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The Viability of Banana Pseudo-Stem Fiber and Coconut Mesh in Gold Recovery using Traditional Sluice Boxes: A Comparative Analysis of Grassroots Innovation

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Abstract

Grassroots Innovations (GIs) are novel alternative and innovative solutions emanating from rural and marginalized communities that seek to address social issues and challenges in these societies. GIs cover a wide array of applications, including the mining sector. One method of mining called Placer mining involves acquisition of valuable materials from deposits that were brought downhill and transported to many rural communities through natural phenomenon. In recent years, the mining industry has generated huge amounts of toxic chemical agents due to various harmful methods which contributed a negative impact towards our environment. Thus, the need for a simple, sustainable, environmental-friendly, and cost-effective method for recovering gold and other valuable materials would be ideal. This study aims to compare the use of two different local materials, Banana pseudo-stem fibers and Coconut mesh, as a potential alternative component in traditional sluice boxes locally known as “Banlasan” and to investigate the application of Banana Pseudo-Stem Fibers and Coconut Mesh (Ginit) in metal particle recovery. This study employs an experimental research design which involves Ore Sample Preparation, and Experimental Ore Processing which includes Gravity Separation (Sluicing), Particle Extraction (Panning), and Metal Particle Measurement. A Comparative Analysis was applied in order to compare the amount of metal recovered (in grams) and percent material recovery (%) using the appropriate statistical analysis. Result shows that the percent material recovery of Banana Pseudo-stem Fiber and Coconut Mesh are 23.5% and 26.08%, respectively. This indicates that Coconut Mesh fiber recovered 10% more metal particles and is more efficient at recovering gold-copper particles than Banana Pseudo-stem Fiber.

Keywords **—Grassroots Innovation, Gold Recovery, Coconut Mesh, Banana Pseudo-Stem Fiber, Sluice Boxes, Placer Mining**

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I. INTRODUCTION

Grassroots Innovations (GIs), as described by the United Nations Development Programme (2021), are indigenous solutions developed by people living in rural and marginalized communities backed by inadequate resources. They are intended to address local issues and frequently lead to sustainable development. GIs are essentially bottom-up solutions occurring in informal and non-market settings which are seldomly featured in mainstream innovation. Historically, Grassroots Innovation has been a critically underdeveloped research, and there is still little knowledge and insights into the innovations emanating from individual citizens of grassroots communities. One reason for this lack of research interest comes from the fact that GIs come in all shapes and sizes, and they are difficult to measure and quantify due to its wide array of applications. While these aspects of GIs make it difficult to study and work, GIs offer a great deal of potential and possibilities. In many developed countries such as the Philippines, grassroots innovators tend to innovate for more practical reasons [1].In recent years, grassroots innovation has gained significant attention as a way to develop affordable and sustainable solutions to pressing social and environmental challenges. The mining industry is a sector that has significant potential for grassroots innovation. In the mining industry, grassroots innovation can play a crucial role in promoting sustainable mining practices thatreduce the environmental impact of mining activities while also ensuring the responsible use of natural resources. Efficiency is another area where GIs can be particularly beneficial to the mining industry. By developing innovative technologies and processes that streamline mining operations, GIs can help to increase productivity and reduce costs. For instance, GIs can create new tools or methods to increase the precision and speed of mineral extraction, reduce the amount of time and resources required for mine development, implement sustainable mining techniques, and improve logistics management and transportation [2]. In this industry, certain GIs and simple technological advancements were manually created by people from various rural communities in mountainous regions. Early in the 1970s, when alluvial placer gold mining was the primary focus, gold and precious ore recovery was primarily accomplished either by direct panning or through the use of innovative crude sluice boxes that utilize available native resources [3].

Banana fiber, a ligno-cellulosic fiber, obtained from the pseudostem of Banana plant (*Musa sepientum*), is a bast fiber with relatively good mechanical properties. These fibers are abundant throughout many places in the Philippines and other countries in Southeast Asia. Banana Fibers have a wide range of applications due to its high tensile strength, degradability, and durability. Banana pseudo-stem is increasingly recognized as a sustainable raw material with several uses. It is a lignocellulosic material extracted from discarded pseudostems of banana plants, which are generally considered waste after harvesting. The fiber has good length/fitness ratio and strength and is considered potential replacement for synthetic fibers in various applications. Moreover, natural fibers have several advantages over synthetic fibers such as low cost, widespread availability, high specific strength, excellent electrical resistance, outstanding thermal insulation, improved acoustic qualities, and are environmentally safe and recyclable [4]. Considered as one of the world's strongest natural fibers, natural banana fibers possess essential advantages such as low density, appropriate stiffness, and high disposability [5].

On the other hand, Coconut fiber is a versatile material that can be used in various applications. It is a natural fiber that is extracted from the outer husk of a ripe coconut and is abundant in tropical countries like the Philippines. It can be used to make a range of products due to its durability, strength, and resistance to moisture and rot. Coconut mesh or locally known as "ginit" is also a natural fibrous material. It has a cloth-like texture that can be found at the side of the base of a palm frond. It also has a high cellulose content and is also known for its adsorption properties [6]. One of the primary chemical constituents of coconut fiber is lignin which has been studied to be an effective adsorbent of organic and heavy metals [7]. Moreover, Coconut fibers also contain high concentrations of cellulose and hemi-cellulose which are notably used as natural adhesives [8].

Although there are numerous grassroots innovations in the country, there are only very limited to none of the considered grassroots innovations in the mining sector that are sustainable and environmentally friendly. Moreover, the mining industry has not yet seen any documented grassroots innovation. Therefore, the researchers aim to address this gap. This study's main problem is to investigate the application of Banana Pseudo-Stem Fibers and Coconut Mesh (Ginit) in copper metal particles' recovery through the utilization of traditional sluice boxes (Banlasan). This study will seek to answer three specific questions (1.) What is the amount of metal particles (copper in grams) recovered by the Banana Pseudo-Stem Fiber and Coconut Mesh (Ginit) for each trial?, (2.) What is the metal particle percent recovery (%) of Banana Pseudo-Stem Fiber and Coconut Mesh (Ginit) for each trial?, and (3.) Is there a significant difference in the amount of metal particles (copper in grams) recovered by Banana Pseudo-Stem Fiber and Coconut Mesh?

II. MATERIALS AND METHODS

In order to conduct this study, gold particle recovery using conventional sluice boxes were utilized. However, processing of ore gold samples should be conducted in-situ (onsite) and cannot be done in school laboratories, thus, this study intends to use copper and additives to represent gold ore. The experimental laboratory design in the study examined the practicality of employing banana pseudo-stem fibers and coconut mesh as long-lasting and environmentally benign substitutes for mercury in gold recovery. The research method flow is presented in the next section.

A. *Research Design*

Experimental research design was employed in this study. The overview of the experimental flow in the conducted study is presented in Figure 1. Based on the figure, copper ore samples as a substitute for gold ore samples were prepared in a science laboratory of Cabadbaran City National High School-Senior High School. Simultaneously, two (2) sluice boxes were constructed with the use of banana pseudo-stem fiber and coconut mesh as an adhesive material for the copper ore samples. After the preparation of the copper ore samples and the sluice boxes, the ore samples were processed through a gravity separation method through sluicing. In this method, a total of 20 trials has been made of which 10 trials for the sluice box using banana pseudo-stem and 10 trials for the sluice box using the coconut mesh. For each trial, one (1) mixture of copper ore samples was being used. The composition of the mixture was presented in detail in the next section.

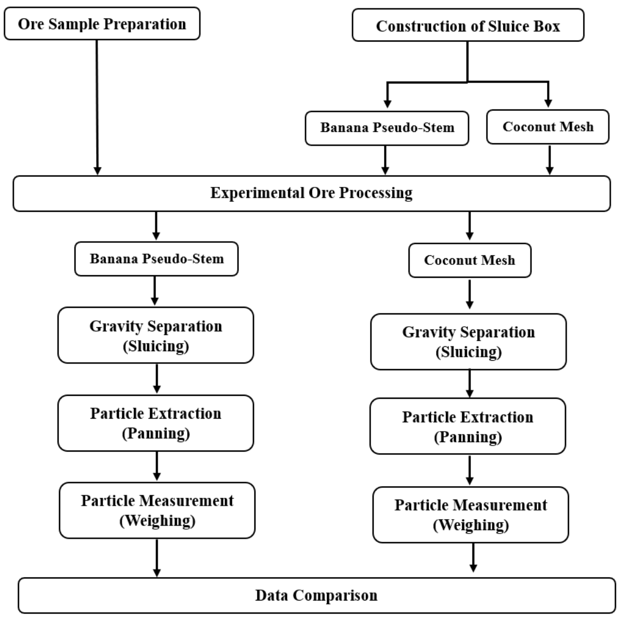


Figure 1. Overview of the Research Methodology

B. Copper Ore Sample Preparation

The copper ore samples are composed of copper, pebbles, sand, soil, and water. The mixture was made to represent a gold ore sample. One (1) copper ore sample mixture was used for every trial. Each mixture was composed of 5g copper, 75ml pebbles, 75ml sand, 75ml soil, and 300ml water. Copper was used as a substitute for gold since the latter is very expensive to be wasted in a laboratory experiment. Basing on the subatomic level, Gold and Copper have equal valence electrons (electrons in the outermost atomic shell). Elements with the same number of valence electrons have identical physical and chemical properties. Additionally, current processing in hydrometallurgical techniques have been created to extract gold directly from copper, nickel, lead, or cobalt ores concentrates (Ferron, 2016). Moreover, there is a correlation of gold recovery in the presence of concentrated copper (Steyn, 2004).

C. Materials in making sluice box

Materials for constructing the sluice box were carefully selected based on their accessibility, affordability, and ease of use. These included 1x1 and 1x2 lumber sticks, plywood, fiberboard (known locally as lawanit), nails, metal grid panel screens, coconut mesh, and banana pseudostems.

The construction of the sluice box involves setting up multiple layers, with each layer having an essential role in capturing gold particles present in the ore sample. The base of the sluice box, usually made of wood, provides a foundation for other layers. The second layer consists of the “lawanit” fiberboard, which is placed on top of the base. The third layer involves the placement of coconut mesh or banana pseudostem, which serves to trap any gold particles and prevent them from being washed away. The fourth layer involves placing a screen on top of the coconut mesh or banana pseudostem. This helps to further filter out any unwanted materials and ensures that only small particles of gold are collected. Finally, at the top of the screen multiple riffles were added. The layers of the “banlasan” sluice box must be arranged properly to ensure that the metal particles are effectively trapped.

The dimensions of the sluice box were precisely determined to be 4.5 inches in width and 18.5 inches in length, resulting in a total surface area of 83.5 inches.

D. Gravity Separation (Sluicing)

The first step in the process of gravity separation through sluicing involved setting up the sluice box with multiple layers, as described in section 5.3. The ore sample was then placed at the top of the sluice box, and water was poured over it. The flow rate was controlled to prevent the copper particles from washing away.

As the water flowed through the sluice box, the copper particles were trapped by the different layers of the sluice box. The riffles of the sluice box also helped in the settling of the copper particles in which it also allowed the copper particles to accumulate in the lower layers of the sluice box. After enough time had passed, the collected metal particles were carefully extracted from the bottom layer of the sluice box.

E. Particle Extraction (Panning)

Following the gravity separation process (sluicing), the next step involved was performing particle extraction. The process involves the use of a gold pan, which is a shallow, wide-bottomed dish made of metal or plastic. The panning process began by adding the extracted ore to the gold pan together with the water, and the mixture was agitated by swirling the pan around in a circular motion.

As the mixture was disturbed, the heavier copper particles settled to the bottom of the pan while the lighter materials such sand and gravel were washed away. The process was repeated multiple times until only a small amount of sediment was left in the pan. The remaining sediment had been carefully inspected for any traces of copper particles. Those particles were then collected using a snuffer bottle and moved to a separate container.

F. Particle Mass Measurement and Percent Recovery

The extracted copper particles were brought to the school science laboratory for measurement. The particles were measured using electronic precision balance (Naugra ®) with a capacity of 600 grams and accuracy of 0.01grams. Prior to measurement, the electronic precision balance was calibrated and assured that the bubble indicator for balance is within the exact location. This is done to get more accurate and precise data. Extracted copper particles for each sluice box for every trial were weighed and recorded. The recorded data were ready for a comparison using statistical analysis.

The material percent recovery is the total amount of output usable and recovered materials by weight as a percentage of the amount by weight of input materials [9].The percent recovery of metal particles through the use of Banana Pseudostem and Coconut Mesh were determined using the equation:

$$Material\ Recovery\ (\%) = \frac{weight\ of\ output\ recovered\ material}{weight\ of\ input\ material}\ X\ 100\%$$

G. Data Analysis

Descriptive and inferential statistics was used to analyze the data using Statistical Package for Social Sciences (SPSS). Sample mean was used to determine the amount of metal particles (copper). Independent sample t-test is used to determine whether there is a significant difference between the mean amount of metal particles gathered from the sluice box with the banana pseudo-stem fiber compared to the sluice box with coconut mesh. The significance level of the independent t-test was set at $p<0.05$.

The formula for t-test for two-independent samples assuming equal population variances is given below:

$$t = \frac{\left(\bar{X}_1 - \bar{X}_2\right) - d_o}{s_p\sqrt{\left(1/n_1\right) + \left(1/n_2\right)}}$$

where $\bar{x}_1$ and $\bar{x}_2$ are the means of the two independent samples

$n_1$and $n_2$are the sizes of the two samples

d_o is the hypothesized difference which is assumed to be zero

s_p is the pooled standard deviation with formula

$$s_p = \sqrt{\frac{\left(n_1-1\right)s1^2 + \left(n_2-1\right)s2^2}{n_1+n_2-2}}$$

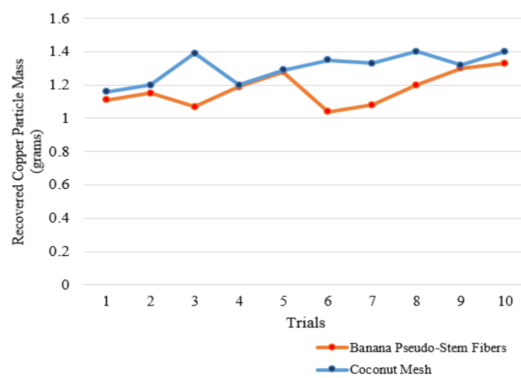
Before using t-test for two independent samples, the researchers verified that its underlying assumptions were satisfied. First, the data is representative of the population, the level of measurement is continuous, the data is normally distributed, and standard deviations of samples are approximately equal. To test whether the data is normally distributed, the researchers used Shapiro-Wilk's Test. The result showed a p-value greater than 0.05 which indicated that the data is approximately normally distributed. The result using Levene's test for the homogeneity of variance also indicates that the variances of the independent groups are not significantly different from each other. Hence, the homogeneity assumption of the variance is met.

III. RESULTS AND DISCUSSIONS

In this section, results on the recovered amount and percent recovery of copper particles with the use of banana pseudo-stem fiber and coconut mesh are presented. It also discusses which among the two materials used in recovering fine copper particles is more efficient. Significant differences between the recovery of the two different materials used are also included.

A. Recovered Copper Mass Measurement and Percent Material Recovery

The recovered mass of copper particles obtained from the banana pseudo-stem and the mass of copper particles obtained



from the coconut mesh is presented in Figure 2.

Figure 2. Recovered mass concentration (in grams) of Banana Pseudo-Stem Fiber and Coconut Mesh

As shown in the figure, the mass obtained from banana pseudo-stem fiber ranges from 1.04g to 1.33g while the mass obtained from coconut mesh ranges from 1.02g to 1.40g. On average, copper particle mass collected from the banana pseudo stem-fiber for ten (10) trials is 1.18g while on the coconut mesh yields a higher mass of 1.30g. Based on the result, the coconut mesh has recovered 10% more copper metal particles than that of the banana pseudo-stem fiber. This means that coconut mesh is more efficient in recovering fine copper particles and thus, more efficient to be used in a sluice box for gold ore recovery.

The percent recovery of copper particles is computed from the recovered material divided by the mass (5g) of copper placed in the mixture for copper ore samples.

Table 1. Amount of Recovered (in grams) and Percent Material Recovery (%) of Banana Pseudo-stem Fiber and Coconut Mesh

	Banana Pseudo-stem Fiber		Coconut Mesh	
Trials	Amount of Metal Recovered (in grams)	Percent Material Recovery (%)	Amount of Metal Recovered (in grams)	Percent Material Recovery (%)
1	1.11	22.2	1.16	23.2
2	1.15	23.0	1.20	24.0
3	1.07	21.4	1.39	27.8
4	1.19	23.8	1.20	24.0
5	1.28	25.6	1.29	25.8
6	1.04	20.8	1.35	27.0
7	1.08	21.6	1.33	26.6
8	1.20	24.0	1.40	28.0
9	1.30	26.0	1.32	26.4
10	1.33	26.6	1.40	28.0
Mean	1.18	23.5	1.30	26.08

Table 1 shows the percent of recovered copper particle mass from the initial mass of copper on the prepared copper ore mixture. The amount of percent recovery using the banana pseudo-stem ranges from 20.8% to 26.6% while on the coconut mesh ranges from 23.2% to 28%. Result shows that the coconut mesh has higher percent recovery than that of the banana pseudo-stem fiber.

Table 2. T-Test for two Independent Samples

Test Statistic	Degrees of Freedom	Sig. (2-tailed) P-value	Decision	Interpretation
$t = -3.003$	18	0.008	Reject Ho	There is a significant difference in the mean amount of metal particles

Table 2 above shows the result of the independent sample t-test. The test statistic is -3.003 with a significance value (p-value) of 0.008 indicating that the result is highly significant. This means that the mean amount of metal particles using banana pseudo-stem fiber is significantly lower compared to the mean amount of metal particles using coconut mesh.

The higher efficiency demonstrated by the Coconut Mesh as compared to the Banana Pseudo-stem fiber in recovering metal particles can be attributed to the chemical components of the fibrous structures of the Coconut Mesh which possess high adsorption capacities. The results agree with various studies which stated that coconut fibers present in the Coconut Mesh contain 45.84% Lignin, while the Banana Pseudo-stem Fibers contains only 18% Lignin [10]. Lignin, which is a primary natural amorphous polymer, contains unique polyphenol structure, aromatic structure, and physicochemical properties that have high tendencies of adsorbing and recovering heavy metals such as gold. The presence of these advantageous chemical characteristics has led to a wide variety of sorbents, particularly heavy metal solvents, that can be potentially obtained from Lignin [11]. Since there is a higher concentration of Lignin component in the Coconut mesh fiber compared to the Banana Pseudo-stem Fiber, therefore, it can be inferred that Coconut mesh fibers have a greater potential of recovering more fine copper-gold particles than that of the banana pseudo-stem fiber which agrees on the experimental results of this study.

IV. CONCLUSIONS

This research study aimed to investigate the efficiency of banana pseudo-stem fiber and coconut mesh in the recovery of metal particles. Through the experimental study, it was found that coconut mesh demonstrated higher efficiency in terms of both the mass of recovered copper particles and the percent recovery compared to banana pseudo-stem fiber. The superior performance of coconut mesh can be attributed to its higher concentration of lignin, which possess high adsorption capacities for heavy metals. These findings emphasize the potential of coconut mesh as a more effective and efficient material for gold recovery.

In conclusion, the results of this study support the use of coconut mesh as a promising alternative over the banana pseudo-stem fiber for gold ore recovery. The findings contribute to the understanding of sustainable and efficient methods in the mining industry, highlighting the potential of utilizing natural fibers with high adsorption capacities which paves the way for environmentally benign gold extraction methods.

This research can be further improved by investigating more possible raw materials as a component for sluice boxes. Furthermore, it is important to acknowledge the limitations of this study, such as the use of copper as a substitute for gold ore and the specific experimental conditions. Future research should consider conducting field trials and examining the long-term durability and effectiveness of coconut mesh in different mining scenarios.

Implementing coconut mesh in traditional sluice boxes is recommended for enhanced gold recovery, especially in rural and marginalized communities where coconut mesh is easily available. This approach outperformed banana pseudo-stem fiber in recovering gold-copper particles. The introduction of Coconut Mesh as an efficient gold recovering material in local sluice boxes will help pave the way for local residents from marginalized communities to use Coconut mesh as a viable instrument for placer mining activities. Moreover, this study would also shed light on the importance of different Grassroots Innovations in our community and help inspire future research.

To foster knowledge sharing and innovation, organizing workshops, conferences, and platforms for stakeholders to exchange ideas and best practices is advised. This collaborative approach will lead to more effective and sustainable mining practices. Collaboration with stakeholders, includingenvironmental groups and government agencies, is crucial to advocate for grassroots innovation and promote environmentally friendly and cost-effective mining practices. Utilizing social media platforms such as Twitter, LinkedIn, and Facebook with relevant hashtags and mentions will increase visibility.Engaging everyone interested in sustainability is key to protecting the environment and achieving sustainable mining.

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