Environmental and Public Health Effects Due to Contamination from Mining Industries in Thailand

Country Report Prepared by
Anong Paijitprapapon[1]

Abstract

Detrimental impacts on human health as a result of mining and related activities have been observed at several places in Thailand. The most serious cases are mainly related to heavy metal and metalloid contamination in waters and soils. Arsenic poisoning as a result of long-term consumption of contaminated shallow well water was first recognized at Nakhon Si Thammarat Province, southern Thailand, in 1987 where chronic arsenic skin lesions were observed in 1,049 patients aged from 4 months to 85 years. Physical and chemical breakdown of arsenopyrite (FeAsS), an associated mineral of tin deposits, was suspected as the major cause. Arsenic concentration in water and soil was found to exceed the acceptable standard and guidelines by a factor of up to 100. A switch in mining methods from dredging to open pitting was interpreted as being the cause of the accelerated dispersion of FeAsS. Owing to several environmental and health mitigation measures, arsenic contamination and public health impacts at this vicinity have been gradually alleviated.

Lead (Pb) contamination in running water and stream sediments around mining and ore dressing sites in the Kanchanaburi Province, western region, was first observed in 1992. Primary and secondary Pb ore have been mined in the area both underground and in open pit for more than half a century. The environmental conditions deteriorated seriously when a tailings pond collapsed due to unusually heavy rain in 1998. A large volume of tailings containing Pb at concentrations ranging from 20,000 - 30,000 mg kg^{-1} *was flushed into the natural drainage and as a result the concentration of Pb in water and bottom sediment increased significantly. This had a severe impact on the people living downstream. Average Pb content in blood of children < 6 years old was as high as 26.45 µg dl*$^{-1}$*. The situation improved after the flotation license was revoked and a clean up program was undertaken at the polluted stream and near the concentrator.*

In another case of heavy metal contamination attributed to the mining industry, high concentrations of Pb in water, sediment and soil in the vicinity of abandoned tin mines was reported from Yala Province in the South of Thailand in 1993. In 1994 edible marine macrophytes in the bay downstream were found to have elevated Pb contents of 4.74 - 26.78 mg kg^{-1} *(Dry Weight). A survey conducted during 1998–2002 however concluded that there are limits to the Pb contamination from the mined out area. Partly this was considered to be due to the alkalinity introduced by the surrounding limestone formations. Lead concentration in running water became lower downstream from the mines but increased again near the bay. The latter was probably influenced by boat repair activities in which Pb-based paints were used. Blood test surveys in 1995 discovered 96% and 98% of examined children from two primary schools in the proximity of the mines and the bay had levels of* $\geq$*10 µg Pb dl*$^{-1}$ *in their blood. Recent follow up data, however, revealed lowering trends in these concentrations.*

[1] Environmental Management and Reclamation Bureau, Department of Primary Industries and Mines, Bangkok, Thailand

In addition to the above there are several other cases waiting to be addressed. These and similar harmful experiences have given rise to public concern as to whether mining can be compatible with sustainable development. People and economies need minerals and metals for survival and therefore mineral development must continue but the crucial issue is how good environmental management can be assured. National regulations and regional and global agreements are formulated and enacted to achieve environmentally friendly economic development. Close cooperation and collaboration among countries, agencies and all stakeholders is also needed to accomplish the common ultimate goal of sustainable development.

Introduction

In accordance with national legislation and policies, the Royal Thai Government has an obligation to notify her citizens annually on the state of the environment including natural resources utilization and conservation as well as environmental quality. Although the overall national environmental aspects during these recent years revealed continued natural resources degradation, the quality of the environment as a whole had shown an improving trend. Ambient air quality monitoring data suggest cleaner outdoor conditions with reducing toxic gas emissions and total particulate matter. The quality of surface water obtained from 47 main rivers and 4 large reservoirs showed signs of recovery. As regards soil and groundwater quality there is a lack of data due to the absence of regular investigation and monitoring. Increasing land use for industrial and community settlements causes impacts to the environment. This is borne out by the rising number of patients suffering from pollution. Health effects in local communities adjacent to mining areas have been disclosed periodically. The environmental and public health impacts from mining activities are relatively severe in terms of coverage and numbers of affected people. These characteristics are clearly related to the enormous areas of disturbed land, bulk waste, long-term operation mis-management and subsequent natural degradation.

This paper emphasizes the environmental and public health impacts resulting from mining and mineral processing. Arsenic contamination in waters and soils as a result of tin mining and concentrating at Ron Phibun District, Nakhon Si Thammarat Province is highlighted as one of the most harmful instances of the last two decades. Lead dispersion from mines and tailing ponds at Kanchanaburi and in Yala Province are other severe incidents requiring continued remedial operations.

Arsenic Contamination in the Vicinity of Tin Mining and Processing

Contaminant Sources and Mechanism of Appraisal

Health problems attributed to arsenic contamination in water supplies in Thailand were first highlighted in 1987, following the diagnosis of a case of arsenical skin cancer at Ron Phibun District, Nakhon Si Thammarat Province. Mining has been an economic activity in the area for longer than a century and it was concluded that mining was the cause of the contamination. Arsenopyrite concentrations of around 1% are associated with economic mineral concentrations of the tin and tungsten minerals cassiterite and wolframite that occur in pegmatite and quartz veins throughout the granite mountain range. It was concluded that this was the sourec of As contamination. Placer deposits had been initially mined by dredging a century ago. During this period, minor arsenic release and contamination was believed to have taken place due to slight variations in groundwater levels.

Consequently, no intensive oxidation had occurred as a result of the dredging operations. However, when during the second half of the century the mining technique was changed to open pit mining of primary ore, exposure of the mineralized layers to the atmosphere stimulated the oxidization processes. Arsenic, contained in disseminated arsenopyrite in soil was liberated as arsenic and arsenous acid into the environment as follows:

$$4\ FeAsS + 13\ O_2 + 6\ H_2O \longrightarrow 4\ FeSO_4 + 4\ H_3AsO_4$$

When a number of the open pit mines were gradually abolished due to the collapse of the world tin market in 1985, the groundwater table recovered and the mobile arsenic compounds were dissolved. This same process on a smaller scale took place in association with smaller mining operations that exploited veins in mountainous terrain through adits or tunnels.

Environmental Investigation and Monitoring

Initial sample analysis indicated As concentrations in water and soil that exceeded the National Water Standard of 0.01 mg l^{-1} and soil guideline value of 50 mg kg^{-1} by up to a factor of 100. Surface water acidity ranged from pH 2.9 to 8.1 with pH increasing towards the lowlands. Arsenic concentrations in acidic waters close to the mining operations were lower than those in neutral waters adjacent to open pit operations.

This indicated that As dissolution and mobility is independent of antecedent pH. Monitoring data from 1992-1997 indicate that arsenic concentrations in running water around mountainous areas averaged 0.5 mg l^{-1} whereas those at the downhill alluvial plain exceeded 1.0 mg l^{-1}. However, longer-term systematic investigation of four major affected streams revealed continually decreasing concentrations of As in surface water.

Shallow groundwater from dug wells also showed decreasing trends in arsenic contamination. In 1990, maximum shallow well water As concentration was 9 mg l^{-1}. However, maximum shallow well water As concentration declined to 5.11 mg l^{-1} in 1994, 2.04 mg l^{-1} in 1999 and 0.60 mg l^{-1} and 0.10 mg l^{-1} in 2000 and 2001, respectively.

It is significant that the wells where the highest concentrations of arsenic were found during annual surveys were not always the same although those wells were normally situated in the same vicinity. This illustrates the complexity of the mechanism of dispersion and precipitation of arsenic and arsenic compounds. Arsenic species in surface and shallow groundwater was dominated by arsenate. Deep groundwater is normally clean since it is geologically confined to carbonate aquifers and separated from polluted shallow groundwater in unconsolidated sediments. However, a few deep wells were contaminated with arsenic probably through seepages in fractured limestone. In these deep groundwater wells arsenite is dominant. Deep well water sources are likely to pose a hidden risk and they need regular monitoring.

Distribution patterns of arsenic in soil and stream sediment corresponding closely with those in shallow groundwater. High arsenic contamination in surface and groundwater samples and soil and plant tissue samples was centered on two villages (Village No.12 and No.2) of Ron Phibun Sub-district covering a small area of 7-10 km^2. Arsenic contamination through inhalation is considered minimal. An investigation of ambient dust was conducted using high-volume samplers and falling-dust jars. The amount of total particulate matter as well as its arsenic content was found to be very low.

Public Health Effects

The Public Health Office at Ron Phibun District in April 1988 revealed that there were 1,049 patients suffering from skin disorders diagnosed as hyperpigmentation, *keratosis* and skin cancer. Their ages varied from 4 months to 85 years and their number was equivalent to 6.56% of the total population of Ron Phibun District. Most patients, over 75%, were diagnosed with pigment changes showing spotty dermal *melanosis* and pinheaded dermal papules on palm and sole. These manifestations and symptoms were related to chronic arsenic poisoning. The patients had been exposed to arsenic toxicity through drinking arsenic contaminated shallow groundwater from dug wells for a long period of time. The 1992 clinical survey reported that 89% of 2,400 pupils had high arsenic levels in their blood and 22% showed skin effects.

In 1995 a Japanese medical examination found no new patients but most registered patients still showed symptoms. Studies also addressed the correlation between patient's lodgings and areas of high arsenic contamination in shallow groundwater. According to a health study published by Oshikava, 1998 only 334 of 818 patients recorded during 1987 were traced and diagnosed for the developments and changes in the manifestation of the disease. Of these, 12 people died from cancer during 1987-1997. Only 16 people showed worse arsenical skin lesions whereas 98 people showed improvements in their condition and the remainder of 208 continued unchanged. A recent clinical survey conducted by the Ministry of Public Health disclosed a declining prevalence of arsenic manifestation from 26.3% in 1994 to 24.4% in 2000. The statistical significance of this 1.9% decline over the 6 year period is not stated. Health impacts from arsenic contamination in Ron Phibun District have recently shown decreases. This indicates the effectiveness of protection and mitigation measures implemented in the area.

Environmental Alleviation Measures

Mitigation measures to alleviate arsenic contamination and eliminate public health risk at Ron Phibun District have been implemented by several relevant organizations including the Ministry of Interior, the Ministry of Public Health, the Ministry of Natural Resources and Environment, the Ministry of Industry and several universities. Significant mitigation measures are listed as follows:

- Provision of large jars and containers for rain water collection
- Provision of clean water from uncontaminated deep wells
- Educating indigenous people to be conscious of arsenic exposure, toxicity and prevention
- Ordering miners and concentrators to implement environmental protection and reclamation to mitigate and remedy arsenic contamination
- Issuing a Ministerial Notification to prohibit mining and concentrating activities in the polluted area
- Collecting arsenic-rich residues from hilly areas and ore dressing plants for disposal in secure landfills
- Carrying out regular systematic environmental and public health monitoring
- Conducting and collaborating in research

Large jars and containers for rainwater collection were given to every house located in the polluted area. More than 80 deep wells were also drilled in Ron Phibun Sub-district. Hand pumps as well as electric pumps have been installed. Some wells were developed for piped water supply systems. Departmental orders were issued for environmental protection and improvements such as confining arsenic-rich waste in concrete lined waste dumps, recycling wastewater, treating effluents before discharge. A Ministerial Notification to prohibit mining activities in areas of Ron Phibun Sub-district was issued in 1994. Licenses for new concessions as well as for extension of mining, panning and ore dressing permits cannot be granted. Arsenic-rich residues collected from abandoned mining and concentrating sites were buried in secure landfill lined with 2 layers of HDPE, 1.5 mm thick. A drain pipeline system for leakage monitoring and observation was constructed to ensure the efficiency and safety of the landfill.

Lead (Pb) Contamination in the Vicinity of Pb Mining and in Areas with Potential for Pb Mineralization

Contaminant Sources and Mechanism Appraisal

Lead contamination in streams and bottom sediments around mining and concentrating areas at Kanchanaburi Province, western region, was initially addressed in 1992. The had area experienced historical mining and mineral processing for several hundreds of years as evidenced by antique mining equipment found in the area and large concentrations of high-grade Pb slag.

For the last 50 years the area has been mined for Pb and associated metals. The primary sulfide minerals found in the area include galena, sphalerite, pyrite and barite, all part of a strata-bound sequence of mineralization. Secondary minerals include cerussite and smithsonite, carbonates of Pb and zinc respectively. Open pit mining was generally utilized to extract these secondary ores. At present ore reserves of 6.72 and 1.90 million metric tons have been identified for primary and secondary deposits respectively.

Mining and mineral processing activities allowed sulfide minerals to be exposed and react with air and water. Oxidation and hydrolysis of sulfide minerals resulted in dissolution and increased mobility of heavy metals and the formation of acid mine drainage. Fortunately the area is geologically surrounded by limestone formations which neutralize acid mine water resulting in the precipitation of dissolved metals. As a result, the effluent from mines and associated flotation plants is normally compliant with the regulatory standards. The Pb contamination and dispersion is therefore suspected to originate from suspended sediments. This conclusion is supported by the results of extraction tests on concentrates and tailings. The leachate from sulfide and carbonate concentrates contained only <0.02-3.04 mg l^{-1} and <0.02-0.04 mg l^{-1} of Pb, respectively, whereas those of tailings contained <0.02-0.74 mg l^{-1} of Pb.

Environmental Investigation and Monitoring

In 1998, due to unusually heavy rain, a pond containing tailings from the flotation plant collapsed. As a result a large volume of mud with a Pb content of 20,000 – 30,000 mg kg^{-1} was flushed into a nearby stream, the Huai Klitty. The dam failure had a severe impact on indigenous people living downstream in Klitty Lang Village where fish from the creek was a major source of protein. In order to review the level and impact of the release of the Pb-rich mud detailed surveying and sampling of the stream and the stream waters in the proximity of the mines and flotation plant have been carried out since 1999. The water quality of Huai Klitty was examined regularly up and down stream from the concentrator over a distance of some 20 km. In 1999, total surface water Pb concentration upstream was 0.02 mg l^{-1}, this increased to 0.53 mg l^{-1} immediately downstream of the plant. At locations further downstream, Pb concentrations showed a decreasing trend before rebounding and fluctuating due to turbulence and the re-suspension of sediments.

Mining and mineral processing in the area takes place in four different locations, the Bo Ngam Mine, the Klitty Ore Concentrator, the Song Tho Mine and the Bo Yai - Bo Hoi Mines. The average concentrations of total Pb in stream water and bottom sediment upstream from the mining and mineral processing areas were 0.016-0.104 mg l^{-1} and 656-24,052 mg kg^{-1} respectively. Within the mining and ore dressing sites, the average concentrations of total Pb in water and sediment increased to 0.074-0.272 mg l^{-1} and 6,811-13,109 mg kg^{-1}. Downstream from the mines and flotation plant Pb concentrations in water and sediment averaged 0.065-0.092 mg l^{-1} and 1,914-40,053 mg kg^{-1}, respectively. It was conspicuous that high concentrations of Pb in bottom sediment throughout the streams pointed not only to contamination but also indicated anomalous values upstream, indicating that undiscovered mineralization may exist there.

Vegetation and aquatic animals from the proximity were collected and analyzed to assess the risk of eating plants and fish. Only a few edible fish species were found to contain Pb at levels exceeding the Maximum Permissible level of 1 mg kg^{-1}. Drinking water from the tap and from streams in 7 villages located around mining and mineral processing areas contained <0.45-16 µg l^{-1}, which is considered safe level for Pb.

Public Health Effects

As the area in general has good potential for Pb mineralization, the clinical surveys carried out by the Ministry of Public Health had been designed to cover not only the Klitty Lang Village affected by the tailings pond failure, but also another 6 villages. Most of these villages have no direct relation with mining or ore dressing activities since they are situated far upstream or out of watersheds influenced by mining. Blood examination at Klitty Lang Village in 1999, 2000 and 2002 showed average Pb contents in adults over 15 years old of 25.05, 29.56 and 21.33 µg dl^{-1}, respectively. Further, in 1999, 2000 and 2002 blood Pb concentrations in children <15 years old, were 24.08, 26.68 and 21.33 µg dl^{-1}, respectively.

The latest blood tests, carried out in 2002 indicated that the population of Klitty Bon Village, situated upstream and adjacent to the flotation plant, approximately 10 km north of Klitty Lang Village, had the highest average Pb content of 36.29 µg dl^{-1} in children <15 years old and 24.92 µg dl^{-1} in adults over 15 years old. It is critical to note that all children examined at the villages of Klitty Lang and Klitty Bon had blood Pb concentrations exceeding the internationally established maximum blood Pb concentration of 10 µg dl^{-1} with maxima of 41 µg dl^{-1} and 69 µg dl^{-1}, respectively. In addition, 86.7% of children at Klitty Lang Village demonstrated blood Pb concentrations ranging from 11-24 µg dl^{-1} whereas 81.8% of those at Klitty Bon Village exhibited blood Pb concentrations > 25 µg dl^{-1}. In the control villages the range of blood Pb contents was 7.47-17.93 µg dl^{-1} in children <15 years old and 5.61-15.09 µg dl in adult in adults over 15 years old with a maximum of 36 µg dl^{-1} and 25 µg dl^{-1} in each demographic group, respectively. In spite of prevalence of excessive Pb content in blood among the whole population, no clinical manifestation related to Pb poisoning has been confirmed. However, children are highly sensitive to Pb and being exposed to excessive Pb levels could cause neurological and hematological defects. The need of intervention to reduce the exposure levels is therefore urgent.

Environmental Alleviation Measures

To alleviate the adverse effects of Pb contamination caused by mining, mineral processing and the failure of the tailings dam, several remedial measures have been implemented on the basis of the "polluter pays" principle. The first immediate responsive measure was the order to stop the flotation process and to renovate the tailings pond. Clean up and reclamation programs to restore the environmental condition in the polluted stream and at the concentrator were established and implemented. Within 2.5 km of the flotation plant 3,753 metric tons of contaminated sediment were excavated from the Huai Klitty and dumped back into a tailing pond or buried in secure landfills. Two rock check dams were constructed across Huai Klitty to entrap remaining contaminated sediment for later excavation and landfill. The site of the Klitty Ore Concentrator has been reclaimed in accordance with the approved closure plan, before the rights were returned to the government. To compensate for the disturbance, the concentrator established a 1 million baht fund for the people of Klitty Lang Village. Agricultural protein, chicken and fish farming were also introduced to the villagers to provide alternative sources of protein to replacing fish from the Huai Klitty. Clinical examination and treatment have been carried on intensively. A number of committees at local, provincial, departmental and ministerial levels have been designated to negotiate, approve, enforce and implement relevant actions for a better quality of life and environment in the affected area. The issue has now also been brought to court.

Heavy Metal Contamination in the Proximity of Abandoned Tin Mines

Contaminant Sources and Mechanism of Appraisal

In 1993, high Pb concentrations in water, sediment and soils collected around abandoned tin mines of Bannang Sta District, Yala Province were reported. In 1994, marine *macrophytes* including sea grass and seaweed, in the bay downstream were found to have elevated Pb contents ranging from 4.74 - 26.78 mg kg^{-1}. These facts gave rise to public concern. In the mineral deposits of the area Zn, Pb and Cur are associated with tin in skarns. Weathering and erosion of various sulfide minerals have become the main driving mechanisms of heavy metal contamination. Samples of water and sediment were periodically collected along the streams from the mining areas to the bay downstream and analyzed for various heavy metals such as Cd, Pb, Zn, Cu, As, Mn and Fe. Lead, As and Mn demonstrated elevated concentrations around the mined out areas. As for Cd, Zn, Cu, and Fe, concentrations remained close to background values. Recent data from systematic surveying during 1998–2002 shows that the contamination of Pb, As and Mn from abandoned mines was confined to within a specific area due to the buffering effect of the alkaline environment generated by the limestone formations in the area. Acid mine drainage with a pH of 2.0 to 3.0 was brought up to pH 7.0 within a distance of 500 meters. The concentration of Pb, As and Mn in running water decreased with increasing distance from the mines. Elevated Pb concentrations were identified again in the bay. This was caused by contamination from other sources probably by boat-repair activities using Pb-based paints.

Environmental Investigation and Monitoring

According to regular investigation on environmental quality in the watershed of abandoned tin mines during 1998-2002, contamination of Pb, As and Mn in surface water showed levels significantly elevated above background. Water samples collected upstream of the mined out area contained potential toxic elements below the standard limits. When the stream passed through the mined out area, most collected water samples showed high contents of Pb, As and Mn. In 1998, prior to the initiation of the mitigation project, Pb, As and Mn concentrations were 0.19, 0.36 and 4.7 mg l^{-1}, respectively.

During the period of project implementation, 1999-2001, the maximum concentrations of Pb, As and Mn decreased to 0.13, 0.21 and 2.10 mg l^{-1}, respectively. In 2002 when the mitigation project had been finished, the maximum concentrations of Pb, As and Mn were lower than 0.08, 0.20 and 1.60 mg l^{-1}, respectively. During 2000-2002, the average concentrations of Pb and Mn were found to be below National Standard limits. As regards arsenic concentration, the average remained high and fluctuated above the National Standard. Nevertheless, where the stream flowed away from the abandoned mine, all metal contents decreased to levels below the National Standard. Lead in sediments upstream of the abandoned tin mines averaged 1,610 mg kg^{-1}, while stream sediments collected on site of the mined out area averaged 5,903 mg kg^{-1}. In contrast, approximately 3 km downstream of the mined out area Pb concentrations decreased significantly to an average of 379 mg kg^{-1}. Lead in soil at residential areas in the vicinity of abandoned tin mines ranged from 197-1,087 mg kg^{-1}. Cultivated fish contained 0.12-0.64 mg Pb kg^{-1}. The highest concentration of Pb in plant tissue was 1.852 mg kg^{-1}.

Public Health Effects

There is no record of any manifestation indicating negative public health effects due to Pb contamination in the area. However, it is undeniable that elevated Pb levels in this particular location contribute to some adverse effects on the local communities. The evidence to support the existence of this problem is found in the results of a study the Prince of Songkhla University in 1995 on Pb contamination among schoolchildren living near the abandoned tin mines of Yala Province.

Two primary schools in the mining area of Bannung Sta District with respectively 46 and 127 pupils aged between 6 to15 years were investigated. Approximately 96% and 74% of children in each school had a Pb-in-blood level of ≥ 10 μg dl^{-1}. Moreover, 24% and 7% of those showed contents ≥ 20 μg dl^{-1}. Most of these children's residences were built in areas of extensive mine waste dumps. In addition, children from two other primary schools located near the bay were examined for Pb-in-blood content. In total 98% of 61 pupils and 65% of 37 pupils demonstrated Pb-in-blood levels of ≥ 10 μg dl^{-1} but only 10% of 61 pupils had blood Pb levels ≥ 20 μg dl^{-1}. This study was limited to children between 6 to15 years as this particular group was thought likely to intake Pb dust by ingestion through putting hands into the mouths. Recent follow up data, however, revealed declining trends in the number of affected pupils and in blood Pb contents. According to 2001 data from the Provincial Public Health Office the average Pb-in-blood content for 250 children from the same schools in mined out areas had decreased to 6.02 μg dl^{-1} with only 11.2% of the pupils having a concentration ≥ 10 μg dl^{-1}. These improvements indicate the effectiveness of the countermeasures implemented in the area since 1999. However, intensive monitoring must be continued to safeguard the health of the affected communities.

Environmental Alleviation Measures

To provide a safe environment to local residents in the vicinity of abandoned tin mines, improvement programs including secure landfill and capture of mine wastes were launched in 1999. A Total of 130,000 m^3 of mine wastes were captured. In total, 30,000 m^3 were buried in a secure landfill lined with HDPE. Another 50,000 m^3 were covered with compacted clay. The remaining 50,000 m^3 were gathered and surrounded with a clay barrier before being covered with compacted clay and topsoil. Earth-cover vegetation and fast growing trees were later planted over 22 acres. The environment and public health have shown signs of improvement. There is a decreasing content of Pb in stream water and in the blood of schoolchildren. Over the next years, more mine waste in the adjacent area will be securely stored to ensure better environmental quality and quality of life for the local residents.

Other Relevant Environmental Problems and Risks

Almost 20 years ago, there was a leak in the pipeline delivering leached sludge containing Cd, Pb and Zn from the Zn refinery in Tak Province. This event caused heavy metal contamination in soil and stream sediment around the plant. Remedial measures included lime stabilization and excavation of contaminated soil and sediment and dumping these back into the secure residue pond of the refinery. An illegal secondary Pb smelter in Ratchaburi Province, central Thailand, was found to contaminate soil and crop nearby for several years through stockpiles of used batteries on bare soil and emissions of Pb fumes and dust. As a result, cows fed with contaminated maize produced contaminated milk. The owner was arrested and the smelter was demolished. The area is now designated as a polluted site and entrance is prohibited.

Soil as well as surface and shallow groundwater in the Northeast in the provinces Sakon Nakhon, Udonthani, Nakhon Ratchasima, Mahasarakam and Nongkay, have been contaminated with salt from natural sources and human activities. Several regulations and measures have been enforced, including area designation for salt production from brine pumping and waste rejection into underground. Close inspection and monitoring to prevent and alleviate salinity impacts on rice paddy fields and surface water quality as well as land subsidence are consistently undertaken. In addition, in 1975 villagers at Rong Kwang District, Phrae Province suffered from Mn poisoning through drinking of contaminated stream water passing through Mn mines. Clinical surveys in 1978 reported that almost 80 villagers manifested the symptoms of *manganism*, including shaking, clumsiness, shuffling walk, abnormal balance, speech difficulties and lack of facial expression. Among the examined people, 76 from 80 had Mn contents in blood over 8 $\mu g\ dl^{-1}$ with a maximum value of 60.93 $\mu g\ dl^{-1}$ and minimum of 5.01 $\mu g\ dl^{-1}$. The recommended maximum allowable limit for Mn in blood is 4 $\mu g\ dl^{-1}$. New sources of clean water were provided and the mines were abolished.

Fluorine (F) contamination in groundwater has been reported in several places especially close to the fluorite mines of northern Thailand. Fluorite concentrations in contaminated areas were found to be over the National Standard of 1 mg F l^{-1} by a factor of 3-4 and sometimes by a factor of 10. The most critical case so far, in Lumphun Province, a few years ago, there were a number of students diagnosed with mottled teeth derived from over-intake of F. This incident has become an incentive for the dental society to initiate an effort for problem prevention and alleviation.

Conclusions and Recommendations

The mining industry has played an important role as a fundamental segment of the economy in supporting and promoting other upstream industries in driving Thailand's economic and social development. It can bring prosperity as well as disaster to society and to the environment. Exploring for and exploiting minerals normally disturbs and deteriorates to some extent the surroundings. Public health risks may result. Harmonious national policies and strategies on the development and conservation of mineral and other natural resources are therefore crucial to secure the quality of people lives.

Environmentally sound management in mining development needs to be planned and implemented from project commencement throughout the operation and to the designed rehabilitation. Environmental protection and mitigation tools should be promulgated and continually enforced to achieve the national and global aims of environmental sound promotion in this sector. Participation of the local community, considered as one of the important stakeholders is through commenting on submitted mining applications.

The enforcement of environmental impact assessment (EIA), land use designation, liability insurance, rehabilitation bond and decentralization of inspection and monitoring of the mining industry are examples of the efforts required to pursue environmental friendly mineral development. International cooperation and collaboration are also necessary for the achievement of the ultimate international goal of sustainable development.