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Environmental health impacts of small-scale gold mining in East Indonesia: mercury pollution and nature conservation

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Abstract

The expansion of small-scale gold mining impacts environmental health and socioeconomic. Research in Bombana District, one of the gold mining centers in eastern Indonesia, was conducted to explore perceptions of the impact of small-scale gold mining on human health and attitudes towards environmental conservation activities related to small-scale gold mining activities. This research uses a quantitative approach with univariate tests to identify respondent characteristics, bivariate tests (Chi-square) to test relationships and frequency differences, and multivariate analysis (regression) to test the direction and magnitude of the relationship. The perception of the impact of small-scale gold mining on human health was not significantly related (p=0.576) to community participation in environmental conservation activities. Attitude variables related to nature conservation are partially significantly related to community participation in environmental conservation activities (p=0.001). Respondents with a poor attitude regarding environmental conservation activities are 17.1 times more likely to not participate in environmental conservation activities than respondents with a good attitude. Although mining activities benefit several sectors, it is undeniably detrimental to the environmental health sector, where one of the critical impacts is the mercury content in the soil and water in the environment around mining. Therefore, local people should take advantage of locally-based nature conservation.

Keywords

small-scale gold mining; nature conservation; environmental health; pollutant

Environmental health impacts of small-scale gold mining in East Indonesia: Mercury pollution and nature conservation

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Abstract

The expansion of small-scale gold mining impacts environmental health and socio-economic. Research in Bombana District, one of the gold mining centers in eastern Indonesia, was conducted to explore perceptions of the impact of small-scale gold mining on human health and attitudes towards environmental conservation activities related to small-scale gold mining activities. This research uses a quantitative approach with univariate tests to identify respondent characteristics, bivariate tests (Chi-square) to test relationships and frequency differences, and multivariate analysis (regression) to test the direction and magnitude of the relationship. The perception of the impact of small-scale gold mining on human health was not significantly related ($p = 0.576$) to community participation in environmental conservation activities. Attitude variables related to nature conservation are partially significantly related to community participation in environmental conservation activities ($p = 0.001$). Respondents with a poor attitude regarding environmental conservation activities are 17.1 times more likely to not participate in environmental conservation activities than respondents with a good attitude. Although mining activities benefit several sectors, it is undeniably detrimental to the environmental health sector, where one of the critical impacts is the mercury content in the soil and water in the environment around mining. Therefore, local people should take advantage of locally-based nature conservation.

Keywords: small-scale gold mining, nature conservation, environmental health, pollutant

1. Introduction

Indonesia is famous for its mining production because it consistently produces a variety of products [1–3]. Products produced by Indonesian mining include iron and its by-products (iron, nickel, manganese, cobalt, titanium, chromite, and molybdenum), precious metals (gold, silver, and platinum), non-precious metals (tin, zinc, copper, lead, and mercury), and rare metals (bauxite and monazite) [4,5]. Southeast Sulawesi, whose capital is Kendari, is one of Indonesia's provinces known to be rich in natural resources. In mid-2008, there was an "explosion" in gold production in Bombana Regency, Southeast Sulawesi, which started with discovering gold nuggets around the Tahi Ite River area. In its development, the local community and miners from outside Bombana Regency and from Sulawesi Island joined in this mining activity.

Various mining activities in Southeast Sulawesi positively impact the community, including job opportunities that can help the local community's economy. This finding is consistent with previous research that small-scale gold mining benefits community members as a source of income, employment, and livelihood. Some call small-scale gold mining a source of community economic development; others call it an activity promoting local businesses, such as mining. Respondents listed "opportunity to acquire property" as the main benefit of mining, followed by "get rich quick" and "alternative ways to a better livelihood" [6].

Small-scale gold mining activities have an impact on the socio-economic aspects of society. Based on

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previous research, people who are unemployed or poor in the vicinity participate in small-scale gold mining activities, or one family member has worked in the small-scale gold mining industry in the last five years. These findings indicate a shift in management of the number of people who have jobs in agriculture and animal husbandry [7]. The socio-economic impacts of small-scale gold mining are related to population displacement, rising prices of necessities, and increasing daily needs [7,8]. Another study also found that there is a perception that small-scale gold mining creates conflict between mine owners [9].

Gold (Au), considered one of the most valuable elements in international trade, is also the most exploited metal in mining production worldwide [8,10–13]. Small-scale gold mining activities adopt basic techniques for searching, extracting, and processing gold ore (Au) in several developing countries, including Indonesia [14,15]. Gold can be found in a free elemental state or combination with other elements, such as silver, copper, and other elements. The results of gold extraction associated with sulfide minerals are then processed by industry. The process includes physical and chemical stages, generally consisting of nine stages: Crushing, Grinding, Classification, Gravity Concentration, Foaming, Re-Grinding, Cyanidation, Electro-winning, and Smelting [16].

Small-scale gold mining process goes through various extraction processes. The final step in gold extraction is heating the amalgam over a candle, burning wood, or using gas to separate the mercury from the gold. According to miners, one gram of gold produces three grams of mercury. The gold ball is then placed on a spoon and burned with a gas stove to remove residual mercury contamination. The result is a smaller ball of pure gold. This phase is one of the most lethal, as burning smoke is inhaled into the local mining environment [17].

Previous research has raised concerns about mercury pollution, which could have long-term impacts on human health [18]. The toxicity caused by mercury is dangerous for the human body [19]. Mercury ranks third in terms of harmful substances for the human body [20]. Mercury vapor released by mining is carried by the wind to surrounding communities so that people can be exposed to mercury and feel its harmful effects [21].

Previous studies have found that another consequence of small-scale gold mining activities is the emergence of environmental pollution [9,22–24]. More specifically, other research found that small-scale gold mining activities generate noise from machine sounds [6], changing poor air circulation [15], and concerns about mercury pollution, which can have long-term effects on human health and aquatic and terrestrial ecosystems [18].

A comprehensive review reports that communities living in areas of small-scale gold mining operations also experience neurological disorders (i.e., tremors, ataxia, memory problems, and visual impairments) due to exposure to mercury released from gold mining operations [25]. Apart from the socio-economic benefits of mining development, the environmental impacts resulting from such activities as pollution sources depend on the extraction method, the scale of activity, the location, and the characteristics of the receiving environment [7]. Previous research showed that 96% of respondents had sufficient information about mining activities, 87% believed that mining activities damaged the environment, and 72% stated that they were detrimental to human health [6]. Other research states that residents with more knowledge/awareness about mercury carry out human health education programs. In addition, health education programs are also always discussed in advance with the village head to get support and approval. This study also shows that health education programs focus on the impact of mercury on human health, in contrast to other programs covering clean technology and mineralogy [26]. On the one hand, small-scale gold mining has a positive impact on the surrounding community's economy. However, it hurts the health and welfare of humans and the environment [27].

We conducted research in Bombana Regency, one of the districts in Southeast Sulawesi Province, which is one of the central locations for legal and illegal gold mining. According to the Ministry of Health, Bombana Regency is also the area that utilizes the Community Health Center program least effectively and only achieved the target of 26.2% in implementing occupational and environmental health. This research explains the factors influencing community participation in environmental conservation related to small-scale gold mining. We carried out statistical tests on the data to examine the factors that influence participation in environmental conservation activities related to small-scale gold mining with independent variables such as perceptions of the impact of small-scale gold mining on health and attitudes towards environmental conservation.

2. Materials and methods

2.1. Study area

The study area covers the entire Bombana District in Eastern Indonesia. Geographically, our research

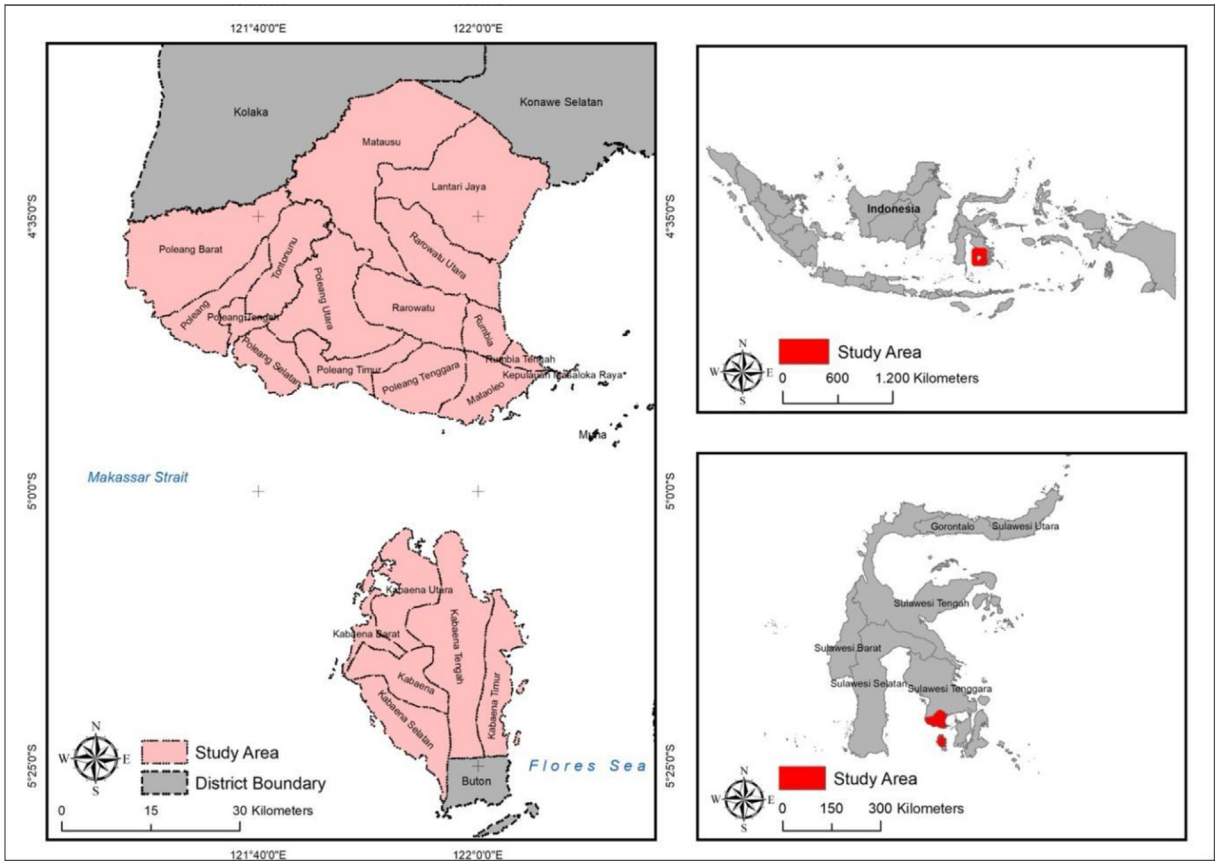

Fig. 1. Bombana regency is the area involved in this study.

location is on two islands (Fig. 1), namely on the island of Sulawesi, which is one of the main islands in Indonesia, and the island of Buton, which is a secondary island in Indonesia, even though both regions are part of Southeast Sulawesi. These areas have diverse mining activities, attracting many companies to exploit these locations (Table 1).

East Indonesia is well-known for unreachable areas that push controversies since they attract different social dynamics within the surrounding community. Arguably, the government still experiences hardship in monitoring East Indonesia. Indeed, diverse uncontrolled mining activities still occur within the areas. Environmental pollution can

Table 1. Mining corporations in Bombana Regency.

AREA		FRANCHISE	MATERIAL
REGENCY/CITY	SUB-DISTRICT		
Bombana	South Kabaena	Almharig, PT	Nickel
Bombana	North Rarowatu	Anugrah Alam Buana Indonesia, PT	Gold
Bombana	East Kabaena	Artha Bumi Mineral, PT	Nickel
Bombana	North Rarowatu	Bahtera Sultra Mining, PT	Gold
Bombana	South Kabaena and Central Kabaena	Bakti Bumi Sulawesi, PT	Nickel
Bombana	North Kabaena	Cahaya Abalong, PT	Nickel
Bombana	Lantari Jaya	Daya Utama Sakti, PT	Gold
Bombana	Centrak Kabaena and East Kabaena	Eka Panca Reksa, PT	Gold
Bombana	North Poleang	Leigerindo Utama, PT	Gold
Bombana	South Kabaena	Margo Karya Mandiri, PT	Nickel
Bombana	Rarowatu Disctrict	Multi Garmindo, PT	Gold
Bombana	Tapuhaka Village, East Kabaena District	Narayana Lambale Selaras, PT	Nickel
Bombana	North Rarowatu	Panca Logam Nusantara, PT	Gold
Bombana	North Kabaena	Pasific Ore Resources, PT	Nickel
Bombana	Lengora Village and Lengora Beach	Rohul Energi Indonesia, PT	Nickel

Source: Director of the Southeast Sulawesi Province Mining Company in 2021 [27].

harm the health of communities, both people who work in the gold mining sector and local communities who do not work in the gold mining sector. The potential for environmental pollution mainly occurs due to the increasing prevalence of small-scale gold mining carried out by the companies mentioned in Table 1 and individual miners.

2.2. Study design and data resource

This study discusses the relationship between the dependent and independent variables. The dependent variable in this research is participation in environmental conservation activities related to small-scale gold mining activities. The independent research variables are perceptions of the impact of small-scale gold mining on human health and attitudes towards environmental conservation. Previous research explains that the consequences of small-scale gold mining activities are environmental pollution, especially soil and water pollution. Other research also found the potential for respiratory and nervous system disorders in communities associated with small-scale gold mining activities [25].

This cross-sectional research was conducted for ten days in Bombana Regency, Southeast Sulawesi, Eastern Indonesia, to obtain primary data from 101 respondents. This research selected respondents using simple random sampling. Meanwhile, research data was collected through structured interviews using questionnaire instruments. The data collected is in the form of respondent characteristics such as age, marital status, place of work, education, religion, and ethnicity. In addition, we also collected data related to the dependent and independent variables in this study. The dependent variable in this research is participation in environmental conservation activities related to small-scale gold mining, such as collecting iron waste and the like from mining equipment, storing remaining mining materials (mercury, arsenic) in particular places (bottles, cans), and not dispose of waste mining materials (mercury, arsenic) into the soil and water. Meanwhile, the independent variable in this research is the perception of human health impacts due to small-scale gold mining activities, such as the perception that working in small-scale gold mining will be at risk of contracting diseases such as acute respiratory infection and the perception that working in small-scale gold mining will be at risk of exposure to heavy metals (mercury, arsenic). Another independent variable is the attitude towards environmental conservation.

2.3. Study management and analysis

All data obtained is first input into the MS Excel application and then imported into the SPSS application. The data then went through univariate, bivariate, and multivariate analysis. The univariate analysis aims to see a picture of respondents' characteristics through frequency distribution. Meanwhile, before carrying out bivariate and multivariate analysis, researchers carried out a normality test on the data obtained during data collection using the Kolmogorov-Smirnov test. The normality test shows that the data is normally distributed. The selection of the type of bivariate and multivariate statistical tests is based on the characteristics of the data and results from the normality test of data. Therefore, we used the chi-square test for bivariate tests and linear regression for multivariate tests. Bivariate analysis using Chi-square examines the relationship between an independent and dependent variable. Thus, this test will show which independent variables are spatially related to the dependent variable. Meanwhile, multivariate analysis uses regression tests to see factors that are related simultaneously. Ultimately, this regression test will show the independent variable that most dominantly influences the dependent variable. The entire analysis process, univariate, bivariate, and multivariate, uses the IBM SPSS 26 application.

3. Results and discussion

3.1. Demographic characteristics

Based on Table 2 above, the dominant respondents are aged 25–34 years, namely 35 respondents (34.7%). As many as 74 (73%) of respondents stated that they were married, while 17 respondents (16.8%) were single, and the rest were living or deceased with divorced status. Location of workers: as many as 64 respondents (63.3%) are in Tahi. In this area, 21 respondents (20.8%) work in Padang Bila, and each of 8 respondents (7.9%) works in Roko-roko and Onggomate. In terms of education, most respondents stated that they had an elementary school education, namely 39 respondents (38.6%), graduated high school/vocational school by 25 (24.8%), graduated junior high school by 24 respondents (23.8%), 10 respondents (9.9%) did not graduate from elementary school. The least were respondents with university graduates, namely only 3 respondents or only 3% of the total respondents. Meanwhile, from the religious

Table 2. Respondents characteristics.

Variable	Frequence	%
Age (year)		
15–24	28	27.7
25–34	35	34.7
35–44	15	14.9
45–54	14	13.9
>54	9	8.9
Marriage status		
Married	74	73.3
Not married yet	17	16.8
Divorced	4	4.0
Divorced by death	6	5.9
Workplace		
Roko–roko Village	8	7.9
Onggomate Village	8	7.9
Padang Bila Village	21	20.8
Tahi Ite Village	64	63.4
Education		
Didn't finish elementary school	10	9.9
Graduated from elementary school	39	38.6
Graduated junior high	24	23.8
Graduated high school	25	24.8
Graduate college	3	3.0
Religion		
Islam	98	97.0
Protestan	3	3.0
Ethnicity		
Tolaki	4	4.0
Bugis	38	37.6
Moronene	25	24.8
Jawa	7	6.9
Makassar	3	3.0
Buton	10	9.9
Toraja	2	2.0
Madura	2	2.0
Muna	5	5.0
Mandar	1	1.0
Flores	1	1.0
Ambon	1	1.0
Sunda	2	2.0

factor, the Muslim respondents dominated as many as 98 respondents (97%), while the remaining 3% or 3 respondents were Protestant.

It is interesting that when we look at the ethnicity factor where there are 13 types of respondent ethnicities, namely Mandar, Ambon, and Flores, each with 1 respondent (1%); Sunda, Toraja, and Madura, each with 2 respondents (2%); 3 respondents (3%) are from the Makassar ethnic group; 4 respondents (4%) are from the Tolaki ethnic group; 5 respondents (5%) are from Muna ethnic group; 7 respondents (6.9%) are from Jawa ethnic group; 10 respondents (9.9%) are from the Buton ethnic group; and from the Moronene ethnic group there are 25 respondents (24,8%). The most dominant is from the ethnic Bugis, namely, as many as 38 respondents (37.6%). The 13 tribes come from all over Indonesia, while the tribes originating from Southeast Sulawesi are the Tolaki, Moronene, and Buton tribes. However, Table 2 shows that migrant tribes, namely the Bugis from mainland South Sulawesi, dominate the local tribes. Thus, we can identify that the community in the research location is a heterogeneous society that integrates into an environment based on sources of livelihood. It is interesting to examine further the domination of non-local tribes over the local tribes of Southeast Sulawesi, which raises the potential for conflict and can become recommendations for different research topics.

3.2. Small-scale gold mining and environmental activities

Based on the results of previous research, small-scale gold mining has been proven to have positive impacts and benefits for the economic lives of communities around the mining area [28]. Small-scale gold mining throughout Indonesia is widely recognized, and its contribution to rural economic development cannot be ignored. These conditions show that gold mining positively impacts workers' economic conditions [29]. However, mining activities related to natural resources can cause environmental impacts [30]. Therefore, we explored the relationship between perceptions of small-scale gold mining impacts on human health, attitudes towards environmental conservation, and participation in environmental conservation activities. Through the chi-square test to see partial relationships, we found two different findings, namely (1) there was no relationship ($p = 0.756$) between the perception of the impact of small-scale gold mining on human health and participation in environmental conservation activities, and (2) there is a significant relationship ($p = 0.001$) between attitudes towards environmental conservation and participation in environmental conservation activities. The frequency or percentage of partial relationships can be seen in Table 3.

More than 56 respondents (55.4%) had a poor perception regarding the human health impacts of small-scale gold mining and lacked participation in environmental conservation activities. Meanwhile, the number of respondents with a good perception of the human health impacts due to small gold mining combined with poor implementation of environmental conservation activities is also relatively high, namely around 35.7% (36 respondents). There were only 9 respondents who carried out good environmental human health activities, of which 5 respondents (4.9%) had unfavorable perceptions regarding human health impacts, and 4 respondents (3.9%) had good perceptions regarding human health impacts. Thus, we can see that the

Table 3. Bivariate analysis.

Variable	Participation in environmental conservation activities related to small-scale gold mining				*p*-value
	Not good		Good		
	f	%	*f*	%	
Perception of human health impacts due to small-scale gold mining activities					
Not good	56	55.4	5	4.9	0.756
Good	36	35.7	4	3.9	
Attitude towards environmental conservation					
Not good	37	36.6	24	23.8	0.001*
Good	36	35.7	4	3.9	

*p-value < 0.05 Chi-square test.

dominant respondents need to participate in environmental conservation activities. Not to mention, most respondents also do not have a good perception of human health impacts. In other words, the dominant respondents think that environmental health mining does not impact their health even though mining practices threaten their health.

Small-scale gold mining uses mercury during the extraction of free gold particles. Most mercury is recycled, but some are lost in rivers, soil, and air [31]. This process can cause water pollution, contributing to environmental pollution [18]. Small-scale gold mining that uses mercury impacts the environment. Small-scale mining and general gold mining negatively impact environmental health [32]. Mining activities have significantly increased environmental mercury (Hg) levels around mining sites [33]. Small-scale gold mining activities contribute 12%, 10%, and 0.63% to atmospheric mercury (Hg) deposition, planktonic methylmercury, and total primary flux of Hg [32].

Gold finds are often in their elemental form or state. It is free or occurs in admixtures of silver, copper, bismuth, platinum group elements, mercury, or other reticulate sulfide crystals, substituted especially in pyrite, arsenopyrite, and chalcopyrite. This form is an invisible or closed form of gold [16]. On Earth, researchers indicate that more than 1000 tons of mercury are released yearly when a mercury-gold mixture is heated [24]. Mercury in the vapor is severe and fatal for mining workers [17]. The highest gold production in Indonesia occurred in 2018, around 130 tons. In many countries, mercury is the primary way to extract gold during mining, usually in large quantities. Over 1000 tons of mercury used in mining enters the environment annually, and an estimated 10 to 19 million people worldwide are at risk of mercury exposure [3]. This topic is essential for extraordinary exploration because it needs a handler to dispose of mine waste, which needs improvement. Releasing toxic substances into soil and water can cause health problems for humans, plants, and animals around open pits and downstream gold (Au) mining [7]. Releasing toxic substances into the soil and air can disrupt the survival of plants and animals around open-pit mines and downstream gold (Au) mining [7]. This condition will also cause significant health impacts for miners and residents [33].

Toxicity caused by mercury in the body can develop quickly. However, the development of mercury content in the body is often not seen and not felt, so that it can cause serious problems. Therefore, mining workers must have an extraordinary approach and attention to maintain their health status [34]. Due to the large number of minerals that become hosts and form sulfide gold ores, some of them can be a source of environmental pollution due to As, chromium (Cr), cadmium (Cd), manganese (Mn), lead (Pb), zinc (Zn), and copper (Cu). Therefore, these elements can potentially be toxic [16]. Previous research results found that the human toxicity value was determined by mercury emissions in gold mining activities (around 80%). However, the level of toxicity can be reduced by using retorts, which will significantly reduce the toxicity impact by around 90% [15].

Previous research shows that one of the impacts of small-scale gold mining activities is water pollution, which impacts human health. Apart from that, small-scale mining activities have also been found to cause respiratory system problems. Several miners were also found to be suffering from pulmonary tuberculosis. Meanwhile, other miners also experience skin problems such as skin lesions or skin cancer [35]. Another study also found that 62.3% said mining activities caused malaria. Respondents believe mosquitoes use holes around the mining environment as a breeding ground [6]. Based on research, through the food chain, the element mercury (Hg), which accumulates in the central nervous system and kidneys, will increase the chance of human health problems, especially chronic poisoning. The main clinical manifestations

are tremors, mental disorders or erectile dysfunction, proteinuria, and gingivitis. Other disorders include allergic or autoimmune disorders due to reduced resistance to infections and cancer [25]. Other research also states that inhaled mercury affects many parts of the human body, including red blood cells, kidneys, and the nervous system. When mercury reaches the lungs, it can damage the nerve lining and attack blood circulation [17].

3.3. Nature conservation by the locals

Based on previous studies, within the study group, 7.5% of subjects reported using personal protective equipment, including gloves, dust masks, and protective goggles. 99% of those surveyed said they had received information that made them aware of the environmental and health risks of artisanal gold mining. As much as 98.5% consider the need for an awareness campaign [17].

Indonesia has natural wealth that residents around mining can utilize. However, this mining activity still has problems related to water, soil, and air pollution. Therefore, workers and the government must be aware of the dangers of mining activities. The explanation above also explains that many chemical compounds are involved in gold extraction, including mercury and other chemical compounds. However, mercury is the most dangerous for human health because it can attack almost every body system.

There needs to be mitigation from the government to increase the knowledge and awareness of the local community because the spread of mercury can be through the air that humans breathe. As a result, people can get cases of the respiratory system. On the other hand, residents who need to work around the mining area claim to be happy with this mining activity. The community views this mining activity as helping their economy. However, only some working in the mining area experience conflicts between owners and fellow employees.

The existence of natural products as a place of work certainly impacts workers' economic situation [21]. However, it is necessary to pay attention that this mining activity has negative impacts, one of which is the presence of arsenic (As), which is toxic to the human body. Among the most critical toxic elements due to their effects on human health, mercury (Hg) and arsenic (As) are highlighted and are considered toxic and dangerous. There is a need to increase public knowledge and awareness regarding the hazards posed by mining activities [7].

Based on other research, knowledge about occupational health safety affects the mercury content in the blood [24]. The presence of high levels of mercury in the body can cause toxicity [19]. Thus, it is necessary to carry out mitigation through drinking water filters [9] or other forms of mitigation that intersect with environmental preservation.

The previous section explained that through the Chi-square test, there was a significant relationship ($p = 0.001$) between nature conservation attitudes and community participation in nature conservation activities. Almost the same as the perceived impact of small-scale gold mining on human health, attitudes towards environmental conservation are also predominantly unfavorable. A total of 61 respondents out of 101 respondents, or more than 50% of respondents, had poor attitudes towards environmental conservation, of which 37 respondents (36.6%) were accompanied by poor community participation in nature conservation activities and the remaining 24 respondents (23.8%) accompanied by community participation in nature conservation activities. Meanwhile, only four respondents (3.9%) had a good attitude towards environmental conservation and community participation in nature conservation activities. In comparison, 36 respondents (35.7%) did not participate in nature conservation activities. At the same time, they had a good attitude that they were related to environmental conservation.

We then tested these factors using linear regression (Table 4). Simultaneous test results using linear regression show that the relationship between attitudes towards nature conservation has a p-value of 0.003, meaning that the variable utilization of nature conservation has an influence and is dominant on environmental activities. The odds ratio value shows that the attitude variable towards environmental conservation contributes 17.1 times to participation in environmental conservation activities related to gold mining practices (confident interval 95%). Our findings are in line with previous research where attitudes have a significant effect on willingness to adopt (WTA) environmentally friendly gold mining practices at

Table 4. Linear regression analysis.

Variable	p-value	OR	95% CI
Perception of human health impacts due to small-scale gold mining activities	0.320	−0.371	−0.164–0.497
Attitude towards environmental conservation	0.003	0.171	0.054–0.543

16.2% [36]. Previous research generally links environmental conservation with mercury, which can threaten environmental sustainability.

Small-scale gold mining activities that only use mercury in their smelting are the primary source of mercury pollution globally. For the most part, without personal protective equipment, amalgam isolation was done by hand, followed by heating with a torch or stove to filter out the mercury and isolate the gold [34]. Once released into water systems, the metallic part of mercury can be oxidized and methylated by microbial or abiotic agents. This process produces the most dangerous type of mercury, methylmercury (MeHg) [21]. Inorganic mercury becomes methylmercury in air and sediment environments. This methylation process involves certain enzymes that convert mercury ions (Hg_2+) into methylmercury (CH_3Hg+). This process can occur in an environment with suitable conditions such as pH, temperature, and certain nutrients. Once formed, methylmercury can accumulate in the bodies of living organisms and become a poison that is dangerous for human and animal health [37].

Meanwhile, for the human health impact variable due to small-scale gold mining practices, a p-value of 0.320 was obtained, which means that this variable does not have a significant relationship with participation in environmental conservation activities related to gold mining practices. It also shows (based on the bivariate analysis results) that the dominant respondents have unfavorable attitudes. This finding is different from previous research, which found that 88.5% of research participants thought that the impact of gold mining on human health was very significant. Attitudes can be influenced by knowledge [38]. Attitudes can be influenced by knowledge. According to previous research, people involved in mining ($n = 63$, 73.2%) know better about the harmful effects of mercury on health than people who work in other jobs. Previous research found that 48.7% of respondents doubted the toxicity of mercury and arsenic, and only 28.7% agreed that both compounds were toxic to humans [39].

Most of the toxicity of methylmercury is due to its high neurotoxicity and ability to cross the blood-brain and placental barriers [21]. Other impacts are respiratory problems and nervous disorders [25]. A mitigation plan is needed to minimize the negative impacts of mining activities, thereby significantly mitigating cases of mercury poisoning [9]. High levels of mercury in mining activities also impact the quality of the surrounding water [18]. Local communities need to be aware of this problem and create awareness to ensure environmental health quality [20].

Environmental awareness campaigns and knowledge are needed regarding the impact of small-scale gold mining on human health [38]. The strategic objective of developing the economic sector is to position the mining sector as an important sector of the national economy and encourage sustainable and competitive investment. The policies implemented must be able to increase and diversify mining production and encourage domestic and foreign private investment in the long term. The strategy in the environmental and social sustainability sector is to promote sound environmental and work safety practices. Establish good relations between social actors in mining and ensure efficiency through citizen participation [8]. At the same time, the implemented policies must promote the responsible use of resources to protect human health and the environment [8,40]. In addition, efforts to increase environmental awareness and the impacts caused by small-scale gold mining practices can be carried out by emphasizing empowerment methods that consider personal experiences, human perceptions, and seasonal impacts [41]. Community empowerment in the context of nature conservation can use the social capital that exists in the community. Social capital can encourage empowerment by building mutual trust and cooperative attitudes in the community. These conditions will then influence the habits and activities of individuals in society, such as the development process in protecting the environment. Increasing empowerment activities will help accelerate the development of intelligent communities, especially in understanding the importance of nature conservation, even in activities that coexist with small-scale gold mining practices [42].

4. Conclusions

Our research results show that the natural conservation utilization factor influences environmental conservation activities. Mining activities in Indonesia are relatively active and produce many natural products that can change the people's economy. On the other hand, problems arise due to mining, such as the emergence of mercury (Hg) in soil and waters. Small-scale gold mining is a sector that positively impacts the local economy but can have an irreversible impact on their health and the environment. Indeed, the mercury content in soil and water harms the human body. In particular, mining workers can experience health problems due to the use of mercury. Spreading mercury is effortless, such as through the air, which the people around the mining area inhale.

The mercury content from the results of mining activities is very detrimental to the local environment's health. The high toxicity of mercury content raises public concern about their health condition. Mercury pollution occurs in many parts of the world, which is the focus of mining owners. The research results show that attitudes towards nature conservation positively affect community participation in carrying out nature conservation activities related to small-scale gold mining activities. Our findings imply they intend to produce a sustainable approach during the mining process, though they have no excellent power to ensure those things are in practice. Therefore, integration between key stakeholders, namely local communities, governments, and corporations, is needed to ensure sustainable small-scale gold mining practices that can affect people's lives economically in the long term and overall environmental health. Thus, our findings, which identify attitudes as the factor most related to community participation in environmental conservation activities, can be a reference for implementing government programs, which are the result of implementing applicable regulations. The government can create education-based programs or other forms to improve good attitudes regarding environmental conservation. Based on this research, the output of this program will also increase community participation in environmental conservation, especially small-scale gold miners. Thus, the implementation of small-scale gold mining by miners will be accompanied by good environmental conservation behavior. The collaboration between the two will be a middle way that mediates the fulfillment of the miners' economy and environmental preservation.

Ethical statement

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Research Ethics Committee, Faculty of Medicine, Universitas Sebelas Maret (protocol code 147/UN27.06.11/KEP/EC/2022 and date of approval on 7 November 2022).

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Conflicts of interest

The authors declare they have no conflict of interest.

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