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Investigation of Aquatic Environment and Social Aspects of Thermal Power Plant Operation in Southern of Thailand

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Abstract

Community acceptance and public participation play essential role in sustainable energy development. This study aimed to investigate the current situations of the aquatic environment and social aspects of Chana thermal power plant operation in Songkhla province of Thailand. Water quality, plankton, macro benthic fauna and fish larvae in the Na Thap River were monthly examined from January 2013 to December 2013. Moreover, 410 of villager households were selected to interview. The results revealed that water quality index can be classified as fairly clean fresh surface water resources used for consumption, but requires special water treatment process before using and for industry. Change of river's flow direction will be increased potential of saltwater intrusion into the freshwater zone in dry season, and about 3% of annual upstream fish catch decrease, was identified. Of the 410 sampled households, most of the respondents were farmers (48.6%), employees (21.1%), local traders (17.8%) and fishermen (5.1%). Most of them (61.4%) had a monthly income 500 USD. About 77.8% of respondents complained that they and family members got sick annually. The majority of 86.6% expressed that they agreed to the power plant operation because of increasing economic growth and community development enabling. Only 13.4% have protested against the project because of environmental impact concerns and livelihood deterioration issues. Our findings indicated that aquatic environmental quality range suitable for the protection of aquatic life and sustaining biodiversity. Overall EGAT's community service programs were highly satisfied. Establishing guidelines for collaboration among the authorities and community's acceptance for reaching countryside happiness are our suggested.

Keywords: community concerns, ecosystem monitoring, local livelihood, thermal pollution, Chana thermal power plant, Na Thap River, Thailand

1. Introduction

Electrical energy is recognized as the backbone of the countries' infrastructure for supporting socioeconomic development. The Electricity Generating Authority of Thailand (EGAT) operates as a state-owned enterprise involved in the generation and transmission of electricity for the whole country. In the southern region of Thailand, Chana thermal power plant located in Songkhla province was approved by the Cabinet according to the resolution of the National Energy Policy Board to construct since 2004 and have commercially transmitted electricity to the grid since 2007.

This power plant is designed to utilize the 140-mile offshore indigenous natural gas of Trans Thai-Malaysia (Thailand) Limited, (TTM), from the natural gas separation plant in the Chana district. This 731.8 MW-combined cycle power plant consists of two main engines; the 242.3 MW of gas turbine and the 247.2 MW of steam turbine. The power plant has consumed the massive water volume approximately 38,880 cubic meters daily from the upstream of the Na Thap River for mechanical cooling system and then discharges warm water into the waters. Fish and shellfish larvae are not strong enough to survive in the water flow occurring at cooling water intakes as well as heated water effluents. Water temperature strongly affects aquatic living organism, particularly dramatic effects on physiological rates (Coulter et al., 2014). Consequently, it may damage or spoil the aquatic ecosystem and fisheries resources and so directly affect the livelihoods of farmer households around the Na Thap River watershed (Chesoh, 2011). Effect of cooling water discharge from many types of industry and energy production in the natural waters is a major worldwide environmental crisis (Felson, 2013). The Na Thap River watershed reflects one of the highest biodiversity of aquatic ecosystems in Thailand (Saheem et al., 2014).

Actually, tropical aquatic ecosystem has a very high biodiversity of valuable flora and fauna and this biodiversity provides numerous benefits for human welfare, including sustaining the living networks and systems that provide us all with food, health, wealth, fuel and the vital services our lives depend on. Damaged or imbalanced ecosystems can cause many problems because it is essential for human survival and environmental stabilizer. Therefore, local inhabitants are concerned about the destruction to aquatic life and the ecosystem caused by the power plant cooling systems that could directly affect to their livelihoods.

According to the notification of the Ministry of Science, Technology and Environment of Thailand on 24 August B.E. 2536 (1993), the power plant project with net productivity of more than 10 MW is required to prepare an environmental impact assessment report and submit it to the Office of National Resources and Environmental Policy and Planning (ONEP). The monitoring of the aquatic environment is very important because it is a tool for assessing the impact of an activity that could be changed from the baseline situation that is caused by the power plant operation. In addition to supply of electricity, EGAT consistently ensures that the operations are managed sustainably, effectively, and efficiently. Community acceptance and public participation are the main key to success in power plant development. Therefore, this study aimed to evaluate the current situation and function of aquatic ecosystem characteristics in the Na Thap River, including water quality, plankton, macrobenthic fauna, and fish larvae communities. Moreover, socioeconomic aspects and attitudes of people toward community service programs of Chana power plant were also investigated. The findings can be applied to the EGAT power plant manager and the authorized agents to establish action plans to rehabilitate aquatic environmental qualities and community well-being improvement.

2. Method

2.1 Study Location

The Na Thap River watershed is located between 7º 06' 28"N and 100º 42' 50" E, 6º 53' 40"N and 100º 38' E, in the Chana district of Songkhla province (Figure 1). This tidal river is one part of the Nathawee River watershed covering 35,000 hectares and originates from several streams in the mountain region of Thailand-Malaysia border. The river is 26.5 kilometers in length and downstream eastward into the Gulf of Thailand, serving as water supply for over 80,000 people of Chana district. Land use along the river consists of forestry, agriculture, fisheries, community, settlement, local business, industry, tourism and mining. The Na Thap River is a dynamic hydrological system; both direction of water flow and water quality varies because of monsoons and human responses. In rainy season, the river typically has a high turbidity, violent water flow and is contaminated by nonpoint source pollution. In summer, water is generally calm, clear, brackish or saline. The Chana thermal power plant is located upstream 22 km from the mouth of the river. The project constructed a 630-meter lateral canal connecting the main river to convey a cooling water supply. And the velocity of water intake is controlled not exceed 0.1 meters per second. The heated effluent will be stored in holding pond for 2 days of retention period prior to draining back into the River.

Due to the tidal river flow regime being extremely dynamic, the river is classified into 3 areas in this study, mainly on the basis of tidal waters salinity intrusion and ecosystem characteristics, for data collection of samples, as follows:

1) The upstream area covers about 7.5 km in length consist of the freshwater ecosystem, secondary peat swamp forest and floodplain area. Moreover, there are municipal and agro industrial development areas.

2) The middle of river area covers about 9 km in length consist the brackish ecosystem, mangrove, intensive shrimp farms and several agro processing factories.

3) Downstream or the mouth of river area covers about 10 km in length consist the saline ecosystem, communities, settlement, fisheries processing activities, fishing port and also intensive shrimp farms and fish cage culture in the main river body.

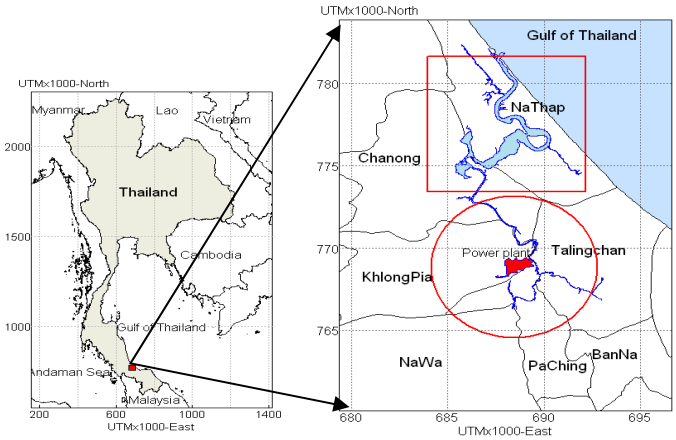

Figure 1. Study areas in 7 sub-districts within 5 kilometers around power plant (circle) and outside 5 kilometers from the plant (square) in Chana district of Songkhla province of Thailand

2.2 Methods and Data Analysis

2.2.1 Aquatic Environmental Characteristics Survey

Water samples were collected and analyzed by applying the standard method (APHA, AWWA, & WEF, 2012) in fieldwork and laboratory inspections. Phytoplankton and zooplankton communities were collected and classified following Smith (1950) and Wongrat (1980). Macro benthic fauna were collected and classified following Bradt (1974); Fitter and Manuel (1986). Fish and aquatic animals were collected by surrounding nets and set bag nets and then were categorized following Rainboth (1996), and Leis and Carson-Ewart (2000) guidelines. Fish larvae were sampled by bongo net following the method sampling eggs, larvae and juvenile fish (Backiel & Welcomme, 1980).

2.2.2 Survey of the Socioeconomic Aspects and Attitude of Local Inhabitants

Four hundred and 10 of head households who living within 5 km surrounding the power plant area and individuals who utilize the River for their livelihoods were selected with probability proportional to size of total household numbers in the villages using Taro Yamane's sample size formula on the basis (Yamane, 1973). Socio-demographic factor, monthly income and expenditure, length of residence, perception with EGAT's community service programs were investigated by using structured questionnaires together with the key informants' in-depth interview.

2.3 Statistical Methods

The study was conducted during January 2013 to December 2013 for 12 months. All statistical analysis was performed by using the R statistical package (R Development Core Team, 2011). Descriptive statistics such as mean, median, percentage and diagram, were calculated. Multiple linear regressions were used to identify the association between outcome and determinants. Each determinant was compared with the overall mean using sum contrasts. Statistical significance was set at $p<0.05$.

3. Results and Discussion

3.1 Aquatic Environmental Characteristics

3.1.1 Water Quality and Heavy Metal Contamination

The results revealed that almost of water quality parameters, physical, chemical and biological characteristics, were in the acceptable range of aquatic animal protection (Table 1). It can be classified into class 4 of Thailand's surface water quality standards; fairly clean, fresh surface water resources used for consumption, but require a special water treatment process before using and for industry. However, soluble lead and nickel in water at some sampling stations were exceeded Thailand surface water quality standard. Therefore, water quality parameters must be continually examined along the river body. No detectable of chlorinated toxic and heavy metals leakage, massive heated cooling water was kept in a huge retention pond prior to be drained by gravity into natural waters. However, some period of both in upstream and downstream exceeded water quality standards, therefore continuously examine surface water quality is necessary.

Table 1. Summary of the water quality parameters examination in the Na Thap River in 2013

Water quality	Unit	Mean	Minimum	Maximum	Standard*
1. Water depth	meter	3.44	0.6	6.8	-
2. Air temperature	°C	31.64	24.0	39.0	-
3. Water temperature	°C	29.97	26.0	34.0	naturally
4. Transparency	centimeter	104.09	25.0	250.0	-
5. Salinity	ppt	13.81	0.0	35.0	-
6. Conductivity	milli S/cm	23.61	0.0	54.9	-
7. Turbidity	FTU	22.52	0.00	54.6	-
8. Water pH	-	6.80	5.00	8.2	5-9
9. Dissolved Oxygen	mg/l	5.55	2.90	8.0	>2.0
10. BOD (5 days, 20°C)	mg/l	1.00	0.00	3.6	<4.0
11. Total dissolved solid	mg/l	13,817	46.00	36,118	-
12. Total suspension solid	mg/l	10.98	0.00	34.0	-
13. Oil and grease	mg/l	0.005	0.00	0.014	-
14. Alkalinity	mg/l	49.51	0.00	110	-
15. Total hardness	mg/l	2,231.9	0.00	5,580	-
16. Sulfate	mg/l	1,533	0.00	4,204	-
17. Nitrate	mg/l	0.095	0.00	0.3343	<5.0
18. Phosphate	mg/l	0.023	0.00	0.2155	-
19. Ammonia-N	mg/l	0.012	0.00	0.1397	<0.5
20. Chloride	mg/l	6,826	0.00	17,495	-
21. Total Iron	mg/l	1.03	0.00	3.02	-
22. Total Coliform	MPN/100 ml	670	20	7,000	-
23. Total fecal coliform	MPN/100 ml	78	20	2,300	-
24. Mercury	mg/l	0.0011	0.0000	0.0284	<0.002
25. Lead	mg/l	0.0407	0.0000	0.2083	<0.05
26. Cadmium	mg/l	0.0147	0.0000	0.0898	<0.05
27. Copper	mg/l	0.0231	0.0000	0.0828	<0.1
28. Manganese	mg/l	0.1650	0.0000	0.7583	<1.0
30. Zinc	mg/l	0.0337	0.0000	0.1703	<1.0
31. Nickel	mg/l	0.1023	0.0000	0.3798	<0.1
32. Chromium	mg/l	0.0285	0.0000	0.2063	<0.05

*Class 4: Fairly clean fresh surface water resources used for: (1) consumption, but requires special water treatment process before using (2) industry.

Influencing factors on water quality variables and aquatic ecological characteristics of the Na Thap River are spatial-temporal change of land use pattern in the upstream area. Due to peat swamp forests around the river bank is continuously destroyed and converted to agriculture farm land, causing soil erosion as well as pollutant effluents from factories and households discharged directly into the river. Change of river's flow direction will be increased potential of saltwater intrusion into the freshwater zone in dry season. This finding was consistent with the report of Lueangthuwapranit et al. (2011), who reported that fluctuations of aquatic ecosystems in the Na Thap River basin largely resulted from salinity and turbidity, which varied seasonally and geographically.

3.1.2 Phytoplankton Community and Distribution

Six divisions and 53 genera of phytoplankton were commonly found, including (1) four genera of Cyanophyta, (2) fourteen genera of Chlorophyta, (3) twenty-six genera of Bacillariophyta, (4) Six genera of Pyrrophyta, (5) two genera of Euglenophyta and (6) one genus of Cryptophyta. Total quantity of phytoplankton was 7,312,590 cells per cubic meter of water volume (218,354-2,420,689) or roughly 1,218,765 cells per cubic meter per sampling station. The three-first dominant were Bacillariophyta, Chlorophyta and Pyrrophyta, average density of

670,200 (55%), 340,026 (27.9%) and 103,205 (8.5%) cells per cubic meter, respectively.

When compared with the pre-operational phase of the power plant, overall species composition in both divisions and genera increasingly occurred, whereas the quantity of phytoplankton decreased particularly Pyrrophyta and Euglenophyta. These results showed that effluents contaminated in the river during this period were lower than those in pre-operational phase. Moreover, both Pyrrophyta and Euglenophyta are bio-indicators of polluted water in natural waters (Gulecal & Temel, 2014). Therefore, plankton bloom phenomena had smaller occurrences. Whereas Chlorophyta and Bacillariophyta useful for fish larvae feeding in the food chain, always occurred near the outflow in upstream areas.

3.1.3 Zooplankton Community and Distribution

There were 11 phyla and 43 types of zooplankton discovered, including, 6 types of Protozoa, 1 type of Coelenterata, 18 types of Rotifera, 1 type of Chaetognatha, 2 types of Nematoda, 2 types of Cladocera, 5 types of Copepoda, 2 types of Eucarida, 1 type of Cirripedia, 3 types of Mollusca, and 1 type of Chordata. Total quantity of zooplankton was 275,723 individuals per cubic meter of water volume per sampling station (93,053-591,642). The three-first dominant were copepod (63.6%), protozoan (12.7%), and rotifer (10.6%), respectively. When compared with the pre-operational phase of the power plant, the overall quantity of zooplankton decreased particularly protozoan. This finding indicated that the water quality was appropriated to the productive ecosystem due to the higher number of protozoan reflects the higher organic matter in the waters (Shukla & Gupta, 2001). Furthermore, increasing amounts of cupboard, cladocera, polychaete, ostracod, okiopheura, mollusk larvae and crustacean was occurring. Cirripedia increased, whereas rotifer decreased due to saline intrusion into inland water.

3.1.4 Macrobenthic Fauna Community and Distribution

Four phyla and 27 species of macro benthic fauna were identified, including the phylum Mollusca (bivalve and gastropod), Arthropoda (shrimp, mantis shrimp, crab and crustacean), Annelida (polychaete) and phylum Echinodermata (sea star). Average density was 327.5 (4.5-1,070) individuals per square meter. The highest quantity was occurred in upstream was about 1,070 individuals per square meter. Bivalve (Mytilopsis adamsi), gammarid and polychaete were the majority groups. Species and abundance of macrobenthic fauna showed decreasingly in quantity, especially non-economic gastropod larvae such as mangrove coastal bivalves and some crustacean resulted from deforestation both in the upstream forest and soil erosion. However, these species were associated with economic aquatic animals in the food chain such as mullets, sea bass, and marine shrimps. Some economic benthos particularly bloody clams, oysters and green mussels were also found.

3.1.5 Fish Larvae Community and Distribution

A total of 58 aquatic animal larvae were commonly found in the average density of 2,652 larvae per 1,000 cubic meters of water volume (1,235-4,570). Downstream was the highest fish larvae occurring in the average density of 4,283 larvae per 1,000 cubic meters approximately 51.4%, followed by in the middle area of the river (30.7%) and upstream only 17.9%. The results showed that brackish fish larvae had increased in the downstream region from pre-operational phase of the power plant on average of 3.5% annually. In addition, high salinity preferred brackish fish larvae had increased continuously due to aquatic environmental factors such as water temperature and dissolved oxygen are usually stable in normal range. Whilst approximately 15 million individuals of fish larvae in upstream areas, were destroyed annually (15% of total upstream) by processing once through a cooling system and about 3% of annual upstream fish catch decrease.

3.2 Socioeconomic Aspects and Attitude of Local Inhabitants

3.2.1 Socio-demographic Aspects of the Respondents' Household

Of the 410 sampled households, more than a haft (51.1%) were the head of households and about 57.8% were female. The moderate number of member in households was 4(1-13). The majority of respondents (54.5%) were 18-45 years old that got primary education level and illiterate 44.9%. Mostly 60.5% were Muslim. For the family occupation, approximate 46.8% of respondents were farmers (rubber plantation, orchard, paddy field and cattle) followed by 21.1% were employees in rubber plantations, fisheries, factories and commercial sectors, 17.8% were trader or seller and about 5.1% engaged in fishing. More than a half of respondents earned a minor occupation. Most of them (61.4%) had a monthly income about 500 USD or less. In addition, about 49.3% of respondents have a family debt amount of 2,170 USD. However, about 50.5% of them earned saving, but more than a half of respondents recognized that a monthly income receiving was not balanced with their expenditure, whereas the Songkhla income per capita was 4,842.3 USD in 2011 (Knoema, 2014).

When compared to pre-operational phase of the power plant project, over a half of the respondents earned

monthly income lower than 300 USD. After that, this proportion was decreased. The daily fish catch was about 5,500 kg or about 121 metric tons monthly. Average annual family income from fishing was about 950 USD. Overall fish catch in the Na Thap River still closed to the pre-operational phase because of recruitment of seasonal migratory fish from the Gulf of Thailand into the river. However, highly valued fish showed decreasing while the smaller fish were more trapping. Therefore, the fishermen stated that their family income unbalance with daily expenditure. Inhabitants always requests for income or occupational support from EGAT's Chana power plant in various activities.

3.2.2 Length of Residence and Community Infrastructure

Almost of respondents live in their community more than 25 years. Mostly of respondents (95.1%) stated that they had no any problem about health care, fair about the daily living environment (48.4%), satisfied with communication and infrastructure in the village (20%), and having good neighbors (13.6%), but dissatisfied with the deteriorated of ecosystem and community environment about 59.6%. Most have access to public electricity and most of the respondents (80.5%) were located in public pipe water service area, whereas the others use water from shallow wells, river and rainfall water. However, they were satisfied to obtain water use by their habits. Mostly purchases bottled drinking water and tap water. Cleanness as well as the inadequate of drinking water is the major problems (32%). About 37.1% got the farming problems. Almost of respondents recognized that they have no problem with road communication and community waste/garbage management. Garbage burning within home area is a widely method of waste disposal.

3.2.3 Environmental and Health Issues

The current environmental issues related to the Chana power plant, all respondents didn't specify directly that polluted environment was generated from the power plant. Conversely, selected respondents stated that some evidence may originate from both directly and indirectly of the power plant operation; about 4.2% of respondents pointed out that they are suffering with a fugitive dust problem in their village and specified directly that generated from the power plant. Terrible smoke (1.1%), noise nuisance (12%), weather temperature increasing (18%), flooding (1.4%), and water pollution (30%) were mentioned that theses caused from the power plant. In addition, some respondents indicated that the power plant was the pollution source causing the declining of fish catch and deterioration of aquatic ecosystem. In this case, EGAT officer should explain the local to understand the power plant electrical generation and non-pointed source of pollution around the Na Thap River basin.

About 77.8% of respondents indicated that they and their family members got sick annually. Most of them got sick from respiratory disease or common cold (81%) followed by muscle aches or pain (30.4%) and allergy and dermatologic disease (22.7%). Almost used health care services from government hospitals and health care center, satisfied their living environment due to good environment, peaceful, safe for life and property and villagers help each other. However, about 80% of respondents presented increasingly of respiratory disease, muscle and allergic illnesses. A study of health impact and risk assessment of urban air pollution in the Klang Valley of Malaysia, indicated that relative risks (RR) for respiratory and cardiovascular morbidity were associated with NO_2 increments and the significant RR outcomes associated with very low SO_2 concentrations (Jamal et al., 2004). That report strongly calls for further investigation of air emission quality of the power plant.

3.2.4 Perception, Attitude and Satisfaction toward EGAT's Community Service Programs

Over a half of respondents indicated that they perceive various EGAT's information of community social service programs and activities; about 55.9% of those received massage and got experience from the neighbors, 30% received from community leaders, 14.6% from EGAT's public relations media and about 12.9% from the monthly village meeting. The most frequency of message receiving was about one time per month, but about 21.3% specified that they was never received any message from EGAT officer.

Perception on the environmental impact issue of Chana power plant showed that about 61.2% of respondents did not receive any environmental measure action and monitoring message from the EGAT. And about 60.7% stated that they did not know about power plant environmental audit committee. However, about 49.5% specified that all audit committees having more beneficial and were recognized in moderate ranking. For the overall message, receiving, 78.3% of respondents living in inner 5 km far from the power plant site informed that they were satisfied with community service programs of Chana power plant in 2013 corresponding to respondents who living outer 5 km far from the power plant site were satisfied about 75.9%. The program of fish and shrimp releasing into the river for increasing productivity was the most favorite, followed by the religion and local traditional support program, and the program on EGAT's supporting the elderly activity. This is because Thai rural inhabitants' lifestyle usually relates to indebtedness of natural resource and their family elders' dependence.

The key success of community acceptance and participation in the south most of Thailand depends on gender (male), educational level, social status in the community, family income and asset holding, ability of accessing information, sense of democracy, public interest, awareness, resource dependence for livelihood, caliber of project public relations staff, frequencies of community visiting and public funding (Chesoh, 2010). The majority of 86.6% expressed that they agreed to the Chana power plant operation because of increasing economic growth and community development enabling. For example, this power plant provides affordable electricity to the remote areas in the lower southern of Thailand and a large number of well-paying jobs for residents of Songkhla province and the surrounding area. And also generates substantial tax revenue in the local area. Only 13.4% of respondents disagreed with the power plant project because of environmental impact concerning and livelihood deterioration issues, including decreasing of fish population and their income, decreasing of agriculture products from water pollution and chemical toxins, health risk from air emission and acid rain. Some recommendation was shown below;

1) Providing some annual development fund for villages located connecting to the power plant.

2) Environmental and energy conservation knowledge should be transferred to the local, village leaders who living around the power plant site together with experience sharing in their networking.

3) Public relationship and mass media, two ways communicating about the power plant activities are necessary for all publicly.

4) EGAT should provide assistance in occupation promotion to the locality such as provide fishing gears, occupational instruments, support additional job for housewives, provide fish, shrimp and blood cockles seeds, mangrove tree growing and rehabilitating, employing more jobs and offers the opportunity for the villagers to work in EGAT's power plant.

5) The relevant authorized government organizations have to strengthen the environmental law enforcement intensely and equality.

4. Conclusion

Overall water quality and aquatic ecosystem characteristics of the Na Thap River and adjacent areas remain appropriate for most aquatic life due to the fertility of the natural food chain of phytoplankton, zooplankton and macro benthic fauna. The downstream and middle areas of the river show a significant role in being a very important habitat for growth and nursery ground especially important economic fish and shellfish species. However, we strongly recommended that further studies and a continuation of ecological monitoring are necessary. The EGAT should be continuously promoted the local participation and all stakeholders for environmental management collaboration and sustained acceptance. We emphasize that integrated sustainable management of ecosystem knowledge transfer from effective learning programs and strengthening action for the socioeconomic livelihood improvement need to be done especially in low income households.

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