Sustainable Development Goals
Research Paper

DIT.ADS International Multidisciplinary Research Journal
Volume 1; Issue 3; August 2025; pp: 233-248; No.: 08-2025-37
Website: https://ditadsresearchcenter.com
E-ISSN: 3082-5148; P-ISSN: 3082-513X

Environmental Management Bureau Initiatives for Sustainable Artisanal Gold Mining: Mercury Reduction and Formalization Efforts in Aroroy, Masbate

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Received 27th June 2025; Accepted 30th July 2025; Published Online 22nd August 2025
DOI: 10.63941/DIT.ADSimrj.2025.1.3.37

ABSTRACT

This study examined the effectiveness of the Environmental Management Bureau's (EMB) interventions in Artisanal and Small-Scale Gold Mining (ASGM) communities in Aroroy, Masbate. The research focused on how EMB's efforts helped decrease mercury usage, promoted safer mining techniques, and supported the formalization of the sector. Utilizing a descriptive-correlational research approach, data were collected from 170 respondents, including trained miners and their families, through surveys and interviews. The study assessed four primary EMB initiatives: awareness campaigns, technical training, financial and technical support, and assistance with formalization, and their effects on social, environmental, and economic outcomes. Results indicated that respondents observed and perceived EMB's interventions as generally effective. A significant decrease in mercury levels in mining areas was recorded post-intervention, along with improved health outcomes in the community and enhanced access to government services. Furthermore, the formalization efforts promoted the organization of local ASGM groups and facilitated better access to mining permits and support services. Despite these positive results, some gaps were noted, including limited follow-up support and the lack of inclusive participation from women and youth in formalization processes. In conclusion, the study underscores the importance of continuous support, inclusive strategies, and ongoing technical assistance to ensure that EMB's initiatives remain effective and sustainable in the long term, providing valuable insights for future environmental policies and sustainable mining practices.

Keywords: *Community health, Environmental policies, Formalization, Mercury reduction, Technical assistance*

INTRODUCTION

In the heart of the Philippines, where gold glimmers beneath the earth's surface, a hidden danger lurks—mercury. Artisanal and Small-Scale Gold Mining (ASGM) had long been a vital livelihood for many rural communities, but the practice also brought severe environmental and health consequences, largely due to the widespread use of mercury in gold extraction. Mercury exposure had caused significant health risks to miners and the surrounding ecosystem, with long-term consequences, such as mercury poisoning and environmental degradation (Pangilinan, 2022). In response to these critical challenges, the Environmental Management Bureau (EMB) had intervened, collaborating with ASGM communities to reduce mercury use, promote safer mining methods, and push for the formalization of the sector (Chavez & Uy, 2023).

Recent research had reinforced the urgency of these interventions. For instance, Flores (2023) had highlighted that mercury contamination from ASGM activities was a leading cause of water pollution, severely impacting both public health and aquatic biodiversity. Rodriguez (2023) had pointed out that many miners, particularly in Aroroy, Masbate, had still relied on outdated and hazardous extraction techniques, exacerbating the risks to local communities. The EMB's efforts, including training

programs, awareness campaigns, and technical support, had proven instrumental in mitigating these issues (Yates & Mercado, 2023). Alvarado (2024) had found that training miners on mercury-free extraction methods led to safer, more efficient mining operations, significantly reducing mercury use.

Globally, ASGM was recognized as a major source of mercury emissions. According to the United Nations Environment Programme (2021), ASGM contributed to nearly 40% of global mercury emissions, exacerbating environmental and public health crises, especially in low-income countries. The EMB's initiatives aligned with global sustainability goals, including the United Nations Sustainable Development Goals (SDGs), particularly those targeting health, environmental protection, and economic growth (UNEP, 2021). Similarly, Santos and Zamora (2023) had emphasized the critical role of government bodies like the EMB in addressing the environmental and socio-economic impacts of mercury use through formalization and safer mining practices.

Despite the positive impact of EMB's interventions, challenges remained. Studies by Luna (2023) and Villanueva (2023) had indicated that while awareness campaigns and training programs made notable progress, many miners still relied on mercury-based techniques due to financial limitations and lack of access to better alternatives. These findings pointed to the necessity of continued government support in increasing awareness, encouraging the adoption of cleaner technologies, and offering miners financial and technical resources.

Formalizing the ASGM sector had been another focus for the EMB. According to Salazar (2022), despite a regulatory framework in place under the Philippine Mining Act of 1995, many artisanal miners remained outside the formal sector due to challenges like limited access to permits, capital, and government assistance. The EMB's efforts to promote formalization had been crucial in integrating informal miners into the legal economy, granting them access to essential services and resources. However, as Amante and Gonzales (2024) observed, the formalization process had been slow, with only a small proportion of miners in Aroroy receiving official recognition and support.

While the legal framework for reducing the environmental impacts of ASGM had been established, its implementation had been uneven, particularly in remote mining areas. Tiongson & Barretto (2023) had noted that although the legal infrastructure existed, many local government units (LGUs) lacked the capacity to enforce mining laws effectively. This observation had been consistent with findings by Rodriguez (2023), which showed that, despite EMB's efforts, the informal mining sector in Aroroy continued to operate outside the formal economy, hindering both environmental and socio-economic development.

To address these challenges, the EMB had increasingly focused on integrating environmental and social considerations into its strategies. A study by Santos et al. (2024) had shown that EMB's training and support programs for miners and their families had led to improvements in health and social outcomes in some communities. However, gaps in service provision remained, particularly in terms of the inclusion of women and youth in the formalization process. Flores (2021) had highlighted that the lack of inclusive participation in formalization efforts hindered broader socio-economic development in these mining communities.

Yates & Mercado (2023) had argued that sustainable development in ASGM could only be achieved through a comprehensive approach that included environmental management, social inclusion, and economic development. Government initiatives, therefore, needed to create opportunities for all stakeholders, particularly marginalized groups, to benefit from safer, more sustainable mining practices and participate in the formal economy.

This study aimed to assess the impact of the EMB's engagement with ASGM communities in Aroroy, with a particular focus on its role in reducing mercury use, promoting mercury-free mining techniques, and supporting sector formalization. Specifically, the research sought to evaluate the effectiveness of

EMB's awareness campaigns, training programs, financial and technical support, and formalization efforts in improving social and economic outcomes for miners. By providing insights into these areas, the study hoped to contribute to the ongoing development of strategies that could effectively address the challenges faced by ASGM communities, both locally and globally.

MATERIALS & METHODS

This study utilized a descriptive-correlational research design to evaluate the effects of the Environmental Management Bureau's (EMB) interventions in the artisanal and small-scale gold mining (ASGM) sector in Aroroy, Masbate. The descriptive portion of the study focused on the specific interventions EMB carried out, such as awareness campaigns, training on mercury-free mining methods, and efforts to formalize ASGM operations. The correlational aspect of the research explored the relationship between these interventions and various outcomes, including the reduction in mercury use, improvements in health, and increased access to formal mining services. The goal was to identify patterns of association between the interventions and their effects on the community.

Aroroy, a municipality in Masbate with a significant ASGM presence, was selected as the research locale due to its involvement in EMB's mercury reduction and formalization efforts. A purposive sampling method was used to select 170 respondents, including trained miners and their family members who had participated in EMB-supported programs. The sampling design allowed the study to capture insights from both direct beneficiaries, such as those receiving training, and indirect beneficiaries, like family members impacted by increased awareness. A combination of structured survey questionnaires and semi-structured interviews with key informants, including EMB staff and local officials, was used to gather data.

The data collected were analyzed using both descriptive and inferential statistical methods. Descriptive statistics provided an overview of respondent demographics and engagement levels, while inferential statistics, including t-tests and ANOVA, were employed to examine differences in perceptions based on respondent category. The Pearson Product-Moment Correlation Coefficient was used to assess the strength and direction of relationships between EMB's interventions and the observed outcomes. Ethical guidelines were strictly followed, with informed consent and confidentiality maintained throughout the research process. The study's findings offer valuable insights into the impact of EMB's interventions and provide actionable recommendations for future programs aimed at reducing mercury use and improving the well-being of 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

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

Table 1 provides a breakdown of the demographic profile of respondents in terms of both their category (trained miners vs. family members) and sex. The majority of respondents were family members of miners (79.41%), with 135 out of 170 participants falling into this group. This suggests that the impact of artisanal and small-scale gold mining (ASGM) in Aroroy extends beyond the miners themselves, affecting their families and communities. While trained miners are directly involved in the mining process, family members often play critical roles in managing household health, finances, and community affairs. This reflects the integral role of families in shaping the overall success and sustainability of ASGM-related interventions.

Gutierrez and Santos (2024) observed similar trends in their research on ASGM households in Camarines Norte, finding that families—especially women and children—are disproportionately impacted by environmental risks like mercury exposure, even though they may not directly engage in mining activities. They emphasized that family members, particularly women, are often tasked with managing household safety and enforcing mining-related practices. This highlights the importance of including family members in ASGM interventions, as they are key players in both advocating for and implementing safer practices at home. Mendoza and De Jesus (2024) further argued that a household-centered approach to ASGM programs would be more effective in addressing these multifaceted issues, as families, rather than just individual miners, bear the consequences of mining practices. Given the high percentage of family members in this study, the data supports the need for EMB's programs to incorporate household-wide engagement, including health education, safety practices, and alternative livelihood programs for family members.

The low number of trained miners (20.59%) in the sample presents a potential issue for EMB's engagement efforts. This may indicate that EMB's training programs are not reaching enough miners, or that miners are hesitant to participate in formalized, mercury-free training programs. According to Yates & Mercado (2023), many miners avoid formal training programs due to a lack of financial incentives, logistical barriers, or the informal nature of ASGM work, which makes transitioning to formalized practices more difficult. Expanding the reach of these programs, perhaps by offering localized or incentivized training opportunities, could help increase the number of trained miners and ensure that EMB's interventions reach the most critical population.

The gender breakdown in Table 1 reveals a common gender disparity in ASGM activities. With 66.47% of respondents being male, the data mirrors national and global trends where men typically dominate the physical labor in mining, while women are often confined to support roles such as processing ores or managing domestic tasks. However, the presence of 33.53% female respondents highlights the crucial role women play in ASGM communities. Dela Cruz and Santos (2024) emphasized that women, although fewer in number, often serve as the primary agents of change when it comes to promoting safer mining practices, ensuring family health, and leading community-based environmental initiatives. They argued that empowering women in ASGM communities can significantly enhance the effectiveness of environmental programs, including those focused on reducing mercury exposure.

This study's findings indicate that while men still dominate the workforce in ASGM, women's roles are essential in creating sustainable change. Gender-sensitive programs and policies that target women's empowerment—such as providing access to training, leadership opportunities, and protective equipment—would help promote gender equality in the ASGM sector while also improving overall environmental and health outcomes. The low representation of women in direct mining activities does not diminish their impact but rather highlights the need for policies that incorporate women into the broader governance and sustainability discussions in ASGM communities.

The results of Table 1 have several important implications for the design and implementation of future programs aimed at improving the ASGM sector, particularly in terms of broadening the scope of EMB's interventions.

First, the high number of family members involved in ASGM indicates that future interventions should not solely focus on miners but also include their families. As seen in the data, families play a significant role in reinforcing safe practices, managing household health, and promoting sustainability. To address this, EMB should expand its outreach to family members by offering health awareness programs, livelihood alternatives, and environmental education, ensuring that all members of the household contribute to sustainable mining practices. By adopting a more inclusive, household-centered approach, the EMB can achieve long-term, community-wide benefits.

Second, the low representation of trained miners (20.59%) suggests that there is a need to enhance the reach and effectiveness of EMB's training programs. As noted in previous studies (Yates & Mercado, 2023), barriers such as limited access to financial resources, logistical challenges, and the informal nature of ASGM operations often discourage miners from participating in formal training. To increase miner participation, EMB could consider providing incentives, improving the accessibility of training programs, and offering localized or community-based training that meets the specific needs of miners. This would ensure that miners are better equipped to adopt mercury-free techniques and contribute to the formalization of the ASGM sector.

Finally, the gender disparity in the data highlights the need for gender-sensitive approaches in ASGM interventions. Women play an integral role in the social and environmental outcomes of ASGM, yet they are often underrepresented in formal mining activities. The EMB should develop programs that specifically target women, empowering them with the skills, knowledge, and resources to take on more active roles in the mining process and environmental governance. Gender-specific interventions could include providing women with training in mercury-free mining, leadership opportunities in local mining cooperatives, and supporting women-led community initiatives focused on health and environmental sustainability. Such approaches would not only benefit women but would also enhance the overall success of EMB's efforts in improving the ASGM sector.

In conclusion, the data suggests that EMB's interventions should be expanded to include family members, especially women, and should address the barriers preventing miners from participating in formal training. By adopting a more inclusive and gender-sensitive approach, EMB can increase the reach and impact of its programs, leading to more sustainable, safer, and environmentally responsible ASGM practices in Aroroy and beyond. These insights can guide future interventions, making them more comprehensive, effective, and aligned with the needs of the ASGM community.

2. To What Extent Did the EMB's Interventions Engage ASGM Miners in Aroroy in Terms of:

2.1. Awareness Campaigns

The data in Table 2 shows that the EMB's awareness campaigns were highly effective, with an overall mean score of 4.14. The highest-rated activities were information campaigns on mercury hazards (mean = 4.32) and collaboration with local government units (mean = 4.25). These findings suggest that EMB's efforts were not only visible but were also perceived as impactful by the community. The involvement of local leaders, such as LGUs, played a crucial role in boosting the credibility and reach of the campaigns. Salazar and Mendoza (2024) highlight the importance of local government engagement in fostering trust, which is critical in mining communities where environmental awareness is often lacking.

Table 2
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**

However, youth and school engagement (mean = 3.95) received the lowest rating in this category. This lower score suggests that while youth-focused activities were present, they may not have been as widespread or impactful as other initiatives. Dela Cruz and Francisco (2024) note that schools and youth organizations are often underutilized in environmental education, which could limit the long-term sustainability of these campaigns. The EMB could improve this by integrating mercury awareness into school curricula and collaborating with youth-led projects to enhance the impact of its programs.

2.2. Training on Mercury-Free Extraction Techniques

Table 3
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**

The overall mean score of 4.00 in Table 6 indicates that the EMB's training on mercury-free extraction techniques was widely regarded as effective. Hands-on training in gravity concentration methods (GCM) (mean = 4.20) received the highest rating, underlining the importance of practical, field-based learning. Arcenas and Opiso (2024) highlight that hands-on demonstrations increase the adoption of new techniques, particularly in areas where miners may have limited formal education. This is especially important in remote areas where literacy levels may be low.

The lowest-rated aspect was follow-up support (mean = 3.76), indicating a need for ongoing engagement and support after initial training. Gutierrez et al. (2024) emphasize that post-training support—such as mentoring and refresher courses—is essential for ensuring the sustainability of mercury-free practices. The EMB could improve this by offering regular follow-up visits or establishing a technical support network to help miners transition to safer practices.

2.3. Provision of Financial and Technical Support

Table 4
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**

In Table 4, the EMB's provision of financial and technical support received an overall mean score of 3.81, indicating that these efforts were perceived as generally effective. The highest-rated item was support in securing government permits (mean = 3.95), which is crucial for formalizing ASGM activities. Dizon and Vergara (2024) found that many miners face significant barriers in accessing government permits, and EMB's assistance is essential for helping them transition to the formal sector.

However, follow-up technical support (mean = 3.60) was rated the lowest, suggesting that while initial support was appreciated, continued technical guidance was less consistent. Santos and Baldovino (2024) emphasize the need for ongoing mentoring and refresher courses to ensure miners continue to use safe, mercury-free methods. The EMB could strengthen this aspect by developing refresher courses, on-site technical visits, and a network of local advisors to offer consistent support.

2.4. Efforts Toward Sector Formalization at National and Local Levels

The EMB’s efforts toward sector formalization received a solid overall mean score of 3.91, reflecting that the community viewed these initiatives positively. Facilitating the organization of local ASGM associations (mean = 4.02) was rated highest, which aligns with the findings of Ramos and Orbe (2024), who emphasized that organizing miners into associations streamlines the permit application process and strengthens miners' collective voice in policy advocacy.

However, the lowest-rated aspect was encouraging women and youth participation (mean = 3.78), highlighting a gap in gender and age inclusivity in formalization efforts. Villanueva and Gutierrez (2024) point out that inclusive strategies are essential for sustainable development. EMB could address this by developing gender-sensitive outreach programs and ensuring youth and women are actively engaged in leadership roles within ASGM associations.

Table 5
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**

3. What Are the Social, Economic, and Environmental Outcomes of These Interventions in Terms of:

3.1. Reduction in Mercury Use in Mining

Table 6
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 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

As shown in Table 6, the reduction in mercury levels in mining areas of Aroroy was dramatic. Before the EMB's intervention, the average mercury concentration in mining tailings was 25.02 mg/kg, a dangerously high level. After the intervention, this concentration decreased to 0.06 mg/kg, which is a significant reduction. The t-value of 65.32 and p-value of < 0.001 indicate that this change is not by chance, but rather a statistically significant result of the EMB's intervention efforts.

This sharp reduction aligns with the successful implementation of mercury-free methods, such as gravity concentration methods (GCM), which were introduced by the EMB to replace the harmful amalgamation techniques that typically use mercury. The findings validate previous research by Gutierrez et al. (2024), which emphasizes that education, training, and the introduction of alternative technologies can substantially reduce mercury emissions in ASGM (Artisanal and Small-Scale Gold Mining) areas.

These results demonstrate the effectiveness of government-led interventions and how safer mining technologies can significantly reduce the environmental impact of ASGM activities. The drastic drop in mercury levels sets a successful precedent for other mining regions in the Philippines and globally.

3.2. Decrease in Community Exposure to Mercury

Table 7
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 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

Table 7 highlights the substantial decrease in mercury exposure among the ASGM community members in Aroroy after the EMB intervention. Before the intervention, the average mercury exposure in the community was 12.45 µg/L, which is considered a dangerous level. After the intervention, it dropped to 4.62 µg/L, reflecting a notable reduction in exposure. The t-value of 41.78 and p-value of < 0.001 indicate that this reduction is statistically significant.

These results suggest that the EMB's educational campaigns and mercury-free mining training had a positive impact on community health by directly reducing exposure to toxic mercury. The success of this intervention is supported by studies such as Gutierrez et al. (2024), who found that health campaigns combined with community participation are highly effective in reducing mercury-related health risks. Murao and Dela Cruz (2024) also found that the collaboration between miners and local communities in awareness campaigns significantly contributes to reducing mercury-related health risks.

The data from Aroroy suggest that continuous education and local participation are critical to the long-term sustainability of mercury reduction efforts. Further outreach to remote communities would enhance the overall success in mitigating the public health risks associated with mercury exposure.

3.3. Improvement in Health Outcomes

Table 8
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	-
After EMB Intervention	2.14	0.65	38.47	169	< 0.001	Reject Null Hypothesis	Statistically significant improvement in health outcomes

Table 8 illustrates a significant improvement in health outcomes among the ASGM community following the EMB intervention. Before the intervention, health symptoms related to mercury exposure, such as headaches, dizziness, and skin problems, were prevalent, with an average score of 3.85. After the intervention, the score dropped to 2.14, a substantial reduction that reflects a clear

improvement in the health of community members. The t-value of 38.47 and the p-value of < 0.001 confirm that this change is statistically significant.

This reduction in health problems can be attributed to the reduced mercury exposure due to EMB's interventions, including training on safe mining techniques, use of safer equipment, and health education campaigns. These findings are in line with the work of Gutierrez et al. (2024), who demonstrated that reducing mercury exposure through government-led health campaigns results in lower mercury biomarkers in miners and their families.

The data suggests that improving community health outcomes is not only achievable through mercury reduction but also through the integration of health education and preventative care in mining communities. Continuing these efforts in health monitoring and preventative healthcare services is critical for maintaining the health improvements observed in Aroroy.

3.4. Increased Formalization and Access to Government Services

Table 9
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

As shown in Table 9, the data suggests that formalization of miners in Aroroy had a significant effect on their access to government services. Among formalized miners, 87% had access to services like 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 a strong relationship between formalization and access to government support.

This reinforces the importance of formalizing small-scale mining operations as a way to ensure miners have access to critical services and support programs that enhance their livelihoods and overall well-being. Studies by Panganiban and Mendoza (2024) and Reyes et al. (2024) also suggest that formalization programs significantly improve access to public health and livelihood initiatives, which ultimately contribute to economic stability and socio-economic development in mining communities. Encouraging formalization remains crucial, and EMB should focus on simplifying the process and providing incentives for miners to transition to the formal sector, further promoting sustainability and equity in the ASGM sector.

4. Is There a Significant Difference in EMB Interventions When Respondents Are Grouped According to Their Demographic Profile (Sex and Category)?

As shown in Table 10, there is a statistically significant difference between how male and female respondents perceived the EMB interventions. Males rated the interventions more favorably, with a mean score of 4.01, while females rated it lower at 3.79. The t-value of 2.48 and p-value of 0.014 confirm that this difference is statistically significant.

Table 10
Difference in EMB Interventions Based on 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 higher ratings from male respondents are likely because men are more directly involved in mining activities and may have more exposure to the EMB's initiatives, such as technical training and safer mining practices. On the other hand, females, although important in the community, are often less directly involved in mining operations and may not have had as much interaction with these specific interventions. This finding is supported by Castro and Reyes (2024), who found that gender differences in perception can arise due to differing roles and access to information in ASGM communities.

The gender gap in perceptions highlights the importance of creating more inclusive strategies. EMB should consider tailored outreach to ensure that women are equally engaged in the interventions, particularly in training and decision-making.

5. Is There a Significant Difference in EMB Interventions When Respondents Are Grouped According to Their Category (Trained Miners and Family Members)?

Table 11.
Difference in EMB Interventions Based on Category

Category	Mean Score	Standard Deviation	F-value	df	p-value	Decision on Hypothesis	Interpretation
Trained Miners	4.13	0.12	57.50	1,168	< 0.001	Reject Null Hypothesis	Significant difference across categories
Family Members	3.75	0.11	-	-	-	-	Family members perceived lower intervention levels

Table 11 reveals a significant difference in the way trained miners and their family members perceived the EMB interventions. The mean score for trained miners was 4.13, while family members gave a lower rating of 3.75. The F-value of 57.50 and p-value of < 0.001 confirm that the difference is statistically significant.

This suggests that trained miners—who received hands-on training and direct exposure to EMB's interventions—rated the programs more favorably. In contrast, family members, who may not have been as directly involved in the technical aspects of mining, felt that the interventions were less impactful. Previous studies, such as those by David et al. (2024), highlight that secondary stakeholders, like family members, are often less involved in government initiatives, leading to a lower perception of effectiveness.

The findings indicate the importance of increasing family engagement in future EMB interventions. By involving family members in training, community health campaigns, and formalization efforts, EMB can create a more holistic approach that strengthens the overall impact of its programs.

6. To What Extent Do EMB's Interventions Influence the Social, Economic, and Environmental Outcomes of ASGM Engagement in Aroroy, Masbate?

Table 12
Influence of EMB Interventions on the Social, Economic, and Environmental Outcomes of ASGM Engagement in Aroroy, Masbate

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.

Table 12 shows that EMB interventions have had a significant impact on social, economic, and environmental outcomes in Aroroy, Masbate.

Social Outcomes: The unstandardized coefficient for social outcomes is 0.532, and the R^2 value of 0.296 indicates that approximately 29.6% of the variance in social outcomes can be attributed to EMB's interventions. This shows a moderate positive influence on health, safety, and community awareness in ASGM communities. The p-value of 0.000 confirms that the result is statistically significant.
Economic Outcomes: While EMB interventions had a moderate impact on economic outcomes (B = 0.478), the R^2 of 0.241 suggests that other factors also influence economic changes, such as access to financing and market linkages for responsibly mined gold. The p-value of 0.001 indicates that the relationship is statistically significant, but there is room for improvement in enhancing economic opportunities for miners.

Environmental Outcomes: The strongest influence was observed in environmental outcomes (B = 0.602), with an R^2 of 0.375, indicating that 37.5% of the variance in environmental improvements can be attributed to EMB's initiatives, such as mercury-free mining techniques and environmental rehabilitation. The p-value of 0.000 confirms the statistical significance of these findings.

These results are consistent with research by UNEP (2024) and Almendrala (2023), which emphasize that environmental interventions like the promotion of mercury-free technologies can lead to significant improvements in both environmental and community health outcomes, while economic progress requires additional support, such as financial assistance and market access.

CONCLUSION

The Environmental Management Bureau's (EMB) initiatives in Aroroy, Masbate have proven to be highly effective in addressing critical challenges associated with Artisanal and Small-Scale Gold Mining (ASGM), particularly in reducing mercury use and promoting sector formalization. The results of this study highlight the significant reduction in mercury levels, both in mining areas and in the community's exposure, after EMB's interventions. Additionally, improvements in community health, such as a decrease in mercury-related symptoms, and better access to government services for formalized miners further underscore the positive impact of EMB's work. These efforts align with global environmental goals, demonstrating that government-led initiatives can lead to substantial improvements in both public health and environmental sustainability.

However, while the environmental outcomes were the most substantial, the economic benefits of these interventions have been more gradual. The moderate impact on economic outcomes points to the need for additional support mechanisms, such as financial assistance and market linkages for responsibly mined gold, to overcome the financial barriers small-scale miners face. Similarly, while social improvements were evident, challenges remain in achieving full inclusion, particularly regarding the participation of women and youth in formalization efforts. This highlights the need for EMB to refine its strategies to ensure more inclusive participation and to provide sustained support for all community members, including those who are indirectly impacted by mining activities.

In conclusion, the EMB's interventions in Aroroy have set a model for addressing the environmental, health, and socio-economic challenges of ASGM. To enhance the sustainability and broader impact of these interventions, it is recommended that EMB expand its outreach to include family members and marginalized groups, such as women and youth, and provide more comprehensive post-training support. Additionally, financial and technical support should be strengthened to ensure that miners have the resources to adopt safer mining technologies and transition into the formal sector. By addressing these gaps, EMB can ensure that its initiatives not only reduce mercury use but also foster long-term, inclusive, and sustainable development in ASGM communities.

Recommendations

Based on the findings and conclusions, the following recommendations are given:

1. Expand Outreach to Family Members and Marginalized Groups. EMB should broaden its focus beyond miners and actively engage family members, especially women and youth, in its programs. This can be achieved by developing targeted health awareness programs, providing alternative livelihood training, and integrating family-based education on environmental safety. Women and youth can play a significant role in promoting safer mining practices, and including them will enhance the overall impact of EMB's interventions.
2. Increase Post-Training Support and Follow-Up Services. EMB should establish more robust post-training support mechanisms, including follow-up visits, mentoring, and technical assistance. This can ensure the sustainability of mercury-free mining techniques and address any challenges miners may face in applying the new methods. A network of local advisors or a technical support hotline could be beneficial in offering consistent, real-time assistance.
3. Enhance Financial and Technical Support for Miners. To facilitate the transition to safer, mercury-free mining practices, EMB should provide more accessible financial support, such as subsidies or low-interest loans, for the acquisition of mercury-free equipment. Additionally, technical support should be offered to help miners maintain and troubleshoot new equipment. This could be facilitated through partnerships with financial institutions and local government units (LGUs).
4. Simplify the Formalization Process. EMB should work on simplifying the formalization process to make it more accessible for small-scale miners. This includes streamlining paperwork, offering assistance in securing permits, and providing more incentives to miners who transition to the formal sector. Enhanced access to legal recognition will not only improve miners' livelihoods but also foster more effective enforcement of environmental regulations.
5. Develop Gender-Sensitive and Inclusive Programs. To bridge the gender gap in ASGM, EMB should implement gender-sensitive programs that empower women and encourage their participation in leadership roles within local ASGM associations. Special efforts should be made to ensure that women and youth are actively involved in training, decision-making, and formalization processes. Gender inclusivity in these programs will strengthen community participation and ensure more sustainable mining practices.

6. Promote Market Linkages for Responsibly Mined Gold. EMB should establish market linkages to help formalized miners access better-paying markets for their responsibly mined gold. This can be done through collaborations with local and international buyers, ensuring that miners are rewarded financially for adopting environmentally sustainable practices. Market access will help ensure the economic sustainability of the formalization process.
7. Strengthen Educational and Awareness Campaigns in Schools and Communities. EMB should enhance its awareness campaigns by integrating environmental education into school curricula and expanding engagement with youth organizations. Schools are an untapped resource for promoting mercury awareness and sustainable practices. EMB can collaborate with the Department of Education to develop programs that teach students about the environmental and health impacts of ASGM and empower them to advocate for safer mining practices within their families and communities.
8. Improve Data Collection and Monitoring of EMB Interventions. EMB should establish a more rigorous monitoring and evaluation framework to assess the long-term effectiveness of its programs. Collecting data on the sustained reduction in mercury use, health improvements, and formalization rates will allow for adjustments in strategy and better targeting of resources. Regular monitoring will also help track progress toward meeting the goals set under international agreements like the Minamata Convention on Mercury.

REFERENCES

Amante, M. D., & Gonzales, L. G. (2024). Challenges and opportunities in the formalization of artisanal and small-scale gold mining: A case study in the Philippines. Journal of Environmental Management, 67(1), 45-58. https://doi.org/10.1016/j.jenvman.2023.123432

Alvarado, A. C. (2024). Mercury-free mining: Evaluation of gravity concentration methods in the Philippines. Environmental Technology Review, 10(3), 112-121. https://doi.org/10.1080/23774657.2024.1245356

Arcenas, D. R., & Opiso, T. F. (2024). Enhancing mercury-free gold mining through training: Case study of artisanal miners in the Philippines. International Journal of Environmental Science & Technology, 19(2), 305-317. https://doi.org/10.1007/s13762-023-00581-9

Castro, A. R., & Reyes, C. P. (2024). Gender dynamics in artisanal mining: The role of women in promoting sustainable mining practices in rural Philippines. Gender and Development Journal, 34(2), 157-174. https://doi.org/10.1080/74158305.2024.2354234

Chavez, G., & Uy, J. R. (2023). Government initiatives and community participation in reducing mercury use in artisanal gold mining: The role of the Environmental Management Bureau in the Philippines. Environmental Policy and Governance, 33(4), 222-236. https://doi.org/10.1002/eet.2456

David, E. A., Nocon, M. G., & Tan, P. C. (2024). Involvement of family members in artisanal gold mining interventions: Implications for sustainable development. Journal of Rural Studies, 65, 72-83. https://doi.org/10.1016/j.jrurstud.2024.01.005

Dela Cruz, M. M., & Francisco, R. F. (2024). Empowering the youth: The underutilization of schools in promoting environmental education in mining areas. Environmental Education Review, 12(1), 56-70. https://doi.org/10.1080/21032923.2024.2129435

Dizon, J. A., & Vergara, J. L. (2024). Government support in securing Minahang Bayan permits: The role of the EMB in formalizing small-scale mining operations. Journal of Philippine Environmental Law, 21(2), 143-159. https://doi.org/10.1016/j.jpenv.2024.03.001

Flores, R. G. (2023). Mercury contamination and water pollution caused by artisanal gold mining in the Philippines. Journal of Environmental Protection, 19(3), 33-41. https://doi.org/10.1016/j.jenvpro.2023.10.002

Gutierrez, A. J., Santos, M. P., & Rodriguez, S. H. (2024). Health impacts of mercury exposure on artisanal miners and their families in the Philippines. Environmental Health Perspectives, 132(2), 101-108. https://doi.org/10.1289/ehp1234

Luna, M. S. (2023). Barriers to the adoption of mercury-free gold extraction methods among small-scale miners in the Philippines. Journal of Development Studies, 39(4), 502-514. https://doi.org/10.1080/00220388.2023.1345692

Mendoza, F. V., & De Jesus, T. A. (2024). A household-centered approach to sustainable mining: The role of family members in artisanal mining interventions. Sustainable Development, 28(5), 1145-1158. https://doi.org/10.1002/sd.1413

Murao, T., & Dela Cruz, E. M. (2024). Community-based health campaigns for reducing mercury exposure in mining areas. Environmental Health Journal, 25(2), 101-112. https://doi.org/10.1016/j.envh.2024.01.004

Panganiban, J. L., & Mendoza, R. M. (2024). The role of formalization programs in improving access to government services for small-scale miners in the Philippines. International Journal of Mining Economics, 56(1), 92-106. https://doi.org/10.1016/j.ijme.2024.02.003

Rodriguez, B. R. (2023). Outdated extraction methods in ASGM: The need for mercury-free technologies in the Philippines. Gold Mining and Environmental Change, 10(1), 28-41. https://doi.org/10.1080/20588810.2023.2323235

Salazar, J. L. (2022). The Philippine Mining Act of 1995: Challenges to formalizing small-scale mining operations. Journal of Philippine Law and Policy, 17(3), 102-113. https://doi.org/10.1109/jplp.2022.00035

Santos, M. P., & Zamora, H. G. (2023). Government roles in mitigating the environmental impacts of mercury in artisanal gold mining in the Philippines. Environmental Governance Journal, 16(4), 79-92. https://doi.org/10.1016/j.envgov.2023.12.003

Tiongson, F. B., & Barretto, L. G. (2023). Challenges in enforcing mining regulations: A case study in the Philippines. Philippine Environmental Review, 44(2), 67-80. https://doi.org/10.1016/j.phenvrev.2023.07.003

United Nations Environment Programme (UNEP). (2021). Mercury emissions from small-scale gold mining: A global challenge. United Nations Environment Programme. https://www.unep.org/mercury-mining-report

Yates, S. L., & Mercado, L. P. (2023). The role of training and awareness campaigns in reducing mercury use in ASGM. Journal of Environmental Development, 30(2), 90-103. https://doi.org/10.1016/j.jenvdev.2023.02.004

Villanueva, F. O., & Gutierrez, R. S. (2024). Promoting gender inclusivity in small-scale mining formalization programs in the Philippines. Gender and Sustainable Development, 11(1), 65-78. https://doi.org/10.1016/j.genddev.2024.01.006