REMOVAL OF LEAD, CADMIUM AND NICKEL IONS FROM AQUEOUS SOLUTION USING RAMBUTAN AND DATE SEEDS AS ADSORBENTS

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UNIVERSITI SAINS MALAYSIA

2025

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by

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Dissertation submitted in partial fulfilment of requirements for the degree of Bachelor of Science in Forensic Science

February 2025

CERTIFICATE

This is to certify that the dissertation entitled "Removal of Lead, Cadmium and Nickel Ions from Aqueous Solution using Rambutan and Date Seeds as Adsorbents" is the bona fide record of research work done by Ms. Olivanesa Clarita Lunus@Linus during the period from October 2025 to January 2025 under my supervision. I have read this dissertation and that in my opinion it conforms to acceptable standards if scholarly presentation and is dully adequate, in scope and quality, as a dissertation to be submitted in partial fulfilment for the degree of Bachelor of Science in Forensic Science.

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DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated and duly acknowledged. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at Universiti Sains Malaysia or other institutions. I grant Universiti Sains Malaysia the right to use the dissertation for teaching, research, and promotional purposes.

(Olivanesa Clarita Lunus@Linus)

Date: 24 February 2025

ACKNOWLEDGEMENT

I wish to express my heartfelt thanks to my supervisor, Dr. Nurasmat Binti Mohd Shukri, for her unwavering support, patience, and invaluable guidance. Her expertise and constructive feedback were instrumental in shaping this research and bringing it to fruition. I am truly grateful for her dedication and encouragement, which served as a cornerstone for the success of this project.

I would also like to extend my sincere appreciation to all the lecturers who provided their assistance, whether directly or indirectly, throughout this process. My deepest gratitude goes to all laboratory assistants for their kind guidance during the experimental phases of this research. A special mention goes to Mr. Wan Sahnusi for generously sharing his expertise, particularly in operating the Flame Atomic Absorption Spectrometer, which was crucial to this study.

To my laboratory partners, Hang Lipo Angelina A/P Ayob and Hazirah Binti Hashim, I am incredibly thankful for your collaboration, support, and camaraderie throughout the research journey. I would also like to express my warmest thanks to all of classmates, friends and my roommate, Wendy Tan, for her unwavering support and motivation during challenging times.

Lastly, my heartfelt gratitude goes to my family, whose unconditional love, support, and encouragement have been my greatest pillar of strength. I am truly blessed to have them by my side, always ready to uplift and inspire me. A special thanks also goes to my best friend, whose steadfast support and care have been invaluable throughout this journey. To everyone who played a part in the completion of this research, no matter how small, thank you from the bottom of my heart.

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LIST OF ABBREVIATIONS AND SYMBOLS

%	Percentage
&	And
°C	Degree Celcius
+	plus
>	Greater than
=	Equal
x	Multiplication
[M]	Concentration of heavy metals
CH	Hydrocarbon group
C=C	Carbon-carbon double bond
C-C	Carbon-carbon single bond
C=O	Carbonyl group
C-O	Carbon-oxygen single bond
C-O-C	Ether linkage
Cd	Cadmium
FAAS	Flame Atomic Absorption Spectroscopy
FTIR	Fourier Transform Infrared Spectroscopy
g	Gram
Hg	Mercury
HNO_3	Nitric Acid
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
L	Liter
mL	Mililiter
mg/kg	Miligrams per kilogram
mg/L	Miligrams per liter
mm	Milimeter
N-H	Amine group
Ni	Nickel
O-H	Hydroxyl group
pH	Measure of acidity or alkalinity
Pb	Lead
ppb	Parts per billion
ppm	Parts per million
R^2	Coefficient of determination
SEM	Scanning Electron Microscopy
WHO	World Health Organization
FAO	Food and Agricultural Organization
et al	And others
µg/L	Micrograms per liter
µm	Micrometer

LIST OF APPENDICES

PENYINGKIRAN ION PLUMBUM, KADMIUM DAN NIKEL DARIPADA LARUTAN AKUEUS MENGGUNAKAN BIJI BUAH RAMBUTAN DAN KURMA SEBAGAI PENJERAP

ABSTRAK

Pencemaran logam berat dalam persekitaran akuatik, terutamanya oleh plumbum (Pb), kadmium (Cd), dan nikel (Ni), menimbulkan risiko alam sekitar dan kesihatan yang ketara disebabkan oleh ketoksikan dan sifatnya yang sukar terurai. Kajian ini menilai potensi biji rambutan (*Nephelium lappaceum*) dan biji kurma (*Phoenix dactylifera*) sebagai biosorben untuk menyingkirkan logam-logam ini daripada larutan akueus. Teknik penjerapan dijalankan di bawah pelbagai keadaan termasuk kepekatan ion logam, dos biosorben, masa sentuhan, dan suhu. Kepekatan ion Pb, Cd, dan Ni diukur menggunakan Spektroskopi Penyerapan Atom Nyalaan (FAAS), manakala biosorben diperincikan sebelum dan selepas rawatan menggunakan Spektroskopi Inframerah Transformasi Fourier (FTIR) untuk mengenal pasti kumpulan fungsi yang terlibat dalam proses penjerapan. Parameter optimum untuk penyingkiran Pb, Cd, dan Ni menggunakan biji rambutan ialah kepekatan awal 1 ppm, dos biosorben sebanyak 0.5 g, tempoh sentuhan 40 minit, dan suhu 30°C, dengan kecekapan penyingkiran masing-masing sebanyak 97.2%, 90.3%, dan 16.1%. Bagi biji kurma, keadaan yang sama menghasilkan kecekapan penyingkiran sebanyak 81.9% untuk Cd dan 48.5% untuk Ni, manakala 96.4% untuk Pb memerlukan masa sentuhan yang lebih lama iaitu 60 minit. Keputusan menunjukkan bahawa kedua-dua biosorben sangat berkesan untuk penyingkiran Pb dan Cd, dengan biji rambutan sedikit lebih unggul secara purata berbanding biji kurma, namun kurang berkesan untuk Ni. Kajian ini menyerlahkan potensi biji rambutan dan kurma sebagai alternatif yang kos efektif dan mesra alam

untuk pemulihan logam berat serta menyumbang kepada penyelesaian rawatan air yang lestari dan memajukan penggunaan sisa pertanian untuk pemulihan alam sekitar.

REMOVAL OF LEAD, CADMIUM AND NICKEL IONS FROM AQUEOUS SOLUTION USING RAMBUTAN AND DATE SEEDS AS ADSORBENTS

ABSTRACT

Heavy metal contamination in aquatic environments, particularly by lead (Pb), cadmium (Cd), and nickel (Ni), poses significant environmental and health risks due to their toxicity and persistence. This study evaluated the potential of rambutan (*Nephelium lappaceum*) and date (*Phoenix dactylifera*) seeds as biosorbents for the removal of these metals from aqueous solutions. Adsorption experiments were conducted under varying conditions of metal ion concentration, adsorbent dosage, contact time, and temperature. The concentrations of Pb, Cd, and Ni ions were measured using Flame Atomic Absorption Spectroscopy (FAAS), while biosorbents were characterised pre- and post-treatment using Fourier Transform Infrared Spectroscopy (FTIR) to identify functional groups involved in the adsorption process. The optimal parameters for Pb, Cd, and Ni removal using rambutan seeds were an initial concentration of 1 ppm, an adsorbent dosage of 0.5 g, a contact duration of 40 minutes, and a temperature of 30°C, achieving removal efficiencies of 97.2%, 90.3%, and 16.1%, respectively. For date seeds, the same conditions yielded removal efficiencies of 81.9% for Cd and 48.5% for Ni, while 96.4% for Pb for 60 minutes of contact time. The results demonstrated that both biosorbents are highly effective for the removal of Pb and Cd, but rambutan slightly higher in average compared to date and less efficient for Ni. This study highlighted the potential of rambutan and date seeds as cost-effective and eco-friendly alternatives for heavy metal remediation,

contributing to sustainable water treatment solutions and advancing the use of agricultural waste for environmental remediation.

CHAPTER 1

INTRODUCTION

1.1 Research Background

Heavy metal contamination in water has become a significant environmental issue due to the toxic, persistent, and bioaccumulative nature of these pollutants in ecosystems. Industrial activities such as mining, electroplating, and manufacturing are major sources, releasing hazardous metals into water bodies. These metals pose grave health risks to both humans and wildlife when consumed in excess. (Mishra et al., 2019) The most typical heavy metals that cause water contamination are lead (Pb), arsenic (As), copper (Cu), cadmium (Cd), nickel (Ni), chromium (Cr), zinc (Zn), cobalt (Co), and mercury (Hg) (Chinmalli & Vijayakumar, 2023). When heavy metals enter the food chain, they may accumulate in high amounts in the human body, causing major health consequences such as cancer, organ damage, nervous system impairment, and, in extreme circumstances, death.

In Malaysia, the most typical heavy metal found in polluted water includes lead (Pb), cadmium (Cd) and nickel (Ni). In study by Islam et al. (2022), assessment of heavy metal in surface water rivers in the Gebeng industrial area, Pahang, Malaysia found that that Pb, Cd and Ni exceeded the Malaysia threshold standard. The permissible level of Pb, Cd and Ni as state in National Water Quality Standards And Water Quality Index (2020), for Cd (<0.01 mg/L), Pb and Ni (<0.05 mg/L). In other studies, the presence of Pb, Cd, and Ni in water contamination has been well-documented, including work by Ibrahim et al. (2020), Ahmed et al. (2020), Zanon et al. (2023), and Ruzi et al. (2024).

Traditional methods for removing heavy metals from contaminated water, such as chemical precipitation, ion exchange and membrane filtration, are often effective but come with significant drawbacks. These methods can be expensive, energy-intensive and may produce toxic sludge. Additionally, their application is often limited by the technical, operational and capital costs, especially in decentralised and developing regions (Zamora-Ledezma et al., 2021). According to a review by Karnwal (2024), various scholars have emphasised the shortcomings of different methods used for heavy metal removal. These methods included precipitation (Sheng et al.,2022), filtration (Adama et al., 2023), ion exchange, carbon adsorption (Razmi et al., 2022), evaporation, membrane technology, reverse osmosis pre-concentration (Micheal et al., 2024), redox, electrowinning (Liu et al., 2022), chelation, wastewater coagulation, and electrochemical processes (Na et al., 2020).

In light of these limitations, there is growing interest in sustainable and cost-effective alternatives, such as using waste materials as biosorbents for heavy metal removal. Several studies have shown that agricultural waste materials, such as rice husk, coconut shells and banana peels, can effectively adsorb heavy metals from water. For instance, a study by Priya et al. (2022), found that rice husk effectively removed lead from wastewater with the removal percentage result of Cr, Pb & Zn metal ions removed up to 87.12 %, 88.63 % & 99.28 %, respectively, while Duwiejuah et al. (2023), highlighted the efficiency of guinea fowl (*Numida meleagris*) eggshells as a low-cost adsorbent for Cd and Ni removal from landfill leachate. However, these studies primarily focused on laboratory-scale experiments, with limited data on the feasibility of applying these materials in real-world settings.

This study aimed to address this gap by exploring the use of agricultural waste, specifically fruit seed waste, as biosorbents for the removal of Pb, Cd and Ni ions from aqueous solutions. Rambutan and date seeds, which are abundant in Malaysia due to the region's fruit production, offer a low-cost and readily available option for water purification. Recent studies by Mohsen & Ghanim (2024), suggested that fruit seeds contain functional groups that may interact with metal ions, making them promising candidates for heavy metal removal. By utilising these seeds, this study did not only addressed heavy metal contamination but also aim to promote the recycling of agricultural waste into a valuable resource.

Although laboratory studies have demonstrated the potential of various waste materials for heavy metal removal, there is limited data on the scalability and practical application of these biosorbents in real-world contexts. This research sought to fill this gap by evaluating the effectiveness of rambutan and date seeds as biosorbents for Pb, Cd and Ni removal under different environmental conditions. Factors influencing biosorption supported by Subburaj & Bharathi (2024), such as initial metal concentration, adsorbent dosage, contact time and temperature, would be optimised to achieve maximum metal removal. An efficiency rate of over 80% was considered indicative of a successful biosorbent.

1.2 Problem Statement

Heavy metal contamination in water, particularly from toxic metals such as Pb, Cd and Ni remains a significant environmental and public health concern in Malaysia. Industrial activities, such as mining and manufacturing, have led to widespread contamination of water sources with these metals. Besides, the unethical dumping of waste into water bodies could cause bioaccumulation of these heavy metal ions into the ecosystem. This will lead to the disperse of heavy metal toxicity to the environment and community. This poses a significant danger to the health of humans which could lead to severe disease such as cancer, dysfunctions nervous system and many more.

Moreover, the availability of conventional water treatment methods, including chemical precipitation, ion exchange and filtration shows the efficiency on removal of heavy metal. However, these techniques mostly needed high cost, energy-intensive and generate toxic sludge which the purification of contaminated water cannot be leaning towards these techniques. Besides, it also limits their feasibility, especially in decentralized and developing regions (Ayach et al., 2024). Since it is not sustainable, this leaves a significant gap for a growing interest in eco-friendly and cost effectiveness alternative adsorbent.

Furthermore, the use of agricultural waste materials, particularly fruit seed waste, which are currently growing in the removal of heavy metal but it is remain largely underexplored since it is a new technique. Currently, the use of fruit seeds waste such as Rambutan and date seeds, which are abundant in Malaysia due to the region's fruit production, have not been thoroughly investigated for their potential as biosorbents for Pb, Cd and Ni removal under varying environmental conditions. Previous studies have focused mainly on laboratory-scale experiments, leaving a gap in understanding their practical applications and efficacy at a larger scale (Dewi & Dewata, 2019), (Pal et al., 2021).

Therefore, this research aimed to address this gap by evaluating the use of rambutan and date seeds as low-cost, sustainable biosorbents for the removal of Pb, Cd and Ni from aqueous solutions. The study assessed the biosorption process by considering factors such as initial metal ion concentration, adsorbent dosage, contact time and temperature. The research will quantify the concentrations of heavy metals post-treatment and estimate the efficiency of the biosorption process, with an efficiency rate of over 80% considered indicative of successful heavy metal removal.

1.3 Objectives

1.3.1 General Objective

To remove Pb, Cd and Ni in aqueous solution using fruit seeds waste using rambutan and date seeds as adsorbent.

1.3.2 Specific Objective

1. To characterise rambutan and date seeds before and after removal of Pb, Cd and Ni ions from aqueous solution using Fourier Transform Infrared Spectroscopy (FTIR).
2. To perform the removal process of Pb, Cd, and Ni ions from aqueous solutions using rambutan and date seeds, analysed through Flame Atomic Absorption Spectroscopy (FAAS).
3. To investigate the effectiveness of adsorption process using rambutan seeds and date seeds as natural waste adsorbents towards the removal of Pb, Cd, and Ni from aqueous solution using different parameters such as initial

concentration of metal ions solutions, adsorbent dosage, contact time and temperature.

1.4 Significance of Study

This study used rambutan and date seeds as biosorbents to remove Pb, Cd and Ni from aqueous solutions, which has significant implications for forensic science, environmental sustainability and public health. By efficiently minimising the pollution of water by these hazardous heavy metals, it aids in protecting human health and minimising the adverse effects associated with heavy metal exposure. The results may guide actions that eliminate contamination, safeguard at-risk communities and foster better ecosystems. This study advocated for the advancement of sustainable and economical water treatment alternatives that diminish dependence on synthetic and chemical remediation methods. Therefore, it can foster a cleaner and healthier ecology, which was essential in tackling worldwide water pollution issues.

In the realm of forensic science, it exemplified how forensic intelligence extends beyond tracing contamination sources to include effective remediation strategies. Environmental forensics is a growing field that investigates violations of environmental laws and regulations. The removal process tested in this study could become part of a toolkit for forensic experts seeking to restore environments affected by illegal waste disposal or industrial accidents involving heavy metals. Additionally, the research into how different parameters would affect the adsorption efficiency could be used to simulate various real-world conditions encountered in pollution events, aiding forensic efforts to determine the source of contamination and its environmental impact.

By demonstrating the effectiveness of rambutan and date seeds in removing heavy metals, it offered a vital tool that enhances forensic efforts to protect public health and environmental safety. This integration of remediation into forensic action plans not only supports the broader goal of environmental protection but also underscores the importance of developing actionable knowledge that can be employed to address contamination proactively, thereby reinforcing the credibility and relevance of forensic science in tackling environmental issues. The integration of forensic science into environmental protection efforts can lead to more effective and sustainable solutions.

CHAPTER 2

LITERATURE REVIEW

2.1 Heavy Metal

Heavy metals constitute a varied group of elements with distinct roles and chemical properties. The majority originate from the transition metals in the Periodic Table and are often characterized by a density above 5 g/cm³, or being at least five times denser than water. These metals are typically characterized by their high density, malleability and ability to conduct electricity. Chemically, they tend to form cations and engage in ionic bonds with other elements (Akbudak et al., 2021). These metals may be classified as either essential or non-essential. Crucial metals, such as manganese (Mn), copper (Cu), nickel (Ni), iron (Fe), and zinc (Zn), are integral to the body's metabolic processes. Copper is essential for haemoglobin synthesis and glucose metabolism. Nevertheless, when present in surplus, these metals can inflict harm on cells. Non-essential metals, including cadmium (Cd), nickel (Ni), arsenic (As), mercury (Hg) and lead (Pb), are poisonous and lack helpful biological roles (Kiran et al., 2021).

2.1.1 Lead

Lead (Pb) is a very toxic, non-degradable heavy metal characterised by a bluish-grey hue, an atomic number of 82, a molecular weight of 207.2, a density of 11.34 g/cm^3, and a melting temperature of 621.43 °F. It may be readily shaped, moulded and utilised to create alloys by combining with other metals. Inorganic lead primarily exists in dust, soil, antiquated paint and various consumer products, whereas organic lead (tetraethyl lead) is present in leaded petrol. Both types of lead are hazardous, however, organic lead complexes are far more toxic to biological systems than inorganic lead. Lead (Pb) is the second most poisonous element following arsenic (As) and constitutes 0.002% of the Earth's crust. Thus, exposure to lead can happen through ingestion, inhalation, or skin contact, resulting in severe health consequences, particularly in children, as it may lead to developmental delays, cognitive impairments and various neurological problem (Kumar et al., 2020).

According to Nazir et al. (2020), lead contamination originates from various primary sources, with industrial effluents being a major contribution. Industrial facilities often discharge untreated wastewater with elevated lead contents into adjacent water bodies and soil. For instance, in areas such as Hayatabad Industrial Estate in Peshawar, Pakistan, lead concentrations in water have been documented between 0.117 and 0.330 ppm, far surpassing the World Health Organization's (WHO) permissible guideline of 0.01 ppm for safe drinking water. Besides, a significant source of lead pollution is automobile exhaust. Historically utilised as a gasoline additive, lead infiltrates the atmosphere and ultimately deposits in urban soil and water, presenting a significant hazard in densely populated regions. Additionally, agricultural practices also contribute to lead contamination, especially through the application of fertilisers and pesticides that may introduce lead into soil and crops. Irrigation utilising tainted water, frequently derived from rivers adjacent to industrial areas, intensifies the issue by adding lead into the food chain (Schupp et al., 2020). Moreover, domestic sources of lead, such lead-based paints and contaminated drinking water, present health hazards, particularly to children, who are more susceptible to lead poisoning (Mielke et al., 2022). In these circumstances, lead concentrations frequently surpass the WHO recommended thresholds, rendering it a significant public health concern.

Lead (Pb) is especially detrimental owing to its capacity to bioaccumulate within the organism over time. It predominantly impacts the neurological system, particularly in children, resulting in developmental disorders, cognitive deficits, and learning disabilities. Lead exposure may result in cardiovascular issues, including hypertension, as well as renal and reproductive organ damage (Kiran et al., 2021b). According to the result in study by Salindra et al. (2022), the results of interviews with 40 respondents in Bondowoso, the majority of those who used the water from wells 8 and 10 reported health issues like skin redness and itching on their hands and arms, and the majority reported hot eyes, itching and redness after consuming lead (Pb) contaminated well water. Thus, this state of lead contamination is likely to be the cause of health issues among those who used the water from these sources.

2.1.2 Cadmium

Cadmium (Cd) is a ductile metal in the form of a blueish or silvery-white powder. It is naturally found in soil (about 0.2 mg/kg), minerals and water. Cd belongs to the group of toxics, carcinogenic and stimulating elements. Cadmium is a soft, bluish-white metal that shares chemical properties with zinc and mercury. It is naturally present in the Earth's crust and frequently arises as a byproduct of mining and refining processes involving zinc, lead, or copper. Cadmium has diverse industrial applications, such as in batteries, electroplating, pigments and alloys. However, it poses significant health hazards due to its high toxicity and carcinogenic nature, leading to its regulation and restricted use in many countries (Campaña et al., 2021).

Cadmium (Cd) is a widespread environmental pollutant, with several sources contributing to its occurrence in aquatic systems. Cadmium emissions, stemming from both natural and anthropogenic activity, can substantially affect water quality. The World Health Organisation (WHO) advises a recommendation limit of 3 µg/L for cadmium in potable water owing to its carcinogenic properties. Cadmium in water predominantly arises from anthropogenic causes, including mining, atmospheric deposition from combustion pollutants, and the application of Cd-containing fertilisers. Cadmium concentrations in soils typically range from 0.01 to 1 mg/kg, with an average of 0.36 mg/kg. Through weathering, cadmium levels can reach up to 5 μg/L in soil water and 1 μg/L in groundwater. These processes increase the potential for cadmium to be released into aquatic environments. Thus, cadmium originates from both natural and human-induced sources, posing significant dangers due to its harmful effects on the environment and human health (Tchounwou et al., 2012).

Cadmium (Cd) in contaminated water can induce acute or chronic toxicity in benthic invertebrates including fish, contingent upon its speciation. Toxicity levels are affected by physico-chemical characteristics including solubility, alkalinity, salinity and organic matter concentration. Upon absorption, cadmium can bioaccumulate in the organs of aquatic organisms, resulting in potential detrimental consequences on their health and functionality (Orata & Sifuna, 2023). Exposure to cadmium from contaminated water can result in both acute and chronic health consequences for both people and animals. It accumulates in essential organs, including the liver and kidneys, leading to possible damage and dysfunction. Prolonged exposure is especially alarming, as it may lead to numerous health complications, including renal dysfunction, skeletal fragility and heightened cancer risk. Exposure routes predominantly include the consumption of contaminated water, presenting significant hazards to communities residing in cadmium-affected regions. Mitigation measures are crucial to avert contamination and safeguard public health (Kussaga, 2024).

2.1.3 Nickel

Nickel is a transition metal widely found in the environment, including air, water and soil. It may originate from natural sources and human activities. Nickel is a robust, ductile, silvery-white transition metal and is the 28th element in the periodic table. It can exist in multiple oxidative states (ranging from −1 to +4); however, the +2 oxidation state Ni^{2+} is the most prevalent in environmental and biological contexts. Nickel is classified as a ferromagnetic element and is naturally found in the Earth's crust, typically in conjunction with oxygen and sulfur as oxides and sulfides (Genchi et al., 2020). Ni is reported as a natural component of soil and water and its present concentration in the Earth's crust is 0.008%. About 3% Ni is Nickel-containing compounds have seen a rising utilization in both industrial and commercial sectors, including electronics, batteries, catalysis, electroplating, coinage, pigments, ceramics, stainless steel and various nickel alloys in recent decades (Janas et al., 2018). However, the utilization of nickel leads to the largely disposal of industrial waste, which can have harmful environmental impacts if not properly managed.

Nickel is widely distributed in the environment, with inputs from both natural and human-made sources. Naturally, nickel is found in soil at concentrations ranging from 4 to 80 ppm, with an average of about 79 ppm. Each year, around 30,000 tons of nickel are released into the atmosphere through natural processes such as windblown dust, volcanic activity and sea salt spray (Begum et al., 2022). In aquatic environments, nickel is present as soluble salts, with concentrations typically ranging from 0.5 to 2 ppb in saltwater and about 0.3 ppb in rivers. However, human activities greatly increase nickel emissions. Groundwater is also affected, as urban runoff and acid rain increase nickel content, with some sources showing levels as high as 980 µg/L. Thus, nickel is naturally present in the environment, human activities such as fossil fuel combustion, mining, and industrial processes have significantly elevated its concentrations, particularly in urban soils and water systems. These increased levels pose potential risks to both environmental and human health, underscoring the need for effective regulation and management of nickel emissions (Begum et al., 2022).

Nickel contamination, whether natural or artificial, profoundly impacts environmental and human health. In plants, although nickel is a vital trace metal, elevated quantities are hazardous, resulting in growth inhibition, diminished crop production and physiological disorders such as chlorosis and root necrosis. It impairs iron metabolism, chlorophyll synthesis and nutrient uptake, significantly affecting plant growth. In humans, exposure to nickel, mostly via inhalation or ingestion, can lead to significant health complications, including respiratory disorders such as chronic bronchitis and lung cancer. Nickel can also result in renal impairment, cardiovascular complications and dermatitis upon dermal absorption. Prolonged exposure induces oxidative stress, hence hastening tissue damage and carcinogenesis (Kiran et al., 2021).

2.2 Analytical Method for Detection of Heavy Metals

The prevalence of dangerous heavy metals in contaminated water bodies has emerged as a major global issue due to the rapid expansion of industrialization, urbanization and the use of chemical substances across many industries (Jeevanantham et al., 2019). Heavy metals, including mercury, lead, arsenic, chromium and cadmium, can exert extensive and harmful impacts on the environment and living creatures (J. Wang, 2018). Industrial wastewater effluents frequently contain diverse heavy metal contaminants, which can significantly endanger water resources if inadequately treated and managed (Raul et al., 2022). To tackle this urgent issue, various contemporary analytical methods have been devised and utilized for the examination of heavy trace metals in contaminated water, including flame atomic absorption spectroscopy, atomic absorption spectroscopy and ICP-MS.

Mohammadi et al. (2019), to determine copper, nickel, manganese and cadmium ions in aqueous samples by flame atomic absorption spectrometry after coprecipitation by $CO(OH)_2$ as a carrier without a chelating agent. The detection limits based on $3S_b/m$ for Cu(II), Ni(II), Mn(II) and Cd(II) in the original solution were 0.2, 0.2, 0.3 and 0.07 ng mL^{-1}. Another study by Duran et al. (2023), described the analysis of Cu(II), Cd(II) and Ni(II) ions in sea and stream waters using Flame Atomic Absorption Spectroscopy. The specific wavelengths used for each element were 324.75 nm for Cu(II), 228.80 nm for Cd(II) and 232.00 nm for Ni(II). The concentration for Cd(II), Cu(II) and Ni(II) in sea water are 4.80 µg/L, 15.4 µg/L and 1.70 µg/L respectively meanwhile in stream water range between 0.70 µg/L to 57.8 µg/L, 7.68 µg/L to 416 µg/L and 1.06 µg/L to 149 µg/L respectively. Hence, we can see that Cd(II) and Ni(II) levels in many of the stream and sea water samples exceed safe limits by WHO and pose environmental concerns.

Moreover, the amounts of selenium (Se), lead (Pb) and zinc (Zn) were assessed in well water samples from Taman District, Sidoarjo Regency (Ngibad, 2023). The amounts of Se, Pb, and Zn in well water sample A were measured at <0.002 mg/L, <0.002 mg/L, and <0.013 mg/L, respectively. In well water sample B, the amounts of Se and Zn were <0.002 mg/L and <0.013 mg/L, respectively, while Pb was identified at 0.002 mg/L. The amounts are below the acceptable limits established by health regulations, indicating that the well water in both samples were within safety requirements for these heavy metals. Another study by Patil & Arya (2024), evaluate the Water Quality Assessment and Heavy Metal Analysis of the Ganga River System and the Effluent Water from SIDCUL at Haridwar using atomic absorption spectroscopy. The results indicate that six dangerous heavy metals (Fe, Mn, Cu, Cd, Zn, and Pb) were analysed for their presence in effluent and water samples. The concentrations of four heavy metals, which include Fe (0.3 mg/l), Pb (0.01 mg/l), Mn (0.4 mg/l) and Cd (0.003 mg/l), not exceeded the acceptable limits established by the World Health Organisation (WHO) guidelines of 2019 in water and wastewater.

Y. Wang & Gao (2024), utilised ICP-MS with quadrupole collision cell technology for the simultaneous determination of nine heavy metals (Cu, Zn, Cd, Pb, Hg, Mn, Cr, Ni, and As) in river sediments and surrounding soil. The kinetic energy discrimination (KED) model effectively eliminated mass spectrum interference, with helium used as the collision gas and Rh as an internal standard to correct matrix effects. The method showed high accuracy and precision, with detection limits ranging from 0.01 to 0.3 μg/g and relative standard deviations (RSDs) below 6.25%. The study highlighted that this approach improves analysis efficiency and minimizes environmental harm associated with reagent use. Besides, a study by Bucurică et al. (2022), assessed the quality of surface water from the Lalomita River, focusing on heavy metals and physicochemical parameters using inductively coupled plasma mass spectrometry (ICP-MS) and electroanalytical methods. Samples were collected upstream of Targoviste City over two months and analyzed for indicators such as pH, resistivity, total dissolved solids and heavy metal concentrations, including Cr, Ni, Pb, Cd, Cu, and Zn. Results showed that lead concentrations were significantly higher than permissible limits under Romanian Order 161/2006 and EU Directive 2008/105/EC, with values reaching up to 65.75 μg/L, which is six times above the World Health Organization (WHO) drinking water guidelines.

2.3 Elimination of Heavy Metals from Water Sources: Advanced Methods

Membrane filtration is particularly efficient in eliminating suspended particles, organic chemicals and inorganic pollutants like as heavy metals. The process is propelled by pressure differentials between the feed side and the permeate side, facilitating the separation of particles according to their size. Diverse membrane filtering methods are utilised based on the required particle size retention, including reverse osmosis (RO), forward osmosis (FO), ultrafiltration (UF) and microfiltration (MF) (Ayach et al., 2024). One of example of implementation of membrane filtration techniques is by Samaei et al. (2020), which use reverse Osmosis (RO) membrane has been used for treatment and purification of industrial wastewaters in Costerfield mining operations, Victoria, Australia. The results indicated that turbidity, total dissolved solids (TDS), Sb, As, Ni, Zn and Fe concentrations are diminished by 85%, 96%, 95%, 66%, 82%, 48% and 10%, respectively, in the final RO permeate. This indicates that the water quality analysis demonstrates the RO unit's effectiveness in enhancing the quality of the final permeate prior to release into surface waters.

Adsorption is an efficient and prevalent method for eliminating heavy metals from industrial effluent. It is a process wherein heavy metal ions are transported from the aqueous phase to the surface of a solid adsorbent. Adsorption may transpire via physical interactions (physisorption) or chemical bonds (chemisorption) between the adsorbent and the metal ions. Various adsorbents are employed for the extraction of heavy metals, encompassing natural materials, industrial by-products, agricultural residues and synthetic polymers (Gupta et al., 2021). Based on Ogidi et al. (2024), conduct a study about treatment of heavy metal such as Ni, Cd and Pb from oilfield wastewater in Niger Delta oilfields using coconut husk-based activated carbon that modified with oxide. The results indicate that the adsorption effectiveness was assessed by measuring the final concentration, revealing reductions of 93.59%, 99.01% and 96.38% for Ni, Cd and Pb respectively. The concentration levels diminished from 0.6121 to 0.039 for Ni, 0.9067 to 0.009 for Cd, and 2.9044 to 0.104

for Pb. The results of this study offer effective strategies to address the environmental challenges associated with heavy metal contamination in oilfield wastewater.

2.4 Natural Waste Material to Remove Heavy Metal Using Fruit Seeds Waste

Natural waste materials are the unwanted or unusable substance that often perceived as having no value. Fruit seeds are one of the examples of natural waste material that comes from agriculture products. It is abundantly available, economical, and require few simple processing. Fruit seeds can act as low cost and eco-friendly adsorbent of heavy metal. The removal of heavy metals from contaminated water using fruit seed waste presents a promising and sustainable approach. Various studies highlight the effectiveness of agricultural waste, particularly fruit seeds, as low-cost adsorbents for heavy metal ions (Tapia-Quiroz et al., 2025).

2.4.1 Rambutan Seed

Rambutan is a fruit that popular in Southeast Asia and was a local fruit in Malaysia. Rambutan seed in other hand was a waste product and it can be a potential adsorbent in removal of heavy metal which includes iron and manganese in drinking groundwater well in Kelantan, Malaysia (Eh Rak & Aweng Eh Rak, 2017). From this study, the result shows that Rambutan seeds can remove iron in groundwater sample by up to 91.38% with optimal dosage of 1/L and up to 90.91% manganese using dosage of 5mg/L. The percentage of heavy metal removal using rambutan was quite high, thus it can be a potential coagulant in water treatment.

Moreover, rambutan seeds exhibited a strong potential for the adsorption of cadmium (Cd) ions in aqueous solutions (Dewi & Dewata, 2019). The study found that the maximum removal capacity of the adsorbent was 14.25 mg/g at an optimal pH of 5. At a concentration of 250 ppm, the adsorption capacity was observed to be 7.14

mg/g. When using a particle size of 90 µm, the removal capacity increased to 13.481 mg/g. Additionally, with a contact time of 60 minutes and a stirring speed of 150 rpm, the removal efficiency reached a peak value of 15.9 mg/g. Besides, the FTIR showed result peak of -OH, CH and CO which contributing in interaction during absorption. This highlighted the effectiveness of rambutan seeds as a low-cost and efficient adsorbent for removing Cd from contaminated water sources, providing an eco-friendly solution for heavy metal and dye contamination in water treatment processes.

2.4.2 Date Seed

Mohsen & Ghanim (2024) performed a study examining the extraction of copper (Cu) and zinc (Zn) from industrial effluents utilising date pits as biosorbents. The date pits were pulverised into a powder and subjected to hydrogen peroxide (H2O2) treatment to augment their surface functionalities, specifically hydroxyl groups (-OH). The biosorption procedure utilised a fixed-bed column, with Fourier Transform Infrared Spectroscopy (FTIR) analysis verifying the active participation of functional groups such as -COO, -CO and -CH in the adsorption mechanism. The result showed that under defined conditions an initial heavy metal concentration of 60 ppm, pH 7, a temperature of 20°C and a flow rate of 8, the removal efficiency attained was 93.7% for Cu and 69.3% for Zn.

Osman et al. (2022), examined the extraction of Ni(II) ions from wastewater utilising date seed powder as an adsorbent. Powdered date seeds were incorporated into 50 mL of stock solution during batch trials and exposed to diverse operational parameters, such as stirring duration, adsorbent quantity, particle size and pH level. It showed that the ideal conditions include stirring duration of 29.15 minutes, particle size of 137.81 µm, adsorbent mass of 0.346 g and a pH of 12.04, the study achieved a nickel removal efficiency of 94.13%. The findings reported the efficacy of agricultural waste, specifically date seed powder, as a sustainable adsorbent for heavy metal remediation in wastewater treatment.

Even though previous research has demonstrated the efficiency of natural adsorbents, particularly fruit seeds, in removing heavy metals from water sources, studies focusing on the application of rambutan and date seeds as adsorbents for Pb, Cd and Ni ions are limited. Furthermore, there is a lack of comprehensive analysis characterising these seeds before and after adsorption and evaluating their adsorption efficiency under varying parameters such as metal ion concentrations, adsorbent dosage, contact time and temperature. This study aimed to address these gaps by characterizing rambutan and date seeds using FTIR, analysing their performance in removing heavy metals through FAAS and investigating the adsorption effectiveness under optimized conditions.

CHAPTER 3

METHODOLOGY

3.1 Chemicals and Reagents

The chemicals and reagents used in this study were analytical grades. Table 3.1 shows the list of chemicals and reagents used in the experiment.

Table 3.1. List of chemicals and reagents used in the study.

Chemicals/Reagents	**Brand**
Distilled Water	-
Deionized Water	-
Nitric Acid. HNO_3	HmbG® chemicals in Darmstadt, German
1000 mg/L Pb Stock Solution	MERCK KGaA, Germany
1000 mg/L Cd Stock Solution	MERCK KGaA, Germany
1000 mg/L Ni Stock Solution	MERCK KGaA, Germany

3.2 Apparatus

Table 3.2 shows the list of apparatus used in the study.

Table 3.2. List of apparatus

Apparatus	**Brands**
50 mL & 100 mL beaker	PYREX
50 mL volumetric flask	HmbG®, Germany
10 mL measuring cylinder	HmbG®, Germany
100 mL measuring cylinder	HmbG®, Germany
25 mL pipette	HmbG®, Germany
Micropipette	DRAGONLAB
Falcon tube (50 ml)	-
Filter paper (150 mm)	Smith Filter Papers
Filter funnel	-
Glass rod	-
Magnetic stirrer	-
Thermometer	G H ZEAL LTD - London - England
Aluminium foil	-
Mortar and Pestel	-
Dropper	-
Spatula	-

3.3 Instrumentation

In table 3 the instrumentation used in the experiment are listed.

Table 3.3. List of instrumentations used in the study

Instruments	Brands
Hot air oven	Labconco
Analytical balance	Sartorius
Hot plate	ERLA®
Flame Atomic Absorption Spectrometer	Perkin Elmer PinAAcle 900F
ATR-FTIR	Bruker ALPHA II
Fume hood	Memmert

3.4 Preparation of Aqueous Solutions

The aqueous solution of Pb, Cd, Ni were prepared from 1000 mg/L of stock solution of each metal. For the preparation of aqueous solution, 50 µL of Pb solution was pipetted from 1000 mg/L of Pb stock solution and diluted into a 50 mL volumetric flask to obtain 1 mg/L of Pb solution. The same steps were repeated for the preparation of Cd and Ni aqueous solutions. A 50 µL of Cd and Ni solutions were pipetted from 1000 mg/L Cr and Ni stock solutions, respectively. Then, it was diluted into a 50 mL volumetric flask to achieve 1 mg/L of Cd and Ni solutions. For 2 mg/L and 3 mg/L of metal ion solution, 100 µL and 150 µL was pipetted respectively from 1000 mg/L of each metal stock solution.

3.5 Preparation of Natural Adsorbent

The natural adsorbents used in this experiment were rambutan and date seeds. Rambutan and dates were purchased at the hypermarket near USM Kubang Kerian and were consumed first to be considered as waste prior to the removal process. The seeds were washed with tap water to remove any impurities adhering at the surface of seeds and then being rinsed with deionised water. Then, the adsorbents were dried in the hot air oven at 60°C overnight until constant weight achieved. After being dried, the adsorbents were grind using a blender until it became mesh powder as shown in Figures 3.1 and 3.2 for rambutan and date seeds powder respectively which it was filtered with filter size of 60 and being kept in the specimen container.

Figure 3.1. Rambutan seeds and in powder form.

Figure 3.2. Date seeds and in powder form.

3.6 Characterisation of natural waste adsorbents

The powder of rambutan and date seeds were analysed with ATR FTIR spectroscopy as shown in Figure 3.6, to characterise the surface of the adsorbents. This analysis was performed to determine the functional groups in rambutan and date seeds that acts to enhance the adsorption process. The FTIR absorbance data were collected between of wavenumber of 4000 to 600 cm^{-1}.

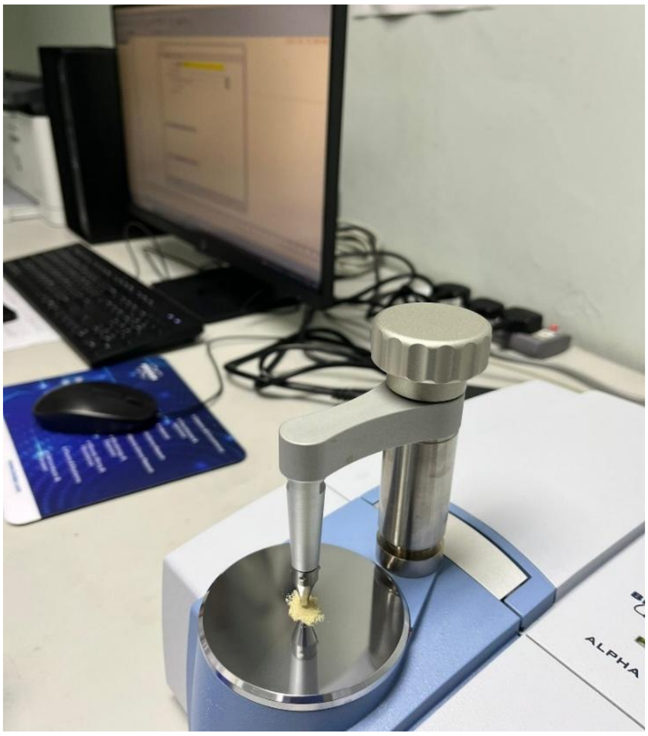

Figure 3. 3. Characterisation of adsorbent using ATR-FTIR.

3.7 Detection of Lead, Cadmium and Nickel in Rambutan and Date Seeds

Acid digestion was performed using concentrated nitric acid (HNO_3) for the screening of Pb, Cd, and Ni concentrations in rambutan and date seed powder samples. A 1.0 g sample of the powdered seeds was placed into a 50 mL beaker, and 10 mL of HNO_3 was added. The beakers were covered with watch glasses and heated on a hot plate