

Lead Contamination Control Plan and Environmental Risk Assessment in the Pattani River Basin and the Upper Maeklong River Basin in Thailand¹

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Abstract

First case study of lead contamination was done in 2002 for Pattani River Basin, Southern Thailand. The contamination was found to be from 2 sources: lead as galena (PbS) from mine waste piles from abandon tin mine 50 years ago at the beginning of Pattani River; and lead oxide (Pb₃O₄) in boat repairing activities at the end of Pattani River. The contamination was first discovered in Banangsata District in Yala Province. Lead concentrations in the fine sediment of less than 53 micron were 390-28,679 mg/kg dry weight. Lead concentrations in human body sampled from the boat repairing workers were in the range of 14.20-32.98 µg/dL. The highest concentrations were mostly found in men. Lead concentrations in human body sampled from residents nearby the boat repairing shop were in the range of 5.74-7.94 µg/dL. In comparison, lowest lead concentrations in control group were in the range of 3.06-7.64 µg/dL. Strategy plans for control, remediation, and rehabilitation of the lead contamination are giving public education in contamination situation, health effect, and pollution prevention. Waste piles of concentration higher than 10,000 mg/kg from the abandon mine will be removed to sanitary landfill. Sedimentation in Pattani River will be removed as well. Boat repairing activities will reduce usage of lead contained products and substitute with non-lead contained products. Lead monitoring in the Pattani River Basin will be continued in order to prevent future contamination in the basin and effects on coastal resources.

Second case study of lead contamination is done in 2003 for the Upper Maeklong River Basin in Kanchanaburi Province, Western of Thailand. Lead in Kanchanaburi Province is in the forms of cerussite (PbCO₃) and galena (PbS). There were no contamination occurred in the area prior to mining industry established. Usually, proper waste management can prevent lead contamination in the environment. However, study showed higher risk for residents in the areas that have mining potential than the areas that have no mining potential. Sediment in the river contains highest lead concentration especially in the mining proximity. There are a few environmental risk factors in the Upper Maeklong River Basin. Soil and sediment were sampled from the mining areas that pose high risk to human and environmental health. Twenty-eight soil samples (78% of all samples) have average lead concentrations higher than average lead concentration in Thailand (55.0 mg/kg dry weight). Sixteen sediment samples have average lead concentration higher than 400 mg/kg dry weight. Analysis of overlaying risk factors showed high risk areas in the mining areas and highest risk areas in the roasting house areas operated in 1997-2000. The high risk areas are subjected to continue environmental monitoring and future remediation.

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Introduction

Lead is one of the elements in nature. It usually found in combination of other elements to form different minerals. It is often found and mined as galena (PbS), cerussite (PbCO₃), and anglesite (PbSO₄). Lead has been mining in Thailand for a few decades now. High lead mining potential is in Kanchaburi province in Western Thailand and where history of lead usage can dated back to thousand years. Lead mining activities can also be found in Chaingmai, Mahongsorn, and Loei provinces in Northern and in Yala province in Southern Thailand. Lead is used in many industrial activities and products. Ninety percent of lead usage in Thailand is for battery production in automotive industry.

Lead is a health hazard for humans. It is undetectable by normal eyes, odorless, and often tasteless. Lead poison in human is from exposed to lead contamination in air, food, water, dust, and soil. Contamination can increase as lead is persistent and bioaccumulate in the environment especially in sediment and organism. Once absorbed into the body, lead may be stored for long periods in mineralizing tissue (i.e., teeth and bones) and then released again into the bloodstream, especially in times of calcium stress (e.g., pregnancy, lactation, osteoporosis), or calcium deficiency. Ninety to ninety-five percent of lead accumulation in human body is in bone and has half-life of 16-20 years. Toxic effects of lead depend on level of accumulation and target organs. They are hematological, neurological, gastro-intestinal, hepatological, gene, and carcinogenic effects.

As cases of high lead contamination in Thailand's environment revealed, study of lead distribution and environmental risk assessment is needed to evaluate the situation and to find control plan and remediation action. Two cases presented here are chose due to nature of contamination that involves basin-wide approach.

I. Pattani River Basin

Pattani River Basin located in Yala and Pattani provinces, Southern Thailand, covers an area of about 74 km². Lead contamination is the primary pollution problems of Pattani River Basin. Lead contamination was first found in the study of Department of Health and Prince of Songkla University in which lead concentration in aquatic animals and water exceeded the National Standard. The contamination was found to be from 2 sources: lead as galena (PbS) from mine waste piles from disused tin mine 50 years ago at the upper part of the Pattani River; and lead oxide (Pb₃O₄) in boat repairing activities at the river mouth of the Pattani River. Lead distribution study was done in 2002 by Pollution Control Department and Prince of Songkla University-Pattani Campus where human and environmental health risk were assessed. The strategy plan for control, remediation, and rehabilitation of lead contamination in the basin were proposed as a result.

Lead Distribution Study and Method

Lead distribution in the environment of Pattani River Basin and in the dockyard area were studied. Different types of samples were collected from the Pattani River Basin and the dockyard area.

1. Pattani River Basin, Pattani and Yala Province

- Streams around disused tin mine area in Tum Ta Lu sub-district, Ban Nang Sta District, Yala Province
Ten stations of water and sediment samples were collected from streams around Tum Ta Lu tin mine area (Table 1 and Figure 1).
- Pattani River, Yala and Pattani Province
Eleven stations of water, sediment, and fish samples were collected from Pattani River in Yala and Pattani Provinces.
- Pattani Bay, Pattani Province
Wastewater samples were collected twice either from effluent outlet or sedimentation pond of seven industrial plants in Pattani Province (Table 2). Sediment samples were collected in Pattani Bay: fifteen stations on first sampling and eighteen stations on second sampling. Sediment samples were wet sieved, by using 125-µm sieve, prior to

digestion and determination of lead. Zooplankton and Benthos Fauna were collected twice from Pattani Bay. Zooplankton was taken by using plankton net with 0.2 μm in pore size. Cockle (*Anadara granosa*) samples were collected as the representative of Benthos Fauna.

2. Dockyard Area, Pattani Province

Air samples were collected twice from three dockyard areas in Pattani Province:

- Inside dockyard working area at Ba Na Sub-district, Muang District
- Dockyard working area at Ba Na and Sa Ba Rang Sub-district, Muang District
- Outside working area at Bu-Dee village, Leam Pho Sub-district, Yaring District

First sampling used Personal Pump (Gilian) Model Gilair-5. Air samples were taken with flow rate of 2.0 L/min for 6 hours at each station pass through MCEF membrane filter with 37 cm in diameter. Second sampling used the high volume air sampler. Air samples were taken with flow rate of 1.02-1.24 m^3/min for 24 hours at each station. All membrane filters were then digested and analyzed for lead concentration with Atomic Absorption Spectrophotometric technique.

Soil dust samples were collected in the cemented dockyard area. Vegetables planted inside dockyard area and nearby factories were collected. Three different types of vegetables were also collected from Pattani municipal market to determine lead residue.

Blood samples were collected from three group of population: dockyard workers, population within 1 km perimeter of dockyard, and population outside dockyard.

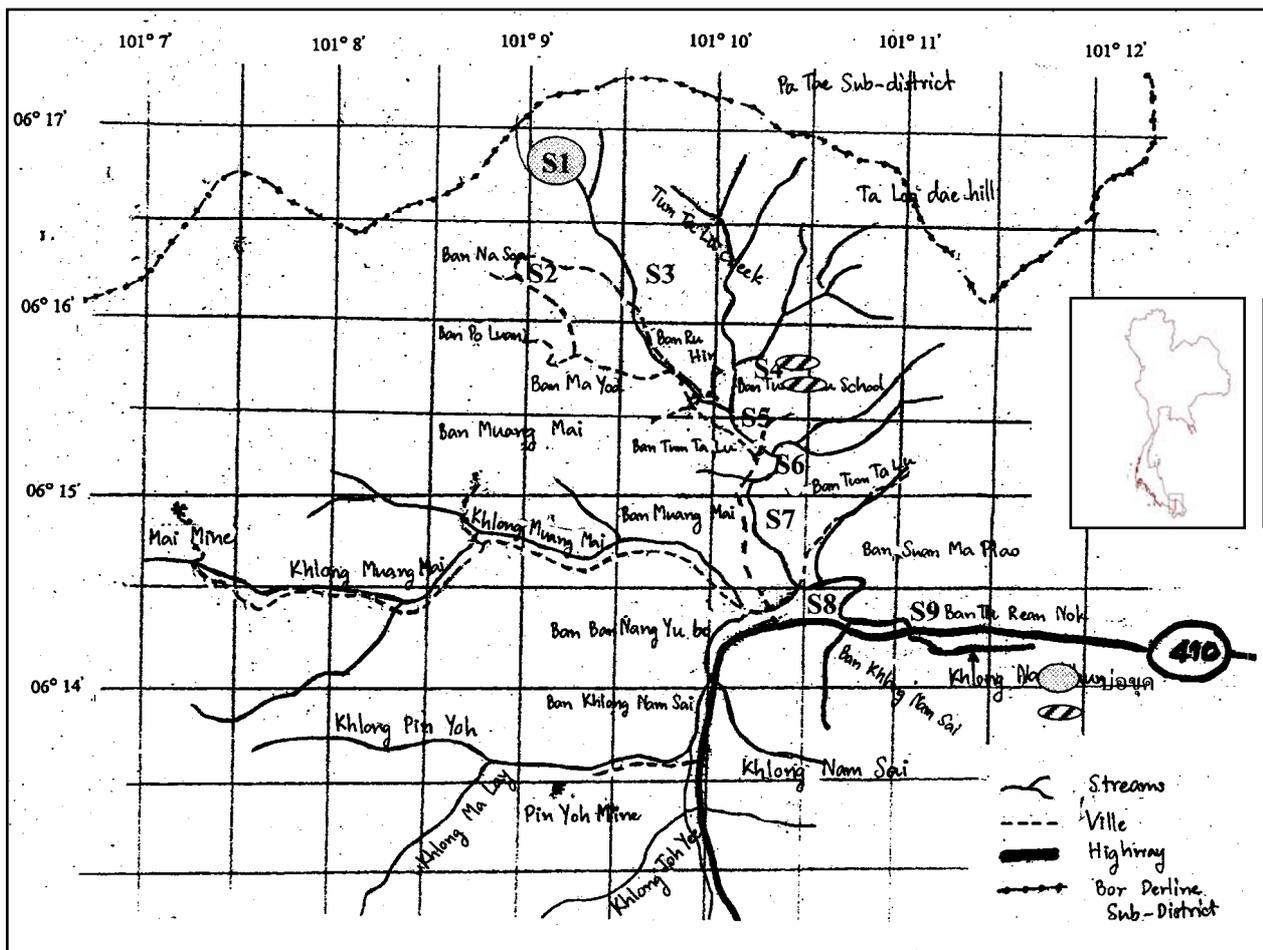


Figure 1 Sampling stations in streams around disused tin mines area at Tum Ta Lu Sub-district, Ban Nang Sta District, Yala Province

Table 1. Blood Samples in the Study Area

Group of Population	Number of samples		
	Adult Male	Adult Female	Children
1. Dockyard workers	16	35	3
2. Population within 1 km perimeter	18	59	-
3. Population outside dockyard	26	4	9

Results and Conclusion

1. Pattani River Basin, Pattani and Yala Province

Lead concentrations as total lead in water samples were found lower than 15 µg/L in most stations and were lower than the maximum lead concentration of 50 µg/L allowed in Thailand's national inland water quality standard. The contamination level of lead in stream sediments was found at 100 to 1000 times higher than that of river and bay sediments. In the first sampling, lead in clay particle (particle size < 53 µm) of sediment samples in streams around Tum Ta Lu disused mine, was found in the range of 390-28,679 mg/kg dry weight. In the second sampling, lead in clay particle of sediment samples in streams from Na Sua and Tum Ta Lu mine was found in the range of 510.6-23720 mg/kg dry weight.

Lead concentrations in fresh water fish samples, i.e. Golden little barb, Siamese rock catfish, and silver rasbora, were found in the range of 0.20-7.70 µg/g dry weight. Higher lead concentrations were found in some fresh water fish samples, i.e. Transverse-barbarb and Hoeven's Slender carp, in the range of 0.42-20.69 µg/g dry weight. The body length of all fish samples caught was less than 15 cm. A bottom feeder, i.e. was found to have lead accumulation at 10 to 20 times higher concentration level than other fishes studied which mainly were middle feeders.

Lead concentrations in all wastewater samples from seven industrial plants were found in lower than 10 µg/L in both samplings. Lead concentrations in bay sediment samples were found in the range of 23.55-181.23 and 33.15-132.04 mg/kg in first and second samplings, respectively.

Lead concentrations in zooplankton and benthic fauna samples in Pattani Bay were found in the range of 0.19-6.54 µg/g dry weight. Lead concentrations in cockle samples in both samplings were found in the range of 0.4-9.1 µg/g dry weight.

2. Dockyard Area, Pattani Province

In the first sampling, lead concentration in soil dust samples in dockyard working area, working surrounding area, and outside of working area was found in the range of 66.10-14246.31, 7.69-49.51, and 7.68-37.72 mg/kg, respectively. In the second sampling, lead concentration in soil dust samples in the same areas were found in the range of 85.79-7211.51, 8.32-124.02, and 1.97-161.00 mg/kg, respectively.

Lead concentrations in vegetable samples from industrial areas were found in the range of 0.17-0.54 µg/g dry weight.

In the first sampling, lead concentrations in air samples inside dockyard working area, working surrounding area, and outside of working area were found in the range of 0.0010-0.0028, 0.0005-0.0024, and 0.0008-0.0014 mg/m³, respectively. In the second sampling, lead concentrations in air samples in the same areas were found at 0.039, 0.013-0.025, and 0.005 µg/m³.

Lead concentrations in blood of dockyard workers were found in the range of 14.20-32.89 µg/dL and highest among three population groups. Lead concentrations in blood of population within 1 km of dockyard and population outside dockyard were found in the range of 7.94-5.74 and 3.06-7.64 µg/dL, respectively.

Risk Assessment of Lead Exposure

1. Risk assessment in Pattani Province

Source of lead contaminant was found to be the red inorganic lead powder using as lead oxide (Pb₃O₄) at dockyard. Exposure pathways were inhalation and ingestion as food and dust. Three areas were studied: dockyard area, dockyard surrounding area, and outside dockyard area (control area). Study found that dockyard workers were at the highest risk among all because lead level in blood and dust samples were found at higher level than other study groups.

2. Risk assessment in disused tin mine area in Tum Ta Lu Sub-district, Ban Nang Sta District, Yala Province

Source of lead contaminant was found to be inorganic lead in open cut tin mine. Exposure pathways were inhalation and ingestion a food and dust. Study found those populations of Tum Ta Lu sub-district were at highest risk of stream sediment exposure.

Strategy Plan for control and rehabilitation of lead contamination in the Pattani River Basin

Public education, such as in Tum Ta Lu sub-district in Bun Nang Sta District, on lead exposure prevention should be given by provincial public health or related organizations. For example, provide information on lead contamination situation and adverse health effects consuming lead contaminated food and water. Lead contaminated waste piles, such as in disused tin mine areas and Na Sua Dug Pond area, should be removed for treatment or to hazardous landfill to prevent further contamination in the environment. Usage of lead contained products should be reduced or substituted with non-lead contained products. Lead contamination monitoring especially in sediment was highly recommended by the research team in order to evaluate lead contamination in the environment for further management.

II Upper Maeklong River Basin

Upper Maeklong River Basin is located in Kanchanaburi Province, Western Thailand, where the primary source of lead (Pb) ores in Thailand. Lead in Kanchanaburi Province is in the forms of cerussite (PbCO_3) and galena (PbS) extensively found in Thongphaphum, Srisawat, and Sangklaburi Districts. Lead contamination was first found in 1989 by Office of National Environment Board in which water in retailing ponds adjacent to the flotation plant in Ban Khitibon in Thongphaphum District contained Pb at 200-7000 times higher than the National Surface Water Quality Standard (0.05 mg/L for Class 2-4). The following study of lead distribution around Srinagarind Dam in Kanchanaburi Province in 1995 found that highly turbid water resulted from various mining processes. The situation was exacerbated by failure of the tailing dam in 1997 when a great amount of contaminated water and sediments spilled over the upper part of tributaries and discharged into Khiti Creek. Lead contamination started from the point of dam failure to the end of Khiti Creek. Pollution Control Department found lead concentration exceeded the National Surface Water Quality Standard (0.05 mg/L). Lead distribution study was done in 2003 by Pollution Control Department and King Mongkut Institution of Technology-Thonburi where human and environmental health risk were assessed along with collecting and utilizing geographic information system. The strategy plan for control, remediation, and rehabilitation of lead contamination in the basin were proposed as a result.

Lead Distribution Study and Method

Compilation of geographic data in form of 1:50,000 map was done by employing the Geographic Information System (GIS). These data included both characteristics and types of lead ore, slope of the study areas, waterway, and flow direction. Also presented are data on human community affected by lead contamination. Results from previous studies on the issue will be reviewed from local sources in the districts of Thongphaphum, Srisawat, and Sangklaburi in Kanchanaburi Province.

In order to obtain representatives of sub-basin in the Upper Maeklong River Basin, sampling stations were selected from waterways with year round availability and accessibility for nearby communities. These areas have present or past mining activities in community settlement, agricultural land, and forest. Areas with and without mining potential were sampling for comparison.

Human blood and ecological samples were collected in Thongphaphum, Srisawat, and Sangklaburi Districts. Human blood samples were collected twice along with behavior surveying to assess human health risk in eight high lead potential area. Forty-five stations were selected to collect seventy-eight water samples three times from creek, rivers, and community water supply sources. Twenty-six water samples were collected from community water supply sources. Sediments, aquatic animals, soil, and vegetables were collected as well. Aquatic animal such as fish, shrimp, mollusk, and crab were collected at least 300 g with types, sizes, and pictures recorded before preserving in ice at 4 °C. One hundred and sixty-one soil samples were collected from the depth of 0-15 cm by 15 cm long polyethylene pipe with 4.0 cm wide diameter. Sampling sites were selected out of range of activities that may effect soil quality, for example, beyond 100 m boundary of roads or 50 m boundary of rivers. Vegetable samples were collected from plants and fruits nearby soil sampling sites.

Results and Conclusion

According to Thailand's National Water Quality Standard, lead concentration in surface water should not exceed 50 $\mu\text{g/L}$. According to Thailand's National Air Quality Standard, lead concentration in air can not exceed 10 $\mu\text{g/m}^3$. The study found:

1. Average lead concentration in water samples was 19 $\mu\text{g/L}$. Lead concentrations in water samples in mining and non-mining potential were 27 and 8.9 $\mu\text{g/L}$, respectively. Lead concentration in river and drinking water samples were in the range of 1.4-4.8 $\mu\text{g/L}$ and 3.2-8.5 $\mu\text{g/L}$, respectively.

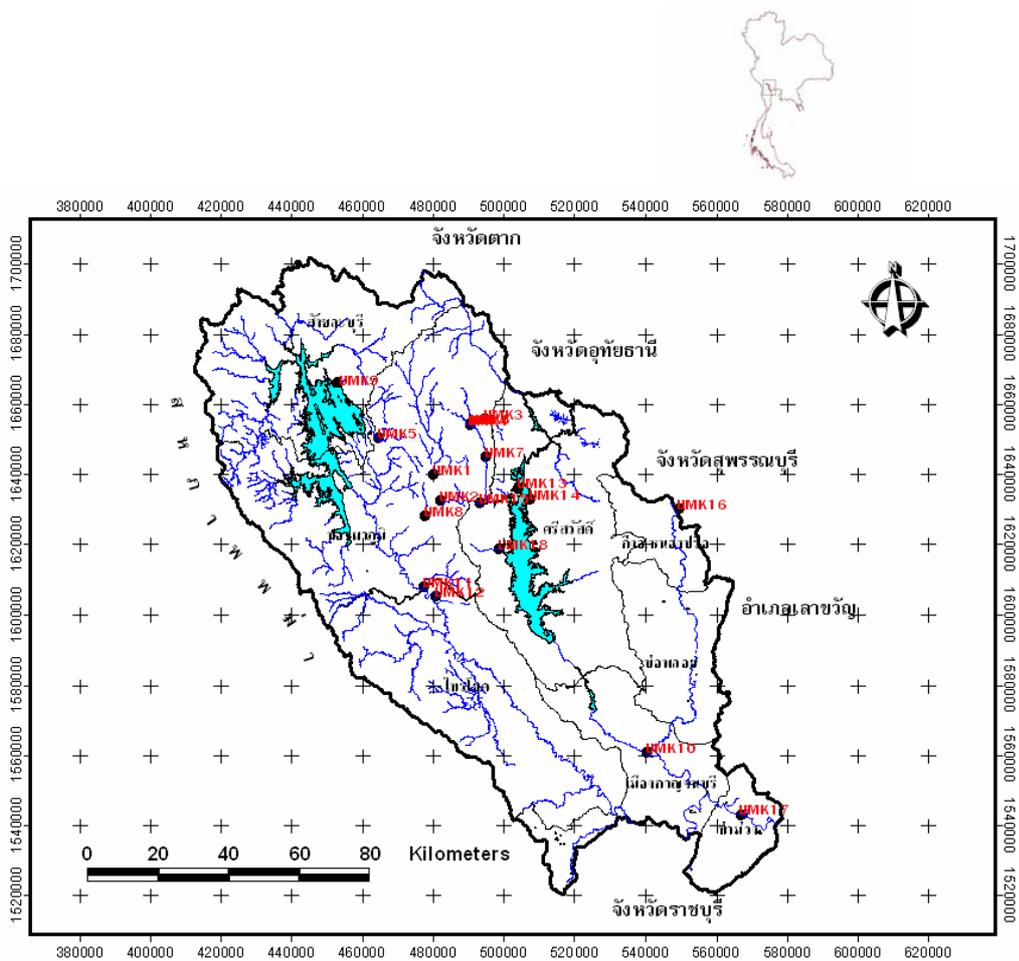


Figure 2 Sampling stations in the Upper MaeKlong River Basin in Kanchanaburi province

2. Average lead concentrations in sediment samples were in the range of 12.24-35,920 mg/g dry weight. Lead concentrations in sediment samples in mining and

non-mining potential were 185-409 and 12-146 mg/g dry weight, respectively. Lead concentrations in sediment samples below floatation plant were in the range of 2,350-61,615 mg/g dry weight.

3. Lead concentrations in aquatic animals were in the range of 0.05-121 mg/kg dry weight. The highest lead concentration was found in mollusk
4. Lead concentrations in soil samples were in the range of 11-7,473 mg/kg dry weight. The highest lead concentration was found at Ban Pa Mai Sapanlao Primary School. Lead concentrations in soil samples in mining and non-mining potential were 117-3,375 and 20-60 mg/kg, respectively.
5. Lead concentration in vegetables samples were in the range of 0.01-5.9 mg/kg.
6. Average lead concentration in air samples found at Ban Pa Mai Sapanlao Primary School was 1.34 $\mu\text{g}/\text{m}^3$.

By overlaying risk factors using GIS, the levels of risk were divided into five levels. First, the lowest risk areas were to be Srisawad, Borploy, Thamoung, Saiyok, Sangklaburi, and Tongphaphum Districts and outside the influences of mining activities. Second, the low risk areas were found to be parts of Srisawat, Sangklaburi, and Tongphaphum Districts as well as Nongpru Sub-district. Third, the moderate risk areas were found to be parts of Srisawad, Sangklaburi, and Tongphaphum Districts. Fourth, the high risk areas were found in the mining areas in Tongphaphum District. Last, the highest risk area was found in the vicinity of Khiti floatation plant in Tongphaphum District.

Risk assessment indicated that sources of contamination were from lead in forms of cerussite ($PbCO_3$) and galena (PbS) where high mining potential and mining activities present. Routes of exposure were identified as ingestion of contaminated water and food and inhalation of contaminated dust in roasting plant and mining areas. As blood test is not yet finalized, complete risk assessment cannot yet summarized.

Strategy Plan for control and rehabilitation of lead contamination in the Upper Maeklong River Basin

At this point, there are three scenarios proposed for environmental management in the Upper Maeklong River Basin.

- Communities remain in the mining area and cancel mining permits.
- Communities remain in the mining area and continue mining activities.
- Communities evacuate from the mining area and continue mining activities.

The second scenario is the most welcome scenario that communities and mining activities would be in the same area with impact remediation.

Comparison of Case Studies

Currently the mine waste piles in the Pattani River Basin were removed to hazardous landfill. Reduction of lead contained products is not yet assessed. Lead contamination monitoring is an on going project of Pollution Control Department, Ministry of Natural Resources and Environment. As for the Upper Maeklong River Basin, Khiti mining activities were suspended as lawsuit is presenting and further evaluation on liability issue is needed.

In both cases, source of contamination was lead as galena from past or present mining activities. Contamination was manmade which exacerbated by improper operations of mining activities and mismanagement of mine waste pile. As lead is a heavy metal, bioaccumulation is of great concern. Beside removal or reduction of contaminants, human and environmental health awareness should be rise to the public. Sufficient knowledge of toxic products handling and exposure prevention will greatly reduce toxic contaminant distribution and human and environmental health risk. Strict regulations and enforcement should be applied toward operations and proper waste management of mining industry.

Reference

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