (2023). Inorganic Nanoparticles-Based Systems in Biomedical Applications of Stem Cells: Opportunities and Challenges. *International Journal of Nanomedicine*, 18(January), 143–182. <https://doi.org/10.2147/IJN.S384343>

Mahmood Aljamali, N., Abdul Baqi Aldujaili, D., & Obaid Alfatlawi, I. (2021). Physical and Chemical Adsorption and its Applications. *International Journal*, 7(2), 1–8.

Mahor, A., Singh, P. P., Bharadwaj, P., Sharma, N., Yadav, S., Rosenholm, J. M., & Bansal, K. K. (2021). Carbon-Based Nanomaterials for Delivery of Biologicals and Therapeutics: A Cutting-Edge Technology. *C*, 7(1), 19. <https://doi.org/10.3390/c7010019>

Mamun, M., & Bindiganavile, V. (2014). Specimen Size Effects and Dynamic

Fracture Toughness of Cement-Based Foams. *Journal of Materials in Civil Engineering*, 26(1), 143–151. [https://doi.org/10.1061/\(asce\)mt.1943-5533.0000784](https://doi.org/10.1061/(asce)mt.1943-5533.0000784)

Mandal, A. K., Paudel, S., Pandey, A., Yadav, P., Pathak, P., Grishina, M., Jaremko, M., Emwas, A. H., Khalilullah, H., & Verma, A. (2022). Guava Leaf Essential Oil as a Potent Antioxidant and Anticancer Agent: Validated through Experimental and Computational Study. *Antioxidants*, 11(11). <https://doi.org/10.3390/antiox11112204>

Maqsood, Q., Hussain, N., Mumtaz, M., Bilal, M., & Iqbal, H. M. N. (2022). Novel strategies and advancement in reducing heavy metals from the contaminated environment. *Archives of Microbiology*, 204(8), 1–18. <https://doi.org/10.1007/s00203-022-03087-2>

Marambio-Jones, C., & Hoek, E. M. V. (2010). A review of the antibacterial effects of silver nanomaterials and potential implications for human health and the environment. *Journal of Nanoparticle Research*, 12(5), 1531–1551. <https://doi.org/10.1007/s11051-010-9900-y>

Mashwani, Z. ur R., Khan, T., Khan, M. A., & Nadhman, A. (2015). Synthesis in plants and plant extracts of silver nanoparticles with potent antimicrobial properties: current status and future prospects. *Applied Microbiology and Biotechnology*, 99(23), 9923–9934. <https://doi.org/10.1007/s00253-015-6987-1>

Mazumder, M. A. R., Tolaema, A., Chaikhemar, P., & Rawdkuen, S. (2023).

Antioxidant and Anti-Cytotoxicity Effect of Phenolic Extracts from *Psidium guajava* Linn. Leaves by Novel Assisted Extraction Techniques. *Foods*, 12(12). <https://doi.org/10.3390/foods12122336>

MEMD. (2018). *REPUBLIC OF UGANDA Ministry of Energy and Mineral Development Policy Goal MINING AND MINERAL POLICY FOR UGANDA 2018*.

Mishra, S., Bharagava, R. N., More, N., Yadav, A., Zainith, S., Mani, S., & Chowdhary, P. (2019). Heavy Metal Contamination: An Alarming Threat to Environment and Human Health. *Environmental Biotechnology: For Sustainable Future*, 103–125. https://doi.org/10.1007/978-981-10-7284-0_5

Mitra, S., Chakraborty, A. J., Tareq, A. M., Emran, T. Bin, Nainu, F., Khusro, A., Idris, A. M., Khandaker, M. U., Osman, H., Alhumaydhi, F. A., & Simal-Gandara, J. (2022). Impact of heavy metals on the environment and human health: Novel therapeutic insights to counter the toxicity. *Journal of King Saud University - Science*, 34(3), 101865. <https://doi.org/10.1016/j.jksus.2022.101865>

Mohapatra, A., Nandal, V., Solanki, M., & Pathak, V. V. (2024). A review on pharmaceutical and environmental applications of guava (*Psidium guajava*) leaves. *Journal of Applied and Natural Science*, 16(2), 607–622. <https://doi.org/10.31018/jans.v16i2.5484>

MoLH&UD. (2022). *Ministry of Lands, Housing & Urban Development Uganda State of Urban Sector Report 2021-2022*.

- Molnár, Z., Bódai, V., Szakacs, G., Erdélyi, B., Fogarassy, Z., Sáfrán, G., Varga, T., Kónya, Z., Tóth-Szeles, E., Szucs, R., & Lagzi, I. (2018). Green synthesis of gold nanoparticles by thermophilic filamentous fungi. *Scientific Reports*, 8(1), 1–12. <https://doi.org/10.1038/s41598-018-22112-3>
- Monroy-Licht, A., Carranza-Lopez, L., De la Parra-Guerra, A. C., & Acevedo-Barrios, R. (2024). Unlocking the potential of Eichhornia crassipes for wastewater treatment: phytoremediation of aquatic pollutants, a strategy for advancing Sustainable Development Goal-06 clean water. *Environmental Science and Pollution Research*, 31(31), 43561–43582. <https://doi.org/10.1007/s11356-024-33698-9>
- Monshi, A., Foroughi, M. R., & Monshi, M. R. (2012). Modified Scherrer Equation to Estimate More Accurately Nano-Crystallite Size Using XRD. *World Journal of Nano Science and Engineering*, 02(03), 154–160. <https://doi.org/10.4236/wjnse.2012.23020>
- Moono, J. (2021). Agenda 2063: The Africa We Want. *Academia Letters*, April. <https://doi.org/10.20935/al1336>
- Nagudi, B. (2011). Status of Geological Resources in By the Embassy of the Republic of Korea in Uganda. In *Student dissertation* (pp. 1–35).
- Nakalembe, C., Dempewolf, J., & Justice, C. (2017). Agricultural land use change in Karamoja Region, Uganda. *Land Use Policy*, 62, 2–12. <https://doi.org/10.1016/j.landusepol.2016.11.029>
- Narkhede, S., Parkhey, P., Dadsena, A., Singhai, A., Phillips, E., & Kolla, V.

- (2024). *Green Synthesis of Silver Nanoparticles for Arsenic (III) Removal from Contaminated Water Journal of Chemical Health Risks*. 14, 1851–1868.
- Nel, A., Xia, T., Mädler, L., & Li, N. (2006). Toxic potential of materials at the nanolevel. *Science*, 311(5761), 622–627. <https://doi.org/10.1126/science.1114397>
- Njagi, E. C., Huang, H., Stafford, L., Genuino, H., Galindo, H. M., Collins, J. B., Hoag, G. E., & Suib, S. L. (2011). Biosynthesis of iron and silver nanoparticles at room temperature using aqueous sorghum bran extracts. *Langmuir*, 27(1), 264–271. <https://doi.org/10.1021/la103190n>
- Ntomba, A. A., Meva, F. E., Ekoko, W. E., Foko, L. P. K., Hondt, E. N., Schlüsener, C., Moll, B., Loe, G. E., Kedi, P. B. E., Fouda, J. Y. S., Janiak, C., & Lehman, L. G. (2020). Biogenic Synthesis of Silver Nanoparticles Using Guava (<i>Psidium guajava</i>) Leaf Extract and Its Larvicidal Action against <i>Anopheles gambiae</i>. *Journal of Biomaterials and Nanobiotechnology*, 11(01), 49–66. <https://doi.org/10.4236/jbnb.2020.111004>
- Nwaichi, O. E., Chuku, L. C., & Oyibo, N. J. (2015). Profile of ascorbic acid, beta-carotene and lycopene in guava, tomatoes, honey and red wine. *International Journal of Current Microbiology and Applied Sciences*, 4(2), 39–43. <http://www.ijcmas.com>
- Nyakairu, G. W. A., Kurzweil, H., & Koeberl, C. (2002). Mineralogical, geochemical, and sedimentological characteristics of clay deposits from

central Uganda and their applications. *Journal of African Earth Sciences*, 35(1), 123–134. [https://doi.org/10.1016/S0899-5362\(01\)00077-X](https://doi.org/10.1016/S0899-5362(01)00077-X)

Oberdörster, G., Oberdörster, E., & Oberdörster, J. (2005). Nanotoxicology: An emerging discipline evolving from studies of ultrafine particles. *Environmental Health Perspectives*, 113(7), 823–839. <https://doi.org/10.1289/ehp.7339>

Ockwig, N. W., Nenoff, T. M., Separation, H., Rev, C., Chem, E., Laurent, S., Forge, D., Port, M., Roch, A., Robic, C., Elst, L. Vander, & Muller, R. N. (2010). *Additions and corrections*. 110(4), 2573–2574.

Of, M., In, S., & Science, H. (2022). *PHYTOCHEMICAL AND ANTIOXIDANT PROPERTIES OF VALUE ADDED GUAVA (Psidium Guajava) PRODUCTS*.

Okafor, V. N., Omokpariola, D. O., Obumselu, O. F., & Eze, C. G. (2023). Exposure risk to heavy metals through surface and groundwater used for drinking and household activities in Ifite Ogwari, Southeastern Nigeria. *Applied Water Science*, 13(4). <https://doi.org/10.1007/s13201-023-01908-3>

Olatunde, O. O., Tan, S. L. Della, & Benjakul, S. (2021). Ethanolic guava leaf extract with different chlorophyll removal processes: Antioxidant properties and its preventive effect on lipid oxidation in Pacific white shrimp. *International Journal of Food Science and Technology*, 56(4), 1671–1681. <https://doi.org/10.1111/ijfs.14788>

Omara, T., Karungi, S., Ssebulime, S., Mohamed Kiplagat, K., Bongomin, O.,

- Ogwang, R., & Akaganyira, S. (2019). Artisanal and Small-scale Gold Mining in Syanyonja, Busia Gold District, South Eastern Uganda: Impacts on the Mining Population and the Environment. *Asian Journal of Geological Research*, 2(4), 1–13. <https://doi.org/10.20944/preprints201910.0298.v1>
- Oyanedel-Craver, V. A., & Smith, J. A. (2008). Sustainable colloidal-silver-impregnated ceramic filter for point-of-use water treatment. *Environmental Science and Technology*, 42(3), 927–933. <https://doi.org/10.1021/es071268u>
- Pan, L., Wang, Z., Zhao, X., & He, H. (2019). Efficient removal of lead and copper ions from water by enhanced strength-toughness alginate composite fibers. *International Journal of Biological Macromolecules*, 134, 223–229. <https://doi.org/10.1016/j.ijbiomac.2019.05.022>
- Pokropivny, V. V., & Skorokhod, V. V. (2007). Classification of nanostructures by dimensionality and concept of surface forms engineering in nanomaterial science. *Materials Science and Engineering C*, 27(5-8 SPEC. ISS.), 990–993. <https://doi.org/10.1016/j.msec.2006.09.023>
- Pradhan, S. K., Pareek, V., Panwar, J., & Gupta, S. (2019). Synthesis and characterization of ecofriendly silver nanoparticles combined with yttrium oxide (Ag-Y₂O₃) nanocomposite with assorted adsorption capacity for Cu(II) and Cr(VI) removal: A mechanism perspective. *Journal of Water Process Engineering*, 32(August), 100917. <https://doi.org/10.1016/j.jwpe.2019.100917>
- Qasem, N. A. A., Mohammed, R. H., & Lawal, D. U. (2021). Removal of heavy

metal ions from wastewater: a comprehensive and critical review. *Npj Clean Water*, 4(1). <https://doi.org/10.1038/s41545-021-00127-0>

Qu, X., Alvarez, P. J. J., & Li, Q. (2013). Applications of nanotechnology in water and wastewater treatment. *Water Research*, 47(12), 3931–3946. <https://doi.org/10.1016/j.watres.2012.09.058>

Ray, S., & Vashishth, R. (2024). From water to plate: Reviewing the bioaccumulation of heavy metals in fish and unraveling human health risks in the food chain. *Emerging Contaminants*, 10(4), 100358. <https://doi.org/10.1016/j.emcon.2024.100358>

Rehman, K., Fatima, F., Waheed, I., & Akash, M. S. H. (2018). Prevalence of exposure of heavy metals and their impact on health consequences. *Journal of Cellular Biochemistry*, 119(1), 157–184. <https://doi.org/10.1002/jcb.26234>

Ruksiriwanich, W., Khantham, C., Muangsanguan, A., Phimolsiripol, Y., Barba, F. J., Sringarm, K., Rachtanapun, P., Jantanasakulwong, K., Jantrawut, P., Chittasupho, C., Chutoprapat, R., Boonpisuttinant, K., & Sommano, S. R. (2022). Guava (*Psidium guajava* L.) Leaf Extract as Bioactive Substances for Anti-Androgen and Antioxidant Activities. *Plants*, 11(24), 1–14. <https://doi.org/10.3390/plants11243514>

Rus, A., Leordean, V. D., & Berce, P. (2017). Silver Nanoparticles (AgNP) impregnated filters in drinking water disinfection. *MATEC Web of Conferences*, 137, 0–5. <https://doi.org/10.1051/mateconf/201713707007>

ŞAhiN, M., Atasoy, M., Arslan, Y., & Yildiz, D. (2023). Removal of Ni(II), Cu(II),

- Pb(II), and Cd(II) from Aqueous Phases by Silver Nanoparticles and Magnetic Nanoparticles/Nanocomposites. In *ACS Omega* (Vol. 8, Issue 38, pp. 34834–34843). <https://doi.org/10.1021/acsomega.3c04054>
- Saleh, T. (2022). *Adsorption technology and surface science* (pp. 39–64). <https://doi.org/10.1016/B978-0-12-849876-7.00006-3>
- Sampath Kumar, N. S., Sarbon, N. M., Rana, S. S., Chintagunta, A. D., Prathibha, S., Ingilala, S. K., Jeevan Kumar, S. P., Sai Anvesh, B., & Dirisala, V. R. (2021). Extraction of bioactive compounds from *Psidium guajava* leaves and its utilization in preparation of jellies. *AMB Express*, *11*(1). <https://doi.org/10.1186/s13568-021-01194-9>
- Sankhla, M. S., Kumari, M., & Nandan, M. (2016). *Heavy Metals Contamination in Water and their Hazardous Effect on Human Health-A Review*. *5*(10), 759–766.
- Schettler, T. (2001). Toxic threats to neurologic development of children. *Environmental Health Perspectives*, *109*(SUPPL. 6), 813–816. <https://doi.org/10.1289/ehp.01109s6813>
- Sdiri, A., Khairy, M., Bouaziz, S., & El-Safty, S. (2016). A natural clayey adsorbent for selective removal of lead from aqueous solutions. *Applied Clay Science*, *126*, 89–97. <https://doi.org/10.1016/j.clay.2016.03.003>
- Sekabira;, K., Oryem Origa;, H., Basamba;, T. A., Mutumba;, G., & Kakudidi, E. (2010). Heavy metal assessment and water quality values in urban stream and rain water. *International Journal of Environmental Science and Technology*,

7(4), 759–770. <https://doi.org/10.1007/BF03326185>

Senanu, L. D., Kranjac-Berisavljevic, G., & Cobbina, S. J. (2023). The use of local materials to remove heavy metals for household-scale drinking water treatment: A review. *Environmental Technology and Innovation*, 29, 103005. <https://doi.org/10.1016/j.eti.2023.103005>

Services, T. Y., Towards, C., Sustainable, M., Goals, D., Authority, E., & Version, D. (2022). ‘Accelerators’: Targeted Youth Services’ Contribution Towards the Attainment of Multiple Sustainable Development Goals (SDGs).

Sheng, T., Qi, Y. J., Lin, X., Hu, P., Sun, S. G., & Lin, W. F. (2016). Insights into the mechanism of nitrobenzene reduction to aniline over Pt catalyst and the significance of the adsorption of phenyl group on kinetics. *Chemical Engineering Journal*, 293(2), 337–344. <https://doi.org/10.1016/j.cej.2016.02.066>

Shi, X., Zhu, Z., Wang, M., Zhai, W., Xu, Z., Yao, J., Song, S., & Zhang, Q. (2013). Effect of TiC coated MWCNT content on friction and wear behavior of MWCNT-Ti₃SiC₂ composites. *Materials Research Bulletin*, 48(2), 315–323. <https://doi.org/10.1016/j.materresbull.2012.10.028>

Shivaraju, H. P., Egumbo, H., Madhusudan, P., & Kumar, K. M. A. (2018). Preparation of Affordable and Multi-functional Clay-based Ceramic Filter Matrix for Treatment of Drinking Water. *Environmental Technology*, 0(0), 1–30. <https://doi.org/10.1080/09593330.2018.1430853>

Singh, A. K., Sharma, P., & Singh, D. K. (2016). Measuring the Influence of

Weather Variables on Productivity of Food-Grain Crops in India: An Application of Just & Pope's Production Technique. *AMBER – ABBS Management Business and Entrepreneurship Review*, 7(2), 29. <https://doi.org/10.23874/amber/2016/v7/i2/121780>

Singh, K. R., Nayak, V., & Singh, R. P. (2021). Introduction to bionanomaterials: an overview. *Bionanomaterials*. <https://doi.org/10.1088/978-0-7503-3767-0ch1>

Suleman, H., Maulud, A. S., Fosbøl, P. L., Nasir, Q., Nasir, R., Shahid, M. Z., Nawaz, M., & Abunowara, M. (2021). A review of semi-empirical equilibrium models for CO₂-alkanolamine-H₂O solutions and their mixtures at high pressure. *Journal of Environmental Chemical Engineering*, 9(1). <https://doi.org/10.1016/j.jece.2020.104713>

Swain, C. K. (2024). Environmental pollution indices: a review on concentration of heavy metals in air, water, and soil near industrialization and urbanisation. *Discover Environment*, 2(1). <https://doi.org/10.1007/s44274-024-00030-8>

Tachakittirungrod, S., Okonogi, S., & Chowwanapoonpohn, S. (2007). Study on antioxidant activity of certain plants in Thailand: Mechanism of antioxidant action of guava leaf extract. *Food Chemistry*, 103(2), 381–388. <https://doi.org/10.1016/j.foodchem.2006.07.034>

Tagesse, W. (2021). Adsorptive Removal of Chromium (VI) Using Silver Nanoparticles Synthesized Via Green Approach with the Extract of *Moringa stenopetala*. *Oriental Journal Of Chemistry*, 37(2), 380–387.

<https://doi.org/10.13005/ojc/370217>

Tamburini, E., Costa, S., Summa, D., Battistella, L., Fano, E. A., & Castaldelli, G. (2021). Plastic (PET) vs bioplastic (PLA) or refillable aluminium bottles – What is the most sustainable choice for drinking water? A life-cycle (LCA) analysis. *Environmental Research*, *196*(October 2020), 110974. <https://doi.org/10.1016/j.envres.2021.110974>

Tao, J., & Rappe, A. (2014). Physical Adsorption: Theory of van der Waals Interactions between Particles and Clean Surfaces. *Physical Review Letters*, *112*, 106101. <https://doi.org/10.1103/PhysRevLett.112.106101>

Thaipong, K., Boonprakob, U., Crosby, K., Cisneros-Zevallos, L., & Hawkins Byrne, D. (2006). Comparison of ABTS, DPPH, FRAP, and ORAC assays for estimating antioxidant activity from guava fruit extracts. *Journal of Food Composition and Analysis*, *19*(6–7), 669–675. <https://doi.org/10.1016/j.jfca.2006.01.003>

Thanigaivel, S., Vinayagam, S., Gnanasekaran, L., Suresh, R., Soto-Moscoso, M., & Chen, W.-H. (2024). Environmental fate of aquatic pollutants and their mitigation by phycoremediation for the clean and sustainable environment: A review. *Environmental Research*, *240*, 117460. <https://doi.org/https://doi.org/10.1016/j.envres.2023.117460>

Tripathy, J., Mishra, A., Pandey, M., Thakur, R. R., Chand, S., Rout, P. R., & Shahid, M. K. (2024). Advances in Nanoparticles and Nanocomposites for Water and Wastewater Treatment: A Review. *Water (Switzerland)*, *16*(11),

1–26. <https://doi.org/10.3390/w16111481>

Valko, M., Leibfritz, D., Moncol, J., Cronin, M. T. D., Mazur, M., & Telser, J. (2007). Free radicals and antioxidants in normal physiological functions and human disease. *International Journal of Biochemistry and Cell Biology*, 39(1), 44–84. <https://doi.org/10.1016/j.biocel.2006.07.001>

Vanlalveni, C., Lallianrawna, S., Biswas, A., Selvaraj, M., Changmai, B., & Rokhum, S. L. (2021). Green synthesis of silver nanoparticles using plant extracts and their antimicrobial activities: a review of recent literature. *RSC Advances*, 11(5), 2804–2837. <https://doi.org/10.1039/d0ra09941d>

Vega-Baudrit, J., Gamboa, S. M., Rojas, E. R., & Martinez, V. V. (2019). Synthesis and characterization of silver nanoparticles and their application as an antibacterial agent. *International Journal of Biosensors & Bioelectronics*, 5(5). <https://doi.org/10.15406/ijbsbe.2019.05.00172>

Vijay Kumar, P. P. N., Pammi, S. V. N., Kollu, P., Satyanarayana, K. V. V., & Shameem, U. (2014). Green synthesis and characterization of silver nanoparticles using *Boerhaavia diffusa* plant extract and their anti bacterial activity. *Industrial Crops and Products*, 52, 562–566. <https://doi.org/10.1016/j.indcrop.2013.10.050>

Walakira, P., & Okot-Okumu, J. (2011). Impact of Industrial Effluents on Water Quality of Streams in Nakawa-Ntinda, Uganda. *Journal of Applied Sciences and Environmental Management*, 15(2). <https://doi.org/10.4314/jasem.v15i2.68512>

- Wang, B., Lan, J., Bo, C., Gong, B., & Ou, J. (2023). Adsorption of heavy metal onto biomass-derived activated carbon: review. *RSC Advances*, 13(7), 4275–4302. <https://doi.org/10.1039/d2ra07911a>
- Wani, K. M., & Uppaluri, R. V. S. (2022). Efficacy of ultrasound-assisted extraction of bioactive constituents from *Psidium guajava* leaves. *Applied Food Research*, 2(1), 100096. <https://doi.org/10.1016/j.afres.2022.100096>
- Wu, W., Wu, Z., Yu, T., Jiang, C., & Kim, W. S. (2015). Recent progress on magnetic iron oxide nanoparticles: Synthesis, surface functional strategies and biomedical applications. *Science and Technology of Advanced Materials*, 16(2). <https://doi.org/10.1088/1468-6996/16/2/023501>
- Yantasee, W., Warner, C. L., Sangvanich, T., Addleman, R. S., Carter, T. G., Wiacek, R. J., Fryxell, G. E., Timchalk, C., & Warner, M. G. (2007). Removal of heavy metals from aqueous systems with thiol functionalized superparamagnetic nanoparticles. *Environmental Science and Technology*, 41(14), 5114–5119. <https://doi.org/10.1021/es0705238>
- Ying, S., Guan, Z., Ofoegbu, P. C., Clubb, P., Rico, C., He, F., & Hong, J. (2022). Green synthesis of nanoparticles: Current developments and limitations. *Environmental Technology and Innovation*, 26, 102336. <https://doi.org/10.1016/j.eti.2022.102336>
- Youth, S. D. G., & Camp, S. (n.d.). *The 2030 Agenda for Sustainable Development's 17 Sustainable Development Goals (SDGs)*.
- Zhang, Y., Qi, Y., Yin, Y., Sun, P., Li, A., Zhang, Q., & Jiang, W. (2020). Efficient

Synthesis of Lactide with Low Racemization Catalyzed by Sodium Bicarbonate and Zinc Lactate. *ACS Sustainable Chemistry and Engineering*, 8(7), 2865–2873. <https://doi.org/10.1021/acssuschemeng.9b06987>

APPENDICES

Appendix 1: SEM analysis of white guava derived AgNPs

| No | Label | Area | mean | Min | Max | Angle | Length |
|----|-------|-------|---------|--------|---------|---------|--------|
| 1 | | 0.82 | 138.009 | 84.846 | 193.385 | -85.601 | 4.544 |
| 2 | | 1.245 | 116.668 | 15 | 163.5 | -84.289 | 7.004 |
| 3 | | 0.638 | 138.144 | 86 | 179.84 | -66.038 | 3.432 |
| 4 | | 0.455 | 177.267 | 96 | 210 | -90 | 2.439 |
| 5 | | 1.123 | 145.757 | 66 | 218 | -90 | 6.273 |
| 6 | | 0.759 | 137.28 | 87 | 183 | 0 | 4.182 |
| 7 | | 1.245 | 78.759 | 0 | 136 | -143.13 | 6.97 |
| 8 | | 1.032 | 122.37 | 39 | 168.27 | -100.62 | 5.673 |
| 9 | | 0.911 | 133.39 | 71 | 192.331 | -105.95 | 5.074 |
| 10 | | 0.698 | 145.897 | 80 | 176.091 | -95.194 | 3.849 |
| 11 | | 0.85 | 148.187 | 86 | 200.794 | -103 | 4.649 |
| 12 | | 0.85 | 134.849 | 47 | 205.477 | -103 | 4.649 |
| 13 | | 0.789 | 118.971 | 80.195 | 154.899 | -108.44 | 4.408 |
| 14 | Mean | 0.878 | 133.504 | 64.465 | 183.199 | -90.403 | 4.857 |
| 15 | SD | 0.233 | 22.561 | 30.187 | 23.494 | 32.427 | 1.339 |
| 16 | Min | 0.455 | 78.759 | 0 | 136 | -143.13 | 2.439 |
| 17 | Max | 1.245 | 177.267 | 96 | 218 | 0 | 7.004 |

Appendix 2: SEM analysis of orange guava derived AgNPs

| No | Label | Area | mean | Min | Max | Angle | Length |
|-----------|--------------|-------------|-------------|------------|------------|--------------|---------------|
| 1 | | 0.918 | 102.833 | 69.429 | 126 | -81.87 | 5.033 |
| 2 | | 0.792 | 112.4 | 78 | 144 | -90 | 4.271 |
| 3 | | 0.855 | 76.556 | 47.846 | 103.231 | -98.746 | 4.681 |
| 4 | | 0.602 | 114.789 | 86 | 142 | -90 | 3.203 |
| 5 | | 0.918 | 116.229 | 72.77 | 158.878 | 39.289 | 5.058 |
| 6 | | 1.267 | 130.631 | 56.341 | 214.556 | -104.744 | 6.992 |
| 7 | | 0.887 | 151.892 | 35 | 230.383 | -77.005 | 4.748 |
| 8 | | 0.602 | 112.368 | 53 | 149 | -90 | 3.203 |
| 9 | | 0.665 | 132.171 | 17 | 220 | -78.69 | 3.629 |
| 10 | | 0.855 | 95.63 | 44 | 132 | -90 | 4.626 |
| 11 | | 0.887 | 154.651 | 105.654 | 192.468 | -72.897 | 4.841 |
| 12 | | 0.95 | 76.078 | 39 | 103.894 | -102.095 | 5.095 |
| 13 | | 0.665 | 122.6 | 88 | 146.4 | 11.31 | 3.629 |
| 14 | | 1.045 | 121.989 | 78 | 178.25 | 7.125 | 5.738 |
| 15 | | 0.728 | 137 | 91 | 253 | -90 | 3.915 |
| 16 | | 1.045 | 107.353 | 83.406 | 136.5 | 21.801 | 5.749 |
| 17 | Mean | 0.855 | 116.573 | 65.278 | 164.41 | -61.658 | 4.651 |
| 18 | SD | 0.179 | 22.529 | 24.343 | 45.464 | 49.77 | 1.013 |
| 19 | Min | 0.602 | 76.078 | 17 | 103.231 | -104.744 | 3.203 |
| 20 | Max | 1.267 | 154.651 | 105.654 | 253 | 39.289 | 6.992 |

Appendix 3: SEM analysis of red guava derived AgNPs

| No | Label | Area | mean | Min | Max | Angle | Length |
|----|-------|-------|---------|---------|---------|----------|--------|
| 1 | | 0.266 | 176.081 | 143.28 | 223.506 | -118.61 | 2.533 |
| 2 | | 0.255 | 239.74 | 204 | 255 | -99.462 | 2.46 |
| 3 | | 0.164 | 230.502 | 167 | 255 | -113.199 | 1.54 |
| 4 | | 0.327 | 218.421 | 122 | 255 | -78.69 | 3.093 |
| 5 | | 0.235 | 201.225 | 167 | 255 | -95.194 | 2.233 |
| 6 | | 0.583 | 97.732 | 35 | 199 | -94.086 | 5.676 |
| 7 | | 0.47 | 204.623 | 158.247 | 248.487 | 20.854 | 4.544 |
| 8 | | 0.286 | 123.491 | 23.449 | 196.938 | -102.995 | 2.697 |
| 9 | | 0.235 | 239.64 | 178 | 255 | -100.305 | 2.26 |
| 10 | | 0.112 | 201.364 | 144 | 247 | -90 | 1.011 |
| 11 | | 0.419 | 216.979 | 127 | 255 | -107.526 | 4.028 |
| 12 | | 0.235 | 212.909 | 88.818 | 255 | -84.806 | 2.233 |
| 13 | | 0.726 | 169.871 | 82 | 251.264 | -75.174 | 7.111 |
| 14 | | 0.879 | 112.227 | 40.017 | 182.125 | -20.556 | 8.637 |
| 15 | | 0.276 | 220.333 | 153 | 255 | -90 | 2.628 |
| 16 | | 0.47 | 158.99 | 99.941 | 215 | 41.424 | 4.584 |
| 17 | | 0.409 | 152.312 | 113 | 185.29 | 30.466 | 3.988 |
| 18 | Mean | 0.373 | 186.849 | 120.338 | 234.624 | -69.286 | 3.603 |
| 19 | SD | 0.203 | 44.599 | 52.661 | 27.762 | 52.469 | 2.018 |
| 20 | Min | 0.112 | 97.732 | 23.449 | 182.125 | -118.61 | 1.011 |
| 21 | Max | 0.879 | 239.74 | 204 | 255 | 41.424 | 8.637 |

Appendix 4. ICP-OES results

| Header_1 | DateTime | MethodName | ResultType | SampleName | Sample Name | Pb | As | Cd | Se | Ni | Cu | Zn | Mn | Cr | Fe | Mg | Al | Hg | Ar (mon) | Ba |
|----------|------------------|------------------|---------------|------------|-------------|-----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|----------|------------|
| Single | 11/02/2025 11:35 | Multielement 001 | Concentration | 9596 | KJ-OO | 250.01361 | 0.00039 | 0.00030 | 0.00120 | 0.00191 | 0.00105 | 0.01682 | 0.00278 | 0.00912 | 0.00600 | 0.00292 | 0.00223 | 0.00367 | --- | > 0.011502 |
| Single | 11/02/2025 11:36 | Multielement 001 | Concentration | 9597 | W-0.1-5-1 | 174.72951 | 0.01100 | 0.01091 | 0.01181 | 0.01252 | 0.01166 | 0.02743 | 0.00289 | 0.01018 | 0.01661 | 0.00293 | 0.00223 | 0.01428 | --- | > 0.011503 |
| Single | 11/02/2025 11:37 | Multielement 001 | Concentration | 9598 | W-0.1-5-2 | 179.97140 | 0.01124 | 0.01094 | 0.01184 | 0.01257 | 0.01173 | 0.02778 | 0.00289 | 0.01020 | 0.02242 | 0.00294 | 0.00224 | 0.01431 | --- | > 0.011504 |
| Single | 11/02/2025 11:38 | Multielement 001 | Concentration | 9599 | W-0.1-5-3 | 182.31103 | 0.00098 | 0.00061 | 0.00075 | 0.00303 | 0.00739 | 0.11232 | 0.00084 | 0.00271 | 0.00380 | 0.00938 | 0.00068 | 0.00229 | --- | > 0.015988 |
| Single | 11/02/2025 11:39 | Multielement 001 | Concentration | 9600 | W-0.1-10-1 | 169.45672 | 0.01159 | 0.00721 | 0.00001 | 0.01364 | 0.01800 | 0.10171 | 0.00095 | 0.00281 | 0.01441 | 0.00948 | 0.00068 | 0.01839 | --- | > 0.015989 |
| Single | 11/02/2025 11:40 | Multielement 001 | Concentration | 9601 | W-0.1-10-2 | 173.01532 | 0.01184 | 0.01804 | 0.00001 | 0.01368 | 0.01808 | 0.10160 | 0.00095 | 0.00282 | 0.01620 | 0.00950 | 0.00068 | 0.01843 | --- | > 0.015990 |
| Single | 11/02/2025 11:41 | Multielement 001 | Concentration | 9602 | W-0.1-10-3 | 173.44785 | 0.00419 | 0.00450 | 0.00120 | 0.01698 | 0.04197 | 0.11100 | 0.00069 | 0.00248 | 0.00084 | 0.00826 | 0.00059 | 0.00130 | --- | > 0.006551 |
| Single | 11/02/2025 11:42 | Multielement 001 | Concentration | 9603 | W-0.1-15-1 | 164.45895 | 0.01480 | 0.00130 | 0.00001 | 0.02759 | 0.00046 | 0.10039 | 0.00001 | 0.00248 | 0.01145 | 0.00836 | 0.00059 | 0.00133 | --- | > 0.006552 |
| Single | 11/02/2025 11:43 | Multielement 001 | Concentration | 9604 | W-0.1-15-2 | 167.58367 | 0.01512 | 0.00135 | 0.00001 | 0.02766 | 0.00046 | 0.10027 | 0.00001 | 0.00253 | 0.01286 | 0.00838 | 0.00060 | 0.00133 | --- | > 0.006553 |
| Single | 11/02/2025 11:44 | Multielement 001 | Concentration | 9605 | W-0.1-15-3 | 171.25376 | 0.00525 | 0.00503 | 0.00118 | 0.02575 | 0.07768 | 0.13854 | 0.00036 | 0.00106 | 0.06043 | 0.00357 | 0.00027 | 0.00069 | --- | > 0.009769 |
| Single | 11/02/2025 11:45 | Multielement 001 | Concentration | 9606 | W-0.1-20-1 | 161.98382 | 0.01586 | 0.00273 | 0.00001 | 0.03636 | 0.00058 | 0.12793 | 0.00000 | 0.00106 | 0.07104 | 0.00367 | 0.00027 | 0.00070 | --- | > 0.009770 |
| Single | 11/02/2025 11:46 | Multielement 001 | Concentration | 9607 | W-0.1-20-2 | 166.51936 | 0.01919 | 0.00277 | 0.00001 | 0.03726 | 0.00058 | 0.12723 | 0.00000 | 0.00108 | 0.07174 | 0.00368 | 0.00027 | 0.00070 | --- | > 0.009771 |
| Single | 11/02/2025 11:47 | Multielement 001 | Concentration | 9608 | W-0.1-20-3 | 171.20022 | 0.01014 | 0.00026 | 0.00120 | 0.04639 | 0.13019 | 0.01682 | 0.00278 | 0.00912 | 0.00600 | 0.00292 | 0.00223 | 0.00367 | --- | > 0.011502 |
| Single | 11/02/2025 11:48 | Multielement 001 | Concentration | 9609 | W-0.1-25-1 | 158.08361 | 0.02075 | 0.00586 | 0.00001 | 0.05700 | 0.00114 | 0.02743 | 0.00003 | 0.00913 | 0.01661 | 0.00293 | 0.00223 | 0.00373 | --- | > 0.011503 |
| Single | 11/02/2025 11:49 | Multielement 001 | Concentration | 9610 | W-0.1-25-2 | 163.77462 | 0.02498 | 0.00591 | 0.00001 | 0.05828 | 0.00114 | 0.03153 | 0.00003 | 0.00930 | 0.02242 | 0.00294 | 0.00224 | 0.00373 | --- | > 0.011504 |
| Single | 11/02/2025 11:50 | Multielement 001 | Concentration | 9611 | W-0.1-25-3 | 164.36420 | 0.00443 | 0.00334 | 0.00119 | 0.01894 | 0.06889 | 0.08371 | 0.00135 | 0.00433 | 0.57614 | 0.00150 | 0.00108 | 0.00367 | --- | > 0.015988 |
| Single | 11/02/2025 11:51 | Multielement 001 | Concentration | 9612 | W-0.2-5-1 | 138.30753 | 0.01504 | 0.00104 | 0.00001 | 0.02955 | 0.00049 | 0.07310 | 0.00002 | 0.00434 | 0.58675 | 0.00151 | 0.00108 | 0.00373 | --- | > 0.015989 |
| Single | 11/02/2025 11:52 | Multielement 001 | Concentration | 9613 | W-0.2-5-2 | 142.45675 | 0.01689 | 0.00145 | 0.00001 | 0.03033 | 0.00053 | 0.07120 | 0.00002 | 0.00442 | 0.58961 | 0.00151 | 0.00108 | 0.00373 | --- | > 0.015990 |
| Single | 11/02/2025 11:53 | Multielement 001 | Concentration | 9614 | W-0.2-5-3 | 144.30869 | 0.00087 | 0.00032 | 0.00119 | 0.00179 | 0.03058 | 0.11100 | 0.00069 | 0.00248 | 0.00084 | 0.00083 | 0.00059 | 0.00002 | --- | > 0.006551 |
| Single | 11/02/2025 11:54 | Multielement 001 | Concentration | 9615 | W-0.2-10-1 | 133.33226 | 0.01148 | 0.01692 | 0.00001 | 0.01240 | 0.00008 | 0.10039 | 0.00001 | 0.00248 | 0.01145 | 0.00084 | 0.00059 | 0.00002 | --- | > 0.006552 |
| Single | 11/02/2025 11:55 | Multielement 001 | Concentration | 9616 | W-0.2-10-2 | 136.13224 | 0.01294 | 0.01728 | 0.00001 | 0.01285 | 0.00010 | 0.09908 | 0.00001 | 0.00253 | 0.01286 | 0.00084 | 0.00060 | 0.00002 | --- | > 0.006553 |

| | | | | | | | | | | | | | | | | | | | | |
|--------|------------------|------------------|---------------|------|------------|-----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|-----|------------|
| Single | 11/02/2025 11:56 | Multielement 001 | Concentration | 9617 | W-0.2-10-3 | 136.47257 | 0.00087 | 0.00032 | 0.00119 | 0.00179 | 0.00622 | 0.11100 | 0.00069 | 0.00248 | 0.44047 | 0.00083 | 0.00059 | 0.00004 | --- | > 0.006551 |
| Single | 11/02/2025 11:57 | Multielement 001 | Concentration | 9618 | W-0.2-15-1 | 126.95691 | 0.00093 | 0.00038 | 0.00122 | 0.00209 | 0.00689 | 0.10994 | 0.00070 | 0.00253 | 0.45663 | 0.00084 | 0.00061 | 0.00004 | --- | > 0.006552 |
| Single | 11/02/2025 11:58 | Multielement 001 | Concentration | 9619 | W-0.2-15-2 | 129.36909 | 0.00125 | 0.00042 | 0.00122 | 0.00235 | 0.00852 | 0.10884 | 0.00071 | 0.00258 | 0.45805 | 0.00084 | 0.00061 | 0.00004 | --- | > 0.006553 |
| Single | 11/02/2025 11:59 | Multielement 001 | Concentration | 9620 | W-0.2-15-3 | 132.20228 | 0.00015 | 0.00061 | 0.00119 | 0.00167 | 0.00263 | 0.13854 | 0.00036 | 0.00106 | 0.00600 | 0.00036 | 0.00027 | 0.00078 | --- | > 0.009769 |
| Single | 11/02/2025 12:00 | Multielement 001 | Concentration | 9621 | W-0.2-20-1 | 123.93175 | 0.00020 | 0.00065 | 0.00122 | 0.00145 | 0.00313 | 0.13807 | 0.00037 | 0.00108 | 0.01661 | 0.00036 | 0.00028 | 0.00080 | --- | > 0.009770 |
| Single | 11/02/2025 12:01 | Multielement 001 | Concentration | 9622 | W-0.2-20-2 | 127.40184 | 0.00043 | 0.00068 | 0.00122 | 0.00125 | 0.00436 | 0.13759 | 0.00037 | 0.00110 | 0.02242 | 0.00365 | 0.00028 | 0.00080 | --- | > 0.009771 |
| Single | 11/02/2025 12:02 | Multielement 001 | Concentration | 9623 | W-0.2-20-3 | 130.98310 | 0.00023 | 0.00039 | 0.00119 | 0.00668 | 0.00018 | 0.01682 | 0.00278 | 0.00912 | 0.00380 | 0.00292 | 0.00223 | 0.00367 | --- | > 0.011502 |
| Single | 11/02/2025 12:03 | Multielement 001 | Concentration | 9624 | W-0.2-25-1 | 127.80696 | 0.00024 | 0.00040 | 0.00122 | 0.00657 | 0.00040 | 0.02064 | 0.00284 | 0.00931 | 0.01441 | 0.00298 | 0.00228 | 0.00375 | --- | > 0.011503 |
| Single | 11/02/2025 12:04 | Multielement 001 | Concentration | 9625 | W-0.2-25-2 | 132.40801 | 0.00029 | 0.00041 | 0.00122 | 0.00646 | 0.00094 | 0.02459 | 0.00288 | 0.00949 | 0.01620 | 0.00299 | 0.00228 | 0.00375 | --- | > 0.011504 |
| Single | 11/02/2025 12:05 | Multielement 001 | Concentration | 9626 | W-0.2-25-3 | 132.88468 | 0.00179 | 0.00099 | 0.00119 | 0.00891 | 0.00409 | 0.08371 | 0.00135 | 0.00433 | 0.00084 | 0.00150 | 0.00108 | 0.00367 | --- | > 0.015988 |
| Single | 11/02/2025 12:06 | Multielement 001 | Concentration | 9627 | W-0.4-5-1 | 109.38095 | 0.00004 | 0.00102 | 0.00122 | 0.00884 | 0.00471 | 0.08206 | 0.00138 | 0.00443 | 0.01145 | 0.00153 | 0.00110 | 0.00375 | --- | > 0.015989 |
| Single | 11/02/2025 12:07 | Multielement 001 | Concentration | 9628 | W-0.4-5-2 | 112.66238 | 0.00026 | 0.00104 | 0.00122 | 0.00878 | 0.00623 | 0.08036 | 0.00139 | 0.00451 | 0.01286 | 0.00154 | 0.00111 | 0.00375 | --- | > 0.015990 |
| Single | 11/02/2025 12:08 | Multielement 001 | Concentration | 9629 | W-0.4-5-3 | 114.12699 | 0.00125 | 0.00113 | 0.00120 | 0.00488 | 0.00535 | 0.11100 | 0.00069 | 0.00248 | 0.06043 | 0.00826 | 0.00059 | 0.00058 | --- | > 0.006551 |
| Single | 11/02/2025 12:09 | Multielement 001 | Concentration | 9630 | W-0.4-10-1 | 104.40568 | 0.00132 | 0.00116 | 0.00122 | 0.00473 | 0.00600 | 0.10994 | 0.00070 | 0.00253 | 0.07104 | 0.00843 | 0.00061 | 0.00060 | --- | > 0.006552 |
| Single | 11/02/2025 12:10 | Multielement 001 | Concentration | 9631 | W-0.4-10-2 | 106.59820 | 0.00169 | 0.00118 | 0.00123 | 0.00459 | 0.00758 | 0.10884 | 0.00071 | 0.00258 | 0.07174 | 0.00845 | 0.00061 | 0.00060 | --- | > 0.006553 |
| Single | 11/02/2025 12:11 | Multielement 001 | Concentration | 9632 | W-0.4-10-3 | 106.86470 | 0.00374 | 0.00183 | 0.00119 | 0.00089 | 0.01293 | 0.13854 | 0.00036 | 0.00106 | 0.00600 | 0.00357 | 0.00027 | 0.00031 | --- | > 0.009769 |
| Single | 11/02/2025 12:12 | Multielement 001 | Concentration | 9633 | W-0.4-15-1 | 97.30530 | 0.00386 | 0.00187 | 0.00122 | 0.00065 | 0.01374 | 0.13807 | 0.00037 | 0.00108 | 0.01661 | 0.00364 | 0.00028 | 0.00032 | --- | > 0.009770 |
| Single | 11/02/2025 12:13 | Multielement 001 | Concentration | 9634 | W-0.4-15-2 | 99.15410 | 0.00450 | 0.00191 | 0.00122 | 0.00044 | 0.01573 | 0.13759 | 0.00037 | 0.00110 | 0.02242 | 0.00365 | 0.00028 | 0.00032 | --- | > 0.009771 |
| Single | 11/02/2025 12:14 | Multielement 001 | Concentration | 9635 | W-0.4-15-3 | 101.32557 | 0.00030 | 0.00001 | 0.01392 | 0.01364 | 0.15222 | 0.11817 | 0.00091 | 0.00311 | 0.00380 | 0.00223 | 0.00367 | 0.00367 | --- | > 0.011502 |
| Single | 11/02/2025 12:15 | Multielement 001 | Concentration | 9636 | W-0.4-20-1 | 93.40508 | 0.01091 | 0.01060 | 0.02453 | 0.02425 | 0.16283 | 0.12878 | 0.00102 | 0.00312 | 0.01441 | 0.00223 | 0.01428 | 0.01428 | --- | > 0.011503 |
| Single | 11/02/2025 12:16 | Multielement 001 | Concentration | 9637 | W-0.4-20-2 | 96.02043 | 0.01094 | 0.01063 | 0.02458 | 0.02432 | 0.16318 | 0.12932 | 0.00102 | 0.00313 | 0.01620 | 0.00224 | 0.01431 | 0.01431 | --- | > 0.011504 |
| Single | 11/02/2025 12:17 | Multielement 001 | Concentration | 9638 | W-0.4-20-3 | 98.71956 | 0.00061 | 0.00046 | 0.01504 | 0.01998 | 0.02308 | 0.02259 | 0.00027 | 0.00954 | 0.00084 | 0.00068 | 0.00229 | 0.00229 | --- | > 0.015988 |
| Single | 11/02/2025 12:18 | Multielement 001 | Concentration | 9639 | W-0.4-25-1 | 89.42987 | 0.01721 | 0.00120 | 0.02565 | 0.03059 | 0.03369 | 0.03320 | 0.00028 | 0.00965 | 0.01145 | 0.00068 | 0.00184 | 0.01839 | --- | > 0.015989 |
| Single | 11/02/2025 12:19 | Multielement 001 | Concentration | 9640 | W-0.4-25-2 | 92.64934 | 0.01724 | 0.00120 | 0.02569 | 0.03067 | 0.03380 | 0.03338 | 0.00028 | 0.00966 | 0.01286 | 0.00068 | 0.00184 | 0.01843 | --- | > 0.015990 |
| Single | 11/02/2025 12:20 | Multielement 001 | Concentration | 9641 | W-0.4-25-3 | 92.98288 | 0.00370 | 0.00001 | 0.02899 | 0.05456 | 0.02440 | 0.00707 | 0.00025 | 0.00748 | 0.06043 | 0.00059 | 0.00130 | 0.00130 | --- | > 0.006551 |
| Single | 11/02/2025 12:21 | Multielement 001 | Concentration | 9642 | W-0.6-5-1 | 65.89609 | 0.02030 | 0.00120 | 0.03960 | 0.01130 | 0.03501 | 0.06080 | 0.00025 | 0.00759 | 0.07104 | 0.00059 | 0.00133 | 0.00133 | --- | > 0.006552 |

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|--------|------------------|------------------|---------------|------|------------|----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|-----|------------|
| Single | 11/02/2025 12:22 | Multielement 001 | Concentration | 9643 | W-0.6-5-2 | 67.87297 | 0.02035 | 0.00120 | 0.03967 | 0.01130 | - | 0.03513 | 0.06080 | 0.00025 | 0.00760 | 0.07174 | 0.00060 | 0.00133 | 0.00133 | --- | > 0.006553 |
| Single | 11/02/2025 12:23 | Multielement 001 | Concentration | 9644 | W-0.6-5-3 | 68.75532 | 0.00513 | 0.00003 | 0.03776 | 0.06592 | 0.01900 | 0.02574 | - | 0.00011 | 0.00368 | 0.00600 | 0.00027 | 0.00069 | 0.00069 | --- | > 0.009769 |
| Single | 11/02/2025 12:24 | Multielement 001 | Concentration | 9645 | W-0.6-10-1 | 54.39796 | 0.02173 | 0.00120 | 0.04837 | 0.01118 | 0.00747 | 0.06118 | - | 0.00011 | 0.00379 | 0.01661 | 0.00027 | 0.00070 | 0.00070 | --- | > 0.009770 |
| Single | 11/02/2025 12:25 | Multielement 001 | Concentration | 9646 | W-0.6-10-2 | 55.54032 | 0.02177 | 0.00120 | 0.04927 | 0.01118 | 0.00817 | 0.06118 | - | 0.00011 | 0.00379 | 0.02242 | 0.00027 | 0.00070 | 0.00070 | --- | > 0.009771 |
| Single | 11/02/2025 12:26 | Multielement 001 | Concentration | 9647 | W-0.6-10-3 | 55.67917 | 0.00826 | 0.00001 | 0.05840 | 0.11843 | 0.15222 | 0.21657 | - | 0.00091 | 0.00311 | 0.00380 | 0.00223 | 0.00367 | 0.00367 | --- | > 0.011502 |
| Single | 11/02/2025 12:27 | Multielement 001 | Concentration | 9648 | W-0.6-15-1 | 46.52253 | 0.02486 | 0.00120 | 0.06901 | 0.01063 | 0.16283 | 0.05837 | - | 0.00091 | 0.00312 | 0.01441 | 0.00223 | 0.00373 | 0.00373 | --- | > 0.011503 |
| Single | 11/02/2025 12:28 | Multielement 001 | Concentration | 9649 | W-0.6-15-2 | 47.40646 | 0.02491 | 0.00120 | 0.07029 | 0.01062 | 0.16693 | 0.05836 | - | 0.00093 | 0.00313 | 0.01620 | 0.00224 | 0.00373 | 0.00373 | --- | > 0.011504 |
| Single | 11/02/2025 12:29 | Multielement 001 | Concentration | 9650 | W-0.6-15-3 | 48.44466 | 0.00344 | 0.00002 | 0.03095 | 0.05713 | 0.05169 | 0.07311 | - | 0.00043 | 0.00153 | 0.00084 | 0.00108 | 0.00367 | 0.00367 | --- | > 0.015988 |
| Single | 11/02/2025 12:30 | Multielement 001 | Concentration | 9651 | W-0.6-20-1 | 42.10229 | 0.02004 | 0.00120 | 0.04156 | 0.01128 | 0.06230 | 0.06004 | - | 0.00043 | 0.00154 | 0.01145 | 0.00108 | 0.00373 | 0.00373 | --- | > 0.015989 |
| Single | 11/02/2025 12:31 | Multielement 001 | Concentration | 9652 | W-0.6-20-2 | 43.28116 | 0.02045 | 0.00120 | 0.04234 | 0.01124 | 0.06420 | 0.06002 | - | 0.00044 | 0.00154 | 0.01286 | 0.00108 | 0.00373 | 0.00373 | --- | > 0.015990 |
| Single | 11/02/2025 12:32 | Multielement 001 | Concentration | 9653 | W-0.6-20-3 | 44.49779 | 0.00042 | 0.00002 | 0.01380 | 0.01881 | 0.02440 | 0.00707 | - | 0.00025 | 0.00748 | 0.06043 | 0.00059 | 0.00002 | 0.00002 | --- | > 0.006551 |
| Single | 11/02/2025 12:33 | Multielement 001 | Concentration | 9654 | W-0.6-25-1 | 45.87750 | 0.01702 | 0.00120 | 0.02441 | 0.01168 | 0.03501 | 0.06080 | - | 0.00025 | 0.00759 | 0.07104 | 0.00059 | 0.00002 | 0.00002 | --- | > 0.006552 |
| Single | 11/02/2025 12:34 | Multielement 001 | Concentration | 9655 | W-0.6-25-2 | 47.52909 | 0.01738 | 0.00120 | 0.02486 | 0.01167 | 0.03632 | 0.06079 | - | 0.00025 | 0.00760 | 0.07174 | 0.00060 | 0.00002 | 0.00002 | --- | > 0.006553 |
| Single | 11/02/2025 12:35 | Multielement 001 | Concentration | 9656 | W-0.6-25-3 | 47.70019 | 0.00042 | 0.00002 | 0.01380 | 0.01881 | 0.02440 | 0.00707 | - | 0.00025 | 0.00748 | 0.00600 | 0.00059 | 0.00004 | 0.00004 | --- | > 0.006551 |
| Single | 11/02/2025 12:36 | Multielement 001 | Concentration | 9657 | W-0.8-5-1 | 68.00120 | 0.00048 | 0.00001 | 0.01410 | 0.01948 | 0.02546 | 0.00855 | - | 0.00025 | 0.00764 | 0.01661 | 0.00061 | 0.00004 | 0.00004 | --- | > 0.006552 |
| Single | 11/02/2025 12:37 | Multielement 001 | Concentration | 9658 | W-0.8-5-2 | 70.04124 | 0.00052 | 0.00001 | 0.01436 | 0.02111 | 0.02656 | 0.00938 | - | 0.00026 | 0.00766 | 0.02242 | 0.00061 | 0.00004 | 0.00004 | --- | > 0.006553 |
| Single | 11/02/2025 12:38 | Multielement 001 | Concentration | 9659 | W-0.8-5-3 | 70.95177 | 0.00162 | 0.00002 | 0.01034 | 0.01109 | 0.00314 | 0.02970 | - | 0.00011 | 0.00368 | 0.00380 | 0.00027 | 0.00078 | 0.00078 | --- | > 0.009769 |
| Single | 11/02/2025 12:39 | Multielement 001 | Concentration | 9660 | W-0.8-10-1 | 63.02593 | 0.00166 | 0.00001 | 0.01056 | 0.01158 | 0.00267 | 0.03047 | - | 0.00011 | 0.00376 | 0.01441 | 0.00028 | 0.00080 | 0.00080 | --- | > 0.009770 |
| Single | 11/02/2025 12:40 | Multielement 001 | Concentration | 9661 | W-0.8-10-2 | 64.34948 | 0.00169 | 0.00001 | 0.01076 | 0.01281 | 0.00219 | 0.03091 | - | 0.00011 | 0.00377 | 0.01620 | 0.00028 | 0.00080 | 0.00080 | --- | > 0.009771 |
| Single | 11/02/2025 12:41 | Multielement 001 | Concentration | 9662 | W-0.8-10-3 | 64.51035 | 0.00031 | 0.00002 | 0.00533 | 0.00181 | 0.15222 | 0.11817 | - | 0.00091 | 0.00311 | 0.00084 | 0.00223 | 0.00367 | 0.00367 | --- | > 0.011502 |
| Single | 11/02/2025 12:42 | Multielement 001 | Concentration | 9663 | W-0.8-15-1 | 53.47541 | 0.00032 | 0.00001 | 0.00544 | 0.00159 | 0.15604 | 0.12418 | - | 0.00093 | 0.00318 | 0.01145 | 0.00228 | 0.00375 | 0.00375 | --- | > 0.011503 |
| Single | 11/02/2025 12:43 | Multielement 001 | Concentration | 9664 | W-0.8-15-2 | 54.49144 | 0.00033 | 0.00001 | 0.00554 | 0.00105 | 0.15999 | 0.07155 | - | 0.00095 | 0.00318 | 0.01286 | 0.00228 | 0.00375 | 0.00375 | --- | > 0.011504 |
| Single | 11/02/2025 12:44 | Multielement 001 | Concentration | 9665 | W-0.8-15-3 | 55.68481 | 0.00092 | 0.00002 | 0.00310 | 0.01668 | 0.05169 | 0.08129 | - | 0.00043 | 0.00153 | 0.06043 | 0.00108 | 0.00367 | 0.00367 | --- | > 0.015988 |
| Single | 11/02/2025 12:45 | Multielement 001 | Concentration | 9666 | W-0.8-20-1 | 48.47764 | 0.00094 | 0.00001 | 0.00317 | 0.01730 | 0.05334 | 0.07838 | - | 0.00044 | 0.00156 | 0.07104 | 0.00110 | 0.00375 | 0.00375 | --- | > 0.015989 |
| Single | 11/02/2025 12:46 | Multielement 001 | Concentration | 9667 | W-0.8-20-2 | 49.83501 | 0.00096 | 0.00001 | 0.00323 | 0.01882 | 0.05504 | 0.07675 | - | 0.00045 | 0.00156 | 0.07174 | 0.00111 | 0.00375 | 0.00375 | --- | > 0.015990 |
| Single | 11/02/2025 12:47 | Multielement 001 | Concentration | 9668 | W-0.8-20-3 | 51.23588 | 0.00105 | 0.00001 | 0.00713 | 0.01794 | 0.02440 | 0.14733 | - | 0.00025 | 0.00748 | 0.00600 | 0.00059 | 0.00058 | 0.00058 | --- | > 0.006551 |

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|--------|------------------|------------------|---------------|------|------------|-----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|-----|------------|
| Single | 11/02/2025 12:48 | Multielement 001 | Concentration | 9669 | W-0.8-25-1 | 51.90283 | 0.00108 | 0.00001 | 0.00728 | 0.01859 | 0.02546 | 0.14585 | 0.00025 | 0.00764 | 0.01661 | 0.00061 | 0.00060 | 0.00060 | --- | > 0.006552 |
| Single | 11/02/2025 12:49 | Multielement 001 | Concentration | 9670 | W-0.8-25-2 | 53.77133 | 0.00110 | 0.00002 | 0.00742 | 0.02018 | 0.02656 | 0.14502 | 0.00026 | 0.00766 | 0.02242 | 0.00061 | 0.00060 | 0.00060 | --- | > 0.006553 |
| Single | 11/02/2025 12:50 | Multielement 001 | Concentration | 9671 | W-0.8-25-3 | 53.96490 | 0.00175 | 0.00002 | 0.01111 | 0.02552 | 0.02125 | 0.12414 | 0.00011 | 0.00368 | 0.00380 | 0.00027 | 0.00031 | 0.00031 | --- | > 0.009769 |
| Single | 11/02/2025 12:51 | Multielement 001 | Concentration | 9672 | W-1-5-1 | 80.10436 | 0.00180 | 0.00001 | 0.01135 | 0.02633 | 0.01947 | 0.12337 | 0.00011 | 0.00376 | 0.01441 | 0.00028 | 0.00032 | 0.00032 | --- | > 0.009770 |
| Single | 11/02/2025 12:52 | Multielement 001 | Concentration | 9673 | W-1-5-2 | 82.50749 | 0.00003 | 0.00001 | 0.01157 | 0.02832 | 0.01995 | 0.12293 | 0.00011 | 0.00377 | 0.01620 | 0.00028 | 0.00032 | 0.00032 | --- | > 0.009771 |
| Single | 11/02/2025 12:53 | Multielement 001 | Concentration | 9674 | W-1-5-3 | 83.58009 | 0.00030 | 0.00001 | 0.01392 | 0.01364 | 0.15222 | 0.11817 | 0.00091 | 0.00311 | 0.00084 | 0.00223 | 0.00367 | 0.00367 | --- | > 0.011502 |
| Single | 11/02/2025 12:54 | Multielement 001 | Concentration | 9675 | W-1-10-1 | 75.12909 | 0.01091 | 0.01060 | 0.02453 | 0.02425 | 0.16283 | 0.12878 | 0.00102 | 0.00312 | 0.01145 | 0.00223 | 0.00143 | 0.01428 | --- | > 0.011503 |
| Single | 11/02/2025 12:55 | Multielement 001 | Concentration | 9676 | W-1-10-2 | 76.70680 | 0.01094 | 0.01063 | 0.02458 | 0.02432 | 0.16318 | 0.12932 | 0.00102 | 0.00313 | 0.01286 | 0.00224 | 0.00143 | 0.01431 | --- | > 0.011504 |
| Single | 11/02/2025 12:56 | Multielement 001 | Concentration | 9677 | W-1-10-3 | 76.89857 | 0.00061 | 0.00046 | 0.01504 | 0.01998 | 0.02308 | 0.02259 | 0.00027 | 0.00954 | 0.06043 | 0.00068 | 0.00023 | 0.00229 | --- | > 0.015988 |
| Single | 11/02/2025 12:57 | Multielement 001 | Concentration | 9678 | W-1-15-1 | 64.82853 | 0.01721 | 0.00120 | 0.02565 | 0.03059 | 0.03369 | 0.03320 | 0.00028 | 0.00965 | 0.07104 | 0.00068 | 0.00184 | 0.01839 | --- | > 0.015989 |
| Single | 11/02/2025 12:58 | Multielement 001 | Concentration | 9679 | W-1-15-2 | 66.06027 | 0.01724 | 0.00120 | 0.02569 | 0.03067 | 0.03380 | 0.03338 | 0.00028 | 0.00966 | 0.07174 | 0.00068 | 0.00184 | 0.01843 | --- | > 0.015990 |
| Single | 11/02/2025 12:59 | Multielement 001 | Concentration | 9680 | W-1-15-3 | 67.50699 | 0.00370 | 0.00001 | 0.02899 | 0.05456 | 0.02440 | 0.00707 | 0.00025 | 0.00748 | 0.00600 | 0.00059 | 0.00013 | 0.00130 | --- | > 0.006551 |
| Single | 11/02/2025 13:00 | Multielement 001 | Concentration | 9681 | W-1-20-1 | 59.05321 | 0.02030 | 0.00120 | 0.03960 | 0.01130 | 0.03501 | 0.00064 | 0.00025 | 0.00759 | 0.01661 | 0.00059 | 0.00013 | 0.00133 | --- | > 0.006552 |
| Single | 11/02/2025 13:01 | Multielement 001 | Concentration | 9682 | W-1-20-2 | 60.70670 | 0.00235 | 0.00120 | 0.03967 | 0.01130 | 0.01727 | 0.00064 | 0.00025 | 0.00760 | 0.02242 | 0.00060 | 0.00013 | 0.00133 | --- | > 0.006553 |
| Single | 11/02/2025 13:02 | Multielement 001 | Concentration | 9683 | W-1-20-3 | 62.41317 | 0.00453 | 0.00003 | 0.03776 | 0.06592 | 0.00900 | 0.03570 | 0.00011 | 0.00368 | 0.00380 | 0.00027 | 0.00007 | 0.00069 | --- | > 0.009769 |
| Single | 11/02/2025 13:03 | Multielement 001 | Concentration | 9684 | W-1-25-1 | 63.57846 | 0.00373 | 0.00120 | 0.04837 | 0.01118 | 0.00747 | 0.00026 | 0.00011 | 0.00379 | 0.01441 | 0.00027 | 0.00007 | 0.00070 | --- | > 0.009770 |
| Single | 11/02/2025 13:04 | Multielement 001 | Concentration | 9685 | W-1-25-2 | 65.86729 | 0.00077 | 0.00120 | 0.04927 | 0.01118 | 0.00817 | 0.00026 | 0.00011 | 0.00379 | 0.01620 | 0.00027 | 0.00007 | 0.00070 | --- | > 0.009771 |
| Single | 11/02/2025 13:05 | Multielement 001 | Concentration | 9686 | W-1-25-3 | 66.10441 | 0.00736 | 0.00001 | 0.05840 | 0.11843 | 0.15222 | 0.07816 | 0.00091 | 0.00311 | 0.00084 | 0.00223 | 0.00037 | 0.00367 | --- | > 0.011502 |
| Single | 11/02/2025 13:06 | Multielement 001 | Concentration | 9687 | O-0.1-5-1 | 182.31103 | 0.00039 | 0.00030 | 0.00120 | 0.00191 | 0.00105 | 0.01682 | 0.00278 | 0.00912 | 0.01145 | 0.00292 | 0.00223 | 0.00373 | --- | > 0.011502 |
| Single | 11/02/2025 13:07 | Multielement 001 | Concentration | 9688 | O-0.1-5-2 | 179.97140 | 0.01100 | 0.01091 | 0.01181 | 0.01252 | 0.01166 | 0.02743 | 0.00289 | 0.01018 | 0.01286 | 0.00293 | 0.00223 | 0.00373 | --- | > 0.011503 |
| Single | 11/02/2025 13:08 | Multielement 001 | Concentration | 9689 | O-0.1-5-3 | 174.72951 | 0.01124 | 0.01094 | 0.01184 | 0.01257 | 0.01173 | 0.02778 | 0.00289 | 0.01020 | 0.06043 | 0.00294 | 0.00224 | 0.00367 | --- | > 0.011504 |
| Single | 11/02/2025 13:09 | Multielement 001 | Concentration | 9690 | O-0.1-10-1 | 169.45672 | 0.00098 | 0.00061 | 0.00075 | 0.00303 | 0.00739 | 0.11232 | 0.00084 | 0.00271 | 0.07104 | 0.00938 | 0.00068 | 0.00373 | --- | > 0.015988 |
| Single | 11/02/2025 13:10 | Multielement 001 | Concentration | 9691 | O-0.1-10-2 | 173.01532 | 0.01159 | 0.00721 | 0.00001 | 0.01364 | 0.01800 | 0.10171 | 0.00095 | 0.00281 | 0.07174 | 0.00948 | 0.00068 | 0.00373 | --- | > 0.015989 |
| Single | 11/02/2025 13:11 | Multielement 001 | Concentration | 9692 | O-0.1-10-3 | 173.44785 | 0.01184 | 0.01804 | 0.00001 | 0.01368 | 0.01808 | 0.10160 | 0.00095 | 0.00282 | 0.00600 | 0.00950 | 0.00068 | 0.00002 | --- | > 0.015990 |
| Single | 11/02/2025 13:12 | Multielement 001 | Concentration | 9693 | O-0.1-15-1 | 164.45895 | 0.00419 | 0.00450 | 0.00120 | 0.01698 | 0.04197 | 0.11100 | 0.00069 | 0.00248 | 0.01661 | 0.00826 | 0.00059 | 0.00002 | --- | > 0.006551 |
| Single | 11/02/2025 13:13 | Multielement 001 | Concentration | 9694 | O-0.1-15-2 | 167.58367 | 0.01480 | 0.00130 | 0.00001 | 0.02759 | 0.00046 | 0.10039 | 0.00001 | 0.00248 | 0.02242 | 0.00836 | 0.00059 | 0.00002 | --- | > 0.006552 |

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|--------|---------------------|---------------------|---------------|------|------------|-----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|-----|------------|
| Single | 11/02/2025 13:14 | Multielement 001 | Concentration | 9695 | O-0.1-15-3 | 171.25376 | 0.01512 | 0.00135 | 0.00001 | 0.02766 | 0.00046 | 0.10027 | 0.00001 | 0.00253 | 0.00380 | 0.00838 | 0.00060 | 0.00004 | --- | > 0.006553 |
| Single | 11/02/2025 13:15 | Multielement 001 | Concentration | 9696 | O-0.1-20-1 | 161.98382 | 0.00525 | 0.00503 | 0.00118 | 0.02575 | 0.07768 | 0.13854 | 0.00036 | 0.00106 | 0.01441 | 0.00357 | 0.00027 | 0.00004 | --- | > 0.009769 |
| Single | 11/02/2025 13:16 | Multielement 001 | Concentration | 9697 | O-0.1-20-2 | 166.51936 | 0.01586 | 0.00273 | 0.00001 | 0.03636 | 0.00058 | 0.12793 | 0.00000 | 0.00106 | 0.01620 | 0.00367 | 0.00027 | 0.00004 | --- | > 0.009770 |
| Single | 11/02/2025 13:17 | Multielement 001 | Concentration | 9698 | O-0.1-20-3 | 171.20022 | 0.01919 | 0.00277 | 0.00001 | 0.03726 | 0.00058 | 0.12723 | 0.00000 | 0.00108 | 0.00084 | 0.00368 | 0.00027 | 0.00078 | --- | > 0.009771 |
| Single | 11/02/2025 13:18 | Multielement 001 | Concentration | 9699 | O-0.1-25-1 | 158.08361 | 0.01014 | 0.00026 | 0.00120 | 0.04639 | 0.13019 | 0.01682 | 0.00278 | 0.00912 | 0.01145 | 0.00292 | 0.00223 | 0.00080 | --- | > 0.011502 |
| Single | 11/02/2025 13:19 | Multielement 001 | Concentration | 9700 | O-0.1-25-2 | 163.77462 | 0.02075 | 0.00586 | 0.00001 | 0.05700 | 0.00114 | 0.02743 | 0.00003 | 0.00913 | 0.01286 | 0.00293 | 0.00223 | 0.00080 | --- | > 0.011503 |
| Single | 11/02/2025 13:20 | Multielement 001 | Concentration | 9701 | O-0.1-25-3 | 164.36420 | 0.02498 | 0.00591 | 0.00001 | 0.05828 | 0.00114 | 0.03153 | 0.00003 | 0.00930 | 0.06043 | 0.00294 | 0.00224 | 0.00367 | --- | > 0.011504 |
| Single | 11/02/2025 13:21 | Multielement 001 | Concentration | 9702 | O-0.2-5-1 | 138.30753 | 0.00443 | 0.00334 | 0.00119 | 0.01894 | 0.06889 | 0.08371 | 0.00135 | 0.00433 | 0.07104 | 0.00150 | 0.00108 | 0.00375 | --- | > 0.015988 |
| Single | 11/02/2025 13:22 | Multielement 001 | Concentration | 9703 | O-0.2-5-2 | 142.45675 | 0.01504 | 0.00104 | 0.00001 | 0.02955 | 0.00049 | 0.07310 | 0.00002 | 0.00434 | 0.07174 | 0.00151 | 0.00108 | 0.00375 | --- | > 0.015989 |
| Single | 11/02/2025 13:23 | Multielement 001 | Concentration | 9704 | O-0.2-5-3 | 144.30869 | 0.01689 | 0.00145 | 0.00001 | 0.03033 | 0.00053 | 0.07120 | 0.00002 | 0.00442 | 0.00600 | 0.00151 | 0.00108 | 0.00367 | --- | > 0.015990 |
| Single | 11/02/2025 13:24 | Multielement 001 | Concentration | 9705 | O-0.2-10-1 | 133.33226 | 0.00087 | 0.00032 | 0.00119 | 0.00179 | 0.03058 | 0.11100 | 0.00069 | 0.00248 | 0.01661 | 0.00083 | 0.00059 | 0.00375 | --- | > 0.006551 |
| Single | 11/02/2025 13:25 | Multielement 001 | Concentration | 9706 | O-0.2-10-2 | 136.13224 | 0.01148 | 0.01692 | 0.00001 | 0.01240 | 0.00008 | 0.10039 | 0.00001 | 0.00248 | 0.02242 | 0.00084 | 0.00059 | 0.00375 | --- | > 0.006552 |
| Single | 11/02/2025 13:26 | Multielement 001 | Concentration | 9707 | O-0.2-10-3 | 136.47257 | 0.01294 | 0.01728 | 0.00001 | 0.01285 | 0.00010 | 0.09908 | 0.00001 | 0.00253 | 0.00380 | 0.00084 | 0.00060 | 0.00058 | --- | > 0.006553 |
| Single | 11/02/2025 13:27 | Multielement 001 | Concentration | 9708 | O-0.2-15-1 | 126.95691 | 0.00087 | 0.00032 | 0.00119 | 0.00179 | 0.00622 | 0.11100 | 0.00069 | 0.00248 | 0.01441 | 0.00083 | 0.00059 | 0.00060 | --- | > 0.006551 |
| Single | 11/02/2025 13:28 | Multielement 001 | Concentration | 9709 | O-0.2-15-2 | 129.36909 | 0.00093 | 0.00038 | 0.00122 | 0.00209 | 0.00689 | 0.10994 | 0.00070 | 0.00253 | 0.01620 | 0.00084 | 0.00061 | 0.00060 | --- | > 0.006552 |
| Single | 11/02/2025 13:29 | Multielement 001 | Concentration | 9710 | O-0.2-15-3 | 132.20228 | 0.00125 | 0.00042 | 0.00122 | 0.00235 | 0.00852 | 0.10884 | 0.00071 | 0.00258 | 0.00084 | 0.00084 | 0.00061 | 0.00031 | --- | > 0.006553 |
| Single | 11/02/2025 13:30 | Multielement 001 | Concentration | 9711 | O-0.2-20-1 | 123.93175 | 0.00015 | 0.00061 | 0.00119 | 0.00167 | 0.00263 | 0.13854 | 0.00036 | 0.00106 | 0.01145 | 0.00036 | 0.00027 | 0.00032 | --- | > 0.009769 |
| Single | 11/02/2025 13:31 | Multielement 001 | Concentration | 9712 | O-0.2-20-2 | 127.40184 | 0.00020 | 0.00065 | 0.00122 | 0.00145 | 0.00313 | 0.13807 | 0.00037 | 0.00108 | 0.01286 | 0.00036 | 0.00028 | 0.00032 | --- | > 0.009770 |
| Single | 11/02/2025 13:32 | Multielement 001 | Concentration | 9713 | O-0.2-20-3 | 130.98310 | 0.00043 | 0.00068 | 0.00122 | 0.00125 | 0.00436 | 0.13759 | 0.00037 | 0.00110 | 0.06043 | 0.00365 | 0.00028 | 0.00367 | --- | > 0.009771 |
| Single | 11/02/2025 13:33 | Multielement 001 | Concentration | 9714 | O-0.2-25-1 | 127.80696 | 0.00023 | 0.00039 | 0.00119 | 0.00668 | 0.00018 | 0.01682 | 0.00278 | 0.00912 | 0.07104 | 0.00292 | 0.00223 | 0.01428 | --- | > 0.011502 |
| Single | 11/02/2025 13:34 | Multielement 001 | Concentration | 9715 | O-0.2-25-2 | 132.40801 | 0.00024 | 0.00040 | 0.00122 | 0.00657 | 0.00040 | 0.02064 | 0.00284 | 0.00931 | 0.07174 | 0.00298 | 0.00228 | 0.01431 | --- | > 0.011503 |
| Single | 11/02/2025 13:35 | Multielement 001 | Concentration | 9716 | O-0.2-25-3 | 132.88468 | 0.00029 | 0.00041 | 0.00122 | 0.00646 | 0.00094 | 0.02459 | 0.00288 | 0.00949 | 0.00600 | 0.00299 | 0.00228 | 0.00229 | --- | > 0.011504 |
| Single | 11/02/2025 13:36 | Multielement 001 | Concentration | 9717 | O-0.4-5-1 | 109.38095 | 0.00179 | 0.00099 | 0.00119 | 0.00891 | 0.00409 | 0.08371 | 0.00135 | 0.00433 | 0.01661 | 0.00150 | 0.00108 | 0.01839 | --- | > 0.015988 |
| Single | 11/02/2025 13:37 | Multielement 001 | Concentration | 9718 | O-0.4-5-2 | 112.66238 | 0.00004 | 0.00102 | 0.00122 | 0.00884 | 0.00471 | 0.08206 | 0.00138 | 0.00443 | 0.02242 | 0.00153 | 0.00110 | 0.01843 | --- | > 0.015989 |
| Single | 11/02/2025 13:38 | Multielement 001 | Concentration | 9719 | O-0.4-5-3 | 114.12699 | 0.00026 | 0.00104 | 0.00122 | 0.00878 | 0.00623 | 0.08036 | 0.00139 | 0.00451 | 0.00380 | 0.00154 | 0.00111 | 0.00130 | --- | > 0.015990 |
| Single | 11/02/2025 13:39 | Multielement 001 | Concentration | 9720 | O-0.4-10-1 | 104.40568 | 0.00125 | 0.00113 | 0.00120 | 0.00488 | 0.00535 | 0.11100 | 0.00069 | 0.00248 | 0.01441 | 0.00826 | 0.00059 | 0.00133 | --- | > 0.006551 |

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|--------|---------------------|---------------------|---------------|------|------------|-----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|------------|------------|
| Single | 11/02/2025 13:40 | Multielement 001 | Concentration | 9721 | O-0.4-10-2 | 106.59820 | 0.00132 | 0.00116 | - | - | 0.00473 | 0.00600 | 0.10994 | 0.00070 | 0.00253 | 0.01620 | 0.00843 | 0.00061 | 0.00133 | --- | > 0.006552 |
| Single | 11/02/2025 13:41 | Multielement 001 | Concentration | 9722 | O-0.4-10-3 | 106.86470 | 0.00169 | 0.00118 | 0.00123 | 0.00459 | 0.00758 | 0.10884 | 0.00071 | 0.00258 | 0.00084 | 0.00845 | 0.00061 | 0.00069 | --- | > 0.006553 | |
| Single | 11/02/2025 13:42 | Multielement 001 | Concentration | 9723 | O-0.4-15-1 | 97.30530 | 0.00374 | 0.00183 | 0.00119 | 0.00089 | 0.01293 | 0.13854 | 0.00036 | 0.00106 | 0.01145 | 0.00357 | 0.00027 | 0.00070 | --- | > 0.009769 | |
| Single | 11/02/2025 13:43 | Multielement 001 | Concentration | 9724 | O-0.4-15-2 | 99.15410 | 0.00386 | 0.00187 | 0.00122 | 0.00065 | 0.01374 | 0.13807 | 0.00037 | 0.00108 | 0.01286 | 0.00364 | 0.00028 | 0.00070 | --- | > 0.009770 | |
| Single | 11/02/2025 13:44 | Multielement 001 | Concentration | 9725 | O-0.4-15-3 | 101.32557 | 0.00450 | 0.00191 | 0.00122 | 0.00044 | 0.01573 | 0.13759 | 0.00037 | 0.00110 | 0.06043 | 0.00365 | 0.00028 | 0.00367 | --- | > 0.009771 | |
| Single | 11/02/2025 13:45 | Multielement 001 | Concentration | 9726 | O-0.4-20-1 | 93.40508 | 0.00030 | 0.00001 | 0.01392 | 0.01364 | 0.15222 | 0.11817 | 0.00091 | 0.00311 | 0.07104 | 0.00223 | 0.00367 | 0.00373 | --- | > 0.011502 | |
| Single | 11/02/2025 13:46 | Multielement 001 | Concentration | 9727 | O-0.4-20-2 | 96.02043 | 0.01091 | 0.01060 | 0.02453 | 0.02425 | 0.16283 | 0.12878 | 0.00102 | 0.00312 | 0.07174 | 0.00223 | 0.01428 | 0.00373 | --- | > 0.011503 | |
| Single | 11/02/2025 13:47 | Multielement 001 | Concentration | 9728 | O-0.4-20-3 | 98.71956 | 0.01094 | 0.01063 | 0.02458 | 0.02432 | 0.16318 | 0.12932 | 0.00102 | 0.00313 | 0.00600 | 0.00224 | 0.01431 | 0.00367 | --- | > 0.011504 | |
| Single | 11/02/2025 13:48 | Multielement 001 | Concentration | 9729 | O-0.4-25-1 | 89.42987 | 0.00061 | 0.00046 | 0.01504 | 0.01998 | 0.02308 | 0.02259 | 0.00027 | 0.00954 | 0.01661 | 0.00068 | 0.00229 | 0.00373 | --- | > 0.015988 | |
| Single | 11/02/2025 13:49 | Multielement 001 | Concentration | 9730 | O-0.4-25-2 | 92.64934 | 0.01721 | 0.00120 | 0.02565 | 0.03059 | 0.03369 | 0.03320 | 0.00028 | 0.00965 | 0.02242 | 0.00068 | 0.00184 | 0.00373 | --- | > 0.015989 | |
| Single | 11/02/2025 13:50 | Multielement 001 | Concentration | 9731 | O-0.4-25-3 | 92.98288 | 0.01724 | 0.00120 | 0.02569 | 0.03067 | 0.03380 | 0.03338 | 0.00028 | 0.00966 | 0.00380 | 0.00068 | 0.00184 | 0.00002 | --- | > 0.015990 | |
| Single | 11/02/2025 13:51 | Multielement 001 | Concentration | 9732 | O-0.6-5-1 | 65.89609 | 0.00370 | 0.00001 | 0.02899 | 0.05456 | 0.02440 | 0.00707 | 0.00025 | 0.00748 | 0.01441 | 0.00059 | 0.00130 | 0.00002 | --- | > 0.006551 | |
| Single | 11/02/2025 13:52 | Multielement 001 | Concentration | 9733 | O-0.6-5-2 | 67.87297 | 0.02030 | 0.00120 | 0.03960 | 0.01130 | 0.03501 | 0.06080 | 0.00025 | 0.00759 | 0.01620 | 0.00059 | 0.00133 | 0.00002 | --- | > 0.006552 | |
| Single | 11/02/2025 13:53 | Multielement 001 | Concentration | 9734 | O-0.6-5-3 | 68.75532 | 0.02035 | 0.00120 | 0.03967 | 0.01130 | 0.03513 | 0.06080 | 0.00025 | 0.00760 | 0.00084 | 0.00060 | 0.00133 | 0.00004 | --- | > 0.006553 | |
| Single | 11/02/2025 13:54 | Multielement 001 | Concentration | 9735 | O-0.6-10-1 | 54.39796 | 0.00513 | 0.00003 | 0.03776 | 0.06592 | 0.01900 | 0.02574 | 0.00011 | 0.00368 | 0.01145 | 0.00027 | 0.00069 | 0.00004 | --- | > 0.009769 | |
| Single | 11/02/2025 13:55 | Multielement 001 | Concentration | 9736 | O-0.6-10-2 | 55.54032 | 0.02173 | 0.00120 | 0.04837 | 0.01118 | 0.00747 | 0.06118 | 0.00011 | 0.00379 | 0.01286 | 0.00027 | 0.00070 | 0.00004 | --- | > 0.009770 | |
| Single | 11/02/2025 13:56 | Multielement 001 | Concentration | 9737 | O-0.6-10-3 | 55.67917 | 0.02177 | 0.00120 | 0.04927 | 0.01118 | 0.00817 | 0.06118 | 0.00011 | 0.00379 | 0.06043 | 0.00027 | 0.00070 | 0.00078 | --- | > 0.009771 | |
| Single | 11/02/2025 13:57 | Multielement 001 | Concentration | 9738 | O-0.6-15-1 | 46.52253 | 0.00826 | 0.00001 | 0.05840 | 0.11843 | 0.15222 | 0.21657 | 0.00091 | 0.00311 | 0.07104 | 0.00223 | 0.00367 | 0.00080 | --- | > 0.011502 | |
| Single | 11/02/2025 13:58 | Multielement 001 | Concentration | 9739 | O-0.6-15-2 | 47.40646 | 0.02486 | 0.00120 | 0.06901 | 0.01063 | 0.16283 | 0.05837 | 0.00091 | 0.00312 | 0.07174 | 0.00223 | 0.00373 | 0.00080 | --- | > 0.011503 | |
| Single | 11/02/2025 13:59 | Multielement 001 | Concentration | 9740 | O-0.6-15-3 | 48.44466 | 0.02491 | 0.00120 | 0.07029 | 0.01062 | 0.16693 | 0.05836 | 0.00093 | 0.00313 | 0.00600 | 0.00224 | 0.00373 | 0.00367 | --- | > 0.011504 | |
| Single | 11/02/2025 14:00 | Multielement 001 | Concentration | 9741 | O-0.6-20-1 | 42.10229 | 0.00344 | 0.00002 | 0.03095 | 0.05713 | 0.05169 | 0.07311 | 0.00043 | 0.00153 | 0.01661 | 0.00108 | 0.00367 | 0.00375 | --- | > 0.015988 | |
| Single | 11/02/2025 14:01 | Multielement 001 | Concentration | 9742 | O-0.6-20-2 | 43.28116 | 0.02004 | 0.00120 | 0.04156 | 0.01128 | 0.06230 | 0.06004 | 0.00043 | 0.00154 | 0.02242 | 0.00108 | 0.00373 | 0.00375 | --- | > 0.015989 | |
| Single | 11/02/2025 14:02 | Multielement 001 | Concentration | 9743 | O-0.6-20-3 | 44.49779 | 0.02045 | 0.00120 | 0.04234 | 0.01124 | 0.06420 | 0.06002 | 0.00044 | 0.00154 | 0.00380 | 0.00108 | 0.00373 | 0.00367 | --- | > 0.015990 | |
| Single | 11/02/2025 14:03 | Multielement 001 | Concentration | 9744 | O-0.6-25-1 | 45.87750 | 0.00042 | 0.00002 | 0.01380 | 0.01881 | 0.02440 | 0.00707 | 0.00025 | 0.00748 | 0.01441 | 0.00059 | 0.00002 | 0.00375 | --- | > 0.006551 | |
| Single | 11/02/2025 14:04 | Multielement 001 | Concentration | 9745 | O-0.6-25-2 | 47.52909 | 0.01702 | 0.00120 | 0.02441 | 0.01168 | 0.03501 | 0.06080 | 0.00025 | 0.00759 | 0.01620 | 0.00059 | 0.00002 | 0.00375 | --- | > 0.006552 | |
| Single | 11/02/2025 14:05 | Multielement 001 | Concentration | 9746 | O-0.6-25-3 | 47.70019 | 0.01738 | 0.00120 | 0.02486 | 0.01167 | 0.03632 | 0.06079 | 0.00025 | 0.00760 | 0.00084 | 0.00060 | 0.00002 | 0.00058 | --- | > 0.006553 | |

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|--------|------------------|------------------|---------------|------|------------|----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|-----|------------|
| Single | 11/02/2025 14:06 | Multielement 001 | Concentration | 9747 | O-0.8-5-1 | 68.00120 | 0.00042 | 0.00002 | 0.01380 | 0.01881 | 0.02440 | 0.00707 | 0.00025 | 0.00748 | 0.01145 | 0.00059 | 0.00004 | 0.00060 | --- | > 0.006551 |
| Single | 11/02/2025 14:07 | Multielement 001 | Concentration | 9748 | O-0.8-5-2 | 70.04124 | 0.00048 | 0.00001 | 0.01410 | 0.01948 | 0.02546 | 0.00855 | 0.00025 | 0.00764 | 0.01286 | 0.00061 | 0.00004 | 0.00060 | --- | > 0.006552 |
| Single | 11/02/2025 14:08 | Multielement 001 | Concentration | 9749 | O-0.8-5-3 | 70.95177 | 0.00052 | 0.00001 | 0.01436 | 0.02111 | 0.02656 | 0.00938 | 0.00026 | 0.00766 | 0.06043 | 0.00061 | 0.00004 | 0.00031 | --- | > 0.006553 |
| Single | 11/02/2025 14:09 | Multielement 001 | Concentration | 9750 | O-0.8-10-1 | 63.02593 | 0.00162 | 0.00002 | 0.01034 | 0.01109 | 0.00314 | 0.02970 | 0.00011 | 0.00368 | 0.07104 | 0.00027 | 0.00078 | 0.00032 | --- | > 0.009769 |
| Single | 11/02/2025 14:10 | Multielement 001 | Concentration | 9751 | O-0.8-10-2 | 64.34948 | 0.00166 | 0.00001 | 0.01056 | 0.01158 | 0.00267 | 0.03047 | 0.00011 | 0.00376 | 0.07174 | 0.00028 | 0.00080 | 0.00032 | --- | > 0.009770 |
| Single | 11/02/2025 14:11 | Multielement 001 | Concentration | 9752 | O-0.8-10-3 | 64.51035 | 0.00169 | 0.00001 | 0.01076 | 0.01281 | 0.00219 | 0.03091 | 0.00011 | 0.00377 | 0.00600 | 0.00028 | 0.00080 | 0.00367 | --- | > 0.009771 |
| Single | 11/02/2025 14:12 | Multielement 001 | Concentration | 9753 | O-0.8-15-1 | 53.47541 | 0.00031 | 0.00002 | 0.00533 | 0.00181 | 0.15222 | 0.11817 | 0.00091 | 0.00311 | 0.01661 | 0.00223 | 0.00367 | 0.01428 | --- | > 0.011502 |
| Single | 11/02/2025 14:13 | Multielement 001 | Concentration | 9754 | O-0.8-15-2 | 54.49144 | 0.00032 | 0.00001 | 0.00544 | 0.00159 | 0.15604 | 0.12418 | 0.00093 | 0.00318 | 0.02242 | 0.00228 | 0.00375 | 0.01431 | --- | > 0.011503 |
| Single | 11/02/2025 14:14 | Multielement 001 | Concentration | 9755 | O-0.8-15-3 | 55.68481 | 0.00033 | 0.00001 | 0.00554 | 0.00105 | 0.15999 | 0.07155 | 0.00095 | 0.00318 | 0.00380 | 0.00228 | 0.00375 | 0.00229 | --- | > 0.011504 |
| Single | 11/02/2025 14:15 | Multielement 001 | Concentration | 9756 | O-0.8-20-1 | 48.47764 | 0.00092 | 0.00002 | 0.00310 | 0.01668 | 0.05169 | 0.08129 | 0.00043 | 0.00153 | 0.01441 | 0.00108 | 0.00367 | 0.01839 | --- | > 0.015988 |
| Single | 11/02/2025 14:16 | Multielement 001 | Concentration | 9757 | O-0.8-20-2 | 49.83501 | 0.00094 | 0.00001 | 0.00317 | 0.01730 | 0.05334 | 0.07838 | 0.00044 | 0.00156 | 0.01620 | 0.00110 | 0.00375 | 0.01843 | --- | > 0.015989 |
| Single | 11/02/2025 14:17 | Multielement 001 | Concentration | 9758 | O-0.8-20-3 | 51.23588 | 0.00096 | 0.00001 | 0.00323 | 0.01882 | 0.05504 | 0.07675 | 0.00045 | 0.00156 | 0.00084 | 0.00111 | 0.00375 | 0.00130 | --- | > 0.015990 |
| Single | 11/02/2025 14:18 | Multielement 001 | Concentration | 9759 | O-0.8-25-1 | 51.90283 | 0.00105 | 0.00001 | 0.00713 | 0.01794 | 0.02440 | 0.14733 | 0.00025 | 0.00748 | 0.01145 | 0.00059 | 0.00058 | 0.00133 | --- | > 0.006551 |
| Single | 11/02/2025 14:19 | Multielement 001 | Concentration | 9760 | O-0.8-25-2 | 53.77133 | 0.00108 | 0.00001 | 0.00728 | 0.01859 | 0.02546 | 0.14585 | 0.00025 | 0.00764 | 0.01286 | 0.00061 | 0.00060 | 0.00133 | --- | > 0.006552 |
| Single | 11/02/2025 14:20 | Multielement 001 | Concentration | 9761 | O-0.8-25-3 | 53.96490 | 0.00110 | 0.00002 | 0.00742 | 0.02018 | 0.02656 | 0.14502 | 0.00026 | 0.00766 | 0.06043 | 0.00061 | 0.00060 | 0.00069 | --- | > 0.006553 |
| Single | 11/02/2025 14:21 | Multielement 001 | Concentration | 9762 | O-1-5-1 | 80.10436 | 0.00175 | 0.00002 | 0.01111 | 0.02552 | 0.02125 | 0.12414 | 0.00011 | 0.00368 | 0.07104 | 0.00027 | 0.00031 | 0.00070 | --- | > 0.009769 |
| Single | 11/02/2025 14:22 | Multielement 001 | Concentration | 9763 | O-1-5-2 | 82.50749 | 0.00180 | 0.00001 | 0.01135 | 0.02633 | 0.01947 | 0.12337 | 0.00011 | 0.00376 | 0.07174 | 0.00028 | 0.00032 | 0.00070 | --- | > 0.009770 |
| Single | 11/02/2025 14:23 | Multielement 001 | Concentration | 9764 | O-1-5-3 | 83.58009 | 0.00003 | 0.00001 | 0.01157 | 0.02832 | 0.01995 | 0.12293 | 0.00011 | 0.00377 | 0.00600 | 0.00028 | 0.00032 | 0.00367 | --- | > 0.009771 |
| Single | 11/02/2025 14:24 | Multielement 001 | Concentration | 9765 | O-1-10-1 | 75.12909 | 0.00030 | 0.00001 | 0.01392 | 0.01364 | 0.15222 | 0.11817 | 0.00091 | 0.00311 | 0.01661 | 0.00223 | 0.00367 | 0.00373 | --- | > 0.011502 |
| Single | 11/02/2025 14:25 | Multielement 001 | Concentration | 9766 | O-1-10-2 | 76.70680 | 0.01091 | 0.01060 | 0.02453 | 0.02425 | 0.16283 | 0.12878 | 0.00102 | 0.00312 | 0.02242 | 0.00223 | 0.00143 | 0.00373 | --- | > 0.011503 |
| Single | 11/02/2025 14:26 | Multielement 001 | Concentration | 9767 | O-1-10-3 | 76.89857 | 0.01094 | 0.01063 | 0.02458 | 0.02432 | 0.16318 | 0.12932 | 0.00102 | 0.00313 | 0.00380 | 0.00224 | 0.00143 | 0.00367 | --- | > 0.011504 |
| Single | 11/02/2025 14:27 | Multielement 001 | Concentration | 9768 | O-1-15-1 | 64.82853 | 0.00061 | 0.00046 | 0.01504 | 0.01998 | 0.02308 | 0.02259 | 0.00027 | 0.00954 | 0.01441 | 0.00068 | 0.00023 | 0.00373 | --- | > 0.015988 |
| Single | 11/02/2025 14:28 | Multielement 001 | Concentration | 9769 | O-1-15-2 | 66.06027 | 0.01721 | 0.00120 | 0.02565 | 0.03059 | 0.03369 | 0.03320 | 0.00028 | 0.00965 | 0.01620 | 0.00068 | 0.00184 | 0.00373 | --- | > 0.015989 |
| Single | 11/02/2025 14:29 | Multielement 001 | Concentration | 9770 | O-1-15-3 | 67.50699 | 0.01724 | 0.00120 | 0.02569 | 0.03067 | 0.03380 | 0.03338 | 0.00028 | 0.00966 | 0.00084 | 0.00068 | 0.00184 | 0.00002 | --- | > 0.015990 |
| Single | 11/02/2025 14:30 | Multielement 001 | Concentration | 9771 | O-1-20-1 | 59.05321 | 0.00370 | 0.00001 | 0.02899 | 0.05456 | 0.02440 | 0.00707 | 0.00025 | 0.00748 | 0.01145 | 0.00059 | 0.00013 | 0.00002 | --- | > 0.006551 |
| Single | 11/02/2025 14:31 | Multielement 001 | Concentration | 9772 | O-1-20-2 | 60.70670 | 0.02030 | 0.00120 | 0.03960 | 0.01130 | 0.03501 | 0.00064 | 0.00025 | 0.00759 | 0.01286 | 0.00059 | 0.00013 | 0.00002 | --- | > 0.006552 |

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|--------|------------------|------------------|---------------|------|------------|-----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|-----|------------|
| Single | 11/02/2025 14:32 | Multielement 001 | Concentration | 9773 | O-1-20-3 | 62.41317 | 0.00235 | 0.00120 | 0.03967 | 0.01130 | 0.01727 | 0.00064 | 0.00025 | 0.00760 | 0.06043 | 0.00060 | 0.00013 | 0.00004 | --- | > 0.006553 |
| Single | 11/02/2025 14:33 | Multielement 001 | Concentration | 9774 | O-1-25-1 | 63.57846 | 0.00453 | 0.00003 | 0.03776 | 0.06592 | 0.00900 | 0.03570 | 0.00011 | 0.00368 | 0.07104 | 0.00027 | 0.00007 | 0.00004 | --- | > 0.009769 |
| Single | 11/02/2025 14:34 | Multielement 001 | Concentration | 9775 | O-1-25-2 | 66.10441 | 0.00373 | 0.00120 | 0.04837 | 0.01118 | 0.00747 | 0.00026 | 0.00011 | 0.00379 | 0.07174 | 0.00027 | 0.00007 | 0.00004 | --- | > 0.009770 |
| Single | 11/02/2025 14:35 | Multielement 001 | Concentration | 9776 | O-1-25-3 | 65.86729 | 0.00077 | 0.00120 | 0.04927 | 0.01118 | 0.00817 | 0.00026 | 0.00011 | 0.00379 | 0.00600 | 0.00027 | 0.00007 | 0.00078 | --- | > 0.009771 |
| Single | 11/02/2025 14:36 | Multielement 001 | Concentration | 9777 | R-0.1-5-1 | 186.85306 | 0.00039 | 0.00030 | 0.00120 | 0.00191 | 0.00105 | 0.01682 | 0.00278 | 0.00912 | 0.01145 | 0.00292 | 0.00223 | 0.00373 | --- | > 0.011502 |
| Single | 11/02/2025 14:37 | Multielement 001 | Concentration | 9778 | R-0.1-5-2 | 192.45865 | 0.01100 | 0.01091 | 0.01181 | 0.01252 | 0.01166 | 0.02743 | 0.00289 | 0.01018 | 0.01286 | 0.00293 | 0.00223 | 0.00373 | --- | > 0.011503 |
| Single | 11/02/2025 14:38 | Multielement 001 | Concentration | 9779 | R-0.1-5-3 | 194.96061 | 0.01124 | 0.01094 | 0.01184 | 0.01257 | 0.01173 | 0.02778 | 0.00289 | 0.01020 | 0.06043 | 0.00294 | 0.00224 | 0.00367 | --- | > 0.011504 |
| Single | 11/02/2025 14:39 | Multielement 001 | Concentration | 9780 | R-0.1-10-1 | 181.99682 | 0.00098 | 0.00061 | 0.00075 | 0.00303 | 0.00739 | 0.11232 | 0.00084 | 0.00271 | 0.07104 | 0.00938 | 0.00068 | 0.00373 | --- | > 0.015988 |
| Single | 11/02/2025 14:40 | Multielement 001 | Concentration | 9781 | R-0.1-10-2 | 185.81875 | 0.01159 | 0.00721 | 0.00001 | 0.01364 | 0.01800 | 0.10171 | 0.00095 | 0.00281 | 0.07174 | 0.00948 | 0.00068 | 0.00373 | --- | > 0.015989 |
| Single | 11/02/2025 14:41 | Multielement 001 | Concentration | 9782 | R-0.1-10-3 | 186.28330 | 0.01184 | 0.01804 | 0.00001 | 0.01368 | 0.01808 | 0.10160 | 0.00095 | 0.00282 | 0.00600 | 0.00950 | 0.00068 | 0.00002 | --- | > 0.015990 |
| Single | 11/02/2025 14:42 | Multielement 001 | Concentration | 9783 | R-0.1-15-1 | 177.34782 | 0.00419 | 0.00450 | 0.00120 | 0.01698 | 0.04197 | 0.11100 | 0.00069 | 0.00248 | 0.01661 | 0.00826 | 0.00059 | 0.00002 | --- | > 0.006551 |
| Single | 11/02/2025 14:43 | Multielement 001 | Concentration | 9784 | R-0.1-15-2 | 180.71743 | 0.01480 | 0.00130 | 0.00001 | 0.02759 | 0.00046 | 0.10039 | 0.00001 | 0.00248 | 0.02242 | 0.00836 | 0.00059 | 0.00002 | --- | > 0.006552 |
| Single | 11/02/2025 14:44 | Multielement 001 | Concentration | 9785 | R-0.1-15-3 | 184.67514 | 0.01512 | 0.00135 | 0.00001 | 0.02766 | 0.00046 | 0.10027 | 0.00001 | 0.00253 | 0.00380 | 0.00838 | 0.00060 | 0.00004 | --- | > 0.006553 |
| Single | 11/02/2025 14:45 | Multielement 001 | Concentration | 9786 | R-0.1-20-1 | 175.11202 | 0.00525 | 0.00503 | 0.00118 | 0.02575 | 0.07768 | 0.13854 | 0.00036 | 0.00106 | 0.01441 | 0.00357 | 0.00027 | 0.00004 | --- | > 0.009769 |
| Single | 11/02/2025 14:46 | Multielement 001 | Concentration | 9787 | R-0.1-20-2 | 180.01515 | 0.01586 | 0.00273 | 0.00001 | 0.03636 | 0.00058 | 0.12793 | 0.00000 | 0.00106 | 0.01620 | 0.00367 | 0.00027 | 0.00004 | --- | > 0.009770 |
| Single | 11/02/2025 14:47 | Multielement 001 | Concentration | 9788 | R-0.1-20-3 | 185.07538 | 0.01919 | 0.00277 | 0.00001 | 0.03726 | 0.00058 | 0.12723 | 0.00000 | 0.00108 | 0.00084 | 0.00368 | 0.00027 | 0.00078 | --- | > 0.009771 |
| Single | 11/02/2025 14:48 | Multielement 001 | Concentration | 9789 | R-0.1-25-1 | 172.27698 | 0.01014 | 0.00026 | 0.00120 | 0.04639 | 0.13019 | 0.01682 | 0.00278 | 0.00912 | 0.01145 | 0.00292 | 0.00223 | 0.00080 | --- | > 0.011502 |
| Single | 11/02/2025 14:49 | Multielement 001 | Concentration | 9790 | R-0.1-25-2 | 178.47895 | 0.02075 | 0.00586 | 0.00001 | 0.05700 | 0.00114 | 0.02743 | 0.00003 | 0.00913 | 0.01286 | 0.00293 | 0.00223 | 0.00080 | --- | > 0.011503 |
| Single | 11/02/2025 14:50 | Multielement 001 | Concentration | 9791 | R-0.1-25-3 | 179.12147 | 0.02498 | 0.00591 | 0.00001 | 0.05828 | 0.00114 | 0.03153 | 0.00003 | 0.00930 | 0.06043 | 0.00294 | 0.00224 | 0.00367 | --- | > 0.011504 |
| Single | 11/02/2025 14:51 | Multielement 001 | Concentration | 9792 | R-0.2-5-1 | 149.72243 | 0.00443 | 0.00334 | 0.00119 | 0.01894 | 0.06889 | 0.08371 | 0.00135 | 0.00433 | 0.07104 | 0.00150 | 0.00108 | 0.00375 | --- | > 0.015988 |
| Single | 11/02/2025 14:52 | Multielement 001 | Concentration | 9793 | R-0.2-5-2 | 154.21410 | 0.01504 | 0.00104 | 0.00001 | 0.02955 | 0.00049 | 0.07310 | 0.00002 | 0.00434 | 0.07174 | 0.00151 | 0.00108 | 0.00375 | --- | > 0.015989 |
| Single | 11/02/2025 14:53 | Multielement 001 | Concentration | 9794 | R-0.2-5-3 | 156.21888 | 0.01689 | 0.00145 | 0.00001 | 0.03033 | 0.00053 | 0.07120 | 0.00002 | 0.00442 | 0.00600 | 0.00151 | 0.00108 | 0.00367 | --- | > 0.015990 |
| Single | 11/02/2025 14:54 | Multielement 001 | Concentration | 9795 | R-0.2-10-1 | 145.25556 | 0.00087 | 0.00032 | 0.00119 | 0.00179 | 0.03058 | 0.11100 | 0.00069 | 0.00248 | 0.01661 | 0.00083 | 0.00059 | 0.00375 | --- | > 0.006551 |
| Single | 11/02/2025 14:55 | Multielement 001 | Concentration | 9796 | R-0.2-10-2 | 148.30593 | 0.01148 | 0.01692 | 0.00001 | 0.01240 | 0.00008 | 0.10039 | 0.00001 | 0.00248 | 0.02242 | 0.00084 | 0.00059 | 0.00375 | --- | > 0.006552 |
| Single | 11/02/2025 14:56 | Multielement 001 | Concentration | 9797 | R-0.2-10-3 | 148.67670 | 0.01294 | 0.01728 | 0.00001 | 0.01285 | 0.00010 | 0.09908 | 0.00001 | 0.00253 | 0.00380 | 0.00084 | 0.00060 | 0.00058 | --- | > 0.006553 |
| Single | 11/02/2025 14:57 | Multielement 001 | Concentration | 9798 | R-0.2-15-1 | 139.53169 | 0.00087 | 0.00032 | 0.00119 | 0.00179 | 0.00622 | 0.11100 | 0.00069 | 0.00248 | 0.01441 | 0.00083 | 0.00059 | 0.00060 | --- | > 0.006551 |

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|--------|------------------|------------------|---------------|------|------------|-----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|-----|------------|
| Single | 11/02/2025 14:58 | Multielement 001 | Concentration | 9799 | R-0.2-15-2 | 142.18280 | 0.00093 | 0.00038 | 0.00122 | 0.00209 | 0.00689 | 0.10994 | 0.00070 | 0.00253 | 0.01620 | 0.00084 | 0.00061 | 0.00060 | --- | > 0.006552 |
| Single | 11/02/2025 14:59 | Multielement 001 | Concentration | 9800 | R-0.2-15-3 | 145.29660 | 0.00125 | 0.00042 | 0.00122 | 0.00235 | 0.00852 | 0.10884 | 0.00071 | 0.00258 | 0.00084 | 0.00084 | 0.00061 | 0.00031 | --- | > 0.006553 |
| Single | 11/02/2025 15:00 | Multielement 001 | Concentration | 9801 | R-0.2-20-1 | 136.81566 | 0.00015 | 0.00061 | 0.00119 | 0.00167 | 0.00263 | 0.13854 | 0.00036 | 0.00106 | 0.01145 | 0.00036 | 0.00027 | 0.00032 | --- | > 0.009769 |
| Single | 11/02/2025 15:01 | Multielement 001 | Concentration | 9802 | R-0.2-20-2 | 140.64650 | 0.00020 | 0.00065 | 0.00122 | 0.00145 | 0.00313 | 0.13807 | 0.00037 | 0.00108 | 0.01286 | 0.00036 | 0.00028 | 0.00032 | --- | > 0.009770 |
| Single | 11/02/2025 15:02 | Multielement 001 | Concentration | 9803 | R-0.2-20-3 | 144.60007 | 0.00043 | 0.00068 | 0.00122 | 0.00125 | 0.00436 | 0.13759 | 0.00037 | 0.00110 | 0.06043 | 0.00365 | 0.00028 | 0.00367 | --- | > 0.009771 |
| Single | 11/02/2025 15:03 | Multielement 001 | Concentration | 9804 | R-0.2-25-1 | 140.29488 | 0.00023 | 0.00039 | 0.00119 | 0.00668 | 0.00018 | 0.01682 | 0.00278 | 0.00912 | 0.07104 | 0.00292 | 0.00223 | 0.01428 | --- | > 0.011502 |
| Single | 11/02/2025 15:04 | Multielement 001 | Concentration | 9805 | R-0.2-25-2 | 145.34549 | 0.00024 | 0.00040 | 0.00122 | 0.00657 | 0.00040 | 0.02064 | 0.00284 | 0.00931 | 0.07174 | 0.00298 | 0.00228 | 0.01431 | --- | > 0.011503 |
| Single | 11/02/2025 15:05 | Multielement 001 | Concentration | 9806 | R-0.2-25-3 | 145.86874 | 0.00029 | 0.00041 | 0.00122 | 0.00646 | 0.00094 | 0.02459 | 0.00288 | 0.00949 | 0.00600 | 0.00299 | 0.00228 | 0.00229 | --- | > 0.011504 |
| Single | 11/02/2025 15:06 | Multielement 001 | Concentration | 9807 | R-0.4-5-1 | 120.79129 | 0.00179 | 0.00099 | 0.00119 | 0.00891 | 0.00409 | 0.08371 | 0.00135 | 0.00433 | 0.01661 | 0.00150 | 0.00108 | 0.01839 | --- | > 0.015988 |
| Single | 11/02/2025 15:07 | Multielement 001 | Concentration | 9808 | R-0.4-5-2 | 124.41502 | 0.00004 | 0.00102 | 0.00122 | 0.00884 | 0.00471 | 0.08206 | 0.00138 | 0.00443 | 0.02242 | 0.00153 | 0.00110 | 0.01843 | --- | > 0.015989 |
| Single | 11/02/2025 15:08 | Multielement 001 | Concentration | 9809 | R-0.4-5-3 | 126.03242 | 0.00026 | 0.00104 | 0.00122 | 0.00878 | 0.00623 | 0.08036 | 0.00139 | 0.00451 | 0.00380 | 0.00154 | 0.00111 | 0.00130 | --- | > 0.015990 |
| Single | 11/02/2025 15:09 | Multielement 001 | Concentration | 9810 | R-0.4-10-1 | 116.21969 | 0.00125 | 0.00113 | 0.00120 | 0.00488 | 0.00535 | 0.11100 | 0.00069 | 0.00248 | 0.01441 | 0.00826 | 0.00059 | 0.00133 | --- | > 0.006551 |
| Single | 11/02/2025 15:10 | Multielement 001 | Concentration | 9811 | R-0.4-10-2 | 118.66030 | 0.00132 | 0.00116 | 0.00122 | 0.00473 | 0.00600 | 0.10994 | 0.00070 | 0.00253 | 0.01620 | 0.00843 | 0.00061 | 0.00133 | --- | > 0.006552 |
| Single | 11/02/2025 15:11 | Multielement 001 | Concentration | 9812 | R-0.4-10-3 | 118.95695 | 0.00169 | 0.00118 | 0.00123 | 0.00459 | 0.00758 | 0.10884 | 0.00071 | 0.00258 | 0.00084 | 0.00845 | 0.00061 | 0.00069 | --- | > 0.006553 |
| Single | 11/02/2025 15:12 | Multielement 001 | Concentration | 9813 | R-0.4-15-1 | 109.69540 | 0.00374 | 0.00183 | 0.00119 | 0.00089 | 0.01293 | 0.13854 | 0.00036 | 0.00106 | 0.01145 | 0.00357 | 0.00027 | 0.00070 | --- | > 0.009769 |
| Single | 11/02/2025 15:13 | Multielement 001 | Concentration | 9814 | R-0.4-15-2 | 111.77961 | 0.00386 | 0.00187 | 0.00122 | 0.00065 | 0.01374 | 0.13807 | 0.00037 | 0.00108 | 0.01286 | 0.00364 | 0.00028 | 0.00070 | --- | > 0.009770 |
| Single | 11/02/2025 15:14 | Multielement 001 | Concentration | 9815 | R-0.4-15-3 | 114.22758 | 0.00450 | 0.00191 | 0.00122 | 0.00044 | 0.01573 | 0.13759 | 0.00037 | 0.00110 | 0.06043 | 0.00365 | 0.00028 | 0.00367 | --- | > 0.009771 |
| Single | 11/02/2025 15:15 | Multielement 001 | Concentration | 9816 | R-0.4-20-1 | 106.11163 | 0.00030 | 0.00001 | 0.01392 | 0.01364 | 0.15222 | 0.11817 | 0.00091 | 0.00311 | 0.07104 | 0.00223 | 0.00367 | 0.00373 | --- | > 0.011502 |
| Single | 11/02/2025 15:16 | Multielement 001 | Concentration | 9817 | R-0.4-20-2 | 109.08276 | 0.01091 | 0.01060 | 0.02453 | 0.02425 | 0.16283 | 0.12878 | 0.00102 | 0.00312 | 0.07174 | 0.00223 | 0.01428 | 0.00373 | --- | > 0.011503 |
| Single | 11/02/2025 15:17 | Multielement 001 | Concentration | 9818 | R-0.4-20-3 | 112.14907 | 0.01094 | 0.01063 | 0.02458 | 0.02432 | 0.16318 | 0.12932 | 0.00102 | 0.00313 | 0.00600 | 0.00224 | 0.01431 | 0.00367 | --- | > 0.011504 |
| Single | 11/02/2025 15:18 | Multielement 001 | Concentration | 9819 | R-0.4-25-1 | 102.45895 | 0.00061 | 0.00046 | 0.01504 | 0.01998 | 0.02308 | 0.02259 | 0.00027 | 0.00954 | 0.01661 | 0.00068 | 0.00229 | 0.00373 | --- | > 0.015988 |
| Single | 11/02/2025 15:19 | Multielement 001 | Concentration | 9820 | R-0.4-25-2 | 106.14747 | 0.01721 | 0.00120 | 0.02565 | 0.03059 | 0.03369 | 0.03320 | 0.00028 | 0.00965 | 0.02242 | 0.00068 | 0.00184 | 0.00373 | --- | > 0.015989 |
| Single | 11/02/2025 15:20 | Multielement 001 | Concentration | 9821 | R-0.4-25-3 | 106.52960 | 0.01724 | 0.00120 | 0.02569 | 0.03067 | 0.03380 | 0.03338 | 0.00028 | 0.00966 | 0.00380 | 0.00068 | 0.00184 | 0.00002 | --- | > 0.015990 |
| Single | 11/02/2025 15:21 | Multielement 001 | Concentration | 9822 | R-0.6-5-1 | 85.80976 | 0.00370 | 0.00001 | 0.02899 | 0.05456 | 0.02440 | 0.00707 | 0.00025 | 0.00748 | 0.01441 | 0.00059 | 0.00130 | 0.00002 | --- | > 0.006551 |
| Single | 11/02/2025 15:22 | Multielement 001 | Concentration | 9823 | R-0.6-5-2 | 88.38405 | 0.02030 | 0.00120 | 0.03960 | 0.01130 | 0.03501 | 0.06080 | 0.00025 | 0.00759 | 0.01620 | 0.00059 | 0.00133 | 0.00002 | --- | > 0.006552 |
| Single | 11/02/2025 15:23 | Multielement 001 | Concentration | 9824 | R-0.6-5-3 | 89.53305 | 0.02035 | 0.00120 | 0.03967 | 0.01130 | 0.03513 | 0.06080 | 0.00025 | 0.00760 | 0.00084 | 0.00060 | 0.00133 | 0.00004 | --- | > 0.006553 |

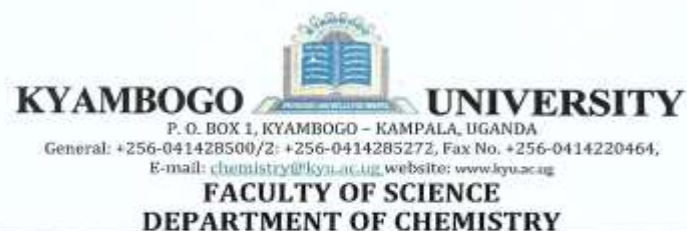
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|--------|---------------------|---------------------|---------------|------|------------|----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|-----|------------|
| Single | 11/02/2025 15:24 | Multielement 001 | Concentration | 9825 | R-0.6-10-1 | 65.71903 | 0.00513 | 0.00003 | 0.03776 | 0.06592 | 0.01900 | - | 0.02574 | 0.00011 | 0.00368 | 0.01145 | 0.00027 | 0.00069 | 0.00004 | --- | > 0.009769 |
| Single | 11/02/2025 15:25 | Multielement 001 | Concentration | 9826 | R-0.6-10-2 | 67.09913 | 0.02173 | 0.00120 | 0.04837 | 0.01118 | 0.00747 | 0.06118 | - | 0.00011 | 0.00379 | 0.01286 | 0.00027 | 0.00070 | 0.00004 | --- | > 0.009770 |
| Single | 11/02/2025 15:26 | Multielement 001 | Concentration | 9827 | R-0.6-10-3 | 67.26688 | 0.02177 | 0.00120 | 0.04927 | 0.01118 | 0.00817 | 0.06118 | - | 0.00011 | 0.00379 | 0.06043 | 0.00027 | 0.00070 | 0.00078 | --- | > 0.009771 |
| Single | 11/02/2025 15:27 | Multielement 001 | Concentration | 9828 | R-0.6-15-1 | 58.29938 | 0.00826 | 0.00001 | 0.05840 | 0.11843 | 0.15222 | 0.21657 | - | 0.00091 | 0.00311 | 0.07104 | 0.00223 | 0.00367 | 0.00080 | --- | > 0.011502 |
| Single | 11/02/2025 15:28 | Multielement 001 | Concentration | 9829 | R-0.6-15-2 | 59.40707 | 0.02486 | 0.00120 | 0.06901 | 0.01063 | 0.16283 | 0.05837 | - | 0.00091 | 0.00312 | 0.07174 | 0.00223 | 0.00373 | 0.00080 | --- | > 0.011503 |
| Single | 11/02/2025 15:29 | Multielement 001 | Concentration | 9830 | R-0.6-15-3 | 60.70809 | 0.02491 | 0.00120 | 0.07029 | 0.01062 | 0.16693 | 0.05836 | - | 0.00093 | 0.00313 | 0.00600 | 0.00224 | 0.00373 | 0.00367 | --- | > 0.011504 |
| Single | 11/02/2025 15:30 | Multielement 001 | Concentration | 9831 | R-0.6-20-1 | 54.13496 | 0.00344 | 0.00002 | 0.03095 | 0.05713 | 0.05169 | 0.07311 | - | 0.00043 | 0.00153 | 0.01661 | 0.00108 | 0.00367 | 0.00375 | --- | > 0.015988 |
| Single | 11/02/2025 15:31 | Multielement 001 | Concentration | 9832 | R-0.6-20-2 | 55.65074 | 0.02004 | 0.00120 | 0.04156 | 0.01128 | 0.06230 | 0.06004 | - | 0.00043 | 0.00154 | 0.02242 | 0.00108 | 0.00373 | 0.00375 | --- | > 0.015989 |
| Single | 11/02/2025 15:32 | Multielement 001 | Concentration | 9833 | R-0.6-20-3 | 57.21508 | 0.02045 | 0.00120 | 0.04234 | 0.01124 | 0.06420 | 0.06002 | - | 0.00044 | 0.00154 | 0.00380 | 0.00108 | 0.00373 | 0.00367 | --- | > 0.015990 |
| Single | 11/02/2025 15:33 | Multielement 001 | Concentration | 9834 | R-0.6-25-1 | 57.69168 | 0.00042 | 0.00002 | 0.01380 | 0.01881 | 0.02440 | 0.00707 | - | 0.00025 | 0.00748 | 0.01441 | 0.00059 | 0.00002 | 0.00375 | --- | > 0.006551 |
| Single | 11/02/2025 15:34 | Multielement 001 | Concentration | 9835 | R-0.6-25-2 | 59.76858 | 0.01702 | 0.00120 | 0.02441 | 0.01168 | 0.03501 | 0.06080 | - | 0.00025 | 0.00759 | 0.01620 | 0.00059 | 0.00002 | 0.00375 | --- | > 0.006552 |
| Single | 11/02/2025 15:35 | Multielement 001 | Concentration | 9836 | R-0.6-25-3 | 59.98375 | 0.01738 | 0.00120 | 0.02486 | 0.01167 | 0.03632 | 0.06079 | - | 0.00025 | 0.00760 | 0.00084 | 0.00060 | 0.00002 | 0.00058 | --- | > 0.006553 |
| Single | 11/02/2025 15:36 | Multielement 001 | Concentration | 9837 | R-0.8-5-1 | 77.85638 | 0.00042 | 0.00002 | 0.01380 | 0.01881 | 0.02440 | 0.00707 | - | 0.00025 | 0.00748 | 0.01145 | 0.00059 | 0.00004 | 0.00060 | --- | > 0.006551 |
| Single | 11/02/2025 15:37 | Multielement 001 | Concentration | 9838 | R-0.8-5-2 | 80.19207 | 0.00048 | 0.00001 | 0.01410 | 0.01948 | 0.02546 | 0.00855 | - | 0.00025 | 0.00764 | 0.01286 | 0.00061 | 0.00004 | 0.00060 | --- | > 0.006552 |
| Single | 11/02/2025 15:38 | Multielement 001 | Concentration | 9839 | R-0.8-5-3 | 81.23457 | 0.00052 | 0.00001 | 0.01436 | 0.02111 | 0.02656 | 0.00938 | - | 0.00026 | 0.00766 | 0.06043 | 0.00061 | 0.00004 | 0.00031 | --- | > 0.006553 |
| Single | 11/02/2025 15:39 | Multielement 001 | Concentration | 9840 | R-0.8-10-1 | 73.15050 | 0.00162 | 0.00002 | 0.01034 | 0.01109 | 0.00314 | 0.02970 | - | 0.00011 | 0.00368 | 0.07104 | 0.00027 | 0.00078 | 0.00032 | --- | > 0.009769 |
| Single | 11/02/2025 15:40 | Multielement 001 | Concentration | 9841 | R-0.8-10-2 | 74.68666 | 0.00166 | 0.00001 | 0.01056 | 0.01158 | 0.00267 | 0.03047 | - | 0.00011 | 0.00376 | 0.07174 | 0.00028 | 0.00080 | 0.00032 | --- | > 0.009770 |
| Single | 11/02/2025 15:41 | Multielement 001 | Concentration | 9842 | R-0.8-10-3 | 74.87338 | 0.00169 | 0.00001 | 0.01076 | 0.01281 | 0.00219 | 0.03091 | - | 0.00011 | 0.00377 | 0.00600 | 0.00028 | 0.00080 | 0.00367 | --- | > 0.009771 |
| Single | 11/02/2025 15:42 | Multielement 001 | Concentration | 9843 | R-0.8-15-1 | 64.11710 | 0.00031 | 0.00002 | 0.00533 | 0.00181 | 0.15222 | 0.11817 | - | 0.00091 | 0.00311 | 0.01661 | 0.00223 | 0.00367 | 0.01428 | --- | > 0.011502 |
| Single | 11/02/2025 15:43 | Multielement 001 | Concentration | 9844 | R-0.8-15-2 | 65.33532 | 0.00032 | 0.00001 | 0.00544 | 0.00159 | 0.15604 | 0.12418 | - | 0.00093 | 0.00318 | 0.02242 | 0.00228 | 0.00375 | 0.01431 | --- | > 0.011503 |
| Single | 11/02/2025 15:44 | Multielement 001 | Concentration | 9845 | R-0.8-15-3 | 66.76617 | 0.00033 | 0.00001 | 0.00554 | 0.00105 | 0.15999 | 0.07155 | - | 0.00095 | 0.00318 | 0.00380 | 0.00228 | 0.00375 | 0.00229 | --- | > 0.011504 |
| Single | 11/02/2025 15:45 | Multielement 001 | Concentration | 9846 | R-0.8-20-1 | 59.38993 | 0.00092 | 0.00002 | 0.00310 | 0.01668 | 0.05169 | 0.08129 | - | 0.00043 | 0.00153 | 0.01441 | 0.00108 | 0.00367 | 0.01839 | --- | > 0.015988 |
| Single | 11/02/2025 15:46 | Multielement 001 | Concentration | 9847 | R-0.8-20-2 | 61.05285 | 0.00094 | 0.00001 | 0.00317 | 0.01730 | 0.05334 | 0.07838 | - | 0.00044 | 0.00156 | 0.01620 | 0.00110 | 0.00375 | 0.01843 | --- | > 0.015989 |
| Single | 11/02/2025 15:47 | Multielement 001 | Concentration | 9848 | R-0.8-20-3 | 62.76905 | 0.00096 | 0.00001 | 0.00323 | 0.01882 | 0.05504 | 0.07675 | - | 0.00045 | 0.00156 | 0.00084 | 0.00111 | 0.00375 | 0.00130 | --- | > 0.015990 |
| Single | 11/02/2025 15:48 | Multielement 001 | Concentration | 9849 | R-0.8-25-1 | 62.62966 | 0.00105 | 0.00001 | 0.00713 | 0.01794 | 0.02440 | 0.14733 | - | 0.00025 | 0.00748 | 0.01145 | 0.00059 | 0.00058 | 0.00133 | --- | > 0.006551 |
| Single | 11/02/2025 15:49 | Multielement 001 | Concentration | 9850 | R-0.8-25-2 | 64.88433 | 0.00108 | 0.00001 | 0.00728 | 0.01859 | 0.02546 | 0.14585 | - | 0.00025 | 0.00764 | 0.01286 | 0.00061 | 0.00060 | 0.00133 | --- | > 0.006552 |

| | | | | | | | | | | | | | | | | | | | | | |
|--------|---------------------|---------------------|---------------|------|------------|-----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|------------|------------|
| Single | 11/02/2025 15:50 | Multielement 001 | Concentration | 9851 | R-0.8-25-3 | 65.11791 | 0.00110 | - | 0.00002 | 0.00742 | 0.02018 | 0.02656 | 0.14502 | 0.00026 | 0.00766 | 0.06043 | 0.00061 | 0.00060 | 0.00069 | --- | > 0.006553 |
| Single | 11/02/2025 15:51 | Multielement 001 | Concentration | 9852 | R-1-5-1 | 98.32927 | 0.00175 | 0.00002 | 0.01111 | 0.02552 | 0.02125 | 0.12414 | 0.00011 | 0.00368 | 0.07104 | 0.00027 | 0.00031 | 0.00070 | --- | > 0.009769 | |
| Single | 11/02/2025 15:52 | Multielement 001 | Concentration | 9853 | R-1-5-2 | 101.27915 | 0.00180 | 0.00001 | 0.01135 | 0.02633 | 0.01947 | 0.12337 | 0.00011 | 0.00376 | 0.07174 | 0.00028 | 0.00032 | 0.00070 | --- | > 0.009770 | |
| Single | 11/02/2025 15:53 | Multielement 001 | Concentration | 9854 | R-1-5-3 | 102.59578 | 0.00003 | 0.00001 | 0.01157 | 0.02832 | 0.01995 | 0.12293 | 0.00011 | 0.00377 | 0.00600 | 0.00028 | 0.00032 | 0.00367 | --- | > 0.009771 | |
| Single | 11/02/2025 15:54 | Multielement 001 | Concentration | 9855 | R-1-10-1 | 93.88766 | 0.00030 | 0.00001 | 0.01392 | 0.01364 | 0.15222 | 0.11817 | 0.00091 | 0.00311 | 0.01661 | 0.00223 | 0.00367 | 0.00373 | --- | > 0.011502 | |
| Single | 11/02/2025 15:55 | Multielement 001 | Concentration | 9856 | R-1-10-2 | 95.85930 | 0.01091 | 0.01060 | 0.02453 | 0.02425 | 0.16283 | 0.12878 | 0.00102 | 0.00312 | 0.02242 | 0.00223 | 0.00143 | 0.00373 | --- | > 0.011503 | |
| Single | 11/02/2025 15:56 | Multielement 001 | Concentration | 9857 | R-1-10-3 | 96.09895 | 0.01094 | 0.01063 | 0.02458 | 0.02432 | 0.16318 | 0.12932 | 0.00102 | 0.00313 | 0.00380 | 0.00224 | 0.00143 | 0.00367 | --- | > 0.011504 | |
| Single | 11/02/2025 15:57 | Multielement 001 | Concentration | 9858 | R-1-15-1 | 84.69196 | 0.00061 | 0.00046 | 0.01504 | 0.01998 | 0.02308 | 0.02259 | 0.00027 | 0.00954 | 0.01441 | 0.00068 | 0.00023 | 0.00373 | --- | > 0.015988 | |
| Single | 11/02/2025 15:58 | Multielement 001 | Concentration | 9859 | R-1-15-2 | 86.30111 | 0.01721 | 0.00120 | 0.02565 | 0.03059 | 0.03369 | 0.03320 | 0.00028 | 0.00965 | 0.01620 | 0.00068 | 0.00184 | 0.00373 | --- | > 0.015989 | |
| Single | 11/02/2025 15:59 | Multielement 001 | Concentration | 9860 | R-1-15-3 | 88.19110 | 0.01724 | 0.00120 | 0.02569 | 0.03067 | 0.03380 | 0.03338 | 0.00028 | 0.00966 | 0.00084 | 0.00068 | 0.00184 | 0.00002 | --- | > 0.015990 | |
| Single | 11/02/2025 16:00 | Multielement 001 | Concentration | 9861 | R-1-20-1 | 79.53612 | 0.00370 | 0.00001 | 0.02899 | 0.05456 | 0.02440 | 0.00707 | 0.00025 | 0.00748 | 0.01145 | 0.00059 | 0.00013 | 0.00002 | --- | > 0.006551 | |
| Single | 11/02/2025 16:01 | Multielement 001 | Concentration | 9862 | R-1-20-2 | 81.76313 | 0.02030 | 0.00120 | 0.03960 | 0.01130 | 0.03501 | 0.00064 | 0.00025 | 0.00759 | 0.01286 | 0.00059 | 0.00013 | 0.00002 | --- | > 0.006552 | |
| Single | 11/02/2025 16:02 | Multielement 001 | Concentration | 9863 | R-1-20-3 | 84.06150 | 0.00235 | 0.00120 | 0.03967 | 0.01130 | 0.01727 | 0.00064 | 0.00025 | 0.00760 | 0.06043 | 0.00060 | 0.00013 | 0.00004 | --- | > 0.006553 | |
| Single | 11/02/2025 16:03 | Multielement 001 | Concentration | 9864 | R-1-25-1 | 83.57598 | 0.00453 | 0.00003 | 0.03776 | 0.06592 | 0.00900 | 0.03570 | 0.00011 | 0.00368 | 0.07104 | 0.00027 | 0.00007 | 0.00004 | --- | > 0.009769 | |
| Single | 11/02/2025 16:04 | Multielement 001 | Concentration | 9865 | R-1-25-2 | 86.58472 | 0.00373 | 0.00120 | 0.04837 | 0.01118 | 0.00747 | 0.00026 | 0.00011 | 0.00379 | 0.07174 | 0.00027 | 0.00007 | 0.00004 | --- | > 0.009770 | |
| Single | 11/02/2025 16:05 | Multielement 001 | Concentration | 9866 | R-1-25-3 | 86.89642 | 0.00077 | 0.00120 | 0.04927 | 0.01118 | 0.00817 | 0.00026 | 0.00011 | 0.00379 | 0.00600 | 0.00027 | 0.00007 | 0.00078 | --- | > 0.009771 | |

Appendix 5: ICP-OES for clay filters

| Header_1 | Date Time | Method Name | Result Type | Sample Name | Sample Name | Pb | As | Cd | Se | Ni | Cu | Zn | Mn | Cr | Fe | Mg | Al | Hg | Ar (mon) | Ba |
|----------|------------------|------------------|---------------|-------------|-------------|-----------|---------|---------|----------|---------|---------|----------|---------|---------|---------|---------|---------|---------|----------|------------|
| Single | 28/03/2025 15:26 | Multielement 001 | Concentration | 9882 | KJO | 248.17397 | 0.00039 | 0.00030 | -0.00120 | 0.00191 | 0.00105 | 0.01682 | 0.00278 | 0.00912 | 0.00600 | 0.00292 | 0.00223 | 0.00367 | --- | > 0.011502 |
| Single | 28/03/2025 15:28 | Multielement 001 | Concentration | 9883 | WW1 | 3.39974 | 0.01100 | 0.00091 | -0.01181 | 0.01252 | 0.01166 | 0.02743 | 0.00289 | 0.01018 | 0.01661 | 0.00293 | 0.00223 | 0.01428 | --- | > 0.011503 |
| Single | 28/03/2025 15:30 | Multielement 001 | Concentration | 9884 | WW2 | 2.44054 | 0.01124 | 0.00094 | -0.01184 | 0.01257 | 0.01173 | 0.02778 | 0.00289 | 0.01020 | 0.02242 | 0.00294 | 0.00224 | 0.01431 | --- | > 0.011504 |
| Single | 28/03/2025 15:32 | Multielement 001 | Concentration | 9885 | WW3 | 4.98557 | 0.00098 | 0.00061 | -0.00075 | 0.00303 | 0.00739 | -0.11232 | 0.00084 | 0.00271 | 0.00380 | 0.00938 | 0.00068 | 0.00229 | --- | > 0.015988 |
| Single | 28/03/2025 15:34 | Multielement 001 | Concentration | 9886 | OO1 | 9.93465 | 0.01159 | 0.00072 | -0.00001 | 0.01364 | 0.01800 | -0.10171 | 0.00095 | 0.00281 | 0.01441 | 0.00948 | 0.00068 | 0.01839 | --- | > 0.015989 |
| Single | 28/03/2025 15:36 | Multielement 001 | Concentration | 9887 | OO2 | 9.95550 | 0.01184 | 0.00080 | -0.00001 | 0.01368 | 0.01808 | -0.10160 | 0.00095 | 0.00282 | 0.01620 | 0.00950 | 0.00068 | 0.01843 | --- | > 0.015990 |
| Single | 28/03/2025 15:38 | Multielement 001 | Concentration | 9888 | OO3 | 9.92224 | 0.00419 | 0.00050 | -0.00120 | 0.01698 | 0.04197 | -0.11100 | 0.00069 | 0.00248 | 0.00084 | 0.00826 | 0.00059 | 0.00130 | --- | > 0.006551 |
| Single | 28/03/2025 15:40 | Multielement 001 | Concentration | 9889 | RR1 | 14.77412 | 0.01480 | 0.00093 | -0.00001 | 0.02759 | 0.00046 | -0.10039 | 0.00001 | 0.00248 | 0.01145 | 0.00836 | 0.00059 | 0.00133 | --- | > 0.006552 |
| Single | 28/03/2025 15:42 | Multielement 001 | Concentration | 9890 | RR2 | 14.73781 | 0.01512 | 0.00135 | -0.00001 | 0.02766 | 0.00046 | -0.10027 | 0.00001 | 0.00253 | 0.01286 | 0.00838 | 0.00060 | 0.00133 | --- | > 0.006553 |
| Single | 28/03/2025 15:44 | Multielement 001 | Concentration | 9891 | RR3 | 14.90880 | 0.00525 | 0.00083 | -0.00118 | 0.02575 | 0.07768 | -0.13854 | 0.00036 | 0.00106 | 0.06043 | 0.00357 | 0.00027 | 0.00069 | --- | > 0.009769 |
| Single | 28/03/2025 15:46 | Multielement 001 | Concentration | 9892 | COMP1 | 1.21580 | 0.01586 | 0.00073 | -0.00001 | 0.03636 | 0.00058 | -0.12793 | 0.00000 | 0.00106 | 0.07104 | 0.00367 | 0.00027 | 0.00070 | --- | > 0.009770 |
| Single | 28/03/2025 15:48 | Multielement 001 | Concentration | 9893 | COMP2 | 0.86865 | 0.01919 | 0.00077 | -0.00001 | 0.03726 | 0.00058 | -0.12723 | 0.00000 | 0.00108 | 0.07174 | 0.00368 | 0.00027 | 0.00070 | --- | > 0.009771 |
| Single | 28/03/2025 15:50 | Multielement 001 | Concentration | 9894 | COMP3 | 0.95274 | 0.01014 | 0.00026 | -0.00120 | 0.04639 | 0.13019 | 0.01682 | 0.00278 | 0.00912 | 0.00600 | 0.00292 | 0.00223 | 0.00367 | --- | > 0.011502 |
| Single | 28/03/2025 15:52 | Multielement 001 | Concentration | 9895 | C1 | 20.62053 | 0.02075 | 0.00586 | -0.00001 | 0.05700 | 0.00114 | 0.02743 | 0.00003 | 0.00913 | 0.01661 | 0.00293 | 0.00223 | 0.00373 | --- | > 0.011503 |
| Single | 28/03/2025 15:54 | Multielement 001 | Concentration | 9896 | C2 | 20.96102 | 0.02498 | 0.00591 | -0.00001 | 0.05828 | 0.00114 | 0.03153 | 0.00003 | 0.00930 | 0.02242 | 0.00294 | 0.00224 | 0.00373 | --- | > 0.011504 |
| Single | 28/03/2025 15:56 | Multielement 001 | Concentration | 9897 | C3 | 20.79301 | 0.00443 | 0.00334 | -0.00119 | 0.01894 | 0.06889 | -0.08371 | 0.00135 | 0.00433 | 0.57614 | 0.00150 | 0.00108 | 0.00367 | --- | > 0.015988 |

Appendix 6: Laboratory results for analysis of lead in water samples



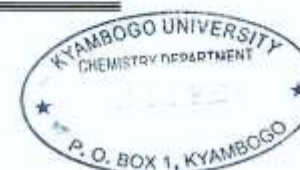
Josephine

13th June, 2025

KIHUMURO JOSEPHINE

STUDENT MSC. WATER AND SANITATION ENGINEERING

KYAMBOGO UNIVERSITY



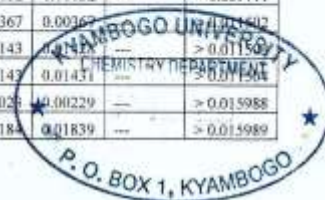
Re: Laboratory Results for analysis of lead in water samples

| Header | Sample Name | Pb | As | Cd | Se | Ni | Cr | Zn | Mn | Co | Fe | Mg | Al | Hg | Ar (ppm) | Ba |
|--------|-------------|-----------|---------|---------|----------|---------|---------|----------|---------|---------|---------|---------|---------|---------|----------|-------------|
| Single | KJ-00 | 250.01361 | 0.00039 | 0.00030 | -0.00120 | 0.00191 | 0.00105 | 0.01682 | 0.00278 | 0.00912 | 0.00600 | 0.00292 | 0.00223 | 0.00367 | --- | > 0.011502 |
| Single | W-0.1-5-1 | 174.72951 | 0.01100 | 0.01091 | -0.01181 | 0.01252 | 0.01166 | 0.02743 | 0.00289 | 0.01018 | 0.01661 | 0.00293 | 0.00223 | 0.01428 | --- | > 0.011503 |
| Single | W-0.1-5-2 | 179.97140 | 0.01124 | 0.01094 | -0.01184 | 0.01247 | 0.01171 | 0.02778 | 0.00289 | 0.01020 | 0.02242 | 0.00294 | 0.00224 | 0.01431 | --- | > 0.011504 |
| Single | W-0.1-5-3 | 182.31103 | 0.00098 | 0.00061 | -0.00075 | 0.00303 | 0.00739 | -0.11232 | 0.00084 | 0.00271 | 0.00380 | 0.00938 | 0.00068 | 0.00229 | --- | > 0.0115086 |
| Single | W-0.1-10-1 | 169.45672 | 0.01139 | 0.00721 | -0.00001 | 0.01364 | 0.01890 | -0.10171 | 0.00093 | 0.00281 | 0.01441 | 0.00948 | 0.00068 | 0.01839 | --- | > 0.0115989 |
| Single | W-0.1-10-2 | 173.01532 | 0.01184 | 0.01804 | -0.00001 | 0.01368 | 0.01898 | -0.10160 | 0.00093 | 0.00282 | 0.01620 | 0.00950 | 0.00068 | 0.01843 | --- | > 0.0115990 |
| Single | W-0.1-10-3 | 173.44785 | 0.00419 | 0.00450 | -0.00120 | 0.01698 | 0.04197 | -0.11190 | 0.00069 | 0.00248 | 0.00084 | 0.00826 | 0.00059 | 0.00130 | --- | > 0.006551 |
| Single | W-0.1-15-1 | 164.45895 | 0.01480 | 0.00330 | -0.00001 | 0.02759 | 0.00046 | -0.10039 | 0.00001 | 0.00248 | 0.01145 | 0.00836 | 0.00059 | 0.00133 | --- | > 0.006552 |
| Single | W-0.1-15-2 | 167.38367 | 0.02512 | 0.00335 | -0.00001 | 0.02766 | 0.00046 | -0.10027 | 0.00001 | 0.00253 | 0.01286 | 0.00836 | 0.00060 | 0.00133 | --- | > 0.006553 |
| Single | W-0.1-15-3 | 171.25376 | 0.00525 | 0.00303 | -0.00118 | 0.02575 | 0.07768 | -0.13854 | 0.00036 | 0.00106 | 0.06043 | 0.00357 | 0.00027 | 0.00069 | --- | > 0.009769 |
| Single | W-0.1-20-1 | 161.98382 | 0.01586 | 0.00273 | -0.00001 | 0.03626 | 0.00058 | -0.12793 | 0.00000 | 0.00106 | 0.07104 | 0.00367 | 0.00027 | 0.00070 | --- | > 0.009770 |
| Single | W-0.1-20-2 | 166.51936 | 0.01919 | 0.00277 | -0.00001 | 0.03726 | 0.00058 | -0.12723 | 0.00000 | 0.00108 | 0.07174 | 0.00368 | 0.00027 | 0.00070 | --- | > 0.009771 |
| Single | W-0.1-20-3 | 171.20022 | 0.01014 | 0.00026 | -0.00120 | 0.04639 | 0.13019 | 0.01682 | 0.00278 | 0.00912 | 0.00600 | 0.00292 | 0.00223 | 0.00367 | --- | > 0.011502 |
| Single | W-0.1-25-1 | 158.08361 | 0.02075 | 0.00586 | -0.00001 | 0.05700 | 0.00114 | 0.02743 | 0.00003 | 0.00913 | 0.01661 | 0.00293 | 0.00223 | 0.00373 | --- | > 0.011503 |
| Single | W-0.1-25-2 | 163.77462 | 0.02498 | 0.00591 | -0.00001 | 0.05828 | 0.00114 | 0.03153 | 0.00003 | 0.00930 | 0.02242 | 0.00294 | 0.00224 | 0.00373 | --- | > 0.011504 |

| | | | | | | | | | | | | | | | | |
|--------|------------|-----------|---------|----------|----------|----------|---------|----------|---------|---------|---------|---------|---------|---------|-----|------------|
| Single | W-0.1-25-3 | 164.36420 | 0.00443 | 0.00334 | -0.00119 | 0.01894 | 0.06889 | -0.08371 | 0.00135 | 0.00433 | 0.57814 | 0.00150 | 0.00108 | 0.00367 | --- | > 0.015988 |
| Single | W-0.2-5-1 | 138.30753 | 0.01504 | 0.00104 | -0.00001 | 0.02955 | 0.00049 | -0.07310 | 0.00002 | 0.00434 | 0.58675 | 0.00151 | 0.00108 | 0.00373 | --- | > 0.015989 |
| Single | W-0.2-5-2 | 142.45675 | 0.01689 | 0.00145 | -0.00001 | 0.03033 | 0.00053 | -0.07120 | 0.00002 | 0.00442 | 0.58961 | 0.00151 | 0.00108 | 0.00373 | --- | > 0.015990 |
| Single | W-0.2-5-3 | 144.30869 | 0.00087 | 0.00032 | -0.00119 | 0.00179 | 0.03058 | -0.11100 | 0.00069 | 0.00248 | 0.00084 | 0.00083 | 0.00059 | 0.00002 | --- | > 0.006551 |
| Single | W-0.2-10-1 | 133.33226 | 0.01148 | 0.01692 | -0.00001 | 0.01240 | 0.00008 | -0.10039 | 0.00001 | 0.00248 | 0.01145 | 0.00084 | 0.00059 | 0.00002 | --- | > 0.006552 |
| Single | W-0.2-10-2 | 136.13224 | 0.01294 | 0.01728 | -0.00001 | 0.01285 | 0.00010 | -0.09908 | 0.00001 | 0.00253 | 0.01286 | 0.00084 | 0.00060 | 0.00002 | --- | > 0.006553 |
| Single | W-0.2-10-3 | 136.47257 | 0.00087 | 0.00032 | -0.00119 | 0.00179 | 0.00622 | -0.11100 | 0.00069 | 0.00248 | 0.44047 | 0.00083 | 0.00059 | 0.00004 | --- | > 0.006551 |
| Single | W-0.2-15-1 | 126.95691 | 0.00093 | 0.00038 | -0.00122 | 0.00209 | 0.00689 | -0.10994 | 0.00070 | 0.00253 | 0.45663 | 0.00084 | 0.00061 | 0.00004 | --- | > 0.006552 |
| Single | W-0.2-15-2 | 129.36909 | 0.00125 | 0.00042 | -0.00122 | 0.00235 | 0.00852 | -0.10884 | 0.00071 | 0.00258 | 0.45805 | 0.00084 | 0.00061 | 0.00004 | --- | > 0.006553 |
| Single | W-0.2-15-3 | 132.20228 | 0.00015 | 0.00061 | -0.00119 | -0.00167 | 0.00263 | -0.13854 | 0.00036 | 0.00106 | 0.00600 | 0.00036 | 0.00027 | 0.00078 | --- | > 0.009769 |
| Single | W-0.2-20-1 | 123.93173 | 0.00020 | 0.00065 | -0.00122 | -0.00145 | 0.00313 | -0.13807 | 0.00037 | 0.00108 | 0.01661 | 0.00036 | 0.00028 | 0.00080 | --- | > 0.009770 |
| Single | W-0.2-20-2 | 127.40184 | 0.00043 | 0.00068 | -0.00122 | -0.00125 | 0.00436 | -0.13759 | 0.00037 | 0.00110 | 0.02242 | 0.00365 | 0.00028 | 0.00080 | --- | > 0.009771 |
| Single | W-0.2-20-3 | 130.98310 | 0.00023 | 0.00039 | -0.00119 | -0.00668 | 0.00018 | 0.01682 | 0.00278 | 0.00912 | 0.00380 | 0.00292 | 0.00223 | 0.00367 | --- | > 0.011502 |
| Single | W-0.2-25-1 | 127.80696 | 0.00024 | 0.00040 | -0.00122 | -0.00657 | 0.00040 | 0.02064 | 0.00284 | 0.00931 | 0.01441 | 0.00298 | 0.00228 | 0.00375 | --- | > 0.011503 |
| Single | W-0.2-25-2 | 132.40801 | 0.00029 | 0.00041 | -0.00122 | -0.00646 | 0.00094 | 0.02459 | 0.00288 | 0.00949 | 0.01620 | 0.00299 | 0.00228 | 0.00375 | --- | > 0.011504 |
| Single | W-0.2-25-3 | 132.88468 | 0.00179 | 0.00099 | -0.00119 | -0.00891 | 0.00409 | -0.08371 | 0.00135 | 0.00433 | 0.00084 | 0.00150 | 0.00108 | 0.00367 | --- | > 0.015988 |
| Single | W-0.4-5-1 | 109.38095 | 0.00004 | 0.00102 | -0.00122 | -0.00884 | 0.00471 | -0.08206 | 0.00138 | 0.00443 | 0.01145 | 0.00153 | 0.00110 | 0.00375 | --- | > 0.015989 |
| Single | W-0.4-5-2 | 112.66238 | 0.00026 | 0.00104 | -0.00122 | -0.00878 | 0.00623 | -0.08036 | 0.00139 | 0.00451 | 0.01286 | 0.00154 | 0.00111 | 0.00375 | --- | > 0.015990 |
| Single | W-0.4-5-3 | 114.12699 | 0.00125 | 0.00113 | -0.00120 | -0.00488 | 0.00535 | -0.11100 | 0.00069 | 0.00248 | 0.06043 | 0.00826 | 0.00059 | 0.00058 | --- | > 0.006551 |
| Single | W-0.4-10-1 | 104.40568 | 0.00132 | 0.00116 | -0.00122 | -0.00473 | 0.00600 | -0.10994 | 0.00070 | 0.00253 | 0.07104 | 0.00843 | 0.00061 | 0.00060 | --- | > 0.006552 |
| Single | W-0.4-10-2 | 106.59820 | 0.00169 | 0.00118 | -0.00123 | -0.00459 | 0.00758 | -0.10884 | 0.00071 | 0.00258 | 0.07174 | 0.00845 | 0.00061 | 0.00060 | --- | > 0.006553 |
| Single | W-0.4-10-3 | 106.86470 | 0.00374 | 0.00183 | -0.00119 | -0.00089 | 0.01293 | -0.13854 | 0.00036 | 0.00106 | 0.00600 | 0.00337 | 0.00027 | 0.00031 | --- | > 0.009769 |
| Single | W-0.4-15-1 | 97.30530 | 0.00386 | 0.00187 | -0.00122 | -0.00065 | 0.01374 | -0.13807 | 0.00037 | 0.00108 | 0.01661 | 0.00364 | 0.00028 | 0.00032 | --- | > 0.009770 |
| Single | W-0.4-15-2 | 99.15410 | 0.00450 | 0.00191 | -0.00122 | -0.00044 | 0.01573 | -0.13759 | 0.00037 | 0.00110 | 0.02242 | 0.00365 | 0.00028 | 0.00032 | --- | > 0.009771 |
| Single | W-0.4-15-3 | 101.32537 | 0.00030 | 0.00001 | 0.01392 | 0.01364 | 0.15222 | 0.11817 | 0.00091 | 0.00311 | 0.00380 | 0.00223 | 0.00367 | 0.00367 | --- | > 0.011502 |
| Single | W-0.4-20-1 | 93.40508 | 0.01091 | -0.01060 | 0.02453 | 0.02425 | 0.16283 | 0.12878 | 0.00102 | 0.00312 | 0.01441 | 0.00223 | 0.01428 | 0.01428 | --- | > 0.011503 |
| Single | W-0.4-20-2 | 96.02043 | 0.01094 | -0.01063 | 0.02458 | 0.02432 | 0.16318 | 0.12932 | 0.00102 | 0.00313 | 0.01620 | 0.00224 | 0.01431 | 0.01431 | --- | > 0.011504 |
| Single | W-0.4-20-3 | 98.71956 | 0.00061 | 0.00046 | 0.01504 | 0.01998 | 0.02308 | 0.02259 | 0.00027 | 0.00954 | 0.00084 | 0.00068 | 0.00229 | 0.00229 | --- | > 0.015988 |
| Single | W-0.4-25-1 | 89.42987 | 0.01721 | 0.00120 | 0.02565 | 0.03059 | 0.03369 | 0.03320 | 0.00028 | 0.00965 | 0.01145 | 0.00068 | 0.00184 | 0.01839 | --- | > 0.015989 |
| Single | W-0.4-25-2 | 92.64934 | 0.01724 | 0.00120 | 0.02569 | 0.03067 | 0.03380 | 0.03338 | 0.00028 | 0.00966 | 0.01286 | 0.00068 | 0.00184 | 0.01839 | --- | > 0.015990 |
| Single | W-0.4-25-3 | 92.98288 | 0.00370 | 0.00001 | 0.02899 | 0.05456 | 0.02440 | 0.00707 | 0.00025 | 0.00748 | 0.06043 | 0.00059 | 0.00133 | 0.00059 | --- | > 0.006551 |
| Single | W-0.6-5-1 | 65.89609 | 0.02030 | 0.00120 | 0.03960 | -0.01130 | 0.03501 | -0.06080 | 0.00025 | 0.00759 | 0.07104 | 0.00059 | 0.00033 | 0.00133 | --- | > 0.006552 |
| Single | W-0.6-5-2 | 67.87297 | 0.02035 | 0.00120 | 0.03967 | -0.01130 | 0.03513 | -0.06080 | 0.00025 | 0.00760 | 0.07174 | 0.00060 | 0.00033 | 0.00133 | --- | > 0.006553 |
| Single | W-0.6-5-3 | 68.75532 | 0.00513 | 0.00003 | 0.03776 | 0.06592 | 0.01900 | -0.02574 | 0.00011 | 0.00368 | 0.00600 | 0.00027 | 0.00060 | 0.00059 | --- | > 0.009769 |



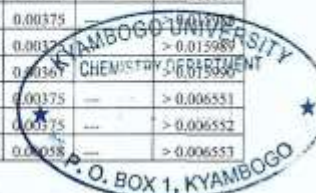
| | | | | | | | | | | | | | | | | |
|--------|------------|----------|---------|----------|---------|----------|----------|----------|---------|---------|---------|---------|---------|---------|-----|------------|
| Single | W-0.6-10-1 | 54.39796 | 0.02173 | 0.00120 | 0.04837 | -0.01118 | 0.00747 | -0.06118 | 0.00011 | 0.00379 | 0.01661 | 0.00027 | 0.00070 | 0.00070 | --- | > 0.009770 |
| Single | W-0.6-10-2 | 55.54032 | 0.02177 | 0.00120 | 0.04927 | -0.01118 | 0.00817 | -0.06118 | 0.00011 | 0.00379 | 0.02242 | 0.00027 | 0.00070 | 0.00070 | --- | > 0.009771 |
| Single | W-0.6-10-3 | 55.67917 | 0.00826 | 0.00001 | 0.05840 | 0.11843 | 0.15222 | 0.21657 | 0.00091 | 0.00311 | 0.00380 | 0.00223 | 0.00367 | 0.00367 | --- | > 0.011502 |
| Single | W-0.6-15-1 | 46.52253 | 0.02486 | 0.00120 | 0.06901 | -0.01063 | 0.16283 | -0.05837 | 0.00091 | 0.00312 | 0.01441 | 0.00223 | 0.00373 | 0.00373 | --- | > 0.011503 |
| Single | W-0.6-15-2 | 47.40646 | 0.02491 | 0.00120 | 0.07029 | -0.01062 | 0.16693 | -0.05836 | 0.00093 | 0.00313 | 0.01620 | 0.00224 | 0.00373 | 0.00373 | --- | > 0.011504 |
| Single | W-0.6-15-3 | 48.44466 | 0.00341 | 0.00002 | 0.03095 | 0.05713 | 0.05169 | 0.07311 | 0.00043 | 0.00153 | 0.00084 | 0.00108 | 0.00367 | 0.00367 | --- | > 0.015988 |
| Single | W-0.6-20-1 | 42.10229 | 0.02004 | 0.00120 | 0.04156 | -0.01128 | 0.06230 | -0.06004 | 0.00043 | 0.00154 | 0.01145 | 0.00108 | 0.00373 | 0.00373 | --- | > 0.015989 |
| Single | W-0.6-20-2 | 43.28116 | 0.02045 | 0.00120 | 0.04234 | -0.01124 | 0.06420 | -0.06002 | 0.00044 | 0.00154 | 0.01286 | 0.00108 | 0.00373 | 0.00373 | --- | > 0.015990 |
| Single | W-0.6-20-3 | 44.49779 | 0.00042 | 0.00002 | 0.01380 | 0.01881 | 0.02440 | 0.00707 | 0.00025 | 0.00748 | 0.06043 | 0.00059 | 0.00002 | 0.00002 | --- | > 0.006551 |
| Single | W-0.6-25-1 | 45.87750 | 0.01702 | 0.00120 | 0.02441 | -0.01168 | 0.03501 | -0.06080 | 0.00025 | 0.00759 | 0.07104 | 0.00059 | 0.00002 | 0.00002 | --- | > 0.006552 |
| Single | W-0.6-25-2 | 47.52909 | 0.01738 | 0.00120 | 0.02486 | -0.01167 | 0.03632 | -0.06079 | 0.00025 | 0.00760 | 0.07174 | 0.00060 | 0.00002 | 0.00002 | --- | > 0.006553 |
| Single | W-0.6-25-3 | 47.70019 | 0.00042 | 0.00002 | 0.01380 | 0.01881 | 0.02440 | 0.00707 | 0.00025 | 0.00748 | 0.06000 | 0.00059 | 0.00004 | 0.00004 | --- | > 0.006551 |
| Single | W-0.8-5-1 | 68.00120 | 0.00048 | -0.00001 | 0.01410 | 0.01948 | 0.02546 | 0.00855 | 0.00025 | 0.00764 | 0.01661 | 0.00061 | 0.00004 | 0.00004 | --- | > 0.006552 |
| Single | W-0.8-5-2 | 70.04124 | 0.00052 | -0.00001 | 0.01436 | 0.02111 | 0.02656 | 0.00938 | 0.00026 | 0.00766 | 0.02242 | 0.00061 | 0.00004 | 0.00004 | --- | > 0.006553 |
| Single | W-0.8-5-3 | 70.95177 | 0.00162 | 0.00002 | 0.01034 | 0.01109 | -0.00314 | 0.02970 | 0.00011 | 0.00368 | 0.00380 | 0.00027 | 0.00078 | 0.00078 | --- | > 0.009769 |
| Single | W-0.8-10-1 | 63.02593 | 0.00166 | -0.00001 | 0.01056 | 0.01158 | -0.00267 | 0.03047 | 0.00011 | 0.00376 | 0.01441 | 0.00028 | 0.00080 | 0.00080 | --- | > 0.009770 |
| Single | W-0.8-10-2 | 64.34948 | 0.00169 | -0.00001 | 0.01076 | 0.01281 | -0.00219 | 0.03091 | 0.00011 | 0.00377 | 0.01620 | 0.00028 | 0.00080 | 0.00080 | --- | > 0.009771 |
| Single | W-0.8-10-3 | 64.51035 | 0.00031 | 0.00002 | 0.00533 | -0.00181 | 0.15222 | 0.11817 | 0.00091 | 0.00311 | 0.00084 | 0.00223 | 0.00367 | 0.00367 | --- | > 0.011502 |
| Single | W-0.8-15-1 | 53.47541 | 0.00032 | -0.00001 | 0.00544 | -0.00159 | 0.15604 | 0.12418 | 0.00093 | 0.00318 | 0.01145 | 0.00228 | 0.00375 | 0.00375 | --- | > 0.011503 |
| Single | W-0.8-15-2 | 54.49144 | 0.00033 | -0.00001 | 0.00554 | -0.00105 | 0.15999 | 0.07155 | 0.00095 | 0.00318 | 0.01286 | 0.00228 | 0.00375 | 0.00375 | --- | > 0.011504 |
| Single | W-0.8-15-3 | 55.68481 | 0.00092 | 0.00002 | 0.00310 | 0.01668 | 0.05169 | -0.08129 | 0.00043 | 0.00153 | 0.06043 | 0.00108 | 0.00367 | 0.00367 | --- | > 0.015988 |
| Single | W-0.8-20-1 | 48.47764 | 0.00094 | -0.00001 | 0.00317 | 0.01730 | 0.05334 | -0.07838 | 0.00044 | 0.00156 | 0.07104 | 0.00110 | 0.00375 | 0.00375 | --- | > 0.015989 |
| Single | W-0.8-20-2 | 49.83501 | 0.00096 | -0.00001 | 0.00323 | 0.01882 | 0.05504 | -0.07675 | 0.00045 | 0.00156 | 0.07174 | 0.00111 | 0.00375 | 0.00375 | --- | > 0.015990 |
| Single | W-0.8-20-3 | 51.23588 | 0.00105 | 0.00001 | 0.00713 | 0.01794 | 0.02440 | -0.14733 | 0.00025 | 0.00748 | 0.00600 | 0.00059 | 0.00058 | 0.00058 | --- | > 0.006551 |
| Single | W-0.8-25-1 | 51.90283 | 0.00108 | -0.00001 | 0.00728 | 0.01859 | 0.02546 | -0.14585 | 0.00025 | 0.00764 | 0.01661 | 0.00061 | 0.00060 | 0.00060 | --- | > 0.006552 |
| Single | W-0.8-25-2 | 53.77133 | 0.00110 | -0.00002 | 0.00742 | 0.02018 | 0.02656 | -0.14502 | 0.00026 | 0.00766 | 0.02242 | 0.00061 | 0.00060 | 0.00060 | --- | > 0.006553 |
| Single | W-0.8-25-3 | 53.96490 | 0.00135 | 0.00002 | 0.01111 | 0.02552 | 0.02125 | -0.12414 | 0.00011 | 0.00368 | 0.00380 | 0.00027 | 0.00031 | 0.00031 | --- | > 0.009769 |
| Single | W-1-5-1 | 80.10436 | 0.00180 | -0.00001 | 0.01135 | 0.02633 | 0.01947 | -0.12337 | 0.00011 | 0.00376 | 0.01441 | 0.00028 | 0.00032 | 0.00032 | --- | > 0.009770 |
| Single | W-1-5-2 | 82.50749 | 0.00003 | -0.00001 | 0.01157 | 0.02832 | 0.01995 | -0.12293 | 0.00011 | 0.00377 | 0.01620 | 0.00028 | 0.00032 | 0.00032 | --- | > 0.009771 |
| Single | W-1-5-3 | 83.58009 | 0.00030 | 0.00001 | 0.01392 | 0.01364 | 0.15222 | 0.11817 | 0.00091 | 0.00311 | 0.00084 | 0.00223 | 0.00367 | 0.00367 | --- | > 0.011502 |
| Single | W-1-10-1 | 75.12909 | 0.01091 | -0.01060 | 0.02453 | 0.02425 | 0.16283 | 0.12878 | 0.00102 | 0.00312 | 0.01145 | 0.00223 | 0.00143 | 0.00143 | --- | > 0.011503 |
| Single | W-1-10-2 | 76.70680 | 0.01094 | -0.01063 | 0.02458 | 0.02432 | 0.16318 | 0.12932 | 0.00102 | 0.00313 | 0.01286 | 0.00224 | 0.00143 | 0.00143 | --- | > 0.011504 |
| Single | W-1-10-3 | 76.89857 | 0.00061 | 0.00046 | 0.01504 | 0.01998 | 0.02308 | 0.02259 | 0.00027 | 0.00054 | 0.06043 | 0.00068 | 0.00025 | 0.00025 | --- | > 0.015988 |
| Single | W-1-15-1 | 64.82853 | 0.01721 | 0.00120 | 0.02565 | 0.03059 | 0.03369 | 0.03320 | 0.00028 | 0.00965 | 0.07104 | 0.00068 | 0.00184 | 0.00184 | --- | > 0.015989 |



| | | | | | | | | | | | | | | | | |
|--------|------------|-----------|---------|---------|----------|----------|---------|----------|---------|---------|---------|---------|---------|---------|-----|------------|
| Single | W-1-15-2 | 66.06027 | 0.01724 | 0.00120 | 0.02569 | 0.03067 | 0.03380 | 0.03338 | 0.00028 | 0.00966 | 0.07174 | 0.00068 | 0.00184 | 0.01843 | --- | > 0.015990 |
| Single | W-1-15-3 | 67.50699 | 0.00370 | 0.00001 | 0.02899 | 0.05456 | 0.02440 | 0.00707 | 0.00025 | 0.00748 | 0.00600 | 0.00059 | 0.00013 | 0.00130 | --- | > 0.006551 |
| Single | W-1-20-1 | 59.05321 | 0.02030 | 0.00120 | 0.03960 | -0.01130 | 0.03501 | 0.00064 | 0.00025 | 0.00759 | 0.01661 | 0.00059 | 0.00013 | 0.00133 | --- | > 0.006552 |
| Single | W-1-20-2 | 60.70670 | 0.00235 | 0.00120 | 0.03967 | -0.01130 | 0.01727 | 0.00064 | 0.00025 | 0.00760 | 0.02242 | 0.00060 | 0.00013 | 0.00133 | --- | > 0.006553 |
| Single | W-1-20-3 | 62.41317 | 0.00453 | 0.00003 | 0.03776 | 0.06592 | 0.00900 | 0.03570 | 0.00011 | 0.00368 | 0.00380 | 0.00027 | 0.00007 | 0.00069 | --- | > 0.009769 |
| Single | W-1-25-1 | 63.57846 | 0.00373 | 0.00120 | 0.04837 | -0.01118 | 0.00747 | 0.00026 | 0.00011 | 0.00379 | 0.01441 | 0.00027 | 0.00007 | 0.00070 | --- | > 0.009770 |
| Single | W-1-25-2 | 65.86729 | 0.00077 | 0.00120 | 0.04927 | -0.01118 | 0.00817 | 0.00026 | 0.00011 | 0.00379 | 0.01620 | 0.00027 | 0.00007 | 0.00070 | --- | > 0.009771 |
| Single | W-1-25-3 | 66.10441 | 0.00736 | 0.00001 | 0.05840 | 0.11843 | 0.15222 | 0.07816 | 0.00091 | 0.00311 | 0.00084 | 0.00223 | 0.00037 | 0.00367 | --- | > 0.011502 |
| Single | O-0.1-5-1 | 182.31103 | 0.00039 | 0.00030 | -0.00120 | 0.00191 | 0.00105 | 0.01682 | 0.00278 | 0.00912 | 0.01145 | 0.00292 | 0.00223 | 0.00373 | --- | > 0.011502 |
| Single | O-0.1-5-2 | 179.97140 | 0.01100 | 0.01091 | -0.01181 | 0.01252 | 0.01166 | 0.02743 | 0.00289 | 0.01018 | 0.01286 | 0.00293 | 0.00223 | 0.00373 | --- | > 0.011503 |
| Single | O-0.1-5-3 | 174.72951 | 0.01124 | 0.01094 | -0.01184 | 0.01257 | 0.01173 | 0.02778 | 0.00289 | 0.01020 | 0.00043 | 0.00294 | 0.00224 | 0.00367 | --- | > 0.011504 |
| Single | O-0.1-10-1 | 169.45672 | 0.00098 | 0.00061 | -0.00075 | 0.00303 | 0.00739 | -0.11232 | 0.00084 | 0.00271 | 0.07104 | 0.00938 | 0.00068 | 0.00373 | --- | > 0.015988 |
| Single | O-0.1-10-2 | 173.01532 | 0.01159 | 0.00721 | -0.00001 | 0.01364 | 0.01800 | -0.10171 | 0.00095 | 0.00281 | 0.07174 | 0.00948 | 0.00068 | 0.00373 | --- | > 0.015989 |
| Single | O-0.1-10-3 | 173.44785 | 0.01184 | 0.01804 | -0.00001 | 0.01368 | 0.01808 | -0.10160 | 0.00095 | 0.00282 | 0.00600 | 0.00950 | 0.00068 | 0.00002 | --- | > 0.015990 |
| Single | O-0.1-15-1 | 164.45895 | 0.00419 | 0.00450 | -0.00120 | 0.01698 | 0.04197 | -0.11100 | 0.00069 | 0.00248 | 0.01661 | 0.00826 | 0.00059 | 0.00002 | --- | > 0.006551 |
| Single | O-0.1-15-2 | 167.58367 | 0.01480 | 0.00130 | -0.00001 | 0.02759 | 0.00046 | -0.10039 | 0.00001 | 0.00248 | 0.02242 | 0.00836 | 0.00059 | 0.00002 | --- | > 0.006552 |
| Single | O-0.1-15-3 | 171.25376 | 0.01312 | 0.00135 | -0.00001 | 0.02766 | 0.00046 | -0.10027 | 0.00001 | 0.00253 | 0.00380 | 0.00838 | 0.00060 | 0.00004 | --- | > 0.006553 |
| Single | O-0.1-20-1 | 161.98382 | 0.00525 | 0.00503 | -0.00118 | 0.02575 | 0.07768 | -0.13854 | 0.00036 | 0.00106 | 0.01441 | 0.00357 | 0.00027 | 0.00004 | --- | > 0.009769 |
| Single | O-0.1-20-2 | 166.51936 | 0.01586 | 0.00273 | -0.00001 | 0.03636 | 0.00058 | -0.12793 | 0.00000 | 0.00106 | 0.01620 | 0.00367 | 0.00027 | 0.00004 | --- | > 0.009770 |
| Single | O-0.1-20-3 | 171.20022 | 0.01919 | 0.00277 | -0.00001 | 0.03726 | 0.00058 | -0.12723 | 0.00000 | 0.00108 | 0.00084 | 0.00368 | 0.00027 | 0.00078 | --- | > 0.009771 |
| Single | O-0.1-25-1 | 158.08361 | 0.01014 | 0.00026 | -0.00120 | 0.04639 | 0.13019 | 0.03682 | 0.00278 | 0.00912 | 0.01145 | 0.00292 | 0.00223 | 0.00080 | --- | > 0.011502 |
| Single | O-0.1-25-2 | 163.77462 | 0.02075 | 0.00586 | -0.00001 | 0.05700 | 0.00114 | 0.02743 | 0.00003 | 0.00913 | 0.01286 | 0.00293 | 0.00223 | 0.00080 | --- | > 0.011503 |
| Single | O-0.1-25-3 | 164.36420 | 0.02498 | 0.00591 | -0.00001 | 0.05828 | 0.00114 | -0.03153 | 0.00003 | 0.00930 | 0.00043 | 0.00294 | 0.00224 | 0.00367 | --- | > 0.011504 |
| Single | O-0.2-5-1 | 138.30753 | 0.00443 | 0.00334 | -0.00119 | 0.01894 | 0.06889 | -0.08371 | 0.00135 | 0.00433 | 0.07104 | 0.00150 | 0.00108 | 0.00373 | --- | > 0.015988 |
| Single | O-0.2-5-2 | 142.45675 | 0.01504 | 0.00104 | -0.00001 | 0.02955 | 0.00049 | -0.07310 | 0.00002 | 0.00434 | 0.07174 | 0.00151 | 0.00108 | 0.00375 | --- | > 0.015989 |
| Single | O-0.2-5-3 | 144.30869 | 0.01689 | 0.00145 | -0.00001 | 0.03033 | 0.00053 | -0.07120 | 0.00002 | 0.00442 | 0.00600 | 0.00151 | 0.00108 | 0.00367 | --- | > 0.015990 |
| Single | O-0.2-10-1 | 133.33226 | 0.00087 | 0.00032 | -0.00119 | 0.00179 | 0.03058 | -0.11100 | 0.00069 | 0.00248 | 0.01661 | 0.00083 | 0.00059 | 0.00375 | --- | > 0.006551 |
| Single | O-0.2-10-2 | 136.13224 | 0.01148 | 0.01692 | -0.00001 | 0.01240 | 0.00008 | -0.10039 | 0.00001 | 0.00248 | 0.02242 | 0.00084 | 0.00059 | 0.00375 | --- | > 0.006552 |
| Single | O-0.2-10-3 | 136.47257 | 0.01294 | 0.01728 | -0.00001 | 0.01285 | 0.00010 | -0.09908 | 0.00001 | 0.00253 | 0.00380 | 0.00084 | 0.00060 | 0.00060 | --- | > 0.006551 |
| Single | O-0.2-15-1 | 126.95691 | 0.00087 | 0.00032 | -0.00119 | 0.00179 | 0.00622 | -0.11100 | 0.00069 | 0.00248 | 0.01441 | 0.00083 | 0.00059 | 0.00060 | --- | > 0.006551 |
| Single | O-0.2-15-2 | 129.36909 | 0.00093 | 0.00038 | -0.00122 | 0.00209 | 0.00689 | -0.10994 | 0.00070 | 0.00253 | 0.01620 | 0.00084 | 0.00060 | 0.00060 | --- | > 0.006552 |
| Single | O-0.2-15-3 | 132.20228 | 0.00125 | 0.00042 | -0.00122 | 0.00235 | 0.00852 | -0.10884 | 0.00071 | 0.00258 | 0.00084 | 0.00084 | 0.00060 | 0.00031 | --- | > 0.006553 |
| Single | O-0.2-20-1 | 123.93175 | 0.00015 | 0.00061 | -0.00119 | -0.00167 | 0.00263 | -0.13854 | 0.00036 | 0.00106 | 0.01145 | 0.00036 | 0.00027 | 0.00002 | --- | > 0.009769 |
| Single | O-0.2-20-2 | 127.40184 | 0.00020 | 0.00065 | -0.00122 | -0.00145 | 0.00313 | -0.13807 | 0.00037 | 0.00108 | 0.01286 | 0.00036 | 0.00028 | 0.00002 | --- | > 0.009770 |



| | | | | | | | | | | | | | | | | |
|--------|------------|-----------|---------|----------|----------|----------|---------|----------|---------|---------|---------|---------|---------|---------|-----|------------|
| Single | O-0.2-20-3 | 130.98310 | 0.00043 | 0.00068 | -0.00122 | -0.00125 | 0.00436 | -0.13759 | 0.00037 | 0.00110 | 0.06043 | 0.00365 | 0.00028 | 0.00367 | --- | > 0.009771 |
| Single | O-0.2-25-1 | 127.80696 | 0.00023 | 0.00039 | -0.00119 | -0.00668 | 0.00018 | 0.01682 | 0.00278 | 0.00912 | 0.07104 | 0.00292 | 0.00223 | 0.01428 | --- | > 0.011502 |
| Single | O-0.2-25-2 | 132.40801 | 0.00024 | 0.00040 | -0.00122 | -0.00657 | 0.00040 | 0.02064 | 0.00284 | 0.00931 | 0.07174 | 0.00298 | 0.00228 | 0.01431 | --- | > 0.011503 |
| Single | O-0.2-25-3 | 132.88468 | 0.00029 | 0.00041 | -0.00122 | -0.00646 | 0.00094 | 0.02459 | 0.00288 | 0.00949 | 0.06600 | 0.00299 | 0.00228 | 0.00229 | --- | > 0.011504 |
| Single | O-0.4-5-1 | 109.38093 | 0.00179 | 0.00099 | -0.00119 | -0.00891 | 0.00409 | -0.08371 | 0.00135 | 0.00433 | 0.01661 | 0.00150 | 0.00108 | 0.01839 | --- | > 0.015988 |
| Single | O-0.4-5-2 | 112.66238 | 0.00004 | 0.00102 | -0.00122 | -0.00884 | 0.00471 | -0.08206 | 0.00138 | 0.00443 | 0.02242 | 0.00153 | 0.00110 | 0.01843 | --- | > 0.015989 |
| Single | O-0.4-5-3 | 114.12699 | 0.00026 | 0.00104 | -0.00122 | -0.00878 | 0.00623 | -0.08036 | 0.00139 | 0.00451 | 0.00380 | 0.00154 | 0.00111 | 0.00130 | --- | > 0.015990 |
| Single | O-0.4-10-1 | 104.40568 | 0.00125 | 0.00113 | -0.00120 | -0.00488 | 0.00535 | -0.11100 | 0.00069 | 0.00248 | 0.01441 | 0.00826 | 0.00059 | 0.00133 | --- | > 0.006551 |
| Single | O-0.4-10-2 | 106.59820 | 0.00132 | 0.00116 | -0.00122 | -0.00473 | 0.00600 | -0.10994 | 0.00070 | 0.00253 | 0.01620 | 0.00843 | 0.00061 | 0.00133 | --- | > 0.006552 |
| Single | O-0.4-10-3 | 106.86470 | 0.00169 | 0.00118 | -0.00123 | -0.00459 | 0.00758 | -0.10884 | 0.00071 | 0.00258 | 0.00084 | 0.00845 | 0.00061 | 0.00069 | --- | > 0.006553 |
| Single | O-0.4-15-1 | 97.30530 | 0.00374 | 0.00183 | -0.00119 | -0.00089 | 0.01293 | -0.13854 | 0.00036 | 0.00106 | 0.01145 | 0.00357 | 0.00027 | 0.00070 | --- | > 0.009769 |
| Single | O-0.4-15-2 | 99.15410 | 0.00386 | 0.00187 | -0.00122 | -0.00065 | 0.01374 | -0.13807 | 0.00037 | 0.00108 | 0.01286 | 0.00364 | 0.00028 | 0.00070 | --- | > 0.009770 |
| Single | O-0.4-15-3 | 101.32557 | 0.00450 | 0.00191 | -0.00122 | -0.00044 | 0.01573 | -0.13759 | 0.00037 | 0.00110 | 0.06043 | 0.00365 | 0.00028 | 0.00367 | --- | > 0.009771 |
| Single | O-0.4-20-1 | 93.40508 | 0.00030 | 0.00001 | 0.01392 | 0.01364 | 0.15222 | 0.11817 | 0.00091 | 0.00311 | 0.07104 | 0.00223 | 0.00367 | 0.00373 | --- | > 0.011502 |
| Single | O-0.4-20-2 | 96.02043 | 0.01091 | -0.01060 | 0.02453 | 0.02425 | 0.16283 | 0.12878 | 0.00102 | 0.00312 | 0.07174 | 0.00223 | 0.01428 | 0.00373 | --- | > 0.011503 |
| Single | O-0.4-20-3 | 98.71956 | 0.01094 | -0.01063 | 0.02458 | 0.02432 | 0.16318 | 0.12932 | 0.00102 | 0.00313 | 0.06600 | 0.00224 | 0.01431 | 0.00367 | --- | > 0.011504 |
| Single | O-0.4-25-1 | 89.42987 | 0.00061 | 0.00046 | 0.01504 | 0.01998 | 0.02308 | 0.02259 | 0.00027 | 0.00954 | 0.01661 | 0.00068 | 0.00229 | 0.00373 | --- | > 0.015988 |
| Single | O-0.4-25-2 | 92.64934 | 0.01721 | 0.00120 | 0.02565 | 0.03059 | 0.03369 | 0.03320 | 0.00028 | 0.00965 | 0.02242 | 0.00068 | 0.00184 | 0.00373 | --- | > 0.015989 |
| Single | O-0.4-25-3 | 92.98288 | 0.01724 | 0.00120 | 0.02569 | 0.03067 | 0.03380 | 0.03338 | 0.00028 | 0.00966 | 0.00380 | 0.00068 | 0.00184 | 0.00002 | --- | > 0.015990 |
| Single | O-0.6-5-1 | 65.89609 | 0.00370 | 0.00001 | 0.02899 | 0.05456 | 0.02440 | 0.00707 | 0.00025 | 0.00748 | 0.01441 | 0.00059 | 0.00130 | 0.00002 | --- | > 0.006551 |
| Single | O-0.6-5-2 | 67.87297 | 0.02030 | 0.00120 | 0.03960 | -0.01130 | 0.03501 | -0.06080 | 0.00025 | 0.00759 | 0.01620 | 0.00059 | 0.00133 | 0.00002 | --- | > 0.006552 |
| Single | O-0.6-5-3 | 68.75532 | 0.02035 | 0.00120 | 0.03967 | -0.01130 | 0.03513 | -0.06080 | 0.00025 | 0.00760 | 0.00084 | 0.00060 | 0.00133 | 0.00004 | --- | > 0.006553 |
| Single | O-0.6-10-1 | 54.39796 | 0.00513 | 0.00003 | 0.03776 | 0.06592 | 0.01900 | -0.02574 | 0.00011 | 0.00368 | 0.01145 | 0.00027 | 0.00069 | 0.00004 | --- | > 0.009769 |
| Single | O-0.6-10-2 | 55.54032 | 0.02173 | 0.00120 | 0.04837 | -0.01118 | 0.00747 | -0.06118 | 0.00011 | 0.00379 | 0.01286 | 0.00027 | 0.00070 | 0.00004 | --- | > 0.009770 |
| Single | O-0.6-10-3 | 55.67917 | 0.02177 | 0.00120 | 0.04927 | -0.01118 | 0.00817 | -0.06118 | 0.00011 | 0.00379 | 0.06043 | 0.00027 | 0.00070 | 0.00078 | --- | > 0.009771 |
| Single | O-0.6-15-1 | 46.52253 | 0.00826 | 0.00001 | 0.05840 | 0.11843 | 0.15222 | 0.21657 | 0.00091 | 0.00311 | 0.07104 | 0.00223 | 0.00367 | 0.00080 | --- | > 0.011502 |
| Single | O-0.6-15-2 | 47.40646 | 0.02486 | 0.00120 | 0.06901 | -0.01063 | 0.16283 | -0.05837 | 0.00091 | 0.00312 | 0.07174 | 0.00223 | 0.00373 | 0.00080 | --- | > 0.011503 |
| Single | O-0.6-15-3 | 48.44466 | 0.02491 | 0.00120 | 0.07029 | -0.01062 | 0.16693 | -0.05836 | 0.00093 | 0.00313 | 0.06600 | 0.00224 | 0.00373 | 0.00367 | --- | > 0.011504 |
| Single | O-0.6-20-1 | 42.10229 | 0.00344 | 0.00002 | 0.03095 | 0.05713 | 0.03169 | 0.07311 | 0.00043 | 0.00153 | 0.01661 | 0.00108 | 0.00367 | 0.00375 | --- | > 0.015989 |
| Single | O-0.6-20-2 | 43.28116 | 0.02004 | 0.00120 | 0.04156 | -0.01128 | 0.06230 | -0.06004 | 0.00043 | 0.00154 | 0.02242 | 0.00108 | 0.00373 | 0.00367 | --- | > 0.015990 |
| Single | O-0.6-20-3 | 44.49779 | 0.02045 | 0.00120 | 0.04234 | -0.01124 | 0.06420 | -0.06002 | 0.00044 | 0.00154 | 0.00380 | 0.00108 | 0.00373 | 0.00367 | --- | > 0.015991 |
| Single | O-0.6-25-1 | 45.87750 | 0.00042 | 0.00002 | 0.01380 | 0.01881 | 0.02440 | 0.00707 | 0.00025 | 0.00748 | 0.01441 | 0.00059 | 0.00002 | 0.00375 | --- | > 0.006551 |
| Single | O-0.6-25-2 | 47.52909 | 0.01702 | 0.00120 | 0.02441 | -0.01168 | 0.03501 | -0.06080 | 0.00025 | 0.00759 | 0.01620 | 0.00059 | 0.00002 | 0.00375 | --- | > 0.006552 |
| Single | O-0.6-25-3 | 47.70019 | 0.01738 | 0.00120 | 0.02486 | -0.01167 | 0.03632 | -0.06079 | 0.00025 | 0.00760 | 0.00084 | 0.00060 | 0.00002 | 0.00375 | --- | > 0.006553 |



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|--------|------------|-----------|---------|----------|----------|----------|----------|----------|---------|---------|---------|---------|---------|---------|-----|------------|
| Single | O-0.8-5-1 | 68.00120 | 0.00042 | 0.00002 | 0.01380 | 0.01881 | 0.02440 | 0.00707 | 0.00025 | 0.00748 | 0.01145 | 0.00059 | 0.00004 | 0.00060 | --- | > 0.006551 |
| Single | O-0.8-5-2 | 70.04124 | 0.00048 | -0.00001 | 0.01410 | 0.01948 | 0.02546 | 0.00855 | 0.00025 | 0.00764 | 0.01286 | 0.00061 | 0.00004 | 0.00060 | --- | > 0.006552 |
| Single | O-0.8-5-3 | 70.95177 | 0.00052 | -0.00001 | 0.01436 | 0.02111 | 0.02656 | 0.00938 | 0.00026 | 0.00766 | 0.06043 | 0.00061 | 0.00004 | 0.00031 | --- | > 0.006553 |
| Single | O-0.8-10-1 | 63.02593 | 0.00162 | 0.00002 | 0.01034 | 0.01109 | -0.00314 | 0.02970 | 0.00011 | 0.00368 | 0.07104 | 0.00027 | 0.00078 | 0.00032 | --- | > 0.009769 |
| Single | O-0.8-10-2 | 64.34948 | 0.00166 | -0.00001 | 0.01056 | 0.01158 | -0.00267 | 0.03047 | 0.00011 | 0.00376 | 0.07174 | 0.00028 | 0.00080 | 0.00032 | --- | > 0.009770 |
| Single | O-0.8-10-3 | 64.51035 | 0.00169 | -0.00001 | 0.01076 | 0.01281 | -0.00219 | 0.03091 | 0.00011 | 0.00377 | 0.00600 | 0.00028 | 0.00080 | 0.00367 | --- | > 0.009771 |
| Single | O-0.8-15-1 | 53.47541 | 0.00031 | 0.00002 | 0.00533 | -0.00181 | 0.15222 | 0.11817 | 0.00091 | 0.00311 | 0.01661 | 0.00223 | 0.00367 | 0.01428 | --- | > 0.011502 |
| Single | O-0.8-15-2 | 54.49144 | 0.00032 | -0.00001 | 0.00544 | -0.00159 | 0.15604 | 0.12418 | 0.00093 | 0.00318 | 0.02242 | 0.00228 | 0.00375 | 0.01431 | --- | > 0.011503 |
| Single | O-0.8-15-3 | 55.68481 | 0.00033 | -0.00001 | 0.00554 | -0.00105 | 0.15999 | 0.07155 | 0.00095 | 0.00318 | 0.00380 | 0.00228 | 0.00375 | 0.00229 | --- | > 0.011504 |
| Single | O-0.8-20-1 | 48.47764 | 0.00092 | 0.00002 | 0.00310 | 0.01668 | 0.05169 | -0.08129 | 0.00043 | 0.00153 | 0.01441 | 0.00108 | 0.00367 | 0.01839 | --- | > 0.015988 |
| Single | O-0.8-20-2 | 49.83501 | 0.00094 | -0.00001 | 0.00317 | 0.01730 | 0.05334 | -0.07838 | 0.00044 | 0.00156 | 0.01620 | 0.00110 | 0.00375 | 0.01843 | --- | > 0.015989 |
| Single | O-0.8-20-3 | 51.23588 | 0.00096 | -0.00001 | 0.00323 | 0.01882 | 0.05504 | -0.07675 | 0.00045 | 0.00156 | 0.00084 | 0.00111 | 0.00375 | 0.00130 | --- | > 0.015990 |
| Single | O-0.8-25-1 | 51.90283 | 0.00105 | 0.00001 | 0.00713 | 0.01794 | 0.02440 | -0.14735 | 0.00025 | 0.00748 | 0.01145 | 0.00059 | 0.00058 | 0.00133 | --- | > 0.006551 |
| Single | O-0.8-25-2 | 53.77133 | 0.00108 | -0.00001 | 0.00728 | 0.01859 | 0.02546 | -0.14585 | 0.00025 | 0.00764 | 0.01286 | 0.00061 | 0.00060 | 0.00133 | --- | > 0.006552 |
| Single | O-0.8-25-3 | 53.96490 | 0.00110 | -0.00002 | 0.00742 | 0.02018 | 0.02656 | -0.14502 | 0.00026 | 0.00766 | 0.06043 | 0.00061 | 0.00060 | 0.00069 | --- | > 0.006553 |
| Single | O-1-5-1 | 80.10436 | 0.00175 | 0.00002 | 0.01111 | 0.02552 | 0.02125 | -0.12414 | 0.00011 | 0.00368 | 0.07104 | 0.00027 | 0.00031 | 0.00070 | --- | > 0.009769 |
| Single | O-1-5-2 | 82.50749 | 0.00180 | -0.00001 | 0.01135 | 0.02633 | 0.01947 | -0.12337 | 0.00011 | 0.00376 | 0.07174 | 0.00028 | 0.00032 | 0.00070 | --- | > 0.009770 |
| Single | O-1-5-3 | 83.58009 | 0.00093 | -0.00001 | 0.01157 | 0.02832 | 0.01995 | -0.12293 | 0.00011 | 0.00377 | 0.00600 | 0.00028 | 0.00032 | 0.00367 | --- | > 0.009771 |
| Single | O-1-10-1 | 75.12909 | 0.00030 | 0.00001 | 0.01392 | 0.01364 | 0.13222 | 0.11817 | 0.00091 | 0.00311 | 0.01661 | 0.00223 | 0.00367 | 0.00373 | --- | > 0.011502 |
| Single | O-1-10-2 | 76.70680 | 0.01091 | -0.01060 | 0.02453 | 0.02425 | 0.16283 | 0.12878 | 0.00102 | 0.00312 | 0.02242 | 0.00223 | 0.00143 | 0.00373 | --- | > 0.011503 |
| Single | O-1-10-3 | 76.89857 | 0.01094 | -0.01063 | 0.02458 | 0.02432 | 0.16318 | 0.12932 | 0.00102 | 0.00313 | 0.00380 | 0.00224 | 0.00143 | 0.00367 | --- | > 0.011504 |
| Single | O-1-15-1 | 64.82853 | 0.00061 | 0.00046 | 0.01504 | 0.01998 | 0.02308 | 0.02259 | 0.00027 | 0.00954 | 0.01441 | 0.00068 | 0.00023 | 0.00373 | --- | > 0.015988 |
| Single | O-1-15-2 | 66.06027 | 0.01721 | 0.00120 | 0.02565 | 0.03059 | 0.03369 | 0.03320 | 0.00028 | 0.00965 | 0.01620 | 0.00068 | 0.00184 | 0.00373 | --- | > 0.015989 |
| Single | O-1-15-3 | 67.50699 | 0.01724 | 0.00120 | 0.02569 | 0.03067 | 0.03380 | 0.03338 | 0.00028 | 0.00966 | 0.00084 | 0.00068 | 0.00184 | 0.00002 | --- | > 0.015990 |
| Single | O-1-20-1 | 59.05321 | 0.00370 | 0.00001 | 0.02899 | 0.05456 | 0.02440 | 0.00707 | 0.00025 | 0.00748 | 0.01145 | 0.00059 | 0.00013 | 0.00002 | --- | > 0.006551 |
| Single | O-1-20-2 | 60.70670 | 0.02030 | 0.00120 | 0.03960 | -0.01130 | 0.03501 | 0.00064 | 0.00025 | 0.00759 | 0.01286 | 0.00059 | 0.00013 | 0.00002 | --- | > 0.006552 |
| Single | O-1-20-3 | 62.41317 | 0.00235 | 0.00120 | 0.03967 | -0.01130 | 0.01727 | 0.00064 | 0.00025 | 0.00760 | 0.06043 | 0.00060 | 0.00013 | 0.00004 | --- | > 0.006553 |
| Single | O-1-25-1 | 63.57846 | 0.00453 | 0.00003 | 0.03776 | 0.06592 | 0.00900 | 0.03570 | 0.00011 | 0.00368 | 0.07104 | 0.00027 | 0.00007 | 0.00004 | --- | > 0.009769 |
| Single | O-1-25-2 | 66.10441 | 0.00373 | 0.00120 | 0.04837 | -0.01118 | 0.00747 | 0.00026 | 0.00011 | 0.00379 | 0.07174 | 0.00027 | 0.00007 | 0.00004 | --- | > 0.009770 |
| Single | O-1-25-3 | 65.86729 | 0.00077 | 0.00120 | 0.04927 | -0.01118 | 0.00817 | 0.00026 | 0.00011 | 0.00379 | 0.00600 | 0.00027 | 0.00007 | 0.00078 | --- | > 0.009771 |
| Single | R-0.1-5-1 | 186.85306 | 0.00039 | 0.00030 | -0.00120 | 0.00191 | 0.00105 | 0.01682 | 0.00278 | 0.00912 | 0.01145 | 0.00292 | 0.00223 | 0.00035 | --- | > 0.006551 |
| Single | R-0.1-5-2 | 192.45865 | 0.01100 | 0.01091 | -0.01181 | 0.01252 | 0.01166 | 0.02743 | 0.00289 | 0.01018 | 0.01286 | 0.00293 | 0.00223 | 0.00035 | --- | > 0.006552 |
| Single | R-0.1-5-3 | 194.96061 | 0.01124 | 0.01094 | -0.01184 | 0.01257 | 0.01173 | 0.02778 | 0.00289 | 0.01020 | 0.06043 | 0.00294 | 0.00224 | 0.00367 | --- | > 0.011504 |
| Single | R-0.1-10-1 | 181.99682 | 0.00098 | 0.00061 | -0.00075 | 0.00303 | 0.00739 | -0.11232 | 0.00084 | 0.00271 | 0.07104 | 0.00938 | 0.00084 | 0.00373 | --- | > 0.015988 |



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|--------|------------|-----------|---------|----------|----------|----------|----------|----------|---------|---------|---------|---------|---------|---------|-----|------------|
| Single | R-0.4-15-3 | 114.22738 | 0.00450 | 0.00191 | -0.00122 | -0.00044 | 0.01573 | -0.13759 | 0.00037 | 0.00110 | 0.06043 | 0.00365 | 0.00028 | 0.00367 | --- | > 0.009771 |
| Single | R-0.4-20-1 | 106.11163 | 0.00030 | 0.00001 | 0.01392 | 0.01364 | 0.15222 | 0.11817 | 0.00091 | 0.00331 | 0.07104 | 0.00223 | 0.00367 | 0.00373 | --- | > 0.011502 |
| Single | R-0.4-20-2 | 109.08276 | 0.01091 | -0.01060 | 0.02453 | 0.02425 | 0.16283 | 0.12878 | 0.00102 | 0.00312 | 0.07174 | 0.00223 | 0.01428 | 0.00373 | --- | > 0.011503 |
| Single | R-0.4-20-3 | 112.14907 | 0.01094 | -0.01063 | 0.02458 | 0.02432 | 0.16318 | 0.12932 | 0.00102 | 0.00313 | 0.06600 | 0.00224 | 0.01431 | 0.00367 | --- | > 0.011504 |
| Single | R-0.4-25-1 | 102.45895 | 0.00061 | 0.00046 | 0.01504 | 0.01998 | 0.02308 | 0.02259 | 0.00027 | 0.00954 | 0.01661 | 0.00068 | 0.00229 | 0.00373 | --- | > 0.015988 |
| Single | R-0.4-25-2 | 106.14747 | 0.01721 | 0.00120 | 0.02565 | 0.03059 | 0.03369 | 0.03320 | 0.00028 | 0.00965 | 0.02242 | 0.00068 | 0.00184 | 0.00373 | --- | > 0.015989 |
| Single | R-0.4-25-3 | 106.52960 | 0.01724 | 0.00120 | 0.02569 | 0.03067 | 0.03380 | 0.03338 | 0.00028 | 0.00966 | 0.00380 | 0.00068 | 0.00184 | 0.00002 | --- | > 0.015990 |
| Single | R-0.6-5-1 | 85.80976 | 0.00370 | 0.00001 | 0.02899 | 0.05456 | 0.02440 | 0.00707 | 0.00025 | 0.00748 | 0.01441 | 0.00059 | 0.00130 | 0.00002 | --- | > 0.006551 |
| Single | R-0.6-5-2 | 88.38405 | 0.02030 | 0.00120 | 0.03960 | -0.01130 | 0.03501 | -0.06080 | 0.00025 | 0.00759 | 0.01620 | 0.00059 | 0.00133 | 0.00002 | --- | > 0.006552 |
| Single | R-0.6-5-3 | 89.53305 | 0.02035 | 0.00120 | 0.03967 | -0.01130 | 0.03513 | -0.06080 | 0.00025 | 0.00760 | 0.00084 | 0.00060 | 0.00133 | 0.00004 | --- | > 0.006553 |
| Single | R-0.6-10-1 | 65.71903 | 0.00513 | 0.00003 | 0.03776 | 0.06592 | 0.01900 | -0.02574 | 0.00011 | 0.00368 | 0.01145 | 0.00027 | 0.00069 | 0.00004 | --- | > 0.009769 |
| Single | R-0.6-10-2 | 67.09913 | 0.02173 | 0.00120 | 0.04837 | -0.01118 | 0.00747 | -0.06118 | 0.00011 | 0.00379 | 0.01286 | 0.00027 | 0.00070 | 0.00004 | --- | > 0.009770 |
| Single | R-0.6-10-3 | 67.26688 | 0.02177 | 0.00120 | 0.04927 | -0.01118 | 0.00817 | -0.06118 | 0.00011 | 0.00379 | 0.06043 | 0.00027 | 0.00070 | 0.00078 | --- | > 0.009771 |
| Single | R-0.6-15-1 | 58.29938 | 0.00826 | 0.00001 | 0.05840 | 0.11843 | 0.15222 | 0.21657 | 0.00091 | 0.00311 | 0.07104 | 0.00223 | 0.00367 | 0.00080 | --- | > 0.011502 |
| Single | R-0.6-15-2 | 59.40707 | 0.02486 | 0.00120 | 0.06901 | -0.01063 | 0.16283 | -0.05837 | 0.00091 | 0.00312 | 0.07174 | 0.00223 | 0.00373 | 0.00080 | --- | > 0.011503 |
| Single | R-0.6-15-3 | 60.70809 | 0.02491 | 0.00120 | 0.07029 | -0.01062 | 0.16693 | -0.05836 | 0.00093 | 0.00313 | 0.06600 | 0.00224 | 0.00373 | 0.00367 | --- | > 0.011504 |
| Single | R-0.6-20-1 | 54.13496 | 0.00344 | 0.00002 | 0.03095 | 0.05713 | 0.05169 | 0.07311 | 0.00043 | 0.00153 | 0.01661 | 0.00108 | 0.00367 | 0.00375 | --- | > 0.015988 |
| Single | R-0.6-20-2 | 55.65074 | 0.02004 | 0.00120 | 0.04156 | -0.01128 | 0.06230 | -0.06004 | 0.00043 | 0.00154 | 0.02242 | 0.00108 | 0.00373 | 0.00375 | --- | > 0.015989 |
| Single | R-0.6-20-3 | 57.21508 | 0.02045 | 0.00120 | 0.04234 | -0.01124 | 0.06420 | -0.06002 | 0.00044 | 0.00154 | 0.00380 | 0.00108 | 0.00373 | 0.00367 | --- | > 0.015990 |
| Single | R-0.6-25-1 | 57.69168 | 0.00042 | 0.00002 | 0.01380 | 0.01881 | 0.02440 | 0.00707 | 0.00025 | 0.00748 | 0.01441 | 0.00059 | 0.00002 | 0.00375 | --- | > 0.006551 |
| Single | R-0.6-25-2 | 59.76858 | 0.01702 | 0.00120 | 0.02441 | -0.01168 | 0.03501 | -0.06080 | 0.00025 | 0.00759 | 0.01620 | 0.00059 | 0.00002 | 0.00375 | --- | > 0.006552 |
| Single | R-0.6-25-3 | 59.98375 | 0.01738 | 0.00120 | 0.02486 | -0.01167 | 0.03632 | -0.06079 | 0.00025 | 0.00760 | 0.00084 | 0.00060 | 0.00002 | 0.00058 | --- | > 0.006553 |
| Single | R-0.8-5-1 | 77.85638 | 0.00042 | 0.00002 | 0.01380 | 0.01881 | 0.02440 | 0.00707 | 0.00025 | 0.00748 | 0.01145 | 0.00059 | 0.00004 | 0.00060 | --- | > 0.006551 |
| Single | R-0.8-5-2 | 80.19207 | 0.00048 | -0.00001 | 0.01410 | 0.01948 | 0.02546 | 0.00855 | 0.00025 | 0.00764 | 0.01286 | 0.00061 | 0.00004 | 0.00060 | --- | > 0.006552 |
| Single | R-0.8-5-3 | 81.23457 | 0.00052 | -0.00001 | 0.01436 | 0.02111 | 0.02656 | 0.00938 | 0.00026 | 0.00766 | 0.06043 | 0.00061 | 0.00004 | 0.00031 | --- | > 0.006553 |
| Single | R-0.8-10-1 | 73.15050 | 0.00162 | 0.00002 | 0.01034 | 0.01109 | -0.00314 | 0.02970 | 0.00011 | 0.00368 | 0.07104 | 0.00027 | 0.00078 | 0.00032 | --- | > 0.009769 |
| Single | R-0.8-10-2 | 74.68666 | 0.00166 | -0.00001 | 0.01056 | 0.01158 | -0.00267 | 0.03047 | 0.00011 | 0.00376 | 0.07174 | 0.00028 | 0.00080 | 0.00032 | --- | > 0.009770 |
| Single | R-0.8-10-3 | 74.87338 | 0.00169 | -0.00001 | 0.01076 | 0.01281 | -0.00219 | 0.03091 | 0.00011 | 0.00377 | 0.06600 | 0.00028 | 0.00080 | 0.00367 | --- | > 0.009771 |
| Single | R-0.8-15-1 | 64.11710 | 0.00031 | 0.00002 | 0.00533 | -0.00181 | 0.15222 | 0.11817 | 0.00091 | 0.00311 | 0.01661 | 0.00223 | 0.00367 | 0.01428 | --- | > 0.011502 |
| Single | R-0.8-15-2 | 65.33532 | 0.00032 | -0.00001 | 0.00544 | -0.00159 | 0.15604 | 0.12418 | 0.00093 | 0.00318 | 0.02242 | 0.00228 | 0.00375 | 0.01431 | --- | > 0.011503 |
| Single | R-0.8-15-3 | 66.76617 | 0.00033 | -0.00001 | 0.00554 | -0.00105 | 0.15999 | 0.07155 | 0.00095 | 0.00318 | 0.00380 | 0.00228 | 0.00375 | 0.00229 | --- | > 0.011504 |
| Single | R-0.8-20-1 | 59.38993 | 0.00092 | 0.00002 | 0.00310 | 0.01668 | 0.05169 | -0.08129 | 0.00043 | 0.00153 | 0.01441 | 0.00108 | 0.00367 | 0.00379 | --- | > 0.015988 |
| Single | R-0.8-20-2 | 61.05285 | 0.00094 | -0.00001 | 0.00317 | 0.01730 | 0.05334 | -0.07838 | 0.00044 | 0.00156 | 0.01620 | 0.00110 | 0.00375 | 0.00375 | --- | > 0.015989 |
| Single | R-0.8-20-3 | 62.76995 | 0.00096 | -0.00001 | 0.00323 | 0.01882 | 0.05504 | -0.07675 | 0.00045 | 0.00156 | 0.00084 | 0.00111 | 0.00375 | 0.00375 | --- | > 0.015990 |



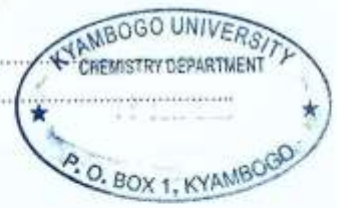
| | | | | | | | | | | | | | | | | |
|--------|------------|-----------|---------|----------|---------|----------|---------|----------|---------|---------|---------|---------|---------|---------|-----|------------|
| Single | R-0.8-25-1 | 62.62966 | 0.00105 | 0.00001 | 0.00713 | 0.01794 | 0.02440 | -0.14733 | 0.00025 | 0.00748 | 0.01145 | 0.00059 | 0.00058 | 0.00133 | --- | > 0.006551 |
| Single | R-0.8-25-2 | 64.88433 | 0.00108 | -0.00001 | 0.00728 | 0.01859 | 0.02546 | -0.14585 | 0.00025 | 0.00764 | 0.01286 | 0.00061 | 0.00060 | 0.00133 | --- | > 0.006552 |
| Single | R-0.8-25-3 | 65.11791 | 0.00110 | -0.00002 | 0.00742 | 0.02018 | 0.02656 | -0.14502 | 0.00026 | 0.00766 | 0.06043 | 0.00061 | 0.00060 | 0.00069 | --- | > 0.006553 |
| Single | R-1-5-1 | 98.32927 | 0.00175 | 0.00002 | 0.01111 | 0.02552 | 0.02125 | -0.12414 | 0.00011 | 0.00368 | 0.07104 | 0.00027 | 0.00031 | 0.00070 | --- | > 0.009769 |
| Single | R-1-5-2 | 101.27915 | 0.00180 | -0.00001 | 0.01135 | 0.02653 | 0.01947 | -0.12337 | 0.00011 | 0.00376 | 0.07174 | 0.00028 | 0.00032 | 0.00070 | --- | > 0.009770 |
| Single | R-1-5-3 | 102.59578 | 0.00001 | -0.00001 | 0.01157 | 0.02832 | 0.01995 | -0.12293 | 0.00011 | 0.00377 | 0.06600 | 0.00028 | 0.00032 | 0.00367 | --- | > 0.009771 |
| Single | R-1-10-1 | 93.88766 | 0.00030 | 0.00001 | 0.01392 | 0.01364 | 0.15222 | 0.11817 | 0.00091 | 0.00311 | 0.01661 | 0.00223 | 0.00367 | 0.00373 | --- | > 0.011502 |
| Single | R-1-10-2 | 95.85930 | 0.01091 | -0.01060 | 0.02453 | 0.02425 | 0.16283 | 0.12878 | 0.00102 | 0.00312 | 0.02242 | 0.00223 | 0.00143 | 0.00373 | --- | > 0.011503 |
| Single | R-1-10-3 | 96.09895 | 0.01094 | -0.01063 | 0.02458 | 0.02432 | 0.16318 | 0.12932 | 0.00102 | 0.00313 | 0.00380 | 0.00224 | 0.00143 | 0.00367 | --- | > 0.011504 |
| Single | R-1-15-1 | 84.69196 | 0.00061 | 0.00046 | 0.01504 | 0.01998 | 0.02308 | 0.02259 | 0.00027 | 0.00954 | 0.01441 | 0.00068 | 0.00023 | 0.00373 | --- | > 0.015988 |
| Single | R-1-15-2 | 86.30111 | 0.01721 | 0.00120 | 0.02565 | 0.03059 | 0.03369 | 0.03320 | 0.00028 | 0.00965 | 0.01620 | 0.00068 | 0.00184 | 0.00373 | --- | > 0.015989 |
| Single | R-1-15-3 | 88.19110 | 0.01724 | 0.00120 | 0.02569 | 0.03067 | 0.03380 | 0.03338 | 0.00028 | 0.00966 | 0.00084 | 0.00068 | 0.00184 | 0.00002 | --- | > 0.015990 |
| Single | R-1-20-1 | 79.53612 | 0.00370 | 0.00001 | 0.02899 | 0.05456 | 0.02440 | 0.00707 | 0.00025 | 0.00748 | 0.01145 | 0.00059 | 0.00013 | 0.00002 | --- | > 0.006551 |
| Single | R-1-20-2 | 81.76313 | 0.02030 | 0.00120 | 0.03960 | -0.01130 | 0.03501 | 0.00064 | 0.00025 | 0.00759 | 0.01286 | 0.00059 | 0.00013 | 0.00002 | --- | > 0.006552 |
| Single | R-1-20-3 | 84.06130 | 0.00235 | 0.00120 | 0.03967 | -0.01130 | 0.01727 | 0.00064 | 0.00025 | 0.00760 | 0.06043 | 0.00060 | 0.00013 | 0.00004 | --- | > 0.006553 |
| Single | R-1-25-1 | 83.57598 | 0.00453 | 0.00003 | 0.03776 | 0.06592 | 0.00900 | 0.03570 | 0.00011 | 0.00368 | 0.07104 | 0.00027 | 0.00007 | 0.00004 | --- | > 0.009769 |
| Single | R-1-25-2 | 86.58472 | 0.00373 | 0.00120 | 0.04837 | -0.01118 | 0.00747 | 0.00026 | 0.00011 | 0.00379 | 0.07174 | 0.00027 | 0.00007 | 0.00004 | --- | > 0.009770 |
| Single | R-1-25-3 | 86.89642 | 0.00077 | 0.00120 | 0.04927 | -0.01118 | 0.00817 | 0.00026 | 0.00011 | 0.00379 | 0.00600 | 0.00027 | 0.00007 | 0.00078 | --- | > 0.009771 |

Analysed by

989

Head of Chemistry Department


Sign: 

Sign: 

Date: 13.08.2025


Date:

Appendix 7: Intorductory Letter


KYAMBOGO UNIVERSITY
P.O. BOX 1 KYAMBOGO, KAMPALA – UGANDA
Tel: +256-41-4285272, Email: deaneng@kyu.ac.ug Website: www.kyu.ac.ug
Office of the Dean, Faculty of Engineering

October 22, 2024

To: The Director,
National Crops Resources Research Institute (NaCRRRI)
Gayaza Road Namulange,
P.O. Box 7084, Kampala, Uganda



Dear Dr.,

RE: LETTER OF INTRODUCTION FOR MS. JOSEPHINE KIHUMURO FOR INFORMATION REGARDING HER MSc RESEARCH STUDY

I extend warm greetings from the Faculty of Engineering, Kyambogo University.

This is to introduce Ms. Kihumuro Josephine, our graduate student with Reg. No. 23/U/GMEW/16034/PE. She is undertaking Master of Science in Water and Sanitation Engineering under the Department of Civil and Environmental Engineering (DCEE). To partially fulfill the requirements for an award of an MSc degree, she is conducting a research study titled "Investigating the Performance of Green Silver Nano Particles using Guava Leaves of Various Genotypes in Uganda for Adsorption of Lead from Water". She is being supervised by Charles Onyutha (PhD).


The first specific objective of Josephine's MSc research study is to identify the various genotypes of Guava (*Psidium guajava* L.) available in Uganda. This is to support decision on which genotypes, based on their characteristics, should be considered for laboratory experiments regarding adsorption of Lead from water based on Green Silver Nano Particles using Guava Leaves. To do so, NaCRRRI of the National Agricultural Research Organization (NARO) at Namulonge has been identified for the relevant information.


Ms. Kihumuro will need assistance with respect to:

- survey of the various species of Guava (*Psidium guajava* L.) available in Uganda and/or specifically at NARO, Namulonge,
- Origins & characteristics of the available species of Guava (*Psidium guajava* L.), and
- any other information deemed relevant for the research.

The necessary support to enable the researcher timely obtain the relevant information for her research will be duly acknowledged in the dissemination of the results from this research.

I shall be grateful for your cooperation and support toward this research.

Sincerely,

Charles Onyutha (PhD)
MWA, MIAH, MIAHS, MIAHR, MEGU, MWRA,
Dean, Faculty of Engineering, Tel: 0752 711 163, Email: conyutha@kyu.ac.ug


II. Dr. Idamulira
Pée handle - assist the student.
Idamulira

APPENDIX 8: INTRODUCTORY LETTER

Date: June 11, 2025

The Director General,
National Agricultural Research Organization (NARO)
P.O. Box 295
Entebbe

Dear Sir, Madam,

RE: KIHUMURO JOSEPHINE

This is to introduce to you the above named student **Reg: No 23/U/GMEW/16034/PE** pursuing Master of Science in Water and Sanitation Engineering, Department of Civil and Environmental Engineering, Kyambogo University.

She intends to carry out research on "Performance of green silver nano particles using *Psidium guajava* leaves for adsorption of lead from water" in partial fulfillment of the requirements of the award of Master of Science in Science in Water and Sanitation of Kyambogo University.

The purpose of this letter therefore is to request you to introduce the student to relevant offices as well as support with any necessary assistance and guidance.

Any assistance rendered to her will be highly appreciated.

Yours sincerely,


Prof. Edwin M. M.
AG. DIRECTOR

11 JUN 2025