Chapter 1

Introduction

River are the major routes, from the land to the sea, of the natural products of weathering and many man-made materials. Compared to the total amounts of dissolved and suspended materials carried by rivers, the mount carried through the atmosphere is relatively small, and the contribution through the direct water run-off from the coastal zone and from ground water is unknown, but is believed to be small.

Dissolved materials and solids held in suspension enter rivers in the course of weathering and erosion of rocks and soils, and as a result of human activity. The tendency of man to settle on river banks, assuring himself a steady water supply, defensive advantages and transportation routes, has inevitably led to input of man-made materials and wastes into the river waters. the growth of cities, industries and agriculture has gradually increased this human input, thereby also increasing, to some extent, input of various materials to the ocean.

The characteristics of the individual river basins, such as thier vegetation, geomorphology, and the mineralogical composition of thier soils and rocks, constitute the background conditions that determine the chemical composition and quantity of materials carried by the river. The human factor superimposed on the natural, pristine conditions largely arises from the technology and culture of the inhabitants of a river basin, the population density and the political and economic awareness of the processes in the river system.

The discharge can also be affected by diversions of river flow for development purposes, industry and power-plant cooling, and to make artificial lakes. Diversion of this kind would have deep effects on the mass balance of which has been perturbed. To date, the ammount of river water diverted into man-made lakes is still very small, but the flow of some of the bigger rivers has been constrained by dams and for other uses of river water (e.g. Nile, Volga, Colorado, Indus, and the Tigris-Euphrates system). Thus, it can be clearly seen that estuaries are an important part of a hydrological cycle, since they determine the amount of riverborne metals entering the coastal environment and alternately the deep ocean. Furthermore, estuaries are often subject to a large input of contaminants due to the fact that industrial areas and cities are often located adjacent to them. Therefore, it is necessary to understand the fate of metals and other contaminants in the estuarine and coastal environment.

Conservative and Non-conservative Behaviour

When river water mixes with seawater, a large number of physical and chemical processes take place which affect the distribution of trace metals over the particulate and dissolved phases and hence the composition of the deposited sediment.

If trace metals behave conservatively in estuary, both thier particulate and dissolved concentration can be calculated from the mixing ratio of marine to fluvial components provided that the composition of the end-member remain constant over the flushing time of the water (Loder and Richard, 1981). Deviation from the theoretical linear mixing curve points to processes other than simple mixing affecting the trace metals (fig. 1).
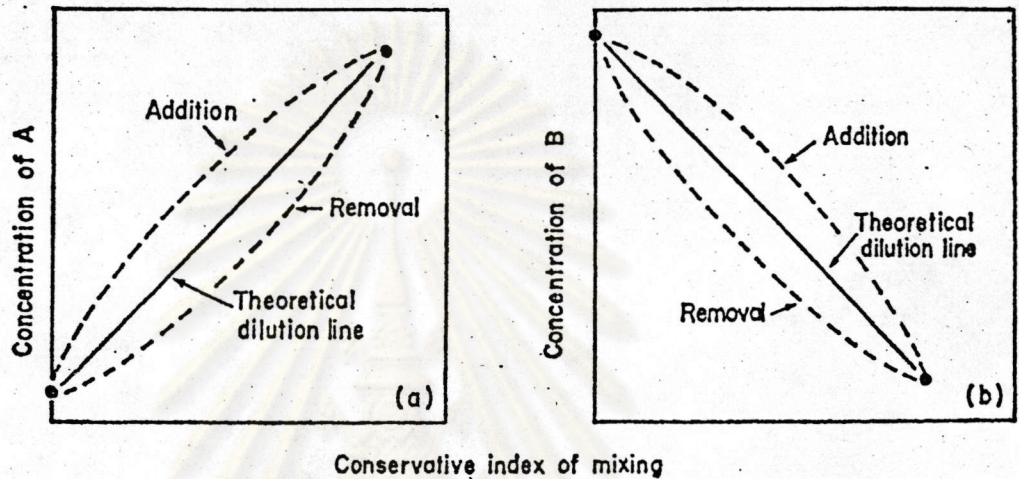
Idealized representation of the relationship between concentration of a dissolved component and a conservative index of mixing, for an estuary in which there are single sources of river and sea water: (a) for a component (A) whose concentration is greater in sea water than in river water and (b) for a component (B) whose concentration is greater in river water than in sea water.

Fig. 1   The Theoretical Dilution Curve.

(From Liss, P. S., 1976.)

In most mixing studies, information on the behaviour of trace metals has been derived from the mixing curve depicting the relationships between dissolved constituents. In principle, however, these observations should be confirmed by analysis of the particulate components (e.g. losses from the dissolved phase should show up as elevated levels in the particulate concentrations).

This approach has been adopted by various researchers in studying estuarine mixing behaviour of elements. It is called the theoretical dilution curve approach. However, there are three principal areas of difficulty in the application of the dilution curve (Liss, 1976):

1. the choice of a conservative index

2. sampling and analysis

3. interpretation of the dilution curve.

These difficulties were discussed in details by Aston (1978). Another approach, the most recent one, was proposed by Sholkovitz (1976) which is called a product approach. Rather than examining the behaviour of constituents by measuring their dissolved concentrations during mixing in situ (the theoretical dilution curve approach or the reactant approach), the examination of particulate materials produced during the experimental mixing of river water and seawater was carried out. Laboratory experiments of various designs have been undertaken to establish the type and extent of chemical reactions that occur when river water mixes with seawater. The limitations of any laboratory study of a natural system are many but when designed realistically and when coupled with field studies, laboratory studies can be powerful tools. The following types of laboratory experiments have been of assistance in the study of estuarine chemistry.

1. Mixing of filtered river water with filtered seawater to

obtain solutions covering the full range of salinity.

These experiments allow one to determine whether flocculation of dissolved river constituents occurs in seawater and to what extent flocculation is controlled by changes in salinity and pH. By collecting the flocculates, the actual products of mixing can be analyzed. This type of experiment also allows the kinetics of flocculation to be studied. There are other variations of this theme. For example, by including the river's natural suspended matter in the mixing experiment, the role of particles in the flocculation process can be established.

Mixing experiments of this type, using river waters from a variety of areas (Scotland, Amazon Basin and the Northeastern United States) have shown that a certain portion of dissolved iron, aluminium, phosphorus, manganese and humic substances exist as colloids and undergo coagulation in estuaries (Sholkovitz,1976; Boyle et al. 1977). The rate of coagulation of iron is fast-in tens of minutes, and the extent of coagulation depends of salinity.

2. Adding specific electrolytes to filtered river water of study the flocculation behaviour in more detail.

By using sodium, magnesium and calcium chlorides and magnesium sulphate (the major cations and anions in seawater) as the flocculatig agents,it is possible to establish the colloidal nature of dissolved matter in river water.

3. The use of ultra-filtered river water in experiments.

By isolating different size-fractions within the dissolved matter of river water, we can determine the size-distribution, composition and estuarine reactivities of colloidal particles. For example, Sholkovitz et al. (1978) have shown that only a small fraction (5-10%) of dissolved organic matter in river water coagulates in seawater. This

fraction consists of the high-molecular-weight humic acids.

4. Precipitation of dissolved humic acids and inorganic elements by varying the pH of filtered river water.

If a filtered river water (starting pH = 6-7) is acidified, then dissolved humic acids begin to precipitate out of solution at pH = 2.5; iron, manganese, phosphorus and aluminium follow suit. In contrast, the pH of the same filtered water can be increased to 10 and none of the above constituents will precipitate. This type of experiment has shown that certain elements like iron, manganese, phosphorus and aluminium have a strong association for humic acids (precipitated by acidification) and that dissolved organic matter can significantly increase the solubilities of certain inorganic elements above those predicted from inorganic solubility products (Sholkovitz, 1976; Eckert and Sholkovitz, 1976).

5. Desorption/adsorption studies of fluvial suspended matter.

By placing fluvial suspended matter in water of various salinities it is possible to determine whether a significant amount of a trace element is lost from the solid to the solution. Recent studies (Weijden et al. 1977; Duinker and Nolting, 1978) have shown that this is not the case for the contaminated suspended material of the river Rhine. It now appears that there is a net removal of dissolved trace metals (iron, copper, zinc and nickel) in estuarine waters (Bewers and Yeats, 1978; Duinker and Nolting, 1977, 1978) which is consistent with the conclusions of the laboratory mixing experiment.

The third, and the least adopted approach, is called a total budget approach which has been applied by Turekain (1971) to the behaviour of silicon in estuaries, and Head (1970) to the behaviour of nutrient discharged into estuarine waters. The main problems in this

approach to conservative behaviour are the collection of sufficient suitable data to allow a realistic budget of inputs and outputs of the dissolved constituents to be formed, and the short coming of this method with regard to the zones over which any additions or removal from solution may occur.

In an idealized sense, chemical behaviour within estuarine water can be considered as that which occurs when waters of different properties are mixed. In a hypothetical estuary, having only two particle-free end-members for mixing, one fresh water and the other saline water, these processes are those of solution chemistry, albeit that these are often complex. The types of physical-chemical variables that control these processes are pH, E_h, ionic strength, the end-member compositions and the proportion in which the source waters are mixed in various parts of the estuary. This oversimplified picture of the behaviour neglects the effects of other characteristics of estuaries. The real situation in an estuary is complicated by the presence of additional water sources, by gradients in the concentration and composition of suspended particulate material, by temporal variations in the compositions of the mixing end-members, especially the inflowing fresh water, by biological activity, by exchanges of dissolved and particulate material with internal sediments and by varying physical oceanographic conditions.

In river water, there were wide variations in both the total concentration of dissolved salts and the composition of the dissolved material with respect to both the major and minor constituents. Coastal seawater, by comparison, can be regarded as having approximately uniform composition, although considerable variations occur for some of the minor constituents. Within each estuary there will be at least one individually characteristic mixing series between dilute and saline

end-members.

The main factors leading to variations in the composition of river waters have been discussed by Livingstone (1963) and Gibbs (1970). Some rivers receive a major part of their dissolved salts in precipitation over the drainage area. Variations in the composition of precipitation and in subsequent evaporation lead to regional and seasonal variations.

Regional variations occur primarily due to the geological character of the drainage area. Temporal variations arise mainly through differences in the proportion of ground water flow and surface runoff (Livingstone, 1963).

The seasonal variations of chemical compositions of river water is generally took place in small watershed. It is appeared that the variation is related to flow rate. Windom et al. (1983) found that arsenic, dissolved organic carbon (DOC), Fe and Cu increase with the increase in flow. This is because the increase in flow will accelerate erosion, thus causing the metal content to increase. However, such behavior in large watershed may occur with much more complexity. For example, the Mississipi where 3 types of climate dominant, only in the northern part water becomes ice in winter. When ice melts in spring, large volume of water from the north is added to the river and maximum flow occurs. Therefore, compositions in water depend on seasonal variation not only in the term of flow but also in the extent of watershed which varies seasonally.

Concentration and compositions of dissolved organic carbon in river water can also have a strong influence on trace metals during mixing of fresh and seawater. Various metals behave non-conservative, because of the destabilization of metal-associated humus colliods

(Sholkovitz, 1976). Bacterial polymerization of colloid (Eaton, 1979) or the change in pH (Sholkovitz, 1976) are the major causes of this distribution.

In order to understand the mixing processes, it is convinient to firstly examine some concepts relating to dissolved constituents before considering the questions arising from particulate associations. The operational, rather than theoretical, nature of the distinction between dissolved and particulate forms, based conventionally on membrane filtration.

Behavior of Dissolved Metals

The compositions of river water varies to a great extent, depending on the main source of dissolved salts. The two major sources are sea salts added to the river with precipitation, and weathering of rock by rain containing carbon dioxide, the latter process being the quantitatively more important one (Burton, 1976). Dissolved constituents and particulate matter are brought to the estuary, where the river mixes with seawater. As a contrast to river water, the composition of seawater is not subject to variations, at least not as far as the major constituents are concerned. In general, the major constituents of river water are calcium and carbonate, while sodium, magnesium, chloride and sulphate form the major part of dissolved seawater constituents.

The mixing of river water with seawater is a drastic process. The increase of ionic strength from approximately 0 to 0.7 M, together with the change of composition, causes removal of some constituents by flocculation and change of dissolved chemical forms of others. Furthermore, biological processes in the estuary may also affect constituent forms (Morris, Mantuara, Bale and Howland, 1978).

The most common method of examining the behavior of the dissolved forms of metals during estuarine mixing is the theoretical dilution approach. It has been pointed out that at very low salinity, errors due to differences in the ion positions of fresh water and seawater can be introduced. In addition, more serious errors can also be introduced by temporal variability in the composition of the fresh water end-member and by the presence of additional, but unnoticed, end-member for mixing.

Salomons and Forstner (1984) have reveiwed the results of various field investigations and concluded that a large number of processes are governing the behavior of dissolved trace metals in estuaries causing deviations from the theoretical mixing curve. These processes are the following;

1. Change in the composition of the end-members

2. Flocculation of colloids

3. Release and/or uptake of dissolved trace metals by bottom sediments

4. Degradation of organic matter and subsequent release or solubilization of trace metals

5. Biological uptake of trace metals

6. Change in adsorption-desorption equilibria due to :

    - change in pH

    - change in salinity

    - change in turbidity

    - formation of new particulate matter.

Some of these processes have been studied in more details in the laboratory. The most simple experiments are those in which the two end-members (seawater and river water) are mixed in various proportions to

obtain the salinity gradient in the estuary (e.g. the influence of bottom sediments is cancelled out). Their experiments (Sholkovitz,1976; 1978; Sholkovitz and Copland, 1981) show that for some rivers and some trace metals (e.g. Fe, Cu, Ni, Co, Cd), flocculation may be an important process for the removal of dissolved trace metals from solution.

Another important removal process is the adsoption-desorption processes. This phenomena can be affected by various processes under estuarine conditions. These processes are as follows;

- oxidation either of organic particles containing trace metals or oxidation of metal sulfides and the surface desorption of trace metals caused by a high dilution ratio (Rohatgi and Chen, 1976)

- the chlorinity increase, which affects a competition between chloride ions and particulates for complexation of the dissolved metals

- the changes in turbidity (turbidity maximum) which offers additional sites for adsorption

- the changes in pH (Mook and Koene, 1975) which affect adsorption-desorption processes significantly;

- the formation of new particulate matter (e.g. iron and manganese hydroxides) as well as the release of dissolved organic matter from the pore waters

- the flocculation of dissolved organic matter and the fact the estuarine particles change thier surface properties, which are consistent with the formation of a macromolecular film (Neihof and Loeb, 1974; Loeb and Neihof, 1977; Hunter and Liss, 1977; 1982) may also affect thier adsorption properties.

The applicability of the results of these laboratory experiments on adsorption-desorption processes to the actual natural water may not help explaning all the questions concerning estuarine mixing. Because in

some experiments, chemically pure forms have been selected as adsorbents such as standard clay minerals and iron on manganese oxides while in the nature these minerals face usually occur in some sources of association (Duinker, 1980). The effect of association may enhance either adsorption or desorption processes.

Behavior of Particulate Metals

The behavior of particulate trace metals in an estuery is essentially related to that of total particulate matter. Laboratory experiments have shown that suspensions which are stable in fresh water environments - by virtue of interparticle repulsive forces between the electrically charged particles - are destabilized by double layer compression in even slightly saline water; the rate of flocculation depends on the extent of particle collisions and thus on particulate matter concentration (Carroll and Starkey, 1960; Whitehouse et al, 1960; Postma, 1967). Flocculation is a reversible process : deflocculation can occur when particles are transported back into freshwater. These observations have been often used to state that fine-grained river-borne particulate matter - of which a considerable fraction may be colloidal (e.g. clay minerals) - is a subject to flocculation on the concentration of suspended matter can be actually be observed in estuaries is very limited.

Particulate material in estuaries originates from numerous sources (Goldberg, 1978):

1. The oceanic sources of particulate matter is characterized by biogenic skeletons of diatoms, coccoliths and foraminifera as well as by clay minerals having specific properties of material originating from coastal sources due to marine erosion;

2. The fluvial source include materials eroded from the catchment area, oxy-hydrates and clay minerals from weathering reactions, organic remains from vascular plants or as humic matter;

3. Airborne anthropogenic particulate matter constitutes an important source locally because of the proximity of industies and urban settlements to most of the world's major estuaries;

4. Organic and inorganic flocculations in suspension are indicative of estuarine sources as are certain authigenic minerals such as iron-phosphates and manganese hydroxides.

Before particulates can be flocculated and precipitated to an appreciable extent by inorganic salts in natural situations, a number of conditions should be met : a large proportion of particulates should posses appropriate surface properties, the particulates should have a considerable concentration (in the order of gram per litre) and suitable flow conditions should allow flocs to form and settle out of suspension, These conditions may not be fulfilled during any set of observations, or may be absent permamently in a particular estuary, partly accounting for the different observations.

A contribution to particulate matter in estuaries is derived from originally dissolved conponents (humic substances) flocculating in the early stages of mixing (Hair and Basetts, 1973), independently from the flocculation of preexisting particles (Eckert and Sholkovitz, 1976; Sholkovitz, 1976). Orgamic matter can also be precipitatd by bacteria (Sheldon, 1967).

A common feature of many estuaries is the existence of a turbidity cloud near the limit of sea salt (Postma, 1967). The turbidity maximum can be explained in term of the dynamic processes that circulate and mix estuarine waters, probably the most important factors in the

deposition of sediments in estuaries (Meade, 1972). In a study by Salomons (1980), the influence of pH, turbidity, chlorinity on the formation of new particulate matter was investigated. The results indicate that if the pH and the suspended matter concentration in the river are equal to that in the estuary, no additional adsorption of dissolved cadmium will take place on the suspended matter, ever a desorption may be found (if the adsorption process is reversible) from the riverine particles. However, the situation is completely different if a turbidity maximum is found in the estuary. Since the residence time of the particles in the estuary is higher than in the water, the river nater is in fact flowing through the turbidity maximum. If the turbidity maximum extends into the freshwater tidal area, the river water with its dissolved trace metals encounters already an increase in suspended matter concentration in the river system. Due to the increase in turbidity, the dissolved metal concentrations decrease to reach a new equilibrium with the suspended matter. When the remaining dissolved trace metals enter the estuarine system, the chloride irons compete with the particulate matter for their complexation. Depending on hydrodynamic conditions (relation between suspended matter concentrations and chlorinity), the decrease in adsorption may be cancelled out by increase in suspended adsorption in the estuary : a zone in which the adsorption is larger compared to with the river up stream from the turbidity maximum (Salomons, 1980).

The presence of internal sources of suspended matter in estuaries complicated the study of particulate-metal behavior. In extreme cases in which strong turbidity maxima exists, the distribution and character of particulate matter can be dominated by resuspended material. It is therefore essential to appreciate the sources and

character of the suspended material before attemping to interprete distributions of particulate metal in term of chemical processes. The estuarine sediments can act as a highly significant third end-member in estuarine mixing relationships. The importance of resuspended sediment to metal distributions in estuaries is well illustrated by the iron-salinity relationship for the St. Lawrence estuary (Bewers and Yeats, 1978). In this estuary, the character of the fresh water end-member for mixing is determined by resuspended sediment within the turbidity maximum rather than by river water.

Diagenetic metal released from sediments have also been revealed solely by trends in the composition of suspended matter. The result of this diagenetic processes is the increase in the concentration of dissolved metals in the interstitial water. Considerable evidence is available to demonstrate the existence of a relatively large reservoir of interstitially dissolved trace metals within the upper layers of reducing sediments, including the estuarine environment (Elderfield and Hepworth, 1975). The concentrations can be many orders of magnitude larger than the solubility values of the sulphides, even in the presence of hydrogen sulphide within the sediment column. It has been postudated that the formation of stable complexes of trace metals and dissolved organic molecules may account for this observation (Presley, Kolodny, Nissenbaum and Kaplan, 1972). Humic substances are the major components of dissolved organic matter (Krom and Sholkovitz, 1977) ; thier ability to form stable complexes with a range of trace metals may well support this suggestion, as has been shown by Lindberg and Harris (1974). Laboratory experiments have shown that trace metals like Cu, Mn, Co, Ni and Zn can be solubilized from their carbonate and sulphide species by the interaction with organic matter (Rachid and Leonard, 1973). Aerobic

bacterial activity has also been demonstrated to be effective in solubilizing metals from their pricipitated sulphides (Duncan and Trussell, 1964). Changes in redox conditions in the sediment induced by large nutrient supply may lead to changes in remobilization of trace metals into interstitial water. Experiments of Lu and Chen (1977) show that Fe and Mn can be released to interfacial seawater under reducing conditions while other elements are removed from seawater as sulphides (Cu, Cd, Ni, Pb, Zn). Competition between inorganic precipitation aand organic complexation were also observed by Hallberg (1973). Organic complexation has been observed to decrease with increasing salinity (Linberg and Harris, 1974).

Enrichment of the overlying water from interstitial water may occur through several mechanisms. The existence of concentration gradients, in particular of dissolved organic matter in the sedimentary column, may be an important pathway through which diffusion into overlying water can take place (Nissenbaum and Swaine, 1976). Remobilization has also been observed as a result of dredging (bella and McCauley, 1974), biological activity in the bottom (Petr, 1977), compaction (Reinhard and Forstner, 1976) and wave action and erosion (Wakeman, 1976).

The transfer processes of trace metals either from partculates into solution or from solution into particulates under estuarine conditions can be better understood if one look at the chemical form of the metal in which it is transported by the river. Duinker (1980) proposed that metals may exist in the following forms;

1. in solution as inorganic ion and both inorganic and organic complexes,

2. adsorbed onto surfaces,

3. in solid organic particles,

4. in coating on detrital particles after coprecipitation with and sorption onto mainly iron and manganese oxides,

5. in lattice positions of detrital crytalline material, and

6. precipitated as pure phases, possibly on detrital particles.

This scheme allows the distinction of trace metal fractions that are readily available (dissolved and adsorbed), fractions that become available after chemical changes (organically bound and in oxide coatings) and forms that are pratically unavailable for release (in crystal structures of suspended particles). The contribution of dissolved species to the total amount of each individual element will differ between rivers (Turekian and Scott, 1967; Kharkar, Turekian and Bertine, 1968; Windom, Beck and Smith, 1971) and may vary drastically over the seasons (Carpenter, 1975).

It can be concluded that removal process is apparently more important than any release that might take place during estuarine mixing. However, it is possible that release and removal of some metals may take place simultaneously (Martin, Nijampurkar and Salvadori, 1978).

General Background of the Study Areas

1. the Mae Klong River

The Mae Klong River is one of the four major rivers, namely are Choa Phraya River, Thachin River, Bang Pakong River, and the Mae Klong. They flow downstream to Upper Gulf of Thailand. The Mae Klong watershed covered the area of 3 provinces, Karnchanaburi, Ratchaburi and Samutsongkram provinces. Almost all areas are plains with medium slope from Mount Tanoasri to alluvial plain of the Mae Klong estuary. The Mae Klong River is originated by two smaller rivers, Kwae Yai and Kwae Noi,

which flow downstream and meet each other at Ban Pak Prak, Ampur Muang, Karnchanaburi, to become the Mae Klong River. Overall length of the Mae Klong River is 140 kms.

The river flows through Ratchaburi province to estuary in Samutsongkram province which is in contact with the Upper Gulf of Thailand. The center area of the watershed around Ratchaburi province is alluvial flood plain, and the lower part of the watershed is alluvial deposit and swamps which is brackish water. Within the region of the upper part of the river, from Ampur Potharam in Ratchaburi to Ampur Muang in Karnchanaburi with the length of 95 Kms., it is mostly mountain, hill and forests. Industrial activities within this area are mostly sugar industries, especially in Ampur Ban Pong in Ratchaburi through Ampur Thamuang in Karnchanaburi province. The lower part of the river, from estuary to Siriluk Bridge in Ratchaburi with the length of 45 Kms.,is mostly alluvial plain and small hill. Most of the activities are agriculture and food product industries. Population are randomly dense on river banks. Most of land in the watershed of Mae Klong river are agricultural land, such as sugarcane fields, tapioca fields, etc. Both sides of the river, from Karnchanaburi to almost the estuary, are mostly rice fields. In Samutsongkram which has salty soils, the area is ued as coconut fields as well as prawn and fish nursery frams. The estuary is fishery area, fishing boats parking areas, fish canning industries etc.

The Mae Klong watershed is situated in the tropical monsoon. The southwest (SW) monsoon is from May until September. After that, the northeast (NE) monsoon is effective from November to May. There are 3 seasons a year, dry season (February - May), Rainy season (May - November), and winter season (December - February).

The meteorological statistical records from Department of

Meteorology, during the last decade, shows that the average monthly rainfall in Karnchanaburi and Ratchaburi is 1,763.8 and 1120.1 mm. respectively. The most raining days were in June and the maximum rainfall was in September.

So far as geological settings of the Mae Klong River is concerned, the upper part of the river is characterised by sedimentary rock which are marine sediment and Metasediment. Limestone is dominant rock type which colour is grey to black. The soil within the area of Ampur Thongpapoom and Sangklaburi of Karnchanaburi province is composed of shale, quartzite, limestone, phillite, and silt stone. Lead and zinc are the major compositions of the limestone within this area. Lead carbonate ($PbCO_3$) as well as lead sulphide are found.

The special character of the Mae Klong River, which is different from other 3 main rivers, is that there are 3 dams, Srinakarindra Dam (including Tha-Thungna), Khoa Laem Dam and Vachiralongkorn Dam over the upper part of the river.

2. Srinakarindra dam

The dam is situated on the Kwae Yai River at Ban Choa Nen, Tambon Thakradarn, Ampur Srisawat in the Karnchanaburi. Water in the dam is for multipurpose uses, mainly for electricity generation, agricultural irrigation as well as fisheries. About 28 Kms. downstream, a small dam, Tha-Thungna, was constructed in order to reserve water released from Srinakarindra dam for electricity generation. The Srinakarindra itself is a clay-core rocky dam with the total height of 104 metre from dam base. Its maximum water retaining level is 180 metre.

Both sides of the dam are natural forests which are natural parks and aquatic life conservation areas. The compositions of rock within the region are quartzite, sandstone and limestone.

The average annual rainfall was 1,021 mm. (in 1970-1973).
The maximum raining days are in September to October and the minimum in
December to March each year. The catchment areas of the dam are 10,880 km^2
with the retaining capacity of 17,745 $\times$ 10^6 m^3 and average depth of 42 m.

There is a mine and ore dressing plant situated at Bor Ngam,
south-west to the dam. The compositions of mineral mined are lead, cadmuim,
copper and zinc.

3. Khao Laem Dam

The dam is constructed against the Kwae Noi stream at Thambon
Thakanoon which is 6 kms. above Ampur Thongpapoom or 150 kms. from Ampur
Muang, the Karnchanaburi. The Kwae Noi is a branch of the Mae Klong
River. The dam was ready to use for multipurpose in 1984, but it is
mainly used for electricity generation.

The geomorphology of the area composes of mountains, which
its height of 70-680 m. above mean sea level, plains between mountains
at the height of 100 m. above mean sea level. It could be characterised
that river terrace is on the left of the dam and cliff is on the right.
The rock within the area of Ampur Thongpapoom and Sangklaburi, where the
dam is located, is composed of shale, quartzite, limestone, phillite,
and silt stone. Limestone within this area is the dominant rock type
which lead and zinc are the major rock-compositions.

The Khao Laem Dam is a rocky dam with pre-stressed concrete
with the total height of 82 m. It could retain water up to 3,720 km^2
with the maximum capacity of 7,452 $\times$ 10^6 m^3.

As Srinakarindra dam, a mine on the south-west of the dam,
discharges waste water into Pakpraek Stream, Ban Rai Stream and Thay
Muang Stream which are downstreamed to the dam.

4. Vachiralongkorn dam

The dam was constructed for agricultural irrigation purpose. It is situated on the Mae Klong River at Tambon Muangchum, Ampur Thamuang, Karnchanaburi where is alluvial plain which grey color soil with low humus contents is found. The water retained could be irrigated to cover the agricultural area of 3×10^6 Rai.

So far as the volume of water retained for irrigation from the Vachiralongkorn Dam is concerned, parts of water come from the Srinakarindra and Khoa Laem dams, and the rest of water volume is from rainfall which runoffs into the river. Thus, the volume of water in the Vachiralongkorn Dam is varied upon the two factors, even in flood season each year (May - October). The water irrigated from dams directly affected water volume in the Mae Klong River. At the same time, it affected the water quality of the river by diluting waste water from various activities which is discharged into the river.

Sources of pollution in the Mae Klong region

The waste water discharged into the Mae Klong River could be divided into 3 sources which as the follows ;

1. Urban pollution

It was reported that the population within the areas of 45,673 sq.km. of the watershed was 205,589 in 1986 (NEB,1987). Almost the urban areas are situated on both sides of the river bank. Thus, water in the river is variously used by people. But those who live far away from the river, underground water is used instead.

This type of waste consists of organic matters, oil & grease, surfactants, food stuffs and other residues. When these matters were discharged into river, the water quality would be deteriorated, especially, dissolved oxygen content. Used water makes up averagely to

80% waste water (NEB, 1987).

2. Agricultural Waste

Normally, it consists of persistent materials which take time to decay, such as fertilizers, herbicides, pesticides (Aldrin, Dieldrin, DDT.,Heptachlor ect.). These matters could accumulate in sediment and marine animals as a chronic (longterm) impacts. However, they could cause acute damage by increasing nutrients which derived from nitrogen and phosphorus of fertilizer.

3. Industrial waste

About 136 industrial complexes which situated in the watershed region discharged thier waste water into the river. These industries produce various products, such as sugar, sand, alcohol and food products etc.

The Objective of the Study

The objectives of this study are as followed;

1. To find out concentrations of heavy metals (Cu, Pb and Fe) through the Mae Klong River at various degrees of salinity, as well as to compare these trace metals' concentrations at degrees of salinity from field surveys with the same degrees of salinity from mixing experiments in laboratory.

2. To determine the variability of salinity and pH which affects concentrations and speciations of the trace metals.