

## Risk Management of Lead and Arsenic Poisoning in Children through Public Participation in Communities near Abandoned Tin Mine, Southern Thailand

Anchalee Pongkaset<sup>1,2</sup>, Banchong Witthayawirasak<sup>1,3,\*</sup>

<sup>1</sup> Faculty of Environmental Management, Prince of Songkla University, Songkla, Thailand

<sup>2</sup> Sirindhorn College of Public Health, Yala, Thailand

<sup>3</sup> Center of Excellence on Hazardous Substance Management (HSM), Bangkok, Thailand

\* Corresponding author: Email: [banjong.v@psu.ac.th](mailto:banjong.v@psu.ac.th)

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### Abstract

Tamtalu Subdistrict, Bannangsta District in Yala Province, southern Thailand was the site of an abandoned tin mine, and was contaminated by lead and arsenic from the mine tailings. As children are a high risk group from these highly toxic contaminants, this study aimed to identify approaches to reduce children's exposure in the area. The study was conducted through participatory action research (PAR) to empower the community strengthen sustainable risk management. The participants were local public health officials, public health volunteers, parents of local children and local community leaders. The participants were engaged in activities relating to risk communication, training on exposure prevention, planning of risk management and implementation of the plan. The children's risks were communicated to the villagers during community meetings. Trainings on how to prevent As and Pb exposure were provided, and preventive strategies planned and implemented. After a six-month period of the intervention, levels of As and Pb in the hair of local children's decreased significantly ( $p < 0.01$  and  $p < 0.05$ , respectively). The parents' knowledge of how to prevent children from As and Pb exposure increased significantly ( $p < 0.01$ ). The results indicated that PAR can be used to mitigate problems of chronic environmental exposure and poisoning. In addition, the Ottawa Chatter concept can be applied for long-term management. Economic status and effective risk reduction programmes are key determinants for successful implementation of local community-based risk management plans.

**Keywords:** Risk management; Participatory action research; Lead; Arsenic; Abandoned mine; Exposure

## Introduction

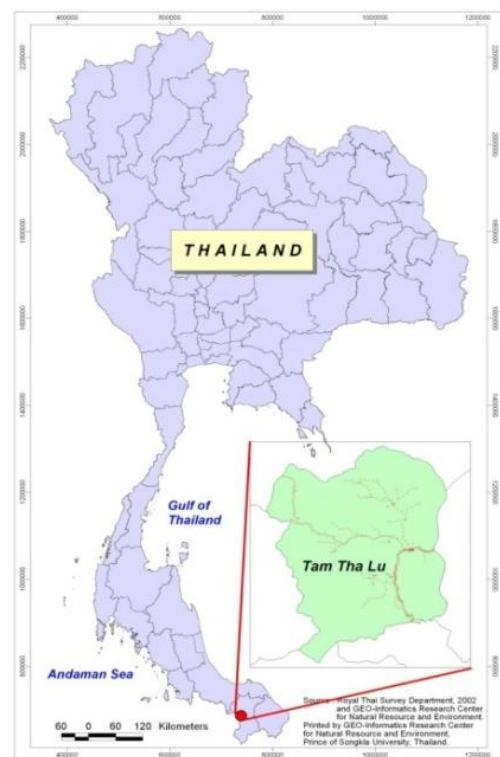
Mining has caused severe long-term environmental contamination by heavy metals and other toxic substances in many countries. Lead (Pb) contamination from mining operations caused the deaths of more than 400 young people in Nigeria due to prolonged exposure and ingestion [1], other potentially harmful elements such as arsenic (As) released from ores during mining operations is a cause of great concern to communities in the vicinity of these mine operations [1]. In Latin America, As residues from mining has contaminated drinking water in 14 out of 20 countries, with the number exposed estimated at 14 million people [2]. Children from 0-6 years old are considered at highest risk from the toxic effects of heavy metals, especially Pb [3]. As is a carcinogen which can affect the level of intelligence and memory over the long period. As also affects pregnant women and babies in the womb [4]. While, Pb affects the nervous system, brain, the growth of the body and the development of children. Pb as little as 2-10  $\mu\text{g dL}^{-1}$  in the blood affects the health of children. Young children were the major group to get toxic effects from Pb exposure [5].

In Thailand, As contamination has been reported at Ron Phibun District, Nakhon Si Thammarat province and Pb contamination at Klity Creek, Kanchanaburi province [6]. Both were caused by mining activities. An abandoned tin (Sn) mine in Tamtalu Subdistrict, Bannangsta District, Yala Province, southern Thailand (Figure 1) was found to be contaminated with both As and Pb [7].

Recently, a risk assessment study was conducted to evaluate chronic As and Pb poisoning among children in communities near an abandoned Sn mine in Tamtalu Subdistrict. The study found an unacceptable level of potential risk (hazard index  $> 1$ ) [7] especially from oral and inhalation exposure. This means that a risk management and prevention plan is urgently

required in order to reduce the chronic long-term exposure of these children to As and Pb. In addition, exposure of As and Pb from source, pathways and receptor (children) cannot be reduced in a short period of time. However, this could be accomplished by focusing on participation of the local community [8] because such an approach would deliver solutions in line with the community's needs and thus, would be likely to be more sustainable in the long term. Communities need to acquire a thorough and common understanding of the causes and modalities of Pb and As contamination, and find ways to manage the problems in order to protect future generations. A paradigm shift is needed in environmental management towards sustainability, requiring a delicate balance of economic, environmental and social considerations [6].

The objective of this study was to reduce exposure of local children to environmental As and Pb in communities located near an abandoned tin mine in Yala Province, southern Thailand.



**Figure 1** Tamtalu subdistrict in Yala Province.

## Materials and methods

### 1) Study design

A participatory action research (PAR) programme was designed to develop a risk management plan to reduce chronic exposure to As and Pb among young children from 4 communities located near an abandoned tin mine in Tamtalu Subdistrict, Bannangsta District, Yala Province, southern Thailand. The PAR plan was first examined during July 2013 to May 2014 by the Ethics Committee on Human Research, Faculty of Medicine, Prince of Songkla University (project code No. 56-246-19-6-2) and given approval to proceed.

### 2) Research participants

A total of 143 research participants were involved in this study, as shown in Table 1. Participants were selected from all stakeholder groups at the local level, based on the “triangle that moves the mountain concept” [9]. In the case of parents, 119 parents of children aged up to six years old who have been living in the communities since birth were randomly sampled.

**Table 1** Summary on research participants

Participants	Number of participants
Health officers	4
Health volunteers	15
Local leaders	5
Children's parents	119
Total	143

### 3) Statistical analyses

A questionnaire was developed to test the parents' knowledge on As and Pb exposure and how to minimize exposure. The quality of the questionnaire was determined by calculating the content validity index (CVI). The CVI was evaluated by three experts in the fields of risk assessment and management. After evaluation, the CVI score of 0.92 was considered as acceptable. The reliability of the test was determined by calculating KR-20 (Kuder-Richardson-20).

The reliability score of 0.75 was also acceptable [10]. A paired t-test was used to compare means of the parents' knowledge, as well as levels of As and Pb in children's hair before and after the implementation of the risk management plan.

### 4) Steps of PAR activities

4.1) The risks faced by local children were communicated to the villagers through several community meetings. In addition, risk communication and training on prevention of As and Pb exposure were also conducted. Following these activities, a consensus was agreed with the community to proceed with development of the risk management plan.

4.2) All research participants were recruited to become actively involved in all stages of the risk management planning process. Preventive strategies were also planned collaboratively by all participants during this activity.

4.3) A risk management plan was then implemented, focusing on reduction of As and Pb exposure through control and mitigation measures at sources, pathways, and receptors of exposure.

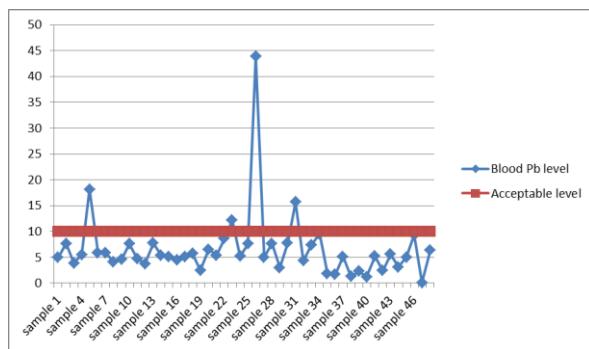
4.4) After six months of implementation of the risk management plan, a monitoring and evaluation programme was conducted via a survey of parents' knowledge as well as the level of As and Pb in children's hair, as compared to levels prior to implementation.

## Results and discussion

### 1) Risk communication

Information related to the risks of As and Pb exposure were communicated to all participants, including 1) What are As and Pb; 2) What are their toxic effects on human health; 3) Why are young children most sensitive to poisoning; 4) Sources of As and Pb contamination; 5) How the area is contaminated with As and Pb; 6) Routes of exposure; 7) Levels of As and Pb in the surrounding environment and the human body; and 8) Children's hair As and blood Pb

levels. Figure 2 shows an example of the method of communication on blood Pb levels. The data of each individual child as well as the process of risk management were also informed to the parents.



**Figure 2** Blood Pb level of children.

After the villagers learned of the risk of exposure that their children and communities faced, the meetings opened for discussions. Many questions were raised such as how to treat children as well as parental health. Furthermore, suggestions on how to avoid exposure were brought to the discussion. Approximately 59 % of participants agreed on the need to drink only water brought in from outside uncontaminated areas instead of consuming local water that was now recognized as contaminated. The same percentage of participants also agreed to cover the contaminated land with cement or clean soil brought from uncontaminated sites. Moreover, 63 % of participants agreed with the use of plants to clean up the contaminated soil. Up to 67 % of participants would seek funding from the Tamtalu Subdistrict Administrative

Organization. Finally, a consensus (100 % agreement) was reached to proceed with the risk management plan. It was evident that the risk communication process had succeeded in its goals to share information, exchange benefits and change behaviour among community members [11].

## 2) Risk management planning

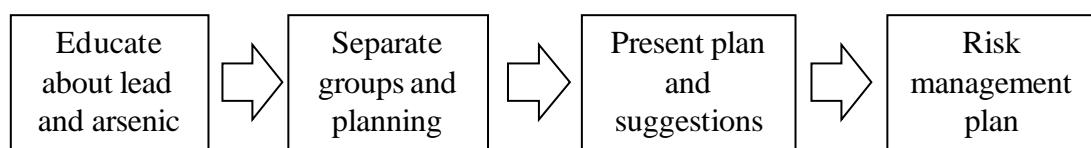
The risk management plan was initiated according several steps shown in Figure 3. All participants (Table 2) were included during these steps.

2.1) The research participants were educated on exposure pathways of As and Pb. In addition, guidelines on how to control the As and Pb exposure, including controlling exposure at sources, pathways and receptors were also delivered to participants.

2.2) The research participants were separated into three groups on a voluntary basis. The first group was made responsible for the plan to control exposure at sources (contaminated soil). The second and third groups were responsible for controlling exposure via pathways (drinking water) and receptors (young children), respectively.

2.3) The research participants in each group presented their plans and received comments and further suggestions to develop more effective, economical and practical options.

2.4) The overall risk management plan was finalized, and responsibility for implementation assigned among the participants.



**Figure 3** Steps of risk management planning.

Since the risk management plan was based on the needs of the community, representatives of each community had to get involved in its implementation, in order to ensure realistic outcomes and benefits for the communities. Note that the PAR tried to change the development paradigm from top-down to bottom-up while making the necessary arrangements to boost community engagement [12]. Based on “A ladder of citizen participation” [13], there are three degrees of participation including 1) non-participation degree, including manipulation and therapy; 2) degree of tokenism, including informing, and consultation; 3) degree of citizen power, including consultation, placation, partnership, delegated power, and citizen control. The PAR was utilized to reach the highest degree of citizen participation.

In the planning steps, the participants expected 100 % of the results of the plan but the achievement depended on many factors, especially the economic status of members of the communities.

### 3) Implementation plan

The risk management plan was implemented by the participants responsible with the cooperation of the parents of the children in each household. The activities and their results are elucidated in Table 2.

#### 3.1) Control at the source

- Coating a contaminated common area of the communities with cement this activity was undertaken by the Tamtalu Subdistrict Administrative Organization.

- Covering contaminated land with clean soil or growing plants capable of absorbing As and Pb from the soil (phytoremediation). The plants used were marigold and pinto bean. 12 out of 16 households adopted this method; the remaining households could not afford the budget for clean soil which cost about 5,000

Baht. In addition, soil around some households was not suitable for growing the plants.

#### 3.2) Control at exposure pathways

- Supply of clean drinking water

- (1) Cleaning rainwater receptacles, because samples of collected rainwater from 2 households were found with As greater than the Thai drinking water standard of  $0.05 \text{ mg L}^{-1}$ .

- (2) Securing a new supply of safe drinking water because drinking water samples collected from 6 households were found with As levels exceeding the Thai drinking water standard of  $0.05 \text{ mg L}^{-1}$ . Sources of drinking water in this area were rainwater, stream water and water from small reservoirs. The new supply of safe drinking water was filtered water produced at other uncontaminated areas. They were sold in 20-L containers for 10-15 Baht per container. Thus, the monthly cost of drinking water was about 60-150 Baht per household or annually 720-1,800 Baht per household. This price was lower than purchase of a drinking water filtration unit which costs at least 9,000 Baht while annual changing filter alone costs about 2,000 Baht.

#### 3.3) Control at the receptor

- Health education

- (1) All the children’s parents were educated about sources and routes of exposure to As and Pb, monitoring and control of As and Pb exposure in the body and the environment. The monitoring was done by research participants and health officials.

- (2) Safe practices for children’s daily activities such as children living in houses where the surrounding soil contained excessive levels of As and Pb. Regular hand washing before consuming food was recommended as a safety practice.

- Special treatment for high exposure group

(1) Blood samples were re-collected from six children with blood Pb levels above  $10 \mu\text{g dL}^{-1}$  [14]. All samples continued to show blood Pb levels above  $10 \mu\text{g dL}^{-1}$ . Therefore, Tamtalu health promotion hospital referred those children to a medical doctor at Bannungsta Hospital for special treatment. In addition, special guidelines were given to their parents as well as treatment with succimer.

(2) Blood Pb level, hair Pb and As levels (biological samples) in this study were collected to confirm the risk of children from As and Pb exposure from the environment in their respective communities. Since a hazard index greater than 1 indicates potential and unacceptable health risks from both elements [5], reduction of child exposure to both elements are required.

#### 4) Monitoring and evaluation

Monitoring and evaluation of the risk management program was conducted after 6 months of implementation of the risk management plan. As clearly shown in Table 3, the parents' knowledge increased significantly ( $p < 0.01$ ). Levels of As ( $p < 0.01$ ) and Pb ( $p < 0.05$ ) in children's hair decreased significantly (Table 3). The decline in As and Pb in hair samples indicated the reduction in As and Pb exposure since the accumulation of As and Pb in hair can be used to indicate the chronic exposure of both elements [15]. According to Pomroy et al. [16], 66 % of As was excreted with half-life = 2.1 d after intake, 30 % with half-life = 9.5 d, and 3.7 % with half-life = 38 d, the rest will be accumulated in the body. While infants and children retain 50 % of intake Pb [17] with slower elimination than adults [18].

**Table 2** Summary of implementation of the risk management plan

Activities	Number of samples targeted	Number of samples achieved	Percentage
<b>Control at source</b>			
- Coat common areas with cement	1 area	1 area	100 %
- Cover contaminated land with clean soil and phytoremediation around homes	16 households	12 households	75 %
<b>Control at exposure pathways</b>			
- Clean rainwater receptacles	2 households	2 households	100 %
- Secure supply of safe drinking water	6 households	6 households	100 %
<b>Control at receptor</b>			
- Health education	119 people	119 people	100 %
- Special treatment for children with high blood Pb levels	8 children	8 children	100 %

**Table 3** Monitoring and evaluation of the risk management

Activities	Mean values		t	p
	Before implementation	After implementation		
Parent's knowledge	6.99 score	9.03 score	-6.31	< 0.01
Children's hair As level	$0.08 \text{ mg kg}^{-1}$	Not detected	3.94	< 0.01
Children's hair Pb level	$1.00 \text{ mg kg}^{-1}$	$0.62 \text{ mg kg}^{-1}$	2.84	< 0.05

## 5) Health promotion

The Ottawa Charter for health promotion [19] was also adopted as an approach for the sustainability in this study. For this step, the research participants tried to find a way to solve the problem and forming new ideas by starting the loop of risk management step again. Research participants found that a health promotion was the right way to solve long term As and Pb exposure. It included 1) building a responsive public policy to support risk management by establishment of funds to remedy the health impact by local leaders and people; 2) creating supportive environments such as cementing ground in public areas contaminated with As and Pb which could reduce the exposure; 3) strengthening community action on continuous surveillance and monitoring of As and Pb levels in the environment and human bodies (especially children) and their exposure through PAR by research participants, health officials and health volunteers; 4) developing self-care skills among community members; and 5) reorienting health services to control chronic As and Pb poisonings by referring children for appropriate treatment.

## Conclusions

The As and Pb contents of the sampled children's hair was significantly reduced over the implementation period ( $p < 0.01$  and  $p < 0.05$ , respectively). The parents' knowledge of how to prevent children from exposure to As and Pb increased significantly ( $p < 0.01$ ). This study involved people from affected communities to participate and take action at all steps of risk management planning and implementation. Therefore, it could be concluded that the PAR and Ottawa Charter can be used together to develop sustainable solutions to chronic exposure to persistent environmental toxins. However, the economic status of community members and proper risk

reduction program are the main factors affecting successful implementation of risk management plans.

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