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Water Quality Assessment in Reservoirs and Wastewater Treatment System of the Mae Moh Power Plant, Thailand

PONGSARUN JUNSHUM[1], PIAMSAK MENASVETA† AND SIRIPEN TRAICHAIYAPORN
Department of Biology, Faculty of Science, Chiang Mai University, Chiang Mai, Thailand
†*Department of Marine Science, Faculty of Science, Chulalongkorn University, Thailand*
[1]Corresponding author's e-mail: pjunshum@hotmail.com

ABSTRACT

Assessment of water quality, from three reservoirs and a wastewater treatment system of the Mae Moh thermal power plant, was conducted during January 2003-February 2004. Statistical analyses showed significant differences between reservoirs and the wastewater treatment system. The reservoirs are less conductivity, total dissolved solids, hardness, silica and heavy metals (As, Pb & Zn) than the wastewater treatment system. Assessment of water quality in the Mae Kham, Mae Chang and Mae Moh reservoirs were classified into class 2 - 3, while settleable solid and oxidation pond, Bio-treatment pond, Diversion pond and South wetland pond in the treatment system were class 5, according to the standard values of surface water quality, recommended by the Pollution Control Department of Thailand. The mean values of arsenic, lead and zinc in water in Mae Moh reservoir, which is the final drainage recipient from this area were 0.004 mg L^{-1}, 0.037 mg L^{-1} and 0.057 mg L^{-1}, respectively. The heavy metals did not exceed both the surface water quality standards and the industrial effluent standards of Thailand. So the effluent from the Mae Moh power plant showed no significant effect on water pollution on the aquatic ecosystem.

Key Words: Power plant; Water quality; Heavy metals; Physico-chemical; Reservoir; Pb; Zn; As; Aetc

INTRODUCTION

Water pollution from domestic, agricultural or industrial wastes sources affect living organisms and make water unfit for uses (Andrew & Jakson, 1996; Cong, 1999). Coal operated thermal power plant can be a source of pollution, because ash derived from burning of coal containing heavy metals such as arsenic (As), cadmium (Cd), lead (Pb), mercury (Hg) and zinc (Zn), can contaminate water in the drainage system, presenting a potential hazard to the environment (Kanungo & Mohapatra, 2000). In addition, sediment or other matter containing insoluble particles (in soil & other solids) can also suspend in water that can ultimately reduce photosynthetic activity in the water and disrupt aquatic food webs (Miller, 1995). In addition, inorganic nutrients, such as water soluble nitrogen and phosphorus, can cause excessive growth of algae, forming algal blooms and eventually cause the serious problem of eutrophication in lakes and reservoirs (Waite, 1984; Miller, 1995; Andrew & Jakson, 1996).

The Mae Moh power plant is a thermal electricity unit, operated by Electricity Generating Authority of Thailand (EGAT). It consists of 13 power generating units, which can be operated continually to produce about 2,625 megawatts at full capacity. All the power generating units use lignite coal fuel to heat water in boilers producing hot steam for operating the generators. The drained water and wastewater activities of the power plant are treated by both physical and biological processes after being released into the main treatment system. The goal of this research was to determine and compare the water quality and concentrations of some heavy metals (As, Pb & Zn) in two water supply reservoirs for the power plant, four ponds in wastewater treatment system and a reservoir, which is the final drainage recipient from the wastewater treatment system of the Mae Moh power plant.

MATERIALS AND METHODS

Studied area. The Mae Moh power plant is located in Mae Moh district, Lampang province, approximately 650 km north of Bangkok (99º46' E, 18º18'N). The power plant requires about 46,000,000 m^3 of water per year for its cooling system and other activities. This amount of water comes from the Mae Kham and Mae Chang reservoirs, which are the main natural water supply. About 25,640 m^3 of industrial wastewater and 200 m^3 of domestic wastewater pass through the power plant's biological wastewater treatment system daily. The biological wastewater treatment system is composed of 4 ponds in series: Settleable solid and oxidation pond, Bio-treatment pond, Diversion pond and South wetland pond. Lastly, treated water from wastewater treatment system discharges into Mae Moh reservoir. Seven sampling sites around the Mae Moh power plant are as follows (Fig. 1): Site 1 Mae Kham reservoir (capacity 36,979,000 m^3); Site 2 Mae Chang reservoir (capacity 105,780,000 m^3); Site 3 Settleable solid and oxidation pond (capacity 20,000 m^3); Site 4 Bio-treatment pond (capacity 100,000 m^3); Site 5 Diversion pond (capacity 100,000 m^3); Site 6 South wetland pond (capacity 192,600 m^3) and Site 7 Mae Moh reservoir (capacity 2,370,000 m^3).

Physico-chemical analyses. Water sample was collected monthly from the seven sampling sites during January 2003 - February 2004. Some parameters including temperature, pH, total dissolved solids (TDS) and conductivity were investigated in situ, using portable electronic measuring instruments (pH meter, Horibra, model D21 & conductivity/TDS meter, Jenway, model 4200). Water samples for chemical and biological analyses were collected near the effluent points at water surface (0.3 m), middle depth and bottom depth for site 1 and 2, while water samples of site 3 – 7 were collected only at the depth of 0.3 m and preserved in ice-box until further processing.

Analyses of dissolved oxygen (DO) and biochemical oxygen demand (BOD) was carried out using Azide Modification method, whereas chemical oxygen demand (COD) was determined by closed reflux method in the laboratory (APHA, AWWA & WEA, 1998; Traichaiyaporn, 2000). Suspended solids (SS) were determined as total nonfilterable residue dried at 105ºC. Hardness and silica (SiO_2) were determined using a Odyssey Spectrophotometer by EDTA titrimetric and Heteropoly Blue methods, respectively (HACH, Odyssey 2500), respectively. Ammonia nitrogen (NH_3-N), total nitrogen (TN), orthophosphate phosphorus (PO_4-P) and total phosphorus (TP) were analysed by Nesslerization method, phenoldisulphonic acid method, persulfate digestion method (HACH, Odyssey 2500), stannous chloride method and persulfate digestion followed by stannous chloride method, respectively (APHA, AWWA & WEA, 1998; Traichaiyaporn, 2000).

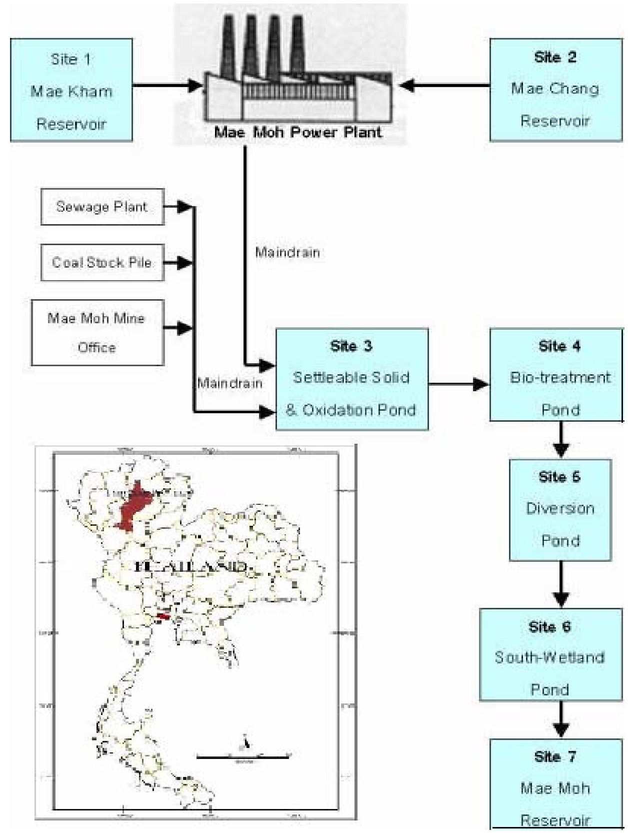
Heavy metal analyses. Water sample was collected in the same period as physicochemical analyses. The sample was digested in concentrated HNO_3 at 80ºC. Analyses of Pb in water samples was performed using a direct air-acetylene flame method by Atomic Absorption Spectrophotometer (AAS, Perkin Elmer model 2380). Arsenic in water was determine by using a hydride generation AAS (APHA, AWWA & WEA, 1998; Cong, 1999), whereas Zinc in water was determined by Zincon method using Odyssey Spectrophotometer (HACH, Odyssey 2500).

Statistical analysis. Differences in each water quality variable and heavy metals between sampling sites were tested using analysis of variance (ANOVA) followed by a Duncan's Multiple Rang Test (DMRT), processed by the SPSS statistics software.

RESULTS AND DISCUSSION

Physico-chemical variables. Results of water quality from the reservoirs around the Mae Moh power plant are shown in Table I. Generally the value of water temperature and pH value recorded at all studied sites met the Pollution Control

Fig. 1. Map of Thailand and schematic diagram of sampling sites around the Mae Moh power plant



Department of Thailand criteria for surface water quality standards (Table II). So there was no thermal pollution around the Mae Moh power plant reservoirs, which was reported previously (Cong, 1999).

The Mae Kham and Mae Chang reservoirs are the upper sampling sites and they would be the least contaminated reservoirs, compared to the four treatment ponds and Mae Moh reservoir. This being the case, the mean values of SS, conductivity, TDS, hardness, BOD, COD, SiO_2, NH_3-N, TN, PO_4-P and TP in the natural reservoirs were lower than the ones in the wastewater treatment system of the power plant (Table I).

These results are in agreement to Cong (1999) who also observed similar values of conductivity, TDS and hardness (303 - 517 µs cm^{-1}, 152 - 249 mg L^{-1} & 130-173 mg L^{-1} $CaCO_3$, respectively). High concentrations of these parameters were observed at the ponds in wastewater treatment system (Table I), because of the industrial wastewater and the domestic wastewater drained into this system bringing in both contaminated soil sediments and ash from the burning of lignite coal, which introduce a lot of unprecipitated suspended matter into the water. These soil sediments and fly ash mainly comprised SiO_2, which is a major factor influencing growth of algae in many reservoirs (Kanungo & Mohapatra, 2000; Pathan *et al.*, 2003; Baba & Kaya, 2004). There were statistical differences in the levels

Table I. Mean and standard deviation for selected physico-chemical characteristics and heavy metals concentrations for the reservoirs of the Mae Moh Power Plant

Variables	Site						
	Mae Kham reservoir	**Mae Chang reservoir**	**Settleable solid and oxidation pond**	**Bio-treatment pond**	**Diversion pond**	**South wetland pond**	**Mae Moh reservoir**
Temperature (ºC)	28.55±2.86ab	26.20±3.14a	31.84 ±3.11b	31.33 ±3.61b	30.82±2.99b	29.05±4.28ab	30.90±3.28b
SS (mg L^{-1})	5.43±3.41a	7.21±4.92a	212.21±190.77b	19.00±18.15a	13.21±8.49a	13.42±19.35a	7.50±3.20a
pH	8.03±0.64b	7.84±0.49b	8.83±0.60c	7.74±0.67b	7.76±0.76b	7.23±0.68a	7.46±0.55ab
Conductivity (μS cm^{-1})	276.00±45.15a	223.23±36.70a	927.57±260.98b	1085.43±410.70bc	1200.07±503.91bc	1264.86±379.64c	1129.33±384.29c
TDS (mg L^{-1})	143.00±29.88a	110.96±22.35a	454.07±192.00b	549.64±254.29bc	607.86±315.95bc	630.00±237.84c	546.50±214.57bc
DO (mg L^{-1})	4.20±1.52a	4.98±1.40a	4.71±1.76a	3.84±1.13a	6.31±3.09b	3.39±1.55a	6.83±1.73b
BOD (mg L^{-1})	1.87±0.85ab	1.51±0.75a	3.82±2.36c	2.52±1.56abc	3.01±1.89b	2.31±1.29abc	2.12±0.73ab
COD (mg L^{-1})	2.03±0.93ab	1.97±1.23a	7.22±2.83d	3.46±1.34ab	3.36±1.84ab	3.69±2.14c	2.89±1.49abc
Hardness (mg L^{-1} $CaCO_3$)	141.06±22.84a	124.57±21.40a	474.50±116.01b	569.06±111.67bc	632.24±180.45cd	703.53±179.07d	524.86±149.25b
Silica (mg L^{-1})	14.70±2.21a	12.19±4.23a	23.62±4.77c	23.65±3.51c	24.43±3.50c	24.35±3.22c	17.28±5.15b
NH_3-N (mg L^{-1})	0.202±0.192a	0.171±0.165a	0.299±0.298a	0.197±0.201a	0.240±0.231a	0.278±0.333a	0.219±0.296a
PO_4-P (mg L^{-1})	0.009±0.007b	0.007±0.006a	0.033±0.033bcd	0.044±0.040d	0.038±0.037cd	0.047±0.048d	0.015±0.025abc
TN (mg L^{-1})	1.631±1.805ab	1.243±0.805a	3.879±2.685bc	2.043±0.851ab	3.114±3.554c	2.907±2.668abc	2.169±1.833ab
TP (mg L^{-1})	0.040±0.027a	0.036±0.024a	0.183±0.183ab	0.120±0.090ab	0.088±0.52ab	0.220±0.490b	0.073±0.069ab
Arsenic (mg L^{-1})	0.001±0.002a	0.001±0.001a	0.035±0.021d	0.018±0.015c	0.016±0.013c	0.012±0.013bc	0.004±0.003ab
Lead (mg L^{-1})	0.004±0.008a	0.004±0.008a	0.40±0.022b	0.037±0.014b	0.035±0.020b	0.037±0.015b	0.037±0.018b
Zinc (mg L^{-1})	0.031±0.025a	0.047±0.031ab	0.070±0.039b	0.075±0.051b	0.067±0.051b	0.065±0.038b	0.057±0.032ab

Means with different letters are statistically different from one another ($p<0.05$)

SS = Suspended solids; TDS = Total dissolved solids; DO = Dissolved oxygen; BOD = Biochemical oxygen demand; COD = Chemical oxygen demand; Ammonia nitrogen (NH_3-N); Orthophosphate phosphorus (PO_4-P); Total nitrogen (TN); Total phosphorus (TP)

of conductivity, hardness, SiO_2, TDS and TP ($P < 0.05$) between the natural water sources and the ponds in wastewater treatment system (Table I).

The levels of conductivity, TDS and hardness slightly increased from the settleable solid and oxidation pond to the South wetland pond which contrasted with the results of Erten-Unal and Wixson (1999), whereas the levels of SS, BOD, COD and inorganic nutrients showed a decreasing trend from settleable solid and oxidation pond to the Mae Moh reservoir. This trend was the result of suspended matter precipitation and the aquatic plant root systems (Izaguirre *et al*., 2001; Razo *et al.*, 2004; Dewedar *et al*., 2006). Concerning only the value of hardness, the Mae Kham and the Mae Chang reservoirs should have moderately hard water (not objectionable for most purposes, requires somewhat more soap for cleaning), whereas the other 4 ponds in wastewater treatment system and Mae Moh reservoir can be classified as with very hard water (requires softening for household or commercial use, Weiner, 2000).

Variation in DO was not pronounced; however, DO levels peaked at the Diversion pond, which may be due to photosynthesis from algae bloom. A very low DO at South wetland pond that can be due to the reason that water surface was covered with a crown of aquatic plants (*Echhornia* sp.). This factor can reduce DO in water and affect respiration of aquatic animals especially when the DO value is lower than 3 mg L^{-1} (Steiner & Combs, 1993).

Heavy metals in water. The level of arsenic (As), lead (Pb) and zinc (Zn) in water were in similar trends, peaking at the settleable solid and oxidation pond (Fig. 2), whereas the lowest values of As, Pb and Zn were found at the Mae Kham and Mae Chang reservoirs. These results match with the determination of As and Pb at the Mae Kham reservoir by Cong (1999). These values were significantly different ($P < 0.05$) between the natural water sources and the reservoirs for wastewater treatment (Table I), due to contamination from power plant effluent in the wastewater treatment ponds. The levels of heavy metals in water showed a reducing trend from the settleable solid and oxidation pond to the Mae Moh reservoir. This trend may have been due to precipitation of suspended matter and by the aquatic plant root systems (*Echhornia* sp., *Ipomoea* sp., *Typha* sp. & *Canna* sp.) in the wastewater treatment system, which can remove heavy metal from water (Hastuti, 1998; Izaguirre *et al.*, 2001; Razo *et al.*, 2004; Saygideger *et al*., 2004).

The higher concentration of Zn has also been previously observed from other geographical locations by many researchers (Knight *et al.*, 1997; Erten-Unal & Wixson, 1999; Lee & Lee, 2001; Edet & Offiong, 2002; Lee *et al*., 2003) due to Zn as a common contaminant in surface water (Weiner, 2000). The average values of Pb and Zn for all studied sites, as well as the average values of As at the Mae Kham, Mae Chang and Mae Moh reservoirs, did not exceed the Surface Water Quality Standards of Thailand (Table II). The mean values of As, Pb and Zn in water especially in Mae Moh reservoir in final drainage recipient from this area were 0.004 ± 0.003 mg L^{-1}, 0.037 ± 0.018 mg L^{-1} and 0.057 ± 0.032 mg L^{-1}, respectively. However, As concentration of 4 ponds in wastewater treatment system was a little bit higher than the maximum permissible limit of the Surface Water Quality Standards but not exceed the Industrial Effluent Standards of Thailand.

CONCLUSION

The assessment of water quality from the three reservoirs around the Mae Moh power plant has classified the Mae Kham, Mae Chang and Mae Moh reservoirs into the water of class 2 - 3 (clean to medium clean fresh surface water resources) according to the value of Surface water

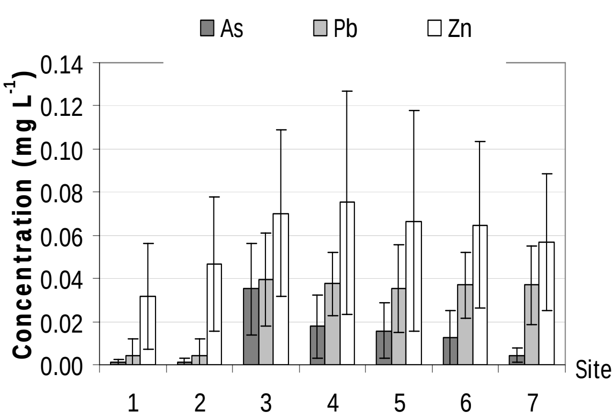
Table II. Maximum values of some water quality parameters and heavy metals for characteristics of surface water quality standards and industrial effluent standards of Thailand (Pollution Control Department of Thailand, 2001)

Parameters		Maximum value surface water	industrial effluent
Temperature	(°C)	normal	40
SS	(mg L^{-1})	not determined	50
pH		5-9	5.5-9
TDS	(mg L^{-1})	not determined	3000
DO	(mg L^{-1})	2	not determined
BOD	(mg L^{-1})	4	20
COD	(mg L^{-1})	not determined	120
NH_3-N	(mg L^{-1})	0.5	not determined
Arsenic	(mg L^{-1})	0.01	0.25
Lead	(mg L^{-1})	0.05	0.20
Zinc	(mg L^{-1})	1.00	5.00

SS = Suspended solids; TDS = Total dissolved solids; DO = Dissolved oxygen; BOD = Biochemical oxygen demand; COD = Chemical oxygen demand; Ammonia nitrogen (NH_3-N)

Fig. 2. Heavy metal changes at the seven sampling sites around the Mae Moh power plant

(Site 1. Mae Kham reservoir, Site 2. Mae Chang reservoir, Site 3. Settleable solid and oxidation pond, Site 4. Bio-treatment pond, Site 5. Diversion pond, Site 6. South wetland pond and Site 7. Mae Moh reservoir)



quality standards recommended by Pollution Control Department of Thailand (2001), while the other 4 ponds in wastewater treatment system were classified into class 5 (water resources suitable for navigation only). However, all investigated water quality parameters as well as arsenic, lead and zinc in Mae Kham, Mae Chang and Mae Moh reservoir from this study did not exceed both in the Surface Water Quality Standards and the Industrial Effluent Standards of Thailand, thereby showing no significant effect on water pollution on the aquatic ecosystem.

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