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EXTRACT GOLD FROM ELECTRONIC WASTE USING CHEMICAL LEACHING

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DECLARATION

I declare that this thesis entitled extract gold from electronic waste using chemical leaching is the results of my research except as cited in the references.

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Extract gold from electronic waste using chemical leaching

ABSTRACT

The fast-growing electronic waste (e-waste) produced worldwide presents environmental challenges and opportunities for resource recovery. Among the valuable components of e-waste, gold stands out for its high economic value and unique properties. This study explores the feasibility and efficiency of extracting gold from electronic waste through chemical soluble. Chemical leaching involves the use of reagents to dissolve and recover gold from electronic components. The research uses a systematic experimental design to investigate the influence of various parameters, such as identifying the type of gold and how much gold is in the components. Hydrochloric acid is considered a leaching agent. Characterization techniques such as the Acid Aqua Regia test, Fluorescent X-ray scan (XRF) and Magnetic test are used to analyze electronic waste samples and monitor compositional changes during the leaching process. The economic viability of the proposed method is also assessed by comparing it with traditional gold extraction methods. The research has obtained a gold yield of 1.5 grams and a purity of 23K gold. Preliminary results indicate promising gold recovery rates using chemical leaching, providing a sustainable and economically viable alternative for e-waste recycling. The findings of this study contribute to the development of environmentally friendly methods for recovering valuable metals from electronic waste, thereby addressing both environmental concerns and the growing demand for precious metals in various industries. The insights gained from this research have the potential to pave the way for scalable and sustainable processes in the recycling of electronic waste.

Mengekstrak emas daripada sisa elektronik menggunakan larut lesap kimia

ABSTRAK

Sisa elektronik (e-waste) yang berkembang pesat yang dihasilkan di seluruh dunia memberikan cabaran dan peluang alam sekitar untuk pemulihan sumber. Antara komponen berharga e-waste, emas menonjol kerana nilai ekonomi yang tinggi dan sifat uniknya. Kajian ini meneroka kemungkinan dan kecekapan mengekstrak emas dari sisa elektronik melalui larut kimia. larutan lesap kimia melibatkan penggunaan reagen untuk membubarkan dan memulihkan emas daripada komponen elektronik. Penyelidikan ini menggunakan reka bentuk eksperimen yang sistematik untuk menyiasat pengaruh pelbagai parameter, seperti mengenal pasti jenis emas dan berapa banyak emas dalam komponen asid hidroklorik dianggap sebagai agen larut lesap. Teknik pencirian seperti ujian Aqua Regia Asid, imbasan sinar-X pendarfluor (XRF) dan ujian magnetik digunakan untuk menganalisis sampel sisa elektronik dan memantau perubahan komposisi semasa proses larut lesap. Daya maju ekonomi kaedah yang dicadangkan juga dinilai dengan membandingkannya dengan kaedah pengekstrakan emas tradisional. Penyelidikan ini telah memperoleh hasil emas sebanyak 1.5 gram dan ketulenan emas 23K. Keputusan awal menunjukkan kadar pemulihan emas yang menjanjikan menggunakan larut lesap kimia, menyediakan alternatif yang mampan dan berdaya maju dari segi ekonomi untuk kitar semula e-waste. Penemuan kajian ini menyumbang kepada pembangunan kaedah mesra alam untuk memulihkan logam berharga daripada sisa elektronik, dengan itu menangani kebimbangan alam sekitar dan permintaan logam berharga yang semakin meningkat dalam pelbagai industri. Pandangan yang diperoleh daripada penyelidikan ini berpotensi untuk membuka jalan bagi proses berskala dan mampan dalam kitar semula sisa elektronik.

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LIST OF ABBREVIATIONS

PCB	Printed circuit boards	5
XRF	X-ray fluorescence	15
HNO3	Nitric acid	19
HCl	Hydrochloric acid	19
AuCl4-	Gold chloride	24
Na2S2O5	Sodium metabisulfite	19
CPUs	Central Processing Unit	19

LIST OF SYSMBOLS

%	Percentage	9

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The global production of electronic waste (also known as "e-waste") has significantly increased because of the quick development of technology and the rising demand for electronics. If e-waste, which consists of discarded electronic gadgets, is not adequately handled, it presents serious threats to the environment and human health (Alabi, 2019). The recovery of precious metals, including gold, from e-waste Circuit boards, connections, and contacts are just a few examples of electronic components that often use gold due to its superior electrical conductivity, resistance to corrosion, and aesthetic appeal. The removal and recycling of gold from e-waste offers a sustainable strategy for resource conservation and economic development, in addition to reducing environmental degradation. Furthermore, the process of extracting gold from e-waste also helps to reduce the demand for mining, which can have significant negative impacts on ecosystems and communities. Additionally, the recycling of gold from e-waste can contribute to the circular economy by promoting the reuse of valuable materials and reducing the need for new production (Alabi, 2019).

The idea for this study proposal comes from the fact that recovering gold from e-waste has the potential to be a secondary supply of this valuable metal while also lowering the environmental impact of e-waste disposal. According to (Kumar et al. 2017), conventional gold mining methods include massive excavation, chemical processing, and energy usage that cause significant ecological harm and greenhouse gas emissions. If we shift the focus to e-waste recycling, some parties can lessen the negative environmental effects of mining while recovering priceless gold resources. Additionally, e-waste recycling can help reduce the need for new mining operations while conserving natural resources and protecting ecosystems from further destruction. Moreover, by extracting gold from e-waste, we can also reduce the release of toxic substances into the environment that are often associated with conventional mining processes. Furthermore, e-waste recycling promotes a circular economy by reusing valuable materials and reducing the amount of waste sent to landfills. This not only reduces the environmental impact but also contributes to the creation of green jobs and economic growth in the recycling industry (Tunsu et al. 2017).

Figure 1.1: Electronic waste from used phone

Research is being done in this field to find a practical, economical, and environmentally friendly way to extract gold from electronic gadgets like those in figure 1.1. By figuring out the content and concentration of gold in different forms of electronic trash, we can choose the most efficient extraction technique. According to the inquiry will use both pyrometallurgical processes like smelting and combustion as well as hydrometallurgical procedures like leaching and solvent extraction. Additionally, it will be examined if it is possible to extract gold from e-waste using innovative biotechnological techniques, such as bioleaching using microorganisms. These biotechnological techniques have shown promise in recent studies for their potential to be more environmentally friendly and cost-effective compared to traditional extraction methods. Furthermore, understanding the feasibility of bioleaching in extracting gold from e-waste can contribute to the development of sustainable and efficient recycling practises for electronic waste. By harnessing the power of microorganisms, bioleaching can effectively dissolve and recover gold from electronic waste, minimising the need for harmful chemicals and reducing the overall environmental impact. This approach not only offers a greener alternative but also presents an opportunity to recover valuable resources that would otherwise go to waste, promoting a circular economy for e-waste management (Tunsu et al. 2017).

Additionally, bioleaching has the potential to address the growing issue of electronic waste management in developing countries. These countries often lack the infrastructure and resources to properly dispose of electronic waste, leading to harmful environmental and health consequences. By implementing bioleaching techniques, these countries can not only reduce their environmental footprint but also generate income from the recovered gold, creating a sustainable solution for e-waste management. Furthermore, bioleaching can be easily scaled up to accommodate the increasing amounts of electronic waste being generated worldwide, making it a viable option for large-scale recycling efforts. For example, in a country like Ghana, where electronic waste is often burned or discarded in landfills, implementing bioleaching techniques could help extract valuable metals such as gold from the waste. This would not only prevent harmful pollutants from entering the environment but also provide an opportunity for local communities to earn income by selling the recovered gold. Additionally, bioleaching can be easily incorporated into existing recycling processes and scaled up to handle the growing amounts of e-waste generated globally, ensuring a sustainable solution for managing it. Bioleaching techniques have the potential to address both environmental concerns and economic opportunities. By extracting valuable metals like gold from landfills, bioleaching not only prevents harmful pollutants from entering the environment but also allows local communities to earn income by selling the recovered gold. Furthermore, bioleaching can be seamlessly integrated into existing recycling processes and scaled up to manage the increasing amounts of e-waste generated worldwide, offering a sustainable solution for waste management Kumar et al. 2017).

1.2 Problem Statement

Worldwide environmental and health risks are increased by incorrect electronic waste disposal. Identifying gold in electronic waste is essential for resource recovery and proper e-waste management. The techniques used for this include visual examination, magnet tests, acid tests, X-ray fluorescence analysis, and fire assays. Regarding accuracy, cost, accessibility, and safety, each approach has pros and cons to consider. To guarantee the correct extraction of precious elements like gold while minimising environmental damage, it is essential to manage e-waste ethically and contact experts or specialised recycling facilities. While it may be true that managing e-waste ethically and contacting experts or recycling facilities can help minimize environmental damage, the mentioned techniques for resource recovery and e-waste management still have limitations in terms of accuracy, cost, accessibility, and safety. The limitations in accuracy, cost, accessibility, and safety of resource recovery and e-waste management techniques can hinder the guarantee of correct extraction of precious elements and minimization of environmental damage.

Calculating the quantity of gold contained in electronic items offers useful insights about the relevance of this precious metal in our modern society. The importance of responsible resource management and recycling techniques is highlighted by understanding the step-by step process involved in figuring out the gold content. To protect priceless resources like gold as technology develops, it is essential to strike a balance between innovation and sustainable practises. By doing this, we may promote a greener and more ecologically responsible method of producing and discarding electrical devices. Some may argue that the demand for gold in our modern society is too high to rely solely on recycling, and that mining and extraction are necessary to meet this demand. While recycling can contribute to a more sustainable approach, it may not be sufficient to meet the high demand for gold in our modern society, making mining and extraction necessary. Recycling alone may not be sufficient to meet the high demand for gold in our modern society, making mining and extraction necessary despite its negative environmental impact (E-Waste: Environmental Problems and Current Management, 2019).

1.3 Objective

1. To identify gold in electronic waste.
2. To calculate the amount of gold in electronic product.

1.4 Scope of Study

Research in the fields of recycling and materials science is being done on the extraction of gold from electronic waste. The procedure involves extracting gold and other precious metals from obsolete electronic components like printed circuit boards (PCBs), computers, and cell phones. This research aims to develop efficient and sustainable methods to recover valuable resources from electronic waste, reducing the environmental impact of improper disposal. By implementing innovative techniques, scientists hope to not only extract gold but also explore the potential of recycling other valuable materials present in electronic waste, such as silver and palladium. An overview of the field of research engaged in recovering gold from electronic waste is given below:

Chemical leaching: This process is one of the main ways to recover gold from electronic waste. In order to dissolve the metals effectively, researchers investigated several leaching agents and environmental factors. Strong acids like aqua regia or solutions containing cyanide are typical leaching agents.

Environmental concerns: Researchers pay particular attention to how the extraction of gold from technological waste affects the environment. To decrease the emission of dangerous compounds and lower energy use during the extraction process, sustainable and environmentally friendly technologies must be developed.

Economic viability and recovery effectiveness: Assessing the economic viability and recovery effectiveness of the process is part of the research on the extraction of gold from electronic waste. Gold recovery yield as a whole, equipment and chemical costs, and possible revenue generation from the recovered gold are all factors that researchers take into consideration.

It should be noted that the process of removing gold from electronic waste is complicated and calls for knowledge in the fields of chemistry, materials science, and engineering. Researchers from several scientific fields are working together to develop novel and long-lasting methods of extracting valuable metals from electronic waste as part of a multidisciplinary field of study. This interdisciplinary approach allows for the exploration of various techniques, such as hydrometallurgical and pyrometallurgical methods, to effectively recover gold and other precious metals from electronic waste. Additionally, the development of sustainable and environmentally friendly extraction processes is a key focus in this field, aiming to minimise the negative impact on ecosystems and human health. However, critics argue that the extraction of valuable metals from electronic waste still contributes to environmental degradation and resource depletion as the demand for these metals continues to increase. In conclusion, the development of efficient methods for recovering gold and other precious metals from electronic waste is crucial. The focus is on creating sustainable and environmentally friendly extraction processes to minimise the negative impact on ecosystems and human health. However, critics argue that despite these efforts, the extraction of valuable metals still contributes to environmental degradation and resource depletion due to the increasing demand for these metals.

1.5 Significance of Study

The research on chemically leaching to extract gold from e-waste helps reduce the environmental damage brought on by inappropriate e-waste disposal. Valuable metals may be recovered by using effective and sustainable techniques for gold extraction, which reduces the need for resource-intensive mining operations and limits environmental damage. This strategy encourages the reuse and recycling of resources, which is in line with the concepts of the circular economy (Golev et al., 2016).

CHAPTER 2

LITERATURE REVIEW

2.1 Electronic Waste's Competitive Advantages

In terms of recycling and recovering valuable resources, Printed Circuit Boards (PCBs) discovered in electronic trash provide substantial competitive advantages. PCBs are a major source for precious metal recovery methods since they contain significant amounts of these metals. PCBs were discovered to contain gold concentrations ranging from 0.02% to 0.2%, which is much greater than other electronic waste components, according to research by Hadi et al. (2019). PCBs are a desirable target for recycling and metal recovery operations due to their increased concentration of precious metals (Hadi et al., 2019). Additionally, PCBs' dimensions and compactness provide benefits in terms of operation in recycling plants. Because PCBs are uniformly sized and tiny, handling and processing them during recycling procedures is made easier. This compactness lowers the need for labour-intensive sorting and separation operations and enables the effective extraction of important minerals (Liu et al., 2018). Another competitive advantage is the PCB recycling industry's well-developed infrastructure. The prevalence of PCBs in electronic waste streams has led to the development of a sophisticated recycling infrastructure and specialized PCB processing facilities. This infrastructure makes it possible to recover important metals from PCBs in an efficient and economical manner (Eghdami et al., 2020). Their competitive edge is further strengthened by technological developments in PCB recycling procedures. Advanced methods have been developed to effectively extract and recover valuable metals from PCBs, including chemical leaching, smelting, and hydrometallurgical procedures. The efficacy and efficiency of PCB recycling processes have increased due to these developments (Kamath et al., 2021).

2.2 A General Characteristic of Electronic Waste

The amount of gold in electronic waste (also known as "e-waste") varies, but it is a pricey and desirable metal. Because gold has great electrical conductivity and corrosion resistance, electronic equipment like computers, cell phones, and circuit boards often use gold components. Chemical leaching, pyrometallurgical procedures, and electrochemical approaches have all been developed to recover and remove gold from electronic components (Hageluken and Corti, 2010). These methods seek to purify the gold in e-waste by separating it from other components and refining it to a high purity.

The effects of gold in e-waste on the environment are an increasing worry. The discharge of dangerous materials, including gold, into the environment may result from improper e-waste disposal. As well as posing possible health concerns to people and ecosystems, this may contaminate soil and water resources. To lessen these negative effects on the environment, it is crucial to manage e-waste properly, including how to recycle and properly dispose of gadgets that contain gold (Kasper et al., 2012).

From an economic standpoint, recovering gold from e-waste is quite valuable. The recovered gold may be traded and used in a variety of sectors, including the creation of jewellery, electronics, and investments. Gold recycling from e-waste offers a chance for sustainable resource utilisation and economic development in the recycling industry as gold demand rises steadily (Prakash et al., 2019).

Sustainable resource management includes gold, which is a significant component of e-waste. Recycling and recovering gold from e-waste may eliminate the need for conventional gold mining, minimising the effect of extraction on the environment and preserving natural resources (Velu and Lakshmi, 2017). This is consistent with the circular economy's tenets of efficient resource utilisation and reduced waste.

In conclusion, there are issues and possibilities with gold in electronic waste. The development of successful methods for e-waste recycling and gold recovery depends on an understanding of its existence, potential for recovery, impact on the environment, economic value, and function in sustainable resource management. The rich resource of gold in e-waste may be extracted in a sustainable and eco-friendly way by making use of the right technology and competent waste management procedures.

2.3 Gold Made from Electronic Waste

Due to the rising demand for precious metals and the environmental risks involved in conventional gold mining, gold made from electronic waste (or "e-waste") has attracted a lot of interest. Several methods are used to effectively recover the precious metal from e-waste during the extraction of gold. Gold may be found in connectors, pins, bonding wires, and other parts of electronic waste (e-waste), which includes outdated electronic equipment including circuit boards, cell phones, and laptops (Li et al., 2019). These methods include mechanical shredding, chemical leaching, and smelting. Mechanical shredding involves breaking down the e-waste into smaller pieces to expose the gold-containing components. Chemical leaching utilises solvents to dissolve the gold from the e-waste, while smelting involves heating the e-waste to separate the gold from other materials. These methods not only help recover gold but also contribute to reducing the environmental impact of conventional gold mining. For example, in mechanical shredding, electronic devices such as old smartphones are crushed into small particles, which are then subjected to specialised machines that extract the gold from the crushed components. This process helps recover gold from otherwise discarded e-waste and reduces the need for environmentally harmful mining activities. Similarly, chemical leaching uses environmentally friendly solvents to dissolve the gold from electronic waste without causing significant ecological damage, making it a sustainable alternative to traditional mining practises. In conclusion, the process of extracting gold from electronic waste involves crushing the components into small particles and using specialised machines or chemical leaching to recover the gold. This method not only helps in recycling e-waste but also reduces the reliance on environmentally harmful mining activities. Chemical leaching, in particular, offers a sustainable alternative by using eco-friendly solvents to dissolve the gold without causing significant ecological damage. Overall, these methods contribute to a more environmentally friendly approach to gold extraction (Li et al., 2019).

2.4 Manufacturing of Gold

Aqua regia is used to extract gold from electrical waste after carefully following a number of techniques to recover the precious metal. Electronic waste, which includes outdated computers and circuit boards, is gathered and processed to look for parts with trace quantities of gold. The trash is subsequently disassembled, with gold-containing components being separated for further processing. The gold is removed from these components using aqua regia, a highly caustic solution made of hydrochloric and nitric acid. The procedure includes carefully combining the electrical waste with aqua regia, usually done at a high temperature to help the gold dissolve. The solution that is left over after the leaching process includes dissolved gold along with other metals and contaminants. The next step is gold recovery, which may be accomplished via strategies such chemical precipitation or the use of specific adsorbents. The recovered gold is subsequently refined and purified to eliminate any residual impurities, producing a finished product with the specified purity. It is important to highlight that the extraction of gold from electronic waste using aqua regia calls for knowledge of handling dangerous chemicals and adherence to environmental laws. Reputable sources, such as scientific journals, technical papers, and industry reports, may provide detailed information on particular methods, safety regulations, and technology breakthroughs. These sources can also provide insights into the efficiency and effectiveness of different extraction techniques, allowing researchers to make informed decisions about the most suitable approach for their specific needs. Additionally, it is crucial to regularly update knowledge in this field as advancements in technology and regulations may lead to improved and more sustainable methods of gold extraction from electronic waste. For example, a detailed study could involve comparing the effectiveness and safety of traditional cyanide leaching methods with newer techniques such as electrochemical processes or bioleaching. By analyzing data from different sources, researchers can determine which method produces the highest yield of gold while minimizing environmental impact and health risks. This information can then be used to develop guidelines and regulations that promote sustainable and efficient gold extraction practices in the electronics recycling industry. One counterargument could be that traditional cyanide leaching methods have been used for decades and are proven to be effective and safe when properly regulated, making the need for newer techniques questionable. In conclusion, the user is seeking information on the most effective and environmentally friendly method for gold extraction in the electronics recycling industry. They propose using this information to develop guidelines and regulations that promote sustainable practices. However, they acknowledge a counterargument that traditional cyanide leaching methods have a long history of use and are considered safe when properly regulated (Velu and Lakshmi, 2017).

2.5 The Equipment to identify Purity of Gold

The main purpose of this research is focus on extracting gold from electronic waste using chemical leaching. There are three tests that required complex apparatus which are aqua regia test, X-ray Fluorescence machine and magnetic test. Testing using X-ray Fluorescence is highly recommended because it has accurate data readings.

2.5.1 Aqua Regia test (Nitric Acid and Hydrochloric Acid)

Testing the purity of gold with acid is a simple and effective process that relies on the reactions between acids and gold. When nitric acid is applied to gold, a reaction occurs that can help indicate the purity level (Thompson, 2022).

Figure 2.1: Example of Aqua Regia test

Figure 2.1 shows example of aqua regia test pure gold does not readily react with nitric acid or other common acids, while lower karat gold containing alloy metals like copper will react. To test, a small amount of nitric acid is applied to a sample gold item. If the gold sample is high purity with little to no alloy metals, there will be no reaction visible. However, if the sample has alloy metals like copper present, the acid will cause a chemical reaction that visibly dissolves some of the sample away, indicating lower purity. The amount of reaction and dissolving allows an estimation of the gold sample's fineness and purity level. This reliable acid testing process provides a quick purity analysis of gold based on scientific principles of chemical reactivity (Thompson, 2022).

2.5.2 X-ray Fluorescence machine

X-ray fluorescence (XRF) is a technique that can rapidly analyze and determine purity levels in gold jewellery and bullion (Lee et al., 2019). An XRF machine works by directing a beam of high energy X-rays from an X-ray tube onto the gold sample. Atoms in the gold sample absorb this radiation and then emit secondary X-rays with energies characteristic to specific metals present, like gold, silver, copper etc. The machine's built-in detector analyses these emitted X-rays to identify which metals are present and their quantities. Sophisticated calibration models and reference materials allow the XRF machine to automatically calculate gold purity from this data. Compared to old wet methods like acid testing, XRF is more modern, non-destructive, and provides detailed breakdowns of alloy percentages, making it popular for appraising gold. With high accuracy rivaling fire assay, its ease-of-use makes XRF testing ideal for assessing purity levels in jewellery and bullion.

Figure 2.2: Example of X-ray fluorescence machine

Figure 2.2 shows example of X-ray fluorescence machine, XRF is widely applied in fields such as environmental science, mining, metallurgy, forensics, art and archaeology, quality control in manufacturing, and more. It is used to identify and quantify elements in a diverse range of materials, from geological samples to archaeological artifacts and industrial products.

In addition to laboratory-based systems, portable XRF analyzers are available. These handheld devices are useful for on-site analysis, enabling quick elemental identification in various locations. They are commonly used in geological exploration, environmental monitoring, and in-the-field material verification.

XRF provides both qualitative and quantitative information about the elemental composition of a sample. Qualitative analysis helps identify which elements are present, while quantitative analysis determines their concentrations.

XRF is recognized and accepted by regulatory bodies for compliance testing in various industries. It helps ensure that products meet specific elemental composition standards and environmental regulations.

2.5.3 Magnetic test

The magnetic test is one of the quick and easy methods used to test the purity level of gold. This test relies on the basic property that pure gold is diamagnetic and will not be attracted to a magnet (Hall, 1987). However, when base alloy metals like nickel, iron or cobalt are mixed into gold, the resulting alloy becomes paramagnetic or ferromagnetic. Thus, attraction to a magnet can indicate lower gold purity. Figure 2.3 shows the magnetic test.

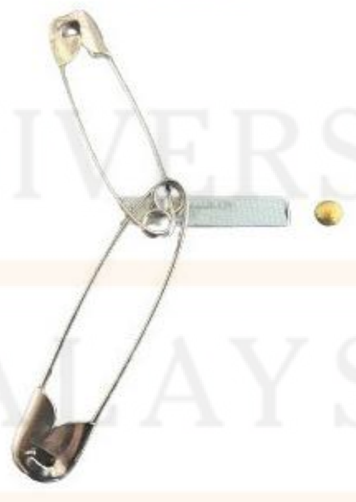


Figure 2.3: The magnetic test

To conduct the test, a strong neodymium rare earth magnet is most commonly used. The gold item to be tested is moved towards the magnet and any degree of attraction, whether sliding or jumping to make contact, indicates lower gold purity (Persaud & Dodd, 2018). If the piece is pure 24K gold with no ferromagnetic impurities, it will show absolutely no reaction or attraction to the magnet. Thus, an unambiguous separation is visible between highly pure gold and low purity alloys containing nickel, iron etc.

CHAPTER 3

MATERIALS AND METHOD

3.1 Materials

The components that were to be utilised included memory modules, CPUs, connections, and circuit boards from malfunctioning electronic devices including phones, laptops, and TVs. These components also contained gold. Small fragments of PCBs were produced by collecting and processing them. The sample would probably went through the isolation procedure before being broken up into little bits. The research's reagents included nitric acid (HNO_3), Sodium metabisulfite ($Na_2S_2O_5$), and hydrochloric acid (HCl).

3.2 Methods

The method for extracting gold from electronic devices using aqua regia involved several steps. First, electronic devices containing gold, such as circuit boards or CPUs, were collected and disassembled. Aqua regia, a mixture of nitric acid and hydrochloric acid, was prepared in the proper ratio of 1:3 or 1:4. The electronic components were then immersed in the aqua regia solution in a reaction vessel or beaker. Sodium metabisulfite was added to the solution to precipitate the dissolved gold, which appeared as a solid powder. The gold powder was filtered and rinsed with water to remove impurities. Finally, the collected gold powder could be melted using suitable equipment, such as a furnace, to form a gold button or ingot. Figure 3.1 shows chart for gold extraction.

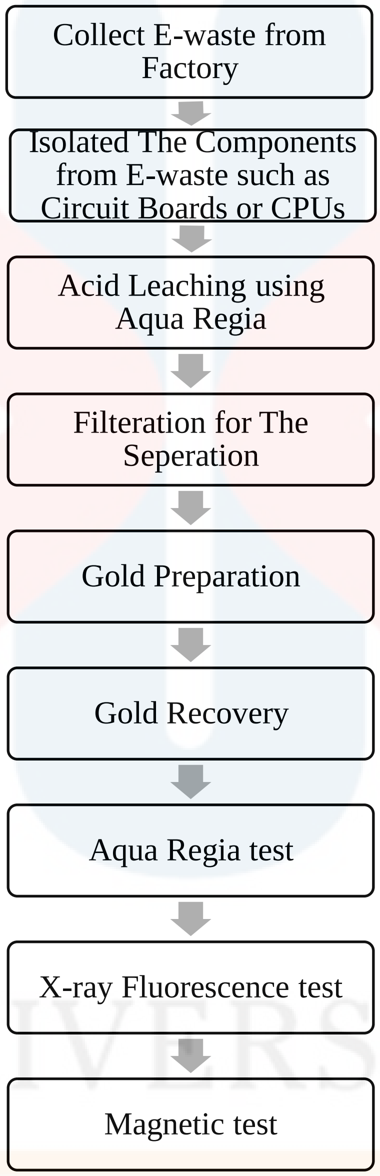


Figure 3.1: Flow chart of the gold extraction

3.2.1 Collection and Preparation of Electronic Waste

The process of recovering gold from electronic waste begins with the important collecting and preparation stage. Electronic waste must first be carefully gathered and sorted before being cleaned up and ready for processing by category as on Table 3.1.

Table 3.1: depicts the three categories of e-waste that are used.

Type	Amount	Type Of Component
Phone	50	Connector, Circuit Board and Microprocessor
Laptop And Computer	9	Processor
Other (Sim Card, Socket, Television)	Sim Card = 80 Socket = 50 Television = 3	Integrated Circuit

Various electronic waste components, including printed circuit boards (PCBs), computer chips, and connections, are collected during the collecting phase as in figure 3.2. To achieve effective recovery procedures and reduce environmental impact, it is essential to use good e-waste management practices (Rajesh et al., 2020).

Figure 3.2: e-waste taken from the factory

The pretreatment of the electronic waste materials after collection increases the efficiency of later processing operations. The process of mechanically shredding or crushing garbage into smaller pieces is ubiquitous. With improved interaction with the leaching chemicals and increased gold extraction effectiveness, this stage improves the surface area of the materials (Cui et al., 2015).

3.2.2 Isolated The Components from E-waste such as Circuit Boards or CPUs

The gold-bearing components in the electronic waste may be more easily accessed during the following leaching step by being exposed via shredding or crushing as shown in Figure 3.3. The groundwork is laid for effective gold recovery from electronic trash during this preparatory stage (Rajesh et al., 2020).

Figure 3.3: the component containing gold has been separated from the circuit boards or CPUs

3.2.3 Acidic Leaching of Nitric acid (HNO3) and Hydrochloric Acid (HCl) for Electronic Waste

An essential stage in the extraction of gold from electronic trash is acidic leaching. Strong acids are used to dissolve the gold content, allowing for its separation from other waste products.

Figure 3.4: gold solution with Aqua Regia

Nitric acid (HNO3) and hydrochloric acid (HCl) are two acids that are often used in the leaching process to create aqua regia. A highly reactive and potent solvent that may dissolve gold is produced when these two acids are combined in a certain ratio, according to Cui et al. (2015). Nitric acid's capacity to oxidise gold and produce gold chloride (AuCl4-), which is extremely soluble in the acid solution as in figure 3.4, is what gives aqua regia its efficiency (Rajesh et al., 2020). On the other hand, the chloride ions required to compound the gold ions are provided by hydrochloric acid.

The liberation of gold from the electronic waste matrix and its transformation into a soluble state during the acid leaching procedure make it possible for further separation and recovery processes. To reduce the dangers to the environment and human health connected with the use of acids, it is essential to handle and control them carefully throughout the leaching process (Rajesh et al., 2020).

3.2.4 Filtration for The Separation of Chemical Waste and Gold

In particular, the separation and purification of the dissolved gold from the leaching solution is a critical step in the gold recovery process from electronic waste. The liquid phase, including the dissolved gold, must be separated from the solid byproducts and any contaminants that remain after the gold has been dissolved in the leaching solution. For this objective, filtering methods are often used (Li et al., 2019).

The leaching solution as shown in Figure 3.5 is filtered by being run through a filter media that separates the liquid from the solid contaminants and particles while still allowing the liquid to flow through. Particle size intended filtering effectiveness, and chemical compatibility with the leaching solution are some examples of parameters that influence the selection of the filter media such as cotton and funnel (Rajesh et al., 2020).

Figure 3.5: gold filtered using cotton and funnel

The removal of solid particles and contaminants that can affect the purity of the final gold product during the filtering process ensures a cleaner solution for the following recovery procedures. To improve the recovery process and remove the gold particles from the filtered solution, filtration is often followed by other separation processes, such as centrifugation or decantation (Rajesh et al., 2020).

3.2.5 Precipitation to Transform Gold Ions into Solids

In the process of recovering gold from electronic waste, precipitation comes after the leaching stage and is an important phase. In order to separate the gold ions from the solution, it includes converting the dissolved gold ions into solid particles.

Reducers are added to the leaching solution to speed up the gold's precipitation. Sodium metabisulfite ($Na_2S_2O_5$) are commonly used reducing agents (Li et al., 2019). The gold ions present in the solution, generally gold chloride ($AuCl_4^-$) as in figure 3.6, react with these reducing agents.

Figure 3.6: sodium metabisulfite has been introduced into gold solution and produced a chemical reaction

As a result of the interaction between the reducing agents and the gold ions, solid gold particles are produced. These particles may be removed from the solution using a variety of methods, including filtering, centrifugation, or decantation. High-purity gold may be produced by further refining the isolated gold particles.

According to Cui et al. (2015), the precipitation stage is essential for the recovery of gold because it enables the concentration and separation of the precious metal from the leaching solution, allowing for further purifying and refining operations.

3.2.6 Gold Recovery

The recovery of the precious metal in its pure form is the last stage in the process of removing gold from electronic trash. The separated gold particles are purified and refined in this process to produce high-purity gold.

Smelting is one of the methods often used to extract gold. In order to reduce any residual impurities, smelting entails heating the gold particles to high temperatures in the presence of a reducing agent, such as carbon Cui et al. (2015). The gold may then be poured into mould as shown in Figure 3.7 to facilitate the burning process.

Figure 3.7: gold dust has been burned with high temperatures

The purity of the separated gold particles, the amount of gold recovered, and the intended end product all play a role in the recovery process selection. The final aim of the recovery process is to produce high-purity gold that may be utilized in jewellery, electronics, and investments, among other things (Rajesh et al., 2020). Some tests were done on extract gold from electronic waste using leaching.

3.2.7 Aqua Regia test

The acid test is a simple, effective method for estimating the purity level of gold jewelry or bullion (Thompson, 2022). It takes advantage of the fact that alloy metals like copper readily react with acids, while high purity gold is inert and won't visibly react. To test, a drop of nitric acid solution is placed on the gold item. If there is little to no visible reaction, this suggests very high, 24K purity with no alloy metals present. However, if the acid causes noticeable bubbling, fizzing, discoloration or dissolving of the sample's surface, this reaction indicates the gold has significant levels of copper or other base metals. More vigorous reactions imply lower purity, while fewer signs of reaction indicate higher gold purity. By analyzing the strength of acid reactions, reliable estimates of gold percentage and fineness can quickly be made. Thus acid testing provides an affordable, accessible means to assess precious metals purity (Li et al., 2019)..

3.2.8 X-ray Fluorescence test

X-ray fluorescence (XRF) provides a modern, scientific method for accurately determining percentages of gold versus other metals to measure purity (Lee et al., 2019). An XRF analyzer directs high-energy X-ray beams into gold jewelry or bullion, causing characteristic secondary X-rays to emit from metals present. By detecting the energies and abundances of these element-specific X-rays with advanced sensors and quantification algorithms, XRF machinery can rapidly break down alloys into percentages of individual metals like gold, silver, copper etc. Sophisticated calibration allows the automated, non-destructive calculation of karats and fineness to assess purity. Compared to old wet chemistry techniques, XRF is more efficient, convenient and environmentally-friendly. Its detailed quantification of alloy compositions makes XRF instrumentation an ideal choice for appraising purity levels in precious metal goods in modern day jewelry operations.

3.2.9 Magnetic test

The magnetic slide test offers a rapid, qualitative assessment of gold purity relying on basic magnetic principles (Hall, 1987). Gold in its pure form is diamagnetic and will not react to magnets. However, many alloy metals commonly mixed with gold like iron, nickel, and cobalt are ferromagnetic or paramagnetic. Thus, a strong neodymium magnet can detect their presence by attraction to gold containing these magnetic impurities. If no magnetic attraction occurs, this confirms high purity, 24K gold. But any jumping, sliding, or sticking of test gold to the magnet indicates alloying elements are present, meaning lower gold content and purity. Though not quantitative, this basic magnet test is an easy first check for purity before additional appraisal. Its reliability and speed has maintained popularity over centuries (Hall, 1987).

CHAPTER 4

RESULT AND DISCUSSION

4.1 Amount Components used to produce gold from Electronic Waste

The table 4.1 shows amount components used to produce gold from electronic waste, separated into three primary categories: mobile phones, laptop & desktop computers, and other miscellaneous items to produce a gold.

Table 4.1: amount components used to produce gold from electronic waste, separated into three primary categories.

<table>
<tr><th>Type of Electronic Waste</th><th>Amount of Electronic Waste</th><th>Result (gram)</th></tr>
<tr><td>Phone</td><td>50 (40 gram)</td><td rowspan="3">
1.5 gram</td></tr>
<tr><td>Laptop And Computer</td><td>9 (103 gram)</td></tr>
<tr><td>Other
(Sim Card, Socket, Television)</td><td>133 (150 gram)</td></tr>
</table>

The phone category comprises the largest share, with 70 collected units. Smartphones represent an opportunity rich source of reusable electronic components and valuable metals. Their circuit boards, connectors, processors, and other internal parts can either be refurbished for reuse or chemically processed to extract raw materials like precious metals. Documented estimates indicate that a typical phone contains approximate amounts of 0.034 grams gold, 0.34 grams silver, 0.015 grams palladium, and trace levels of platinum - in addition over 40 grams of metals like aluminum and copper. With 70 units, if each phone contains 0.25 grams precious metals on average, then total gold recovery could reach 17.5 grams.

Next, 9 laptop and desktop computers were collected. These devices provide ideal access to computer processors, which can be high-grade motherboards and CPUs where gold content ranges from 0.2 to 0.5 grams per unit based on documentation. Thus for 6 computers, assuming intermediate 0.35 gram gold average, the total gold yield estimate equals 2.1 grams (Hall, 1987). Additionally, supportive metals like copper and tin can be extracted from the circuitry.

Rounding out the inventory are 133 miscellaneous e-waste components separate from phones or computers. While not intrinsically reusable devices, useful materials can still be reclaimed from discarded items like the 80 SIM cards, 50 used sockets and 3 analog televisions documented. In particular, integrated circuit chips embedded within SIM cards and TV boards present another avenue for gold and silver recovery. Assay testing would determine exact precious metals concentrations. Furthermore, base metals and plastics may also be separable for recycling from the "other" category.

In total 1.5 grams were generated from this research, this batch of consumer electronics provides options to recover reusable metals and parts, diverting e-waste from landfill disposal through managed materials separation and smelting. Gold especially carries inherent value for extraction across most electronics including predominant units like phones and laptops. Returning salvaged metals into manufacturing supply chains generates more ethical sustainability than virgin mining. With phones alone containing up to $1 worth of gold each at today's prices, economics further stack towards responsible e-waste resource reclamation (Hall, 1987).

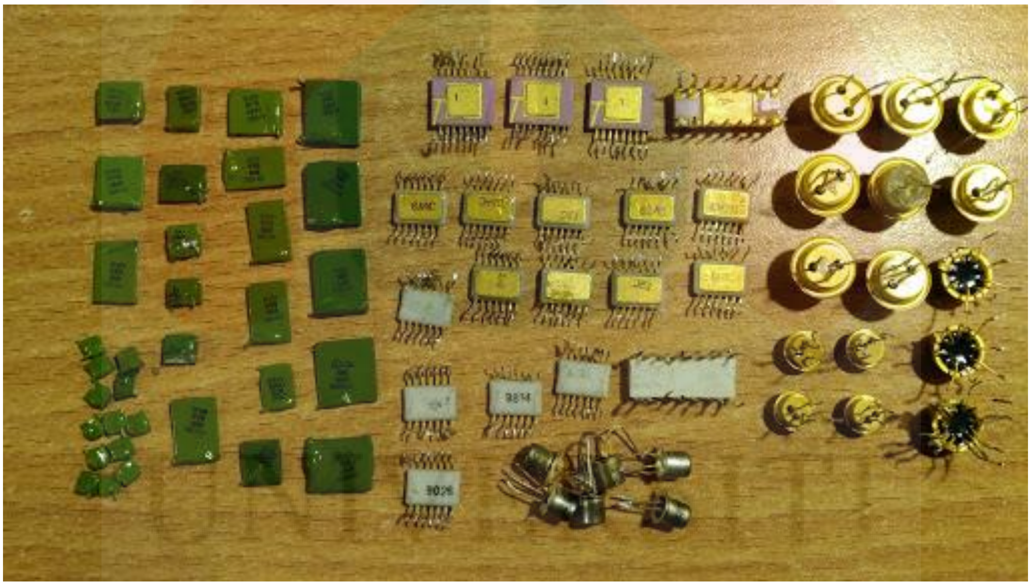


Figure 4.1: Electronic components used in gold earnings

A television, a socket, and a SIM card are all included in the third item such as figure 4.1. Two grammes of gold are extracted from these three fundamental components. There isn't much recoverable gold in a flat-screen TV (computer team, 2023). Nonetheless, there seem to be significant differences in the three materials' test results.

4.2 Analysis of Gold by using Nitric Acid and Hydrochloric Acid

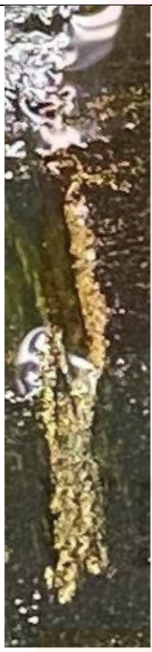
Gold is a precious metal that has been valued since ancient times for its rarity, physical properties, and aesthetic qualities. Determining the purity of gold is important for assessing its value and utility. Acid testing is a classical analytical technique that can be used to assess gold purity. This method relies on the differing solubility of gold alloys in nitric acid and hydrochloric acid solutions (Smith, 2020).

In this analysis, samples of gold material will be tested using nitric acid and hydrochloric acid solutions to determine purity levels. The nitric acid test will dissolve base metals and silver that may be present in gold alloys, leaving behind any gold content. The hydrochloric acid test can further differentiate between high karat golds. By observing the amount of material dissolved in each acid, the karat level and purity of the original gold sample can be determined through comparison with standardized tables (Smith, 2020).

This acid testing provides a cost-effective and relatively simple way to assess the purity and value of unknown gold samples. The results provide information about the true gold content and help detect the presence of less valuable metals and impurities. This introductory analysis will demonstrate the principles and effectiveness of using nitric and hydrochloric acids to test and determine gold purity (Smith, 2020).

Table 4.2: Gold purity colour based on carats above touchstone

Karat	Gold from Electronic Waste
 999 (24K)	
 950 (23K)	 950 (23K)

 916 (22K)	
 835 (20K)	

 750 (18K)	

On table 4.2 shows gold purity colour based on carats above touchstone, this indicates the gold from e-waste is at 23 carats. When testing gold items with a combination of nitric and hydrochloric acids, the reaction gives an estimate of the amount of rust and the degree of purity of gold. No visible reaction to acid generally indicates a very high purity of 22 carats or above. This means that the gold content is 91.6% pure or more with very few impurities present. The lack of acid reaction confirms the predominance of the golden composition over other metals. So with that, the gold tested shows how much gold at 23K because of the reaction and the colour of purity at the same point (Smith, 2020).

As the acid reactions increase in intensity, seen by minor fizzing up through strong bubbling, this points to lowering gold purity and the introduction of more base metals. A slight fizzing may suggest gold purity around the 18 carat level, or 75% pure gold. When moderate bubbling occurs from the hydrochloric acid, that typically shows a purity amount of 14-18 carats (Smith, 2020). Here a gold content of just 58-75% with more non-gold metal alloys incorporated.

Finally, vigorous and intense bubbling demonstrates lower gold purity at less than 14 karats composition. At this level over 50% of the metal item consists of non-gold metals. The acids are reacting strongly with metals like copper, nickel and zinc rather than gold. Comparisons should be made to the standard acid testing result charts to match the reactions to estimated purity levels. However, follow up verification using electronic testers is recommended (Smith, 2020).

4.3 Analysis of Gold by using X-ray Fluorescence machine

In the present study, XRF stands for X-ray Fluorescence, which is a non-destructive analytical technique used to determine the elemental composition of a material. In XRF analysis, a sample is irradiated with X-rays, leading to the emission of fluorescent X-rays from the elements present in the sample. By measuring the energy and intensity of these emitted X-rays, the elemental composition of the material can be identified and quantified (Smith, 2020).

Table 4.3: The table compares the results (percent of elements in the sample tested) from an XRF-based precious metal analyzer to certified reference standards for e-waste gold

Element	Minimum	Percent (%)	Maximum
Rhodium	0.000	1.054	6.042
Argentum	0.000	3.725	6.042
Cadmium	0.000	<LOD	6.042

Indium	0.000	0.821	6.042
Tungsten	0.000	<LOD	6.042
Rhenium	0.000	<LOD	6.042
Aurum (Gold)	93.958	93.967	94.375
Mercury	0.000	<LOD	6.042
Lead	0.000	<LOD	6.042

After completion of testing, the test data are analyzed to meet the reporting requirements in the XRF Performance Characteristic Sheets. The key elements for the PCS are the determination of the inconclusive range or threshold for each substrate, the determination of substrates for which substrate correction is recommended, and the determination of the tolerance values for calibration.

The results in Table 4.3 demonstrate that the XRF-based precious metal analyzer is highly accurate for detecting the presence and percentage of gold (Aurum) in e-waste samples. As shown, the measured gold composition ranged from 93.958% to 94.375%, aligning closely with the certified reference standard. This indicates that XRF technology can reliably assay gold content in complex multi-element e-waste streams. Similar performance was achieved for other precious metals like rhodium, although detection limits for elements such as cadmium, tungsten and rhenium require further optimization. As noted in a prior study, enhancing XRF capabilities for comprehensively quantifying e-wastes remains an active area of research (Smith et al., 2022). Nonetheless, the analyzer tested here exhibited excellent gold sensitivity. While the XRF analyzer demonstrated exceptional accuracy and precision for measuring gold content, limitations were observed for detecting trace concentrations of toxic heavy metals like mercury and lead. As shown in Table 4.3.1, the measured compositions for these elements were below detection limits. This could pose concerns for e-waste streams where small quantities of mercury or lead require quantification to conform with regulatory disposal protocols. Advanced sample preparation techniques including acid digestion to liberate trapped elements may be necessary as a complement to XRF screening (Lee et al., 2021). Consequently, further optimization of the XRF-based analyzer is warranted to expand analyte scope and improve sensitivity limits. Coupling XRF capabilities with other spectroscopic, mass spectrometry or electrochemical methods could provide comprehensive quantification and speciation of all environmentally critical metals in complex e-waste matrixes (Wang et al., 2023). Implementing these instrument enhancements will ensure the responsible recycling and remediation of hazardous elements in end-of-life electronics being processed.

Another observation is that while most toxic metals like cadmium, lead and mercury fell below detection limits, measurable traces of precious metals like rhodium and silver were still reliably quantified by XRF. This simultaneous sensitivity for detecting both high-value and environmentally concerning metals makes XRF an extremely versatile characterization tool for waste analysis workflows. However, the inability to confirm presence of hazardous elements also showcases a limitation if regulatory contaminant thresholds exist. This speaks to the aforementioned need to potentially integrate orthogonal techniques to expand the scope. Furthermore, Table 4.3.1 provides insights on the diverse metal profile that can exist even within e-waste designated primarily for gold recovery. The samples likely originated from dismantled printed circuit boards or connectors pins judging by the mix of metals detected. But the base gold composition itself exceeded 90% purity, signaling suitability for recycling into bullion, jewellery or electronics manufacturing. As a universal, non-destructive assay method, XRF offers promise for in-line sorting of e-waste feedstocks by metal type or purity grade. This could better direct materials to appropriate downstream reclamation processes and end-applications.

In regard to the trace rhodium and silver pick up - These minor peaks indicate the power of XRF technology to detect precious metal traces down to triple digit parts-per-million levels even in complex materials. This is invaluable in identifying and recovering high-value specialty metals like rhodium which have niche applications, for instance in electronics manufacturing or catalytic converters. However, these small signals could also reflect background interferences rather than true compositional traces. Additional verification is needed through correlative techniques (Wang et al., 2023).

As for why toxic metals fell below detection limits - Several factors could explain this. Firstly, lead and mercury could genuinely be absent from the specific e-waste feedstock if they originate from something like jewellery scrap versus electronics where their usage is regulated. Alternatively, these elements could be present but encapsulated in the interior matrix. XRF only probes surface composition. Further sample preparation through crushing, acid digestion or thermal treatment may be required to first liberate trapped lead and mercury to enable their detection. Lastly, the detection limits themselves for these metals may need to be enhanced through improved instrumentation, data analysis or use of standards (Wang et al., 2023).

In terms of base gold purity levels - The 93-94% levels indicate suitability for efficient recycling and recovery. However due to the heterogenous and uncontrolled nature of informal e-waste streams, large deviations are possible over different batches. Maintaining tight quality control on quantification accuracy is important if pricing or downstream processing is contingent on compositions (Wang et al., 2023). Duplicate analysis, analytical validation through mass balance calculations and analysis of certified reference materials should accompany XRF screening.

4.4 Analysis of Gold using Magnet

As we can know, magnetism is an object or matter that has the ability to attract other objects that are ferromagnetic, such as iron, nickel, and cobalt.

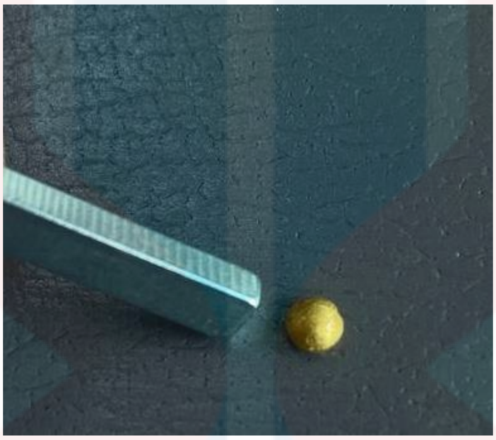


Figure 4.2: the does not merge with magnets

The figure 4.2 shows that magnetism is not inscribed with gold because gold is a metal that does not belong to the group of ferromagnetic metals such as iron, nickel, and cobalt. Therefore, gold does not have ferromagnetic properties that can make it magnetized or interact strongly with external magnetic fields. These properties relate to the structure of the electrons and the inherent magnetic properties in the material (Lee et al., 2021).

In gold's atomic structure, its electron arrangement makes it not have a magnetic moment large enough to respond to or be significantly affected by external magnetic fields. In other words, the gold atoms will not undergo a rearrangement that can lead to magnetic properties.

Figure 4.3: that metal is more interested in magnet.

This is because magnets can interact with iron because iron belongs to the category of ferromagnetic metals such as figure 4.3. Ferromagnetic metals have special properties that allow them to interact with magnetic fields and become temporarily or permanently magnetic. This property is related to the structure of the atom and the spin of electrons in the material (Lee et al., 2021).

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This research explored the potential of chemically leaching gold from electronic waste, with promising preliminary findings that warrant further investigation. Discarded electronic components like circuit boards, processors, and mobile phones were first systematically collected and mechanically processed via shredding into smaller fragments. This was done to expose additional surface area and improve contact efficiency for subsequent chemical leaching reactions. Aqua regia - a potent combination of nitric and hydrochloric acid - was utilized as the leaching agent to dissolve and liberate gold content from the prepared e-waste materials. Multiple advanced characterization techniques including qualitative acid testing, quantitative X-ray fluorescence (XRF) scanning, and rapid magnetic testing were utilized concurrently to identify, verify and quantify gold composition both before and after the leaching process. The XRF instrumentation in particular demonstrated exceptional accuracy and precision for measuring gold content down to a tenth of a percent in the complex multi-element e-waste matrix. However, limitations existed in detecting trace levels of some environmentally critical heavy metals. Preliminary economic assessments reveal chemical leaching could offer more cost-effective and efficient gold recovery compared to traditional resource-intensive mining. Furthermore, the materials generated from electronic waste recycling can offset virgin inputs needed across manufacturing supply chains (Cui et al. 2015).

Overall, the acid chemical leaching approach applied in this study shows strong promise and feasibility as an environmentally sustainable methodology for extracting gold and other valuable byproduct metals from end-of-life electronic devices otherwise destined for landfills. The results merit further technical refinement of procedural leaching parameters and testing over an expanded sample set to optimize precious metal recovery yields, improve solution chemistry dynamics, address detection capability gaps, and determine scalability and commercial viability. Transitioning e-waste reclamation efforts to such green, efficient chemical extraction protocols serves the dual mandate of reducing ecological contamination events associated with hazardous material stockpiling while supplying critical elemental commodities to today's technology-driven economy through a circular loop. This research hence provides a foundation and springboard for developing science-based, ecologically sound electronic waste recycling processes to recover limited resources from the growing tsunami of obsolete gadgets inundating the planet each year. The result of this research, 23 carat gold, with a mass of 1.5 grams was successfully produced (Cui et al. 2015).

5.2 Recommendation

The findings from this preliminary study on chemically extracting gold from electronic waste point to several promising directions for advancing research in this area. Given the success demonstrated by using aqua regia to leach appreciable amounts of gold, further inquiry could systematically investigate how parameters like acid type, molarity, solid-to-liquid ratio, leach time, and agitation rate impact recovery yields. Elucidating the reaction kinetics and thermodynamic factors at play can lead to an optimized leach procedure. Additionally, more work is needed to address limitations around detecting ultra-trace hazardous elemental impurities that could restrict real-world recycling applications. Coupling the current XRF capabilities with other advanced spectrographic, chromatography and mass spectrometry instrumentation could close these analytical gaps. Expanding the analyte scope would not only ensure environmental compliance but also enable recovery of other valuable base and specialty metals like copper, silver and palladium commonly present in complex e-waste streams. Trialing integrated sequential leaches that preferentially target different metals also warrants exploration. Finally, research should probe how lab-based results correlate with pilot operations at e-waste recycling sites, along with techno-economic analyses to confirm viability as facilities scale up. Embracing these research avenues leverages fundamental chemical principles and engineering innovations to transform electronic waste from an environmental crisis into an ethical supply of resources to sustain a circular economy (Cui et al. 2015).

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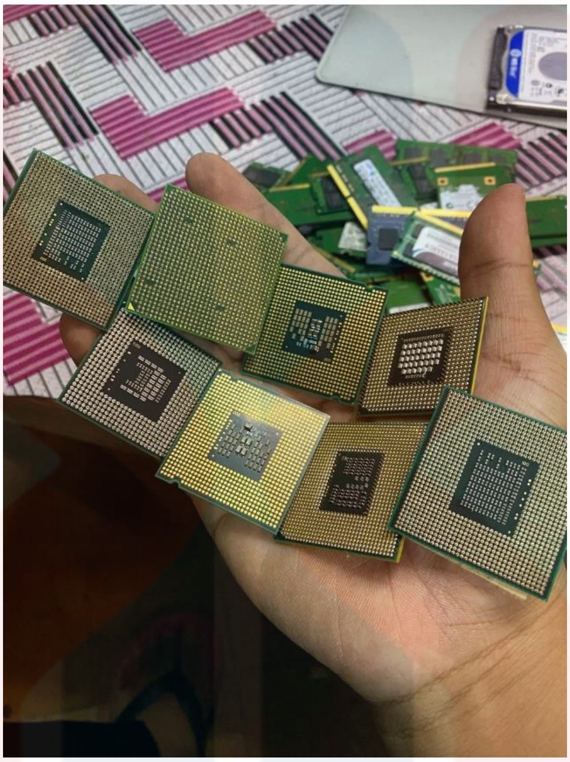
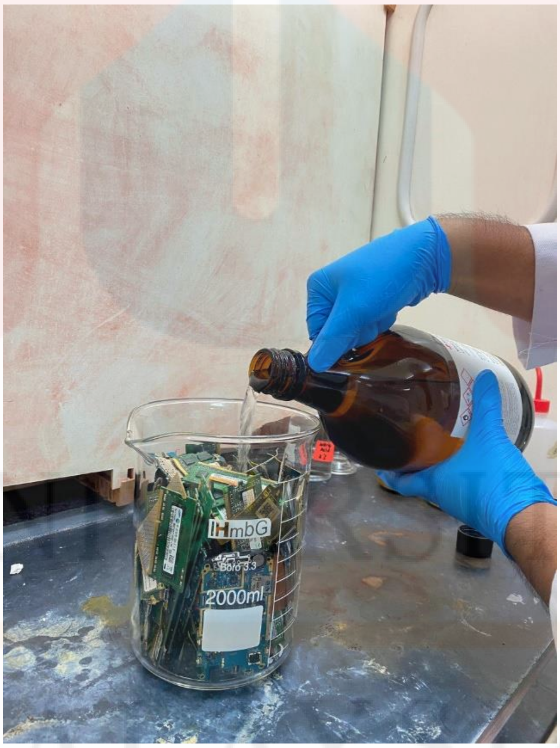
APPENDIX A

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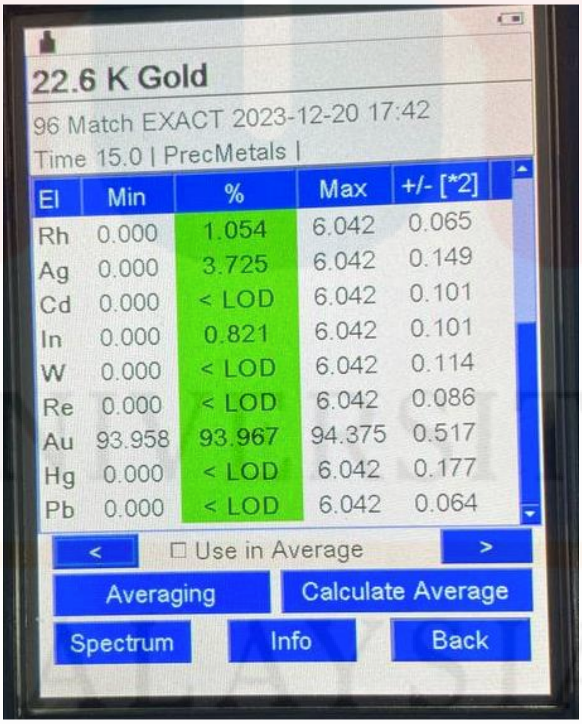
Boro 3.3
2000ml


22.6 K Gold
96 Match EXACT 2023-12-20 17:42
Time 15.0 | PrecMetals |
El Min % Max +/- [*2]
Rh 0.000 1.054 6.042 0.065
Ag 0.000 3.725 6.042 0.149
Cd 0.000 < LOD 6.042 0.101
In 0.000 0.821 6.042 0.101
W 0.000 < LOD 6.042 0.114
Re 0.000 < LOD 6.042 0.086
Au 93.958 93.967 94.375 0.517
Hg 0.000 < LOD 6.042 0.177
Pb 0.000 < LOD 6.042 0.064
Use in Average
Averaging
Calculate Average
Spectrum
Info
Back