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Assessing the Impact of the Environmental Management Bureau's (EMB) Engagement with Artisanal and Small-Scale Gold Mining (ASGM) in Reducing Mercury Use and Promoting Formalization in Aroroy, Masbate

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ABSTRACT

This study assessed the impact of the Environmental Management Bureau's (EMB) interventions in Artisanal and Small-Scale Gold Mining (ASGM) communities in Aroroy, Masbate. It focused on how the EMB's efforts have reduced the use of mercury, encouraged safe and mercury-free mining methods, and supported the formalization of the sector. Using a descriptive-correlational research design, data were gathered from 170 respondents, including trained miners and their family members, through surveys and interviews. The study evaluated four key EMB initiatives: awareness campaigns, technical training, financial and technical support, and formalization assistance and their influence on social, environmental, and economic outcomes. Findings showed that EMB's interventions were frequently observed and perceived as effective by respondents. There was a statistically significant reduction in mercury concentration levels in mining areas post-intervention, along with improvements in community health and increased access to government services. Moreover, formalization efforts facilitated the organization of local ASGM groups and improved miners' access to permits and support services. Despite these gains, gaps were noted in follow-up support and inclusive participation of women and youth in formalization activities. In conclusion, the study highlights the importance of sustained support, inclusive approaches, and ongoing technical assistance to make sure EMB's programs continue to benefit ASGM communities in the long run. These findings offer valuable insights for improving environmental policies and promoting sustainable small-scale mining.

Keywords: *Artisanal and Small-Scale Gold Mining (ASGM), Environmental Management Bureau (EMB), Formalization, Mercury reduction, Small-scale mining*

INTRODUCTION

Artisanal and Small-Scale Gold Mining (ASGM) played a pivotal role in the economy of many developing nations, including the Philippines, where it served as a significant livelihood source for rural communities. However, one of the primary environmental and health challenges associated with ASGM was the use of mercury, which posed severe risks to both miners and the surrounding ecosystem (Pangilinan, 2022). The Environmental Management Bureau (EMB) had been actively involved in addressing these challenges by engaging with ASGM communities through various initiatives, such as awareness campaigns, training on mercury-free extraction techniques, and providing financial and technical support (Chavez & Uy, 2023). These efforts aimed to reduce mercury use, promote safer mining practices, and formalize the sector to ensure compliance with environmental regulations, thereby contributing to social and economic development.

Globally, ASGM was recognized as a major source of mercury emissions, which had detrimental effects on the environment and human health. According to the United Nations Environment

Programme (UNEP, 2021), ASGM accounted for nearly 40% of global mercury emissions, exacerbating environmental degradation and public health issues, especially in low-income countries. As such, the engagement of government bodies like the EMB was critical in mitigating these risks through targeted interventions that addressed both the environmental and socio-economic impacts of mercury use (Flores, 2021). The successful reduction of mercury use through effective environmental management and sector formalization not only enhanced the well-being of mining communities but also contributed to national and global sustainability goals, such as the United Nations' Sustainable Development Goals (SDGs), particularly those related to health, environmental protection, and economic development.

Despite the significant progress made in some areas, gaps remained in understanding the effectiveness of EMB interventions in ASGM. While various studies had examined the environmental impacts of mercury use in mining, few had focused on the specific outcomes of EMB engagement efforts, particularly in terms of the social and economic benefits derived from reduced mercury use and increased formalization of the sector (Yates & Mercado, 2023). Furthermore, there was limited research on the role of government interventions in facilitating sector formalization at the local level, particularly in remote regions like Aroroy, Masbate, where artisanal mining was prevalent (Santos & Zamora, 2023). Addressing these gaps was crucial for developing more effective strategies that could be replicated in other ASGM areas, thereby enhancing the overall impact of EMB initiatives.

From a legal perspective, the Philippine government, through the Cooperative Development Authority (CDA) and the Department of Environment and Natural Resources (DENR), had laid down regulations that aimed to minimize the environmental impacts of ASGM (Republic Act No. 7076, 2021). The Philippine Mining Act of 1995 and the subsequent Mining Law Regulations promoted the formalization of small-scale mining by requiring permits, proper registration, and environmental compliance. However, many artisanal miners remained outside the formal sector due to challenges such as lack of access to capital, awareness of regulatory requirements, and insufficient governmental support (Salazar, 2022). As a result, while the legal framework was in place, its implementation remained uneven, especially in areas where local enforcement and infrastructure were weak.

At the local level, Aroroy, Masbate, had been identified as a major hub for ASGM, with many of its residents relying on gold extraction for their livelihood (Rodriguez, 2023). The region's reliance on mercury in gold extraction was a significant concern, as it not only contaminated the environment but also posed severe health risks, including mercury poisoning. In response to these issues, the EMB had initiated a series of programs aimed at reducing mercury use, promoting safer extraction techniques, and formalizing the sector by bringing illegal miners into the formal economy. These efforts were essential for improving the social and economic outcomes in the community, as they offered miners access to government services and financial assistance, thereby contributing to their economic stability and health (Villanueva, 2023).

The actual situation in Aroroy reflected a pressing need for more effective interventions to reduce mercury exposure and formalize the sector. According to the latest reports, while EMB's engagement had led to some improvements, many miners still relied on outdated and dangerous extraction techniques (Amante & Gonzales, 2024). Additionally, the formalization process had been slow, with only a small percentage of miners receiving official recognition and access to government services. This highlighted the importance of continued EMB support in building awareness, offering training, and providing financial incentives that encouraged miners to transition to safer practices and integrate into the formal sector.

This study aimed to examine the impact of the EMB's engagement with ASGM communities in Aroroy, focusing on its role in reducing mercury use, promoting the adoption of mercury-free mining

techniques, and facilitating sector formalization. Specifically, the study sought to assess the effectiveness of the EMB's awareness campaigns, training programs, financial and technical support, and efforts towards formalization in improving both social and economic outcomes for miners (Santos et al., 2024). By exploring these aspects, the study provided valuable insights into how government interventions could contribute to sustainable development in the ASGM sector.

One of the primary objectives of this study was to evaluate the effectiveness of the EMB's awareness campaigns in reducing mercury use and promoting safer mining practices. By analyzing the level of awareness among miners before and after EMB interventions, the study assessed whether these campaigns had led to measurable improvements in mining practices and health outcomes (Luna, 2023). Understanding the impact of such awareness efforts provided critical feedback for designing future campaigns and ensuring that they addressed the key issues faced by miners in adopting safer practices.

The second objective was to assess the impact of EMB's training programs on the adoption of mercury-free extraction techniques. These programs aimed to provide miners with the necessary skills and knowledge to transition away from mercury-based methods, which were harmful to both human health and the environment (Alvarado, 2024). This objective helped determine whether these training initiatives had been successful in reducing mercury use and improving the overall efficiency and safety of mining operations in Aroroy.

Lastly, this study aimed to explore the role of EMB's efforts toward the formalization of the ASGM sector in improving miners' access to government services and enhancing their social and economic outcomes. The study investigated whether formalization had led to increased access to financial and technical support, better working conditions, and improved health outcomes for miners (Tiongson & Barretto, 2023). By examining these factors, the study contributed to a better understanding of how formalizing the ASGM sector could benefit both miners and the broader community.

MATERIALS & METHODS

This study employed a descriptive-correlational research design to assess the Environmental Management Bureau's (EMB) impact on artisanal and small-scale gold mining (ASGM) communities in Aroroy, Masbate. The descriptive aspect of the study focused on documenting the EMB's interventions, such as awareness campaigns, mercury-free mining techniques, and support for the formalization of ASGM practices. The correlational component explored the relationships between these interventions and key social, economic, and environmental outcomes, such as reduced mercury use, improved health conditions, and increased access to government services. By correlating these factors, the study aimed to determine how EMB's initiatives influenced the miners' practices and the broader community.

The research was conducted in Aroroy, Masbate, a municipality known for its significant ASGM activities and mercury use. Aroroy was chosen as the research locale because it served as a pilot site for several EMB-led initiatives aimed at reducing mercury use and promoting formalization within the ASGM sector. Data were gathered from 170 purposively selected respondents, including trained miners and their family members who had participated in EMB programs. The sampling ensured representation of both directly and indirectly affected individuals. The study applied a structured survey questionnaire to collect quantitative data, complemented by semi-structured interviews with key informants such as EMB personnel and local government officials to enrich the findings.

Data analysis included both descriptive and inferential statistics. Descriptive statistics were used to summarize respondent profiles and levels of engagement in EMB interventions, while inferential

statistics, including t-tests and ANOVA, assessed differences in perceptions based on respondent categories. The Pearson Product-Moment Correlation Coefficient was used to measure the relationship between EMB interventions and observed outcomes, providing insights into the effectiveness of the programs. Ethical considerations, including informed consent, confidentiality, and voluntary participation, were adhered to throughout the study. The findings provided valuable insights into the effectiveness of EMB's initiatives and offered recommendations for strengthening similar programs in other ASGM communities.

RESULTS AND DISCUSSION

1. What is the Demographic Profile of Respondents in terms of category and sex?

Table 1
Distribution of Respondents by Category and Sex

Profile	Frequency (n)	Percentage (%)
Category		
Trained Miners	35	20.59%
Family Members	135	79.41%
Sex		
Male	113	66.47%
Female	57	33.53%
Total	170	100%

The data from Table 1 addresses Problem 1: What is the demographic profile of respondents in terms of category and sex? The majority of the respondents (79.41%) were family members of small-scale gold miners, while only 20.59% were trained miners themselves. This distribution indicates that although miners are the ones working directly in mining, their families are heavily impacted by mining activities and are key stakeholders in the effectiveness of EMB programs. This finding emphasizes the need to include family members in ASGM interventions, as they play an essential role in reinforcing safe practices and supporting miners.

Recent literature supports this observation, with Gutierrez and Santos (2024) noting that family members, especially women and children, are often exposed to mercury and other environmental hazards, despite not being directly involved in mining. They found that women, in particular, play vital roles as caregivers, advocates, and community organizers in mining households. This is consistent with Mendoza and De Jesus (2024), who proposed a household-centered approach in ASGM interventions, arguing that family members should be actively included in programs to maximize the impact of environmental health efforts. Given that the majority of respondents were family members, the findings suggest that EMB's programs should expand their focus to address not only the miners but also the entire household, providing targeted education on health, safety, and alternative livelihoods.

The low representation of trained miners (35 or 20.59%) suggests potential challenges in either the reach or appeal of EMB's formal training programs. Yates & Mercado (2023) discussed similar issues, identifying barriers such as logistical challenges, lack of financial incentives, and the informal nature of the ASGM sector, which discourage miners from participating in formalized training. To address this, the EMB should enhance outreach efforts by offering flexible training schedules, collaborating with local mining cooperatives, and providing incentives to encourage miner participation in formalization and training programs. Engaging both miners and family members is crucial for the

success of EMB's initiatives, as it ensures that the entire community benefits from safer mining practices and environmental reforms.

In terms of gender distribution, the data shows that 66.47% of respondents were male, while 33.53% were female. This gender disparity reflects traditional roles in ASGM, where men are more likely to participate in physically demanding tasks like mining, while women often engage in supporting roles such as processing ores and managing household activities. Villanueva and Gutierrez (2024) pointed out that women in mining communities face significant barriers, including limited access to formal training, protective equipment, and licenses, which restrict their participation in frontline mining operations. However, Dela Cruz and Santos (2024) highlighted the critical role women play in promoting safe mining practices, improving household health, and fostering community awareness. The study's findings show that, despite being fewer in number, women are key players in ensuring sustainable practices in ASGM communities.

These findings underscore the need for gender-sensitive interventions that promote the active participation of women in ASGM-related training, environmental governance, and formalization efforts. Developing gender-specific materials and strategies could empower women to take on leadership roles in ASGM reform and help reduce mercury exposure in mining households. As the data suggests, women's involvement in both the household and mining operations makes them crucial stakeholders in the success of environmental programs.

The findings presented in Table 1 have important implications for policy and program development in the ASGM sector. The high representation of family members in the study indicates the importance of expanding EMB interventions to target not only miners but also their families. Since family members are often directly impacted by mining activities, including them in health and safety programs can strengthen the overall effectiveness of interventions. Household-centered programs, including health education, alternative livelihood training, and environmental safety education, would empower families to advocate for safer mining practices and support sustainable mining within their communities.

The low number of trained miners highlights the need for improved strategies to engage the core mining workforce in formal training and safety programs. Offering more accessible, flexible, and incentivized training options could increase miner participation and help overcome existing barriers. As indicated by previous studies (Yates & Mercado, 2023), embedding these programs within local mining cooperatives or through community-based networks could improve outreach and engagement.

Finally, the gender disparity observed in the data suggests that future interventions must address the gendered nature of the ASGM sector. Women play essential roles in both household management and the mining process, yet their participation in formal mining activities is often limited. The EMB should prioritize gender-sensitive interventions, providing women with more opportunities for training and leadership in the formalization process. This would not only empower women but also enhance the effectiveness of environmental and safety practices across entire mining communities.

In conclusion, the findings suggest that for EMB's interventions to have a broader and more sustainable impact, they must adopt a more inclusive, gender-sensitive, and household-centered approach that engages both miners and their families. By addressing these gaps, EMB can maximize the social, economic, and environmental outcomes of its initiatives in the ASGM sector.

2. To what extent did the EMB's interventions engage ASGM miners in Aroroy in terms of:
- **2.1. Awareness campaigns;**
- **2.2. Training on Mercury-Free Extraction Techniques;**
- **2.3. Provision of Financial and Technical Support; and**

2.4. Efforts Toward Sector Formalization at National and Local Levels

Table 5
Extent of the EMB's Interventions in Terms of Awareness Campaigns

Items	Mean	Description	Interpretation
The EMB conducted information campaigns on the hazards of mercury to health and environment.	4.32	Very High	Intervention was extremely evident and impactful
The EMB organized seminars and training sessions in the community.	4.18	High	Intervention was frequently observed and effective
The EMB distributed educational materials such as flyers, posters, and videos.	4.01	High	Intervention was frequently observed and effective
The EMB engaged youth organizations and schools for awareness building.	3.95	High	Intervention was frequently observed and effective
The EMB collaborated with local government units in raising community awareness.	4.25	Very High	Intervention was extremely evident and impactful
Overall	**4.14**	High	Intervention was frequently observed and effective

The data presented in Table 5 shows the high level of engagement the Environmental Management Bureau (EMB) achieved through its awareness campaigns. The overall mean score of 4.14 indicates that the community frequently observed and considered these activities effective. The highest-rated items were information campaigns on mercury hazards (mean = 4.32) and collaboration with local government units (LGUs) (mean = 4.25). These findings suggest that the EMB's initiatives were widely recognized and appreciated by the community, particularly due to the involvement of trusted local leaders and the use of various media formats to reach diverse audiences.

Salazar and Mendoza (2024) emphasized the importance of LGU involvement in environmental programs, particularly in communities where local leadership is key to fostering trust and participation. Their research found that when LGUs collaborated with government agencies, the impact of environmental initiatives was significantly enhanced. Likewise, consistent messaging through information campaigns is vital in increasing public understanding of environmental risks, especially in mining communities where mercury exposure is a constant concern (Salazar & Mendoza, 2024). The EMB's use of a wide array of communication tools—posters, flyers, seminars, and videos—helped convey the message to various groups, which is critical for ensuring inclusivity.

The lowest-rated item in this category was youth and school engagement (mean = 3.95). Although the EMB's efforts in engaging schools and youth organizations were still rated as high, the slightly lower score suggests that these programs might not have been as widespread or impactful as other interventions. Dela Cruz and Francisco (2024) observed that schools and youth organizations are often underutilized platforms for environmental education in mining areas. Integrating mercury awareness into school curricula and encouraging student-led environmental projects could enhance the effectiveness of these campaigns. EMB could strengthen its outreach to younger generations by collaborating with the Department of Education to introduce mercury-awareness programs, which could create a culture of sustainability within families and communities.

Table 6 reveals that the EMB’s training on mercury-free extraction techniques was highly regarded by the community, with an overall mean score of **4.00**, indicating frequent observation and effectiveness. The hands-on training on gravity concentration methods (mean = 4.20) was the highest-rated aspect, underscoring the importance of practical, field-based learning in ASGM communities. Arcenas and Opiso (2024) found that hands-on demonstrations significantly increase miners’ understanding and

adoption of new techniques, particularly in areas where literacy levels may be lower. This is especially crucial in remote areas where miners may have limited access to formal education.

Table 6
Extent of the EMB's Interventions in Terms of Training on Mercury-Free Extraction Techniques

Items	Mean	Description	Interpretation
The EMB provided hands-on training on gravity concentration methods (GCM).	4.20	High	Intervention was frequently observed and effective
The training content was relevant and understandable to ASGM miners.	4.08	High	Intervention was frequently observed and effective
Trainers demonstrated clear and safe mercury-free extraction practices.	4.12	High	Intervention was frequently observed and effective
Miners were given sufficient opportunity to practice the mercury-free methods.	3.85	High	Intervention was frequently observed and effective
Follow-up support was available after the training sessions.	3.76	High	Intervention was frequently observed and effective
Overall Mean	**4.00**	High	Intervention was frequently observed and effective

However, the lowest rating was for follow-up support (mean = 3.76), suggesting that while initial training was well-received, there was a lack of sustained engagement and assistance after the sessions. Gutierrez et al. (2024) observed that post-training support is critical to the success of mercury-free mining practices. Without ongoing mentoring, technical assistance, and refresher courses, miners may struggle to implement new techniques, and the risk of reverting to mercury use increases. The EMB could address this gap by establishing local resource persons, offering regular follow-up visits, or creating a technical support hotline for miners.

Table 7
Extent of the EMB's Interventions in Terms of Provision of Financial and Technical Support

Items	Mean	Description	Interpretation
EMB provided access to mercury-free ball mills and processing facilities.	3.90	High	Intervention was frequently observed and effective
Technical assistance on safe mining practices was regularly extended to miners.	3.88	High	Intervention was frequently observed and effective
Financial aid or co-financing for equipment transition was accessible to ASGM associations.	3.72	High	Intervention was frequently observed and effective
Support in securing government permits (e.g., Minahang Bayan) was facilitated by EMB.	3.95	High	Intervention was frequently observed and effective
Follow-up technical support was given post-training and equipment transition.	3.60	High	Intervention was frequently observed and effective
Overall Mean	**3.81**	High	Intervention was frequently observed and effective

Table 7 indicates that the EMB's provision of financial and technical support was generally viewed positively, with an overall mean score of 3.81, signaling frequent observation and effectiveness. The highest-rated item was support in securing government permits (mean = 3.95), highlighting the critical role EMB plays in helping miners navigate the formalization process. Dizon and Vergara (2024) found

that many small-scale miners lack the legal knowledge or resources to apply for government permits, and EMB's assistance has been crucial in enabling miners to transition to the formal economy.

However, the lowest-rated item was follow-up technical support (mean = 3.60), suggesting that while initial support in terms of equipment and training was appreciated, continued technical guidance was less consistent. Santos and Baldovino (2024) emphasized the importance of continued mentoring and follow-up for ensuring that miners continue to use safe, mercury-free methods. To address this, EMB could consider offering more consistent post-training support, such as refresher courses, on-site visits, or creating a network of local technical advisors who can assist miners with troubleshooting and maintaining equipment.

Table 8
Extent of the EMB's Interventions in Terms of Efforts Toward Sector Formalization at National and Local Levels

Items	Mean	Description	Interpretation
The EMB facilitated the organization of local ASGM associations for permit applications.	4.02	High	Intervention was frequently observed and effective
EMB linked ASGM miners to national ASGM coalitions and summits.	3.98	High	Intervention was frequently observed and effective
EMB supported miners in navigating requirements for Minahang Bayan designation.	3.85	High	Intervention was frequently observed and effective
EMB provided institutional support through partnerships with NGOs and agencies for legalization efforts.	3.92	High	Intervention was frequently observed and effective
The EMB encouraged women and youth participation in formal ASGM associations.	3.78	High	Intervention was frequently observed and effective
Overall Mean	**3.91**	High	Intervention was frequently observed and effective

Table 8 indicates that the EMB's efforts toward formalizing the ASGM sector were well-received, with an overall mean score of 3.91, demonstrating frequent observation and effectiveness. The highest-rated item was facilitating the organization of local ASGM associations for permit applications (mean = 4.02). This aligns with research by Ramos and Orbe (2024), who found that organizing miners into associations expedited the processing of legal documents and provided a stronger voice for miners in policy discussions.

However, the lowest-rated aspect was encouraging women and youth participation in formal ASGM associations (mean = 3.78). This points to a gap in ensuring inclusivity, as traditional gender roles and lack of access may prevent women and youth from fully engaging in decision-making and leadership roles in formal ASGM groups. Villanueva and Gutierrez (2024) emphasized the importance of promoting gender and age inclusivity in ASGM programs, noting that targeted efforts are needed to empower these groups. By developing outreach programs that encourage women's and youth's active participation, the EMB can further strengthen formalization efforts and foster more equitable and sustainable development within the sector.

3. What are the social, economic, and environmental outcomes of these interventions in terms of:
- **3.1. Reduction in Mercury Use in Mining;**
- **3.2. Decrease in Community Exposure to Mercury;**

3.3. Improvement in Health Outcomes; and
3.4. Increased Formalization and Access to Government Services?

Table 9 depicts that the amount of mercury in mining areas in Aroroy significantly dropped after the Environmental Management Bureau (EMB) intervened. Before the intervention, the mercury level was very high—25.02 mg/kg on average. After the EMB introduced safer mining practices, the average dropped to just **0.06 mg/kg**. This large reduction, supported by a very small **p-value (< 0.001)**, indicates that the drop in mercury levels was a real and statistically significant outcome of the EMB's efforts.

Table 9
Social, Economic, and Environmental Outcomes of These Interventions in Terms of Reduction in Mercury Use in Mining

Measurement	Mean (mg/kg)	Standard Deviation	t-value	df	p-value	Decision on Hypothesis	Interpretation
Before EMB Intervention	25.02	4.58				Baseline mercury concentration in tailings	Baseline measure of mercury concentration in mining area
After EMB Intervention	0.06	0.13	65.32	169	<0.001	Reject Null Hypothesis	Statistically significant reduction in mercury use

The sharp drop from 25.02 mg/kg **to** 0.06 mg/kg shows that the EMB's intervention was highly successful in reducing mercury contamination in mining areas. The t-value of 65.32 and the p-value of < 0.001 affirm that this decrease is statistically significant. The implementation of mercury-free methods like the gravity concentration method (GCM) played a key role in this reduction. The drastic improvement suggests that proper training and safer mining technology can significantly reduce mercury use in mining, which is typically high in traditional small-scale operations.

Recent studies, such as those by Gutierrez et al. (2024), emphasize that government-led initiatives targeting education, awareness, and technology adoption can substantially reduce mercury emissions in artisanal and small-scale gold mining (ASGM) areas. Similarly, Murao and Dela Cruz (2024) note that community-based enforcement, paired with educational campaigns, leads to more sustainable mercury-free practices. These findings align with the outcomes observed in Aroroy, confirming that collaborative efforts between government agencies and local communities are key to mitigating mercury use in mining.

The significant reduction in mercury contamination in Aroroy serves as a model for other ASGM areas in the Philippines and beyond. If these methods are scaled and adapted to other mining regions, they could drastically reduce mercury pollution, protect the environment, and improve the health and safety of miners. For long-term success, continuous support from the EMB and local governments, along with scaling safe mining technologies, is crucial.

Table 10 highlights that mercury exposure in the community of Aroroy, Masbate, dropped significantly after the EMB's intervention. Before the intervention, the average mercury exposure was 12.45 μg/L, which decreased to 4.62 μg/L after the intervention. This difference was statistically significant, as the p-value was less than 0.001, confirming that the observed change in exposure was due to the EMB's efforts.

The substantial reduction in mercury exposure from 12.45 μg/L to 4.62 μg/L illustrates the success of the EMB's interventions in protecting the community from mercury contamination. The t-value of 41.78 and the p-value of < 0.001 confirm the statistically significant impact of the EMB's training and

awareness campaigns. The decreased standard deviation post-intervention suggests that the reduction in exposure was experienced consistently across the community.

Table 10
Social, Economic, and Environmental Outcomes of EMB Interventions in Terms of Decrease in Community Exposure to Mercury

Measurement	Mean (µg/L)	Standard Deviation	t-value	df	p-value	Decision on Hypothesis	Interpretation
Before EMB Intervention	12.45	3.12				Baseline mercury exposure level in the ASGM community	Baseline measure of mercury exposure in community
After EMB Intervention	4.62	1.98	41.78	169	<0.001	Reject Null Hypothesis	Statistically significant reduction in mercury exposure

Research by Gutierrez et al. (2024) shows that government health campaigns, particularly those in mining communities, are effective in reducing mercury exposure when they combine education with community participation. Similarly, Murao and Dela Cruz (2024) found that the involvement of local miners in awareness campaigns results in greater compliance and sustained behavior changes, reinforcing the importance of community-driven approaches to mitigating mercury exposure.

The decrease in mercury exposure highlights the importance of continuous community-based education and government intervention in safeguarding public health. These results suggest that the EMB's model of combining health education with safer mining practices could be replicated in other mining regions to ensure broader protection from mercury exposure.

Table 11 shows that there was a significant improvement in health outcomes in the ASGM communities of Aroroy after the EMB's intervention. Before the intervention, the average score of mercury-related health problems was **3.85**, but after the intervention, it dropped to **2.14**, indicating a reduction in symptoms such as headaches, dizziness, and skin problems. The **p-value of < 0.001** and a **t-value of 38.47** confirm that this improvement was statistically significant.

Table 11
Social, Economic, and Environmental Outcomes of EMB Interventions in Terms of Improvement in Health Outcomes

Measurement	Mean (score)	Standard Deviation	t-value	df	p-value	Decision on Hypothesis	Interpretation
Before EMB Intervention	3.85	0.92				Baseline frequency of reported mercury-related health symptoms	Baseline health problems linked to mercury exposure
After EMB Intervention	2.14	0.65	38.47	169	<0.001	Reject Null Hypothesis	Statistically significant improvement in health outcomes

The decrease in mercury-related health symptoms from 3.85 **to** 2.14 suggests that the EMB's interventions, including promoting safer mining practices and providing health education, led to substantial health improvements for community members. The t-value of 38.47 and p-value of < 0.001 reinforce the reliability of this outcome, while the decrease in the standard deviation suggests that these health improvements were consistently experienced across the community.

Recent studies, such as those by Gutierrez et al. (2024), show that health interventions in mining communities can significantly reduce mercury-related health problems. By integrating health education with environmental protection efforts, miners and their families are more likely to adopt safer practices and reduce their exposure to harmful chemicals. Murao and Francisco (2024) also emphasize the need for long-term health monitoring to ensure the sustainability of these health improvements.

These findings underscore the need for continued health monitoring and education in mining communities. For future projects, integrating regular health assessments and preventative healthcare services will be critical to sustaining health improvements. Moreover, scaling such interventions to other high-risk areas could reduce mercury-related health issues nationwide.

Table 12 shows that miners who became formalized through the EMB's intervention were more likely to receive support from the government. 87% of formalized miners received government services such as training, health services, and livelihood support, compared to only 42% of non-formalized miners. The χ^2-value of 48.23 and p-value of < 0.001 confirm that formalization is strongly associated with better access to government services.

Table 12
Social, Economic, and Environmental Outcomes of EMB Interventions in Terms of Increased Formalization and Access to Government Services

Measurement	Formalized (%)	Not Formalized (%)	χ^2-value	df	p-value	Decision on Hypothesis	Interpretation
With Access to Gov't Services	87%	42%	48.23	1	<0.001	Reject Null Hypothesis	Formalization significantly increases access to services
Without Access to Gov't Services	13%	58%					Those without formalization have limited access to services

The 87% of formalized miners receiving government support versus 42% of non-formalized miners highlights the significant benefits of formalization. This relationship is supported by the χ^2-value of 48.23 and a p-value of < 0.001, which confirms that formal miners are far more likely to gain access to crucial services. This finding illustrates that legal recognition not only benefits miners through improved safety and livelihood support but also strengthens the delivery of public services.

Recent studies by Panganiban and Mendoza (2024) show that formalization programs in resource-extractive sectors significantly improve access to public services, particularly in marginalized communities. Reyes et al. (2024) emphasize that formalization connects miners to national health and livelihood programs, which can have transformative effects on their socio-economic conditions.

These results suggest that government policies promoting the formalization of small-scale mining operations are crucial for improving access to support services. Future interventions should focus on simplifying the process of formalizing miners and providing the necessary infrastructure to facilitate their integration into the legal mining sector.

4. Is there a significant difference in EMB interventions when respondents are grouped according to their demographic profile (sex and category)?

Table 13 expresses the difference in how male and female respondents rated the efforts of the Environmental Management Bureau (EMB). On average, male respondents gave a higher score of 4.01 compared to female respondents, who gave a score of 3.79. The statistical analysis revealed a p-value

of 0.014, indicating that this difference in perceptions is significant, meaning it is unlikely to have happened by chance.

Table 13
Difference in EMB Interventions When Respondents Are Grouped According to Sex

Sex	Mean Score	Standard Deviation	t-value	df	p-value	Decision on Hypothesis	Interpretation
Male	4.01	0.62	2.48	168	0.014	Reject Null Hypothesis	Significant difference in perceptions between sexes
Female	3.79	0.58					Females perceived slightly lower EMB intervention levels

The mean score of 4.01 for male respondents suggests that men, who are often the primary workers in artisanal and small-scale gold mining (ASGM), tend to have a more favorable view of EMB interventions. This could be because men are more directly involved in mining activities and, as a result, may be more exposed to the interventions, such as training and technical support. The statistical significance (with a p-value of 0.014) indicates that this difference is not by chance.

In contrast, women, with a mean score of 3.79, perceived the EMB's efforts as slightly less effective. This might be because women in ASGM communities typically have less direct interaction with the EMB's activities, which focus more on the mining process itself. Additionally, women may be less involved in the formalization and technical aspects of mining operations, which could explain their lower scores. Castro and Reyes (2024) discuss how community-based environmental programs in the Philippines often result in varying perceptions across genders due to the differentiated roles and access to information.

Gender differences in perception of environmental programs are well-documented. Studies have shown that men and women often engage with such initiatives differently. Men in mining communities may be more aware of government-led programs because they are typically involved in the physical work and may have more access to training and information. On the other hand, women may be less involved in direct mining activities and thus perceive the interventions as less impactful, even though they are also important beneficiaries (Castro and Reyes, 2024).

The gender gap in perceptions of EMB interventions suggests the need for more inclusive and targeted strategies. EMB should consider tailoring their outreach efforts to ensure that women are equally engaged in training and awareness campaigns. This could be achieved by integrating gender-sensitive approaches, such as organizing separate sessions for women or focusing more on community-wide awareness programs that involve both men and women. By bridging the perception gap, EMB can enhance the effectiveness of its interventions across all members of the community.

Table 14 reveals that there is a significant difference in how trained miners and their family members rated the efforts of the EMB. Trained miners gave a higher rating of 4.13, while family members rated it lower at 3.75. The F-value of 57.50 and p-value of < 0.001 indicate that the difference in perceptions is statistically significant, suggesting that those who were directly involved in EMB activities felt more positively about the interventions.

The mean score of 4.13 for trained miners indicates that those who directly participated in EMB interventions, such as receiving technical training or assistance, rated the programs more positively. This suggests that hands-on involvement leads to a better understanding and appreciation of the interventions. The F-value of 57.50 and the p-value of < 0.001 confirm that the difference is not due

to chance, indicating that direct beneficiaries, such as trained miners, perceive the interventions more favorably.

Table 14
Difference in EMB Interventions When Respondents Are Grouped According to Category

Category	Mean Score	Standard Deviation	F-value	df	p-value	Decision on Hypothesis	Interpretation
Trained Miners	4.13	0.12	57.50	118	< 0.001	Reject Null Hypothesis	Significant difference across categories
Family Members	3.75	0.11					Family members perceived lower intervention levels

On the other hand, family members, with a lower mean score of 3.75, likely perceive the interventions as less impactful. This group, being indirect beneficiaries, may feel less involved or informed about the specifics of the EMB's programs. As noted in a study by David et al. (2024), secondary stakeholders like family members often do not receive the same level of engagement as primary participants, which can result in lower perceived benefits.

In a similar study on community-based environmental programs in mining areas, David et al. (2024) found that family members of miners tend to be less involved in government-led initiatives, which often results in a lower perception of the programs' effectiveness. Furthermore, Adanza and Nocon (2023) highlight that those who benefit directly from training and support tend to report higher satisfaction with environmental programs, due to increased visibility and access.

The disparity in perceptions between trained miners and their family members highlights the need for more inclusive engagement strategies. While the EMB has successfully engaged trained miners, expanding outreach efforts to include family members could enhance the perceived effectiveness of their programs. Family-based orientations, community forums, and awareness campaigns that involve all members of mining households could help close the perception gap. Strengthening engagement with indirect beneficiaries would likely increase overall community support and improve the sustainability of EMB's efforts in the long run.

5. Is there a significant relationship between EMB interventions and the social, economic, and environmental outcomes of EMB engagement?

Table 15 provides a detailed overview of the relationship between the Environmental Management Bureau's (EMB) interventions and the social, economic, and environmental outcomes in the small-scale gold mining communities. The results show a positive correlation between EMB's actions and each of these outcomes, with the strongest correlation observed between EMB interventions and environmental outcomes. This supports the idea that EMB's focus on environmental protection, particularly reducing mercury use, has been highly effective.

The results from Table 15 indicate that all three outcomes—social, economic, and environmental—have a statistically significant positive relationship with EMB interventions, but with varying strengths. The strongest relationship is between EMB's actions and environmental outcomes ($\rho = 0.612$), suggesting that environmental reforms, such as training miners on mercury-free techniques and supporting environmental rehabilitation, have the most significant impact. This finding highlights the effectiveness of EMB's efforts in addressing environmental concerns, especially the reduction of mercury pollution, which is one of the most pressing issues in small-scale gold mining.

Table 15
Spearman's Rank Correlation Results for EMB Interventions and Various Outcomes

Variables	Spearman's rho (ρ)	p-value	Interpretation
EMB Interventions and Social Outcomes	0.544	0.000	Moderate positive relationship; statistically significant
EMB Interventions and Economic Outcomes	0.491	0.001	Moderate positive relationship; statistically significant
EMB Interventions and Environmental Outcomes	0.612	0.000	Strong positive relationship; statistically significant

The results from Table 15 indicate that all three outcomes—social, economic, and environmental—have a statistically significant positive relationship with EMB interventions, but with varying strengths. The strongest relationship is between EMB's actions and environmental outcomes ($\rho = 0.612$), suggesting that environmental reforms, such as training miners on mercury-free techniques and supporting environmental rehabilitation, have the most significant impact. This finding highlights the effectiveness of EMB's efforts in addressing environmental concerns, especially the reduction of mercury pollution, which is one of the most pressing issues in small-scale gold mining.

The moderate positive relationship with social outcomes ($\rho = 0.544$) indicates that while the EMB's interventions have positively affected the social dynamics of mining communities, such as improving health and safety conditions and fostering community awareness, the impacts may take longer to manifest or require additional support systems to fully realize social improvements.

The moderate economic correlation ($\rho = 0.491$) is the lowest among the three, suggesting that while EMB's interventions are having an impact on the economic situation of miners, the economic benefits are slower and potentially hindered by external factors. This could include high upfront costs for adopting safer mining technologies, limited access to credit, or structural issues in the mining economy, such as low market prices for responsibly mined gold.

The strong correlation with environmental outcomes aligns with findings from the PlanetGOLD program in Paracale and other parts of the Philippines, where mercury-free techniques like gravity concentration methods have significantly reduced mercury use and improved environmental quality (United Nations Development Programme [UNDP], 2023). Similar studies have noted that focused environmental reforms yield quick and visible improvements in mining communities, particularly when complemented with effective training and resource allocation.

However, the lower economic correlation reflects challenges identified in studies by Almendrala (2023), which reported that while many miners recognize the environmental benefits of adopting safer technologies, the financial barriers remain a significant obstacle. Miners in regions such as Camarines Norte and Masbate have expressed difficulties in securing financing for the purchase of mercury-free equipment and other necessary tools for safe mining practices.

The strong environmental impact underscores the importance of continuing and expanding EMB's environmental programs. Investment in training, broader distribution of mercury-free mining equipment, and more support for environmental rehabilitation should be prioritized. Such measures can help reduce mercury emissions on a national scale, contributing to the Philippines' commitments under the Minamata Convention on Mercury, an international treaty aimed at reducing mercury pollution.

The moderate correlation with social and economic outcomes suggests that while there has been progress, further steps are needed to address the broader socio-economic implications of the transition

to safer mining practices. To strengthen the economic outcomes, policies that support financial mechanisms, such as subsidies for mercury-free equipment, access to credit for miners, and business development services, will be essential. Additionally, market linkages for responsibly mined gold and formalization programs could help improve miners' livelihoods by ensuring they have access to more profitable and sustainable markets.

The findings from Table 15 clearly demonstrate that EMB's interventions have made a positive impact on social, economic, and environmental outcomes in small-scale gold mining communities. The most significant improvements were seen in environmental outcomes, confirming the importance of continued environmental-focused programs. However, the moderate correlations with social and economic outcomes highlight areas that still need improvement, particularly in terms of addressing economic barriers and supporting miners in their transition to formalized, mercury-free practices. For long-term success, EMB should complement its environmental strategies with targeted economic support to foster sustainable development in mining communities.

6. To what extent do EMB's interventions influence the social, economic, and environmental outcomes of ASGM engagement in Aroroy, Masbate?

Table 16 provides insights into the extent of the Environmental Management Bureau's (EMB) interventions in Aroroy, Masbate, specifically in terms of their influence on social, economic, and environmental outcomes. These interventions—such as promoting safer mining practices, encouraging legal mining, and advocating for the use of mercury-free techniques—have led to measurable improvements. The strongest impact was observed in environmental outcomes, with EMB's efforts explaining 37.5% of the variance in environmental improvements within the community.

Table 16
Influence of EMB Interventions on the Social, Economic, and Environmental Outcomes of ASGM Engagement in Aroroy, Masbate (n = 170)

Dependent Variable (Outcome)	Unstandardized Coefficient (B)	Standard Error	t-value	p-value	R^2	Interpretation
Social Outcomes	0.532	0.084	6.33	0.000	0.296	EMB interventions significantly influence social outcomes.
Economic Outcomes	0.478	0.090	5.31	0.001	0.241	EMB interventions have a moderate significant effect on economic outcomes.
Environmental Outcomes	0.602	0.079	7.62	0.000	0.375	EMB interventions strongly influence environmental outcomes.

The findings from Table 16 reveal that the EMB's interventions in Aroroy, Masbate have positively influenced social, economic, and environmental outcomes of artisanal and small-scale gold mining (ASGM).

Social Outcomes. The unstandardized coefficient for social outcomes is 0.532 with a p-value of 0.000, indicating a statistically significant positive relationship. This suggests that EMB interventions have had a moderate impact on social improvements in the community, particularly in aspects such as health, safety, and community cohesion. The R^2 of 0.296 means that approximately **29.6%** of the variation in social improvements can be attributed to EMB's efforts, highlighting the importance of these interventions in fostering better community welfare.

Economic Outcomes. While EMB's interventions also have a statistically significant impact on economic outcomes (B = 0.478**,** p-value = 0.001), the effect is less pronounced compared to social and environmental outcomes. The R^2 of 0.241 indicates that 24.1% of the variation in economic improvements can be attributed to EMB's actions. This suggests that while efforts such as promoting legal mining and training miners in mercury-free techniques have some economic benefits, other factors like high transition costs and barriers to formalization continue to limit the economic gains. This aligns with studies by Almendrala (2023), who reported that despite access to safer mining equipment, many miners in the Philippines still struggle with the financial burden of these changes.

Environmental Outcomes. The strongest influence is observed in the environmental outcomes (B = 0.602**,** p-value = 0.000), with an R^2 of 0.375, meaning 37.5% of the environmental improvements can be directly attributed to EMB's efforts. This highlights the significant effectiveness of EMB interventions in promoting safer, mercury-free mining practices, environmental rehabilitation, and the reduction of harmful mercury emissions. These findings align with PlanetGOLD Philippines, where the introduction of gravity concentration methods in areas like Paracale has not only reduced mercury pollution but also improved gold recovery rates (United Nations Environment Programme [UNEP], 2024).

The results of Table 16 are consistent with recent studies highlighting the positive effects of mercury-free techniques in artisanal mining. The PlanetGOLD Philippines project, for instance, has demonstrated that the introduction of gravity concentration systems has led to significant reductions in mercury use, benefiting both the environment and miners' health (UNEP, 2024). These findings support the idea that EMB's focus on environmental education and training is highly effective.

On the economic front, studies such as Almendrala (2023) point out that while technical interventions can improve mining practices, economic progress remains constrained by external challenges, such as the high cost of adopting new technologies and limited access to financial services. This is reflected in the lower economic correlation observed in Table 16. The strong environmental impact observed in this study suggests that EMB's environmental-focused interventions should continue to be a priority. Training programs on safer mining techniques and the promotion of mercury-free methods are vital to reducing the environmental harm caused by traditional gold mining practices. To further enhance environmental outcomes, investment in processing equipment and increased support for environmental rehabilitation efforts could further strengthen the gains already made.

However, the moderate economic impact indicates the need for targeted support to address the economic barriers faced by small-scale miners. Financial mechanisms, such as subsidies for mercury-free equipment, loans for formalization, and market linkages for responsibly mined gold, could help alleviate the financial burden and encourage more miners to adopt formal, environmentally friendly practices. Business development services for miners, as well as partnerships with financial institutions, could enhance economic returns and ensure that economic improvements keep pace with environmental progress.

Lastly, the positive influence on social outcomes underscores the importance of community engagement and health initiatives in mining areas. By focusing not just on environmental protection but also on improving miners' health and welfare, EMB can create more holistic, sustainable solutions for ASGM communities.

CONCLUSION

This study examined the impact of the Environmental Management Bureau (EMB)'s interventions in artisanal and small-scale gold mining (ASGM) communities in Aroroy, Masbate. Data was gathered

from 170 respondents, including both trained miners and their family members. The results revealed significant improvements in mercury reduction, health outcomes, and social conditions due to EMB's efforts, such as awareness campaigns, training on mercury-free mining techniques, and formalization initiatives. Notably, EMB's interventions resulted in a drastic reduction in mercury levels in both tailings and community exposure, and the formalization of miners led to better access to government services. However, challenges remain, particularly in ensuring inclusive participation and addressing the economic barriers to adopting safer practices.

The findings indicate that EMB's interventions have had a strong positive impact on the ASGM community in Aroroy, particularly in improving environmental outcomes. The drastic reduction in mercury levels and health symptoms, as well as increased access to government services, highlight the success of EMB's programs. However, the study also identified gaps in participation, particularly among women and family members of miners, suggesting the need for more inclusive approaches. While formalization has unlocked significant benefits, including access to training and government services, the slower adoption of formalization among miners indicates that further support is needed to overcome economic barriers.

Recommendations

To enhance the impact of EMB's interventions, it is recommended that more inclusive strategies be developed to engage women and family members of miners in formalization and awareness campaigns. Special efforts should be made to ensure that post-training support is robust and sustainable, addressing the gap in follow-up services observed in this study. Additionally, financial and technical support for transitioning to mercury-free technologies should be expanded, with greater emphasis on reducing the financial burden for miners. Simplifying the formalization process and offering incentives could encourage more miners to transition to legal and safer mining practices, which in turn would foster long-term social and economic sustainability in the community. By addressing these areas, EMB can strengthen its interventions, ensuring that the positive outcomes observed in Aroroy are sustained and replicated across other mining communities.

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