

Chapter 6

CONCLUSIONS AND RECOMMENDATIONS

6.1. CONCLUSION

6.1.1. Physical - Chemical characteristics of surface and ground water

During six months monitoring the quality of surface and ground water at surrounding the Mae Moh Mine and Power Plant, several physical and chemical parameters can be concluded.

Temperature can cause an increase chemical reactions of heavy metals and then result in high concentrations in water, especially, arsenic concentrations as in the three wells inside the mining area which have high temperatures. High temperature may increase chemical reactions of rocks, soil, and even lignite.

Due to being bordered by a limestone mountain on the east site of Mae Moh basin, the average pH values of surface and ground water are mostly in the range of 6 to 8.5 (Table 6.1.1). pH could has a very important role in controlling the mobility of heavy metals in soil to ground water and release from sediment to surface water in the reservoirs.

Conductivity and total dissolved solids are relatively high in the Mae Moh Reservoir. The maximum total dissolved solids are 1,280 mg/l in surface water and 2,610 mg/l in ground water. High values of total dissolved solids in ground water came mostly from seepages and deep wells inside the mine pit (Table 6.1.1).

Table 6.1.1: Variations in physical and chemical characteristics of surface and ground water

Parameter	Place	Variation				Month	
		Max	Min	Mean	Std	Max	Min
Temperature (°C)	AR	33	24	30	3	Jul	Dec
	MKR	34	25	30	2	Oct	Dec
	MMR	33	22	29	3	Aug	Dec
	CT	30	22	28	2	Oct	Dec
	N	29	26	27	1	Oct	Dec
	SP	35	26	31	3	Oct	Nov
	M	48	34	41	5	Aug	Oct
	S	31	21	27	2	Oct	Dec
pH	AR	8.5	6.8	7.7	0.5	Jul	Dec
	MKR	8.7	6.5	7.9	0.5	Jul	Jul
	MMR	8.0	7.0	7.6	0.3	Aug	Sep
	CT	5.9	4.4	5.2	0.5	Aug	Dec
	N	7.2	5.1	6.6	0.5	Oct	Oct
	SP	7.5	4.3	6.7	0.9	Nov	Oct
	M	8.3	6.7	7.5	0.4	Oct	Dec
	S	10.0	3.9	7.0	1.9	Jul	Dec

AR = Ang Kaset (Control Reservoir)

MKR = Mae Kham Reservoir

MMK = Mae Moh Reservoir

CT = Control well

N = Northern site

SP = Seepage site

M = Mining site

S = Southern site

Std = Standard deviation

Table 6.1.1: Variations in physical and chemical characteristics of surface and ground water (cont'.)

Parameter	Place	Variation				Month	
		Max	Min	Mean	Std	Max	Min
Conductivity ($\mu\text{S/cm}$)	AR	5,200	176	1,135	1,610	Aug	Jul
	MKR	1,304	238	481	287	Sep	Jul
	MMR	2,500	196	1,504	766	Nov	Aug
	CT	2,400	159	720	812	Nov	Jul
	N	1,413	372	708	258	Aug	Jul
	SP	5,130	213	2,149	1,618	Jul	Aug
	M	2,820	201	1,710	777	Dec	Aug
	S	1,152	233	761	253	Oct	Aug
TDS (mg/l)	AR	1,260	81	282	420	Nov	Jul
	MKR	641	120	233	139	Sep	Jul
	MMR	1,280	435	909	245	Nov	Sep
	CT	1,230	80	270	373	Nov	Jul
	N	427	259	340	55	Nov	Dec
	SP	2,610	400	1,332	840	Aug	Jul
	M	1,500	221	924	379	Jul	Aug
	S	876	276	457	148	Dec	Oct

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Table 6.1.1: Variations in physical and chemical characteristics of surface and ground water (cont'.)

Parameter	Place	Variation				Month	
		Max	Min	Mean	Std	Max	Min
Dissolved	AR	6.2	3.6	4.8	0.9	Jul	Sep
Oxygen	MKR	6.1	2.4	4.8	0.9	Aug	Jul
(m/l)	MMR	7.2	1.7	4.2	1.7	Nov	Sep
	CT	4.2	0.0	2.6	1.3	Aug	Dec
	N	4.2	0.0	1.7	1.1	Aug	Dec
	SP	5.9	0.0	2.2	1.7	Nov	Dec
	M	5.5	0.3	2.2	1.4	Aug	Dec
	S	3.5	0.0	1.7	0.8	Dec	Dec
Total	AR	105	83	91	5	Dec	Oct
Alkalinity	MKR	181	101	124	18	Nov	Oct
(mg/l)	MMR	242	118	163	38	Dec	Dec
	CT	54	8	30	15	Oct	Jul
	N	267	157	215	37	Sep	Jul
	SP	1,753	127	707	629	Nov	Jul
	M	1,528	680	990	321	Nov	Oct
	S	570	13	258	185	Nov	Dec

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Table 6.1.1: Variations in physical and chemical characteristics of surface and ground water (cont'.)

Parameter	Place	Variation				Month	
		Max	Min	Mean	Std	Max	Min
Acidity (mg/l)	AR	7	0	4	2	Nov	Aug
	MKR	13	0	6	4	Aug	Oct
	MMR	20	8	13	4	Nov	Oct
	CT	122	31	61	25	Oct	Nov
	N	62	22	39	11	Oct	Dec
	SP	166	11	63	43	Sep	Aug
	M	73	0	36	19	Jul	Oct
	S	132	0	32	33	Nov	Aug
Total	AR	113	73	91	12	Sep	Jul
Hardness (mg/l)	MKR	611	124	197	122	Sep	Nov
	MMR	1,564	184	780	371	Dec	Jul
	CT	61	6	38	16	Aug	Nov
	N	384	183	280	66	Aug	Jul
	SP	1,721	334	710	445	Aug	Dec
	M	149	48	89	28	Dec	Jul
	S	530	14	259	167	Jul	Nov

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According to Thai standards, there is no risk of pollution entering to the Mae Chang River. If without regularly monitoring wastewater treatment system, the water quality may degraded and caused many unpredictable problems for natural ecosystems. Most Ground water quality is also acceptable and can be used for domestic consumption such as bathing, washing, cooking which requires treatment before use. Ground water from three wells inside the mining area and three seepages can not be used for any purposes related to living thing or human health.

6.1.2. Risk of selected elements in surface and ground water

Based on the amounts of selected elements during six months of monitoring, concentrations of most selected elements in surface and ground water are under the World Health Organization standards (1993) for drinking purposes and National Standards of Thailand (1989) for drinking purposes and environmental pollution control. Arsenic, manganese, and iron are really found in high concentrations in some ground water sites at certain time.

Arsenic concentrations range from under the detection limit to 502 micrograms per liter. Highest concentrations came from three wells drilled through the gravel beds of Huai King formation which are the lowest deposits of Mae Moh Tertiary sequences (Table 6.1.2). The maximum concentration is about 50 times above the WHO (1993) standard and 10 times of the National Standards of Thailand. Ground water from these three wells is very contaminated. The high water temperature suggested the contamination could come from geothermal system.

Table 6.1.2: Variations in concentrations of selected elements in surface and ground water.

Parameter	Place	Variation of concentration				Month	
		Max	Min	Mean	Std	Max	Min
Mn (µg/l)	AR	36	13	21	6	Jul	Sep
	MKR	824	13	135	191	Jul	Oct
	MMR	586	70	242	126	Nov	Sep
	CT	165	12	63	57	Jul	Dec
	N	1,414	8	458	510	Jul	Aug
	SP	2,189	36	445	682	Sep	Dec
	M	42	<dl	13	14	Sep	Dec
	S	289	<dl	107	92	Oct	Jul
Fe (µg/l)	AR	151	<dl	29	38	Jul	Sep-Dec
	MKR	302	<dl	60	77	Aug	Dec
	MMR	587	<dl	142	143	Dec	Aug
	CT	208	<dl	69	73	Dec	Dec
	N	13,480	<dl	3,887	4,693	Oct	Jul
	SP	2,844	<dl	477	873	Nov	Dec
	M	2,752	<dl	674	842	Sep	Jul
	S	2,199	<dl	463	571	Sep	Dec

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S: Southern site

dl: detection limit, Std = Standard deviation

Table 6.1.2: Variations in concentrations of selected elements in surface and ground water (cont').

Parameter	Place	Variation of concentration				Month	
		Max	Min	Mean	Std	Max	Min
Pb ($\mu\text{g/l}$)	AR	36	<dl	4	9.8	Jul	MO
	MKR	69	<dl	10	19	Jul	Dec
	MMR	22	<dl	4	7.8	Nov	MO
	CT	19	<dl	2	4.6	Nov	MO
	N	29	<dl	6	10.3	Jul	Nov
	SP	29	<dl	6	9.8	Nov	MO
	M	32	<dl	6	11.3	Nov	Dec
	S	43	<dl	5	10.8	Jul	Nov
As ($\mu\text{g/l}$)	AR	1	<dl	dl	0.4	Oct	MO
	MKR	2	<dl	1	0.6	Aug	Nov
	MMR	16	2	6	3.9	Oct	Sep
	CT	<dl	<dl	<dl	0.00		MO
	N	3	<dl	2	1.4	Aug	Nov
	SP	6	<dl	3	1.6	Jul	Dec
	M	502	52	308	184.6	Sep	Oct
	S	2	<dl	1	1.4	Jul	Oct-Dec

AR: Ang Kaset (Control Reservoir); MKR: Mae Kham Reservoir

MMK: Mae Moh Reservoir; CT: Control well

N: Northern site; SP: Seepage site

M: Mining site; S: Southern site

dl: detection limit; MO: Most the time

Std = Standard deviation

Arsenic in surface water was found to be higher in the Mae Moh Reservoir than in the Mae Kham Reservoirs. The maximum concentration, which was found in the Mae Moh Reservoir, is 16 micrograms per liter. The control site confirmed that surface water in the Mae Moh basin are contaminated by mining and power plant activities (Table 6.1.2).

Lead was found intermittently in surface and ground water. It varies from under the detection limit to 69 micrograms per liter. High values, which were found in the Mae Kham Reservoir (Table 6.1.2), appeared in surface water and are about 9 times over the WHO (1993) standard. Most lead concentrations were below the Thai standards.

Manganese varies from under the detection limit to 2,189 $\mu\text{g/l}$ (Table 6.1.2). The level above the WHO (1993) standard came from ground water well N1 in Ban Tha Si village. It ranges from 564 to 1,414 $\mu\text{g/l}$. The seepage SP3 in the west of the mine is also high manganese concentrations with ranging of 141 to 2,189 $\mu\text{g/l}$ during September to December.

Iron ranges from under the detection limit to 13,480 $\mu\text{g/l}$ (Table 6.1.2). High values came from a deep well (N1) in Ban Tha Si village, a the deep well (S2) in the south of the mine, and seepage SP3 in the west of the mine.

Mercury, chromium, and molybdenum were always found under the detection limit in both surface and ground water. There is no evidence to indicate any environmental risk of these heavy metals contamination in surface and ground water.

Concentrations of the selected elements are higher in ground water than in surface water. Most of them appeared to be high in surface water at the beginning of the rainy season when water runoff and dissolution large amounts of mineral from the top soil.

6.2. RECOMMENDATIONS

Based on the results of six months monitoring, environmental conditions at Mae Moh Mine and Power Plant are serve. The environmental risk management should be considered. Environmental management planning should be done which includes environmental monitoring and management planning.

Wastewater management should be regularly monitored to check water quality before release into natural ecosystems, particularly, to the Mae Moh Reservoir. It is necessary to monitor and assess the effectiveness of aquatic plants in the wetland system and frequently replace the aquatic plants, which have high-accumulated heavy metal from the wastewater.

Arsenic is the most serious water contamination. It should be considered as the most risk to surface and ground water contaminant to human health and the environment. Ground water from the three wells inside the mining area should be discharge into wetlands before release to the natural water systems.

The study should be continued January to June for completely all year data. This will enable the development of an environmental management plan.

People surrounding the Mae Moh Mine and Power Plant often collect aquatic organisms, mainly fish, in the Mae Moh and Mae Kham Reservoirs for consumption. It is necessary to carry out detailed a research to detect amounts of some toxic elements that could be accumulated in fish tissue. With adequate scientific data about heavy metals in the environment at Mae Moh, variation targets for environmental health management can be implemented.