CHAPTER 1

INTRODUCTION

1. Introduction

One of the most obvious, pervasive, and world-wide water quality problem is eutrophication of closed water bodies such as lakes, reservoirs, bays, and inland seas. Some water bodies are naturally eutrophic in that they receive sufficient supplies of aquatic plant nutrients, mainly phosphorus and nitrogen, from natural sources to produce excessive growth of algae and macrophytes (Okada, 1989).

By definition, Eutrophication is the process of nutrient enrichment (primarily N and P) that stimulates algal blooms, primary productivity and massive growth of macrophytes. Blooming and finally collapse of algae may lead to hypoxia/anoxia and hence mass mortality of benthos and fish over large area. Sensitive species may be eliminated and major changes in ecosystem function may occur. Deteriorating environmental quality adversely affects an amenity, recreational value and the tourist industry (Wu, 1999).

At the present time, excessive biological production in the form of macrophytes could be observed in Pattani Dam during dry season of the year; however, it has not yet been known what the state the dam water is. Further, the Pattani Dam Reservoir is situated in the Pattani River, Yala province. This province had a number of abandoned mines; therefore, the drainage from these abandoned mines in the upstream area could run into tributaries of the Pattani River, where the high concentrations of metals, especially lead, has been found (Everraarts and Swennen, 1987; Arrykul and Kooptarnon, 1993; Tutep, 1994; Chompikul, 1997). Therefore, it is possible that metals contaminated in the river water could be accumulated in the sediment of the dam with high concentrations as well.

Although previous studies were conducted to examine metals by several researchers (Everraarts and Swennen, 1987; Arrykul and Kooptarnond, 1993; Tutep, 1994; Chompikul, 1997), the studies did not include sediment from Pattani Dam Reservoir, which is the irrigation and flood control reservoir situated in flood plain of Pattani River. However, the high level of lead in the water of the dam has been reported (NIDA, 1999).

Eutrophication and metals contamination have potential hazard to natural resources and to human health. In this respect, ecological risk assessment can provide an estimate of these risks and a tool for managing such risks.

Risk assessment has become an increasingly important tool for investigating the nature and magnitude of human health and ecological impact during the last two decades (Lipton *et al*., 1993). Nowadays, risk assessment and risk management are more commonly used as powerful tools in environmental management, especially when zero discharge or no development are not the best option (Wu, 1999). Risk of certain pollutants may be expressed as ecological risk (i.e. their potential and probability in changing structure and function of ecosystems, spatial scale of change etc.), and public health risk (e.g. in terms of number of people affected, severity of disease etc.). Economic loss (in terms of monetary loss and resource loss), as well as reversibility and time for recovery from pollution effects are also important elements in risk assessment (Wu, 1999).

The purpose of this thesis is to characterize the potential ecological risk associated with the eutrophication and the concentration of lead in sediment in Pattani Dam.

This study will provide important information on the potential ecological risk of Pattani Dam. In addition, the study will permit us to know possible sources of nutrient and lead contamination, and will suggest a cleanup option, which could be useful to officers responsible for developing and implementing of water quality management plan.

2. Review of Literatures

2.1 Contamination of Lead in Pattani River

Several researchers have studied the contamination of lead in Pattani River and found that water and sediments in the river were contaminated by lead with high concentration.

Everaarts and Swennen (1987) reported that sediments taken from the mouth of Pattani River in 1985 had lead contents up to 242 mg/kg. For marine invertebrates collected from Pattani Bay at the same time, the lead contents were up to 20.8 mg/kg and 18.4 mg/kg in the polychaete *Dendronereis* and the bivalve *Glauconome virens*, respectively.

The Ministry of Public Health reported the findings of analyses of water samples taken from 4 stations along Pattani River in 1991. They found that water in the river just north of Banang Sata District had lead levels of between 60 and 100 μg/L, whereas the recommendation of lead in drinking water issues by the U.S. Environmental Protection Agency is 5 μg/L (USEPA, 1988).

Arrykul and Kooptarnon (1993) analyzed sediment samples collected from several stations along Pattani River in March and July 1992 and reported lead contents ranging from 1,148 mg/kg to 3,333 mg/kg. The highest lead contents of sediments occurred in areas close to and downstream of the abandoned tin mining operations in the upper reaches of Pattani River some 100 km from the river mouth. Lead contents of soils in the Pattani River Basin in October of the same year ranged from 0.4 to 218 mg/kg, with the highest levels in the alluvial plain within about 25 kilometers of the river mouth, while the levels of lead in suspended solids in November showed a gradual decline from over 400 mg/kg in the upper reaches to around 100 mg/kg at the river mouth. In the same year, Tutep (1994) analyzed sediments sample from 15 stations along Pattani River in Yala province. The highest levels, 6,069 mg/kg, recorded from close to and downstream of the abandoned tin mine was reported.

The high lead contents derived from the tin mining operation in Yala province was confirmed again by the Ministry of Public Health (1994) after analyzing of water samples taken in August 1992 and June 1993.

Chompikul *et al*., (1997) analyzed samples of water and sediments taken from 19 stations along downstream of Pattani River in December 1995 and found to have lead content ranging from undetectable concentrations to 55 µg/L and 80 µg/L in water collected at the surface level and at one-meter depth below the surface level, respectively. The range of lead concentrations in sediment samples was 19.0 to 183.5 mg/kg with the arithmetic mean 95 mg/kg.

2.2 Eutrophication

Eutrophication is the process of nutrient enrichment (primarily N and P) that stimulates algal blooms, primary productivity and massive growth of macrophytes. Blooming and finally collapse of algae may lead to hypoxia/anoxia and hence mass mortality of benthos and fish over large area. Sensitive species may be eliminated and major changes in ecosystem function may occur. Deteriorating environmental quality adversely affects an amenity, recreational value and the tourist industry (Wu, 1999). Indeed, increases in nutrient concentration, phytoplankton biomass and productivity, alteration of nutrient ratios, and significant changes in the structure and composition of many key function groups of organism have been reported by several authors (Hansson and Rudstam, 1990; Recknagel *et al*., 1998; Håkanson, 1999; Smith; Tilman and Nekola, 1999; Wu, 1999)

Common measures of eutrophication include total nutrient concentrations (phosphorus and nitrogen), chlorophyll-*a* (a measure of algal density), Secchi depth (a measure of transparency), organic nutrient forms (nitrogen and carbon), and hypolimnetic dissolved oxygen depletion (Walker, 1996).

Håkanson (1999) stated among the most useful, operational ecological effect variables for eutrophication are the Secchi depth, chlorophyll-*a* concentration, hypolimnetic oxygen demand and oxygen concentration.

Celballos; Konig and Oliverira (1998) studied the three lakes located in northeast Brazil in 1989 to 1991 by choosing a simplified set of parameters useful to characterize the trophic state of the three water bodies using principal components analysis for statistical data treatment. They reported the simplified set composed of 7 parameters, namely fecal coliform, turbidity, orthophosphate, nitrate, dissolved oxygen (DO), BOD_5, and pH.

Thaweeburus (1994) applied the Water Quality Index (WQI) to assess water quality of the upper part of Songkhla lagoon, Thailand and the four found trophic state indicators included in the WQI equation are pH, DO, BOD_5, PO_4-P and transparency.

For limiting nutrient, it is evident that the concentration of lake total phosphorus (TP) can be influenced by emissions from many type of sources, such as point sources (e.g. domestic sewage, industries and fish farm), atmospheric deposition (to the lake surface and the catchment area), internal loading (linked to resuspension, diffusion, etc.) and, often most important, tributary input (Håkanson, 1999).

2.3 Classification of Lake

There have been presented many criteria to classify lakes, among which the deterministic and probabilistic criteria recommended by the Organization for Economic Cooperation and Development (OECD; Vollenweider and Kerekes, 1982) are widely used as reference criteria for eutrophication level assessment of inland waters and marine transitional systems. The OECD probabilistic classification, defined an 'open boundary system', i.e. without fixed lower and upper limits for each trophic class, is based on overlapping lognormal probability distributions for each trophic category, defined by corresponding annual means and standard deviations of the most relevant variables of water quality (Table 1 Figure 1). It refers to single analytical variables like chlorophyll-*a*, total nitrogen and total phosphorus concentrations as well as peaks of chlorophyll-*a* and secchi depth measurements.

Those variables are recommended because of their expected inter-correlated response coupled with the trophic degree of a water body (Vollenweider and Kerekes, 1982)

Table 1 Preliminary classification of trophic state in the OECD eutrophication program (Vollenweider and Kerekes, 1982; Dodds *et al*., 1996)

Variable (annual geometrical means)	Oligotrophy	Mesotrophy	Eutrophy
Chlorophyll-*a* (μg/L)	1.7	4.7	14.3
Mean ± S.D.	0.8 - 3.4	3.0 - 7.4	6.7 - 31
Mean ± 2 S.D.	0.4 - 7.1	1.9 - 11.6	3.1 - 66
Total P (μg/L)	8.0	26.7	84.4
Mean ± S.D.	4.85 - 13.3	14.5 - 49	48 - 189
Mean ± 2 S.D.	2.9 - 22.1	7.9 - 90.8	16.8 - 424
Total N (μg/L)	661	753	1875
Mean ± S.D.	371 - 1181	485 - 1170	861 - 4081
Mean ± 2 S.D.	208 - 2103	313 - 1816	395 - 8913
Secchi depth (m)	9.9	4.2	2.45
Mean ± S.D.	5.9 - 16.5	2.4 - 7.4	1.5 - 4.0
Mean ± 2 S.D.	3.6 - 27.5	1.4 -13	0.9 - 6.7

Trophic classifications for lakes have a rich history and stem from differences in lake ecosystem function and phytoplankton communities over the range of lake types (Dodds *et al*., 1998). General functional characteristics exist among lakes within each of the major trophic state categories, including oligotrophic , eutrophic, and mesotrophic lakes. Dodds *et al*. (1998) provided a brief description of the characteristics of the three lake types mentioned above as follows:

Oligotrophic lakes have low nutrients, low algal biomass, high clarity, and deep photic zones. Eutrophic lakes can have frequent cyanobacterial blooms, high total nutrients, and wide swings in dissolved oxygen (DO) concentrations (potential anoxia) and pH. Mesotrophic lakes have intermediate characteristics. The boundaries placed between these categories by aquatic scientists are similar but not universal, in part because biota (Dodds *et al.*, 1998).

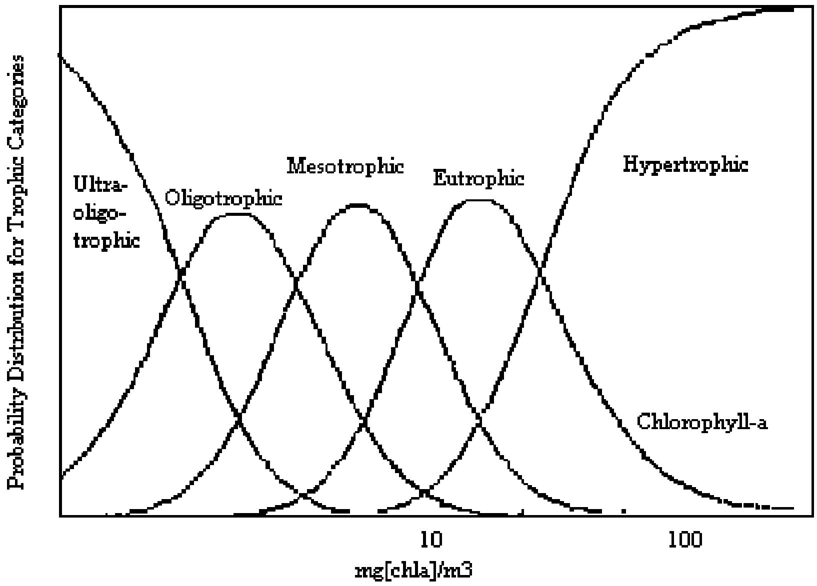

Figure 1 Probability distributions for different trophic categories as a function of mean chlorophyll-*a* concentrations (mg/m^3) on logarithmic scale (slightly modified from Zurlini, 1996)

2.4 Ecological Risk Assessment

This review addresses ecological risk assessment (EcoRA) concepts and methods since 1997 to date. It focuses on definitions involving ecological risk assessment, innovations in risk assessment methods, published applications of ecological risk assessment, and addition or updates to guidance documents. The review is mainly revised from Cura (1998); however, ecological risk assessment methodologies associated with eutrophication and with lead contaminating in sediments were added.

During the last two decades risk assessment has become an increasingly important tool for investigating the nature and magnitude of human health and ecological impact (Lipton *et al*., 1993). Risk assessment is the scientific method of confronting and expressing uncertainty in predicting the future. Risk is the chance of some degree of damage in some unit of time or the probability of frequency of occurrence of an event with a certain range of adverse consequences (Lohani *et al*., 1997).

In general, the two major of risk in environmental perspective are those to human health and those to ecosystem integrity (Lohani *et al*., 1997). Such risk may be express as ecological risk (i.e. their potential and probability in causing dysfunction of population, changes in structure and function of ecosystems, spatial scale of change, etc.) and human health risk (e.g. in term of number of people affected severity of disease, etc) (Wu, 1999).

There are some evident differences between human health risk assessment and ecological risk assessment although they are both identified pathways and mechanisms of exposure to physical, chemical or biological factor of concerns. Human health risk assessment focus on the most sensitive, maximally exposed individuals, whereas ecological risk assessments rely on professional knowledge for the assessment of ecological risks to relevant individuals, population, communities or ecosystems. The purpose of an ecological risk assessment is to contributed to the sustainable utilization and management of the environment through scientifically credible evaluations of the ecological effects of environmental changes (Claassen, 1999).

Both of the mentioned risks can be analyzed using Environmental Risk Assessment (ERA) methodology. By definition, ERA is the analysis by identification, quantification, and evaluation of existing or potential hazards to natural resources and human health. The term "natural resources" comprises all elements in the ecosystem which contribute to the quality of human life (Thaweeburus, 1998). However, if only ecological risk to be assessed, such assessment is generally called ecological risk assessment (EcoRA). In deed, EcoRA is a subset of ERA, it deals with the condition of ecosystem rather than human health or individual organisms (Lohani *et al*., 1997). In meaning, EcoRA can be described as a process for estimating the likelihood of adverse ecological impact resulting from anthropogenic stress (Munns, 1998).

Nowadays, there is not yet any widely applicable, established procedure for EcoRA (Lohani *et al*., 1997). Nevertheless, Cura (1998) recommended the U.S. Environmental Protection Agency framework for ecological risk assessment can be accepted as the paradigm for most ecological risk assessment. The framework consists of three primary steps: Problem Formulation, Analysis, and Risk Characterization (Figure 2). Providing the profiles of these steps, Munns (1998) stated that some of the goals of Problem Formulation are (1) to evaluate exiting information concerning stressors, receiving ecosystems, and potential ecological effects; (2) to identify assessment endpoint (value ecological conditions or processes) to be protected; and (3) to develop a conceptual model describing potential risk to assessment endpoints. The analysis step involves characterization of exposure conditions in time and space, as well as evaluation of ecological effects potentially resulting from those levels of exposure. Analysis step involves a variety of empirical and modeling activities, with the ultimate goal of developing profiles of exposure and effect. These profiles are synthesized into estimates of ecological risk during the Risk Characterization step. Characterization activities may be either qualitative or quantitative, and are directed toward providing the information necessary to make informed environmental management decisions (Munns, 1998).

The U.S.EPA 's framework has been successfully applied to the assessment of ecological impacts in the U.S.A. and Canada (USEPA, 1993; SETAC, 1996). Recently, it has been applied to integrated environmental management in South Africa (Claassen, 1999).

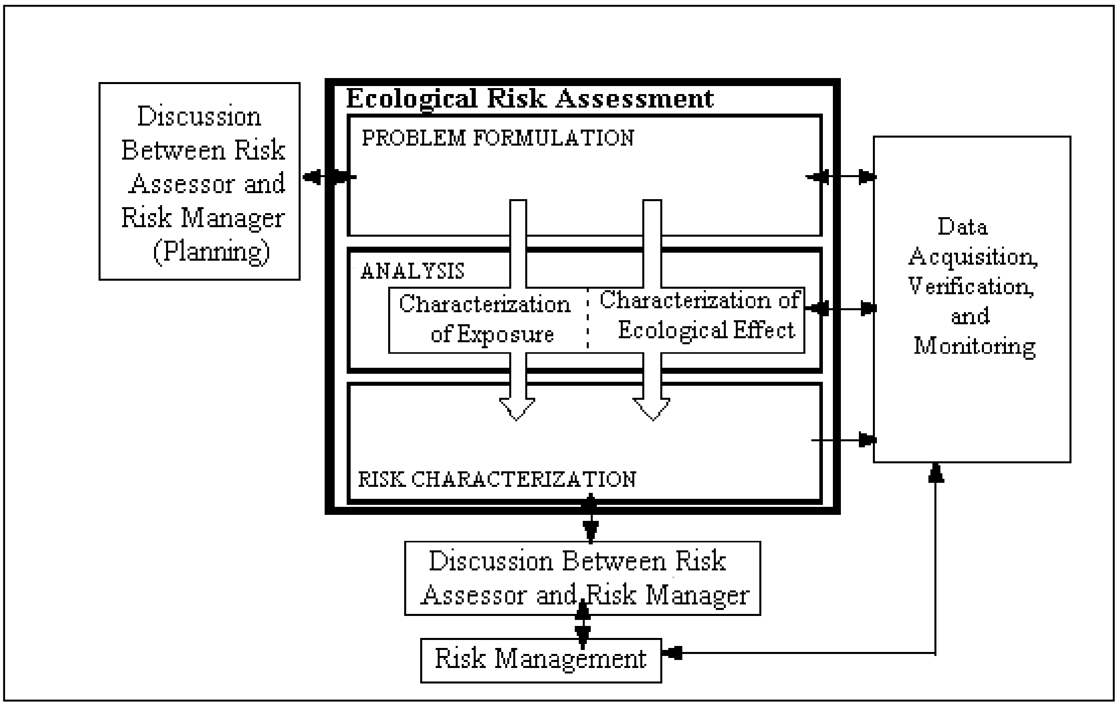

Figure 2 EPA's framework for ecological risk assessment (USEPA, 1996)

Ecological risk associated with eutrophication has reviewed by few authors. For instance, Wu (1999) reviewed the ecological risk associated with eutrophication in marine environment. The author provided reasons why the problem of eutrophication is likely to be exacerbated in the coming years and described the ecological risk on seven topics, including change in structure and function of ecosystems, effect on coral reef, algal and toxic blooms, public health risk, trends, recovery, and challenges. However, the assessment methodology was not reviewed.

Håkanson (1999) presented the Potential Ecological Risk (PER) approach to ecosystem assessment. Case studies are used to provide examples for the major chemical threats to Swedish lakes and coastal ecosystem, acidification, eutrophication and toxic contamination of mercury, rediocaesium and chlorinated organics. In assessing ecological risk associated with nutrient in lakes, his approach base on several models, all of which are not applicable for dams/reservoirs.

Thaweeburus (1998) developed a framework of criteria for ecological interpretation, stressing its importance on Environmental Impact Assessment (EIA), Environmental Risk Assessment (ERA), and environmental planning of areas in conflict between the demand for and protection of natural resources. In the risk assessment process, the literatures were reviewed to describe the existing then treated with statistical methods including cluster analysis, factor analysis, correlation coefficient, and multiple regression. Water Quality Index (WQI), Trophic State Index (TSI) and Trophic State Classification Criteria of the OECD were also applied as water indices. Ultimate result, the five main risk areas of Songkhla lagoon were reported, and macrophyte was found to be an effective bioindicator of nutrient enrichment in the lagoon.

Ecological risk assessment of metals in sediments has been studied, more widely than assessing ecological risk of nutrient, by several researchers around the world (Håkanson, 1980; Ankley *et al*., 1996; Fernandes, 1997; He; Wang and Tang, 1998; and Kwon and Lee, 1998). The typical assessment approach involves calculation of simple ratio of the environmental exposure concentration (measured or modeled concentration of metals in surface sediments) to biological benchmark concentrations (sediment quality criteria or pre-industrial reference value). This is the qualitative approach to characterize risk (Munns, 1998).

2.5 Factors Influencing the Toxicity of Lead (USEPA, 1999b)

Lead toxicity in freshwater is effected by three important factors: the persistence, environmental fate, and bioaccumulation of lead. The data of these factors are summarized below to aid in the interpretation and highlight the various uncertainties associated with this risk assessment.

The information summarized below as well as a more extensive review of the existing data on the environmental fate of lead is contained in The Environmental Fate of Lead and Lead Compounds (USEPA, 1999b) and in the references contained therein.

2.5.1 Persistence and Environmental Fate of Lead

Although metals and metal compounds, including lead and lead compounds, may be converted from the metal to a metal compound or from one metal compound to another in the environment, the metal cannot be destroyed. Thus, metals are obviously persistent in the environment in some form. The form of the metal that exists in the environment depends on its environmental fate.

In the soil environment, lead may bind strongly by mechanisms such as the formation of insoluble complexes with organic material, clay minerals, phosphate, and iron-manganese oxides common in many soils. These mechanisms can lower the levels of soluble lead in soils. However, some of the lead in the soil environment (0.2 to 1%) may be water soluble.

The extent of sorption appears to increase with increasing pH. Under acidic conditions, levels of lead in soil water can increase significantly. The solubility of lead increases linearly in the pH range of 3 to 6. At a pH of 5 to 9, heavy metals such as lead may bind to the surface of clay minerals. Cation exchange capacity (CEC, related to soil clay content) and pH also influence the capacity of soil to immobilize lead. Generally, as the CEC and pH increase, the capacity of a soil to sorb lead increases. Conversely, soils with lower CEC and pH tend to have a lower capacity to sorb lead. It has been found that a pH drop from 5.5 to 4.0 would reduce estimated soil absorption capacity 1.5 times, thereby increasing the concentration of available lead in soil water.

A number of field studies demonstrate the effect of environmental conditions on the mobility of lead in soils. In all of these studies, variables including pH, soil organic matter content and the chemical species of lead present, had a significant influence on soil lead mobility. Data indicate that when the pH and soil organic matter content are low and conditions favor the formation of soluble forms of lead, the mobility of lead increases. Therefore, decreasing pH can lead to increasing concentrations of lead in soil water.

Other studies demonstrate that when pH and soil organic matter are high, lead mobility in soils is decreased.

The levels of soluble lead in surface waters depend on the pH of the water and the dissolved salt content. Equilibrium calculations show that at a pH greater than 5.4, the total solubility of lead is approximately 30 micrograms per liter (mg/L) in hard water and approximately 500 mg/L in soft water. In soft water, sulfate ions limit the lead concentration in solution through the formation of lead sulfate. The lead carbonates limit lead in solution at a pH greater than 5.4

Concentrations as high as 330 mg/L could be stable in water at a pH near 6.5 and an alkalinity of about 25 milligrams (mg) bicarbonate ion per liter. In other waters, where alkalinity and pH are higher, the relative concentrations of soluble lead may be lower.

Lead also forms complexes with organic matter in water. The organic matter includes humic and fulvic acids that are the primary complexing agents in soils and widely distributed in surface waters. The presence of fulvic acid in water has been shown to increase the rate of solution of lead sulfide 10 to 60 times

At pH levels near neutral (i.e., about 7.0), soluble lead-fulvic acid complexes are present in solution. As pH levels increase, the complexes are partially decomposed, and lead hydroxide and carbonate are precipitated, and may either remain suspended or fall to the sediment. Other studies have shown that humic acid in freshwater is capable of complexing various amounts of metals. In some circumstances, this process could potentially reduce the levels of soluble lead present.

At neutral pH, lead generally moves from the dissolved to the particulate form with ultimate deposition in sediments. There is evidence that in anaerobic sediments, lead can undergo biological or chemical methylation. This process could result in the remobilization and reintroduction of transformed lead into the water column where it could be available for uptake by biota, and volatilization to the atmosphere. However, tetramethyl lead may be degraded in aerobic water before reaching the atmosphere.

In conclusion, USEPA (1999b) stated that processes commonly observed in the environment can result in the release of bioavailable (ionic) lead where it can be bioaccumulated by organisms. These processes may occur in aquatic environments with low pH and low levels of clay and organic matter. Under these conditions, the solubility of lead is enhanced and if there are no sorbing surfaces and colloids, lead ion can remain in solution for a sufficient period to be taken up by biota. Lead sorption to soil organic matter has been shown to be pH dependent. Decreasing pH can lead to increasing concentrations of lead in soil water; while increasing pH can lead to decreasing concentrations of lead in soil water.

USEPA (1999b) concluded that under many environmental conditions lead is available to express its toxicity and to bioaccumulate.

2.5.2 Bioaccumulation and Aquatic Bioaccumulation Data for Lead

Bioaccumulation is a general term that is used to describe the process by which organisms may accumulate chemical substances in their bodies. The term bioaccumulation refers to uptake of chemicals by organisms both directly from water and through their diet. The USEPA has defined bioaccumulation as the net accumulation of a substance by an organism as a result of uptake from all environmental sources. The nondietary accumulation of chemicals in aquatic organisms is referred to as bioconcentration, and may be described as the process through which a chemical is distributed between the organism and environment based on the chemical's properties, environmental conditions, and biological factors such as an organism's ability to metabolize the chemical. The USEPA has defined bioconcentration as the net accumulation of a substance by an aquatic organism as a result of uptake directly from the ambient water through gill membranes or other external body surfaces. A chemical's potential to bioaccumulate can be quantified by measuring or predicting the chemical's bioaccumulation factor (BAF). The USEPA has defined the BAF as the ratio of a substance's concentration in tissue of an aquatic organism to its concentration in the ambient water, in situations where both the organism and its food are exposed and the ratio does not change substantially over time. A chemical's potential to bioaccumulate can also be quantified by measuring or predicting the chemical's bioconcentration factor (BCF). The USEPA has defined the BCF as the ratio of a substance's concentration in tissue of an aquatic organism to its concentration in the ambient water, in situations where the organism is exposed through water only and the ratio does not change substantially over time.

A review of the ecotoxicological literature indicates by the USEPA (1999b) that bioconcentration values of lead in aquatic plants and animals are often above a bioconcentration/bioaccumulation factor of 1,000. Lead is bioaccumulated by aquatic organisms such as plants, bacteria, invertebrates, and fish. The principal form that is believed to be accumulated is divalent lead (i.e., lead in its plus 2 oxidation state). It has been shown that fish held in water at a pH of 6.0 accumulate three times as much lead as fish held in water at a pH of 7.5, thus as pH decreases the availability of divalent lead increases. Older organisms usually have the highest body burdens, and lead accumulates in bony tissues to the greatest extent (Several sources cited by USEPA, 1999b).

Additional information concerning lead's bioaccumulation potential is summarized in the bioaccumulation support document for this proposed rule. In general, bioconcentration values for four freshwater invertebrate species ranged from 499 to 1,700. BCFs for two species of freshwater fish were much lower, 42 and 45. However, certain fish tissues have much higher BCF values, e.g., the BCF value for the intestinal lipids in rainbow trout were as high as 17,300. Freshwater phytoplankton and algae accumulate or concentrate lead to very high levels (e.g., greater than 10,000x). These data indicate that many of the BCF values and measured environmental concentration factors for lead are above 1,000 with several species having BCF or observed concentration factors above 5,000. There are also a few fish tissues that have BCFs greater than 10,000, though most of the available fish data are below 5,000 (Several sources cited by USEPA, 1999b).

2.5.3 Human Bioaccumulation of Lead

Although lead has no known biological function in humans, it is readily absorbed through the gut and can be absorbed by inhalation and, to some extent by dermal contact. Absorption of lead can occur as a result of exposure to air-borne forms of lead, as well as ingestion or contact with contaminated soil and dust.

Children and developing fetuses are known to absorb lead more readily than adults and to excrete it at a lower total rate. These findings are especially significant since young children are most susceptible to the adverse effects associated with lead exposure. Lead absorption varies from very low levels (e.g., 5%) up to essentially 100%. Lead absorption appears to be linked to particle size, the chemical composition, and other factors. Long-lasting impacts on intelligence, motor control, hearing, and neurobehavioral development of children have been documented at levels of lead that are not associated with clinical intoxication and were once thought to be safe. An analysis of human blood-lead level data collected from most recent National Health and Nutrition Examination Surveys, showed that approximately 4.4% of the nation's children aged 1-5 years have blood-lead concentrations at or above 10 micrograms per deciliter (mg/dL), which is the current action level established by the Centers for Disease Control. While this is a significant improvement over the 88% of children who had blood lead levels above this threshold in 1976, before the phase-out of lead in gasoline, it is still cause for concern because it leaves nearly 900,000 children aged 1-5 with unacceptably high blood-lead levels.

Once lead is absorbed in the body, it is primarily distributed to the blood, and brain) and to the mineralizing tissue (bones and teeth). In one study it was shown that in adults, following a single dose of lead, one-half of the lead absorbed from the original exposure remained in the blood for approximately 25 days after exposure, in soft tissues for about 40 days, and in bone for more than 25 years. Once in the bone, lead can re-enter the blood and soft tissues. Under certain circumstances, such as pregnancy and lactation, lead can more readily re-enter blood and soft tissues. Thus, accumulation of lead in bone can serve to maintain elevated blood lead levels years after exposure. The total amount of lead in long-term bone retention can approach 200 mg for adult males 60-70 years old (and even higher with occupational exposure). For adults, up to 94% of the total amount of lead in the body is contained in the bones and teeth but for children only about 73% is stored in their bones. While the increase in bone lead level across childhood is modest, the total accumulation rate is actually 80-fold when the 40-fold increase in skeletal mass that children undergo is taken into account. While lead absorption rates are influenced by several parameters, including route of exposure, chemical speciation, the physical/chemical characteristics of the lead and the exposure medium, as well as the age and physiological states of the exposed individual, there is substantial documentation that a significant amount of lead can be absorbed and accumulated in humans (Several sources cited by USEPA, 1999b).

2.5.4 USEPA's Conclusions from the Review of the Available Data on Lead

USEPA (1999b) concluded that lead and lead compounds are highly persistent and highly bioaccumulative. The persistence of lead in the environment is not in question since, as a metal, lead cannot be destroyed in the environment. With respect to whether lead or lead compounds released to the environment will result in lead that is bioavailable, the data indicate that under many environmental conditions lead does become available. The conclusion that lead is bioavailable in the environment bioaccumulation of lead in aquatic organisms and in humans as a result of environmental exposures. As for lead's bioaccumulation potential, lead has been shown to bioaccumulate in laboratory studies and has been found to bioaccumulate in organisms observed in the environment. These data indicate that many of the BCF values and measured environmental concentration factors for lead are above 1,000 with several species having BCF or observed concentration factors above 5,000. The references cited for blue mussels include a range of values, the upper end of which is very close to 5,000 (i.e., 4,985). There are also a few fish tissues that have BCFs greater than 10,000, though most of the available fish data are below 5,000.

A high concern for the bioaccumulation potential for chemicals with BCF values above 1,000 is consistent with the discussion of BCF values in the recent proposed rule on PBT chemicals (January 5, 1999, 64 FR 688). In addition, there is considerable information on the accumulation of lead in humans, including children who are the most susceptible to the toxic effects of lead. The data on lead's persistence and availability in the environment, the observed high bioaccumulation values in aquatic organisms, and lead's ability to accumulate in humans, are the basis for EPA's conclusion that lead and lead compounds are highly persistent and highly bioaccumulative.

3. Objectives

The objectives of this study were as follows:

3.1 To characterize ecological risk associated with eutrophication and contamination of lead in the Pattani Dam Reservoir.

3.2 Use macrophytes as bioindicators in the surveillance of water quality in the reservoir.

3.3 Provide a description of potential ecological risk of the reservoir to living organisms.