CHAPTER 1

INTRODUCTION

1.1 GENERAL

Estuaries are important coastal ecosystems and play a significant role in the overall economy of coastal water. It provides a haven for many plants and animals increasing biodiversity. Estuaries discharge large quantity of nutrients into ocean. The nature and distribution of the flora and fauna in an estuary is controlled by the fluctuations in the physio-chemical characteristics of water (Murugan 1991). Accelerated population growth and development in the coastal zone, accompanied by increasing urbanization and industrialization cause adverse environmental impacts, which have compromised the ecological integrity of many estuaries.

At present four billion people inhabit land areas within 60 km of the world’s coastlines, and causing considerable stress on sensitive estuarine habitats. Various human activities and conflicting uses in coastal watersheds and neighbouring estuarine waters have contributed greatly to the impaired water quality, diminished resources, habitat loss and alteration (Clark 1992). Many of the important cities and major ports in the world are located on the banks of estuaries. A hydrodynamic study of an estuary is extremely useful to know the pollutant transport phenomenon. The water current and tidal level of estuary has a direct effect on pollutant transport and dispersion.

The movement of water within the estuaries is an important factor in determining the distribution of dissolved substances such as pollutants or
nutrients and their consequences with the exposure of estuarine habitats to those substances. Estuarine transport can be studied by field observation as well as analytical and numerical modeling. The combination of field data and model is the most effective approach to quantify the movement of water since the observational and modeling strategies complement each other. Models help to understand the phenomenon of governing natural systems and also to forecast the change in the system. Field data can be used to calibrate and validate the developed model.

1.2 ESTUARIES

Estuaries and backwaters represent a transitional zone between freshwater and sea water, and form an important integral part of the marine environment. An estuary is a semi-enclosed coastal body of water which has a free connection with the open sea and within which the sea water is measurably diluted with the fresh water derived from land drainage (Pritchard 1967). Estuaries are characterized by the tidal motions communicated from the sea, and by gradients of salinity and density associated with the progressive admixture of river water and seawater. The action of gravity upon the density difference between seawater and freshwater tends to cause vertical salinity stratification and a convection flow known as estuarine circulation. Freshwater flow and tides are the dominant variables determining flow, the distribution of salinity and circulation within the estuary.

Estuaries are classified according to their geomorphology and their salinity stratification. Based on geomorphology, estuaries are classified as drowned river valley estuary, bar-built estuary, fjord-type estuary and tectonic estuary. With respect to salinity stratification, Estuaries are classified as salt wedge or highly stratified (where freshwater flow dominates tidal currents), partially mixed or moderately stratified (where freshwater flow and tidal currents
are relatively balanced), and well-mixed or vertically homogeneous (where tidal currents dominate freshwater flow).

Estuaries are complex and important areas where the mankind has modified significantly the natural systems. Complex flow and transport processes in estuaries resulting from the interaction of tidal forcing, surface wind stress, irregular topography, and density stratification due to mixing of fresh and salt water tend to increase the residence time of pollutants in the estuary. These factors may lead to local accumulation, where pollutant concentrations reach levels that are harmful to the aquatic environment.

1.3 ESTUARINE POLLUTION

Sea is used as a dumping place for the waste of any kind. About three-quarter of the pollution entering the ocean comes from inland human activities. Pollution occurs when concentrations of various chemical or biological constituents exceed the permissible level stipulated by the competent controlling authority, which in turn creates a negative impact on ecosystem or human health. Marine Pollution is defined as "Introduction of man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects harmful to living resources, hazard to human health, hindrance to marine activities including fishing, impairment of quality for use of sea-water, and reduction of amenities."

An estuary is polluted when a substance which degrades the water quality enters the waterway and alters its natural functions. Polluted water can harm plants and animals, restrict recreation, spoil natural scenery and damage economic uses or pose a threat to fisheries. The marine and estuary water quality are degraded rapidly by various human activities viz, domestic sewage disposal, industrial effluent disposal, port and harbour activities, navigation, aquaculture and agricultural flooded water etc. Marine pollutants not only affect individual
organisms alone, but also influence the whole habitats, especially the most complex and biologically sensitive shallow water habitats. The hardest hit habitats are estuaries, the hugely productive coastal areas at the mouths of rivers where freshwater and seawater meet. One part of oil for every 10 million parts of water is enough to seriously affect the reproduction and growth of the most sensitive bay and estuarine species. Water from across the catchment eventually finds its way into the estuary. This means that pollutants from all land uses in the catchment can also end up in the estuary.

1.3.1 Source of Estuary and Marine Pollution

Pollution remains a major problem worldwide. Because a wide array of point (Municipal sewage treatment plants, industrial effluent outfall, combined sewer overflows, etc.) and non-point (Agricultural run-off, urban run-off, Construction run-off, mining run-off, oil spills, and silvicultural run-off, etc.) pollution sources promote nutrient and organic carbon loading, pathogen impairment, and chemical contamination of estuarine waters (Clark 1992). Figure 1.1 shows the sources of marine pollution.

Source: US Environmental Protection Agency 1986

Figure 1.1 Sources of Marine and Estuary Pollution
Land based sources contribute 44% to the total amount of marine pollution, Air based sources represent a total of 33%, Maritime transportation (which includes accidental and purposive oil spills, and dumping of ship garbage etc.) accounts for 12%, Dumping (which includes all other purposive dumping such as when a garbage barge goes to sea for the express purpose of dumping its load) represents 10% of the total and offshore production (the pollution coming from oil platforms etc.) contributes to 1% of the total. Table 1.1 shows the sources of marine and estuary pollution and Table 1.2 points out the effects of marine pollution.

**Table 1.1 Sources of pollution in Estuary and Marine waters**

<table>
<thead>
<tr>
<th>Sources</th>
<th>Common pollutant categories</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Point sources</strong></td>
<td></td>
</tr>
<tr>
<td>Municipal sewage treatment plants</td>
<td>Bio Chemical Oxygen Demand(BOD), bacteria, nutrients, ammonia, toxic chemicals</td>
</tr>
<tr>
<td>Industrial facilities</td>
<td>Toxic chemicals, BOD</td>
</tr>
<tr>
<td>Combined sewer overflows</td>
<td>BOD, bacteria, nutrients, turbidity, total dissolved solids, ammonia, toxic chemicals</td>
</tr>
<tr>
<td><strong>Non – Point sources</strong></td>
<td></td>
</tr>
<tr>
<td>Agricultural run-off</td>
<td>Nutrients, turbidity, total dissolved solids, toxic chemicals</td>
</tr>
<tr>
<td>Urban run-off</td>
<td>Turbidity, bacteria, nutrients, total dissolved solids, toxic chemicals</td>
</tr>
<tr>
<td>Construction run-off</td>
<td>Turbidity, nutrients, toxic chemicals</td>
</tr>
<tr>
<td>Mining run-off</td>
<td>Turbidity, acids, toxic chemicals</td>
</tr>
<tr>
<td>Septic systems</td>
<td>Bacteria, nutrients</td>
</tr>
<tr>
<td>Landfills/spills</td>
<td>Toxic chemicals, miscellaneous substance</td>
</tr>
<tr>
<td>Silvicultural run-off</td>
<td>Nutrients, turbidity, toxic chemicals</td>
</tr>
</tbody>
</table>

Source: US Environmental Protection Agency 1986)
Table 1.2 Effects of Marine Pollution

<table>
<thead>
<tr>
<th>Type</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrients</td>
<td>Feed algal blooms in coastal waters; Decomposing algae depletes Dissolved Oxygen (DO); killing other marine life; Can spur algal blooms (red tides); releasing toxins that can kill fish and poison people.</td>
</tr>
<tr>
<td>Sediments</td>
<td>Cloud water; impede photosynthesis below surface waters; Clog gills of fish. Smother and bury coastal ecosystems; Carry toxins and excess nutrients.</td>
</tr>
<tr>
<td>Pathogens</td>
<td>Contaminate coastal swimming areas and seafood; spreading cholera, typhoid and other diseases.</td>
</tr>
<tr>
<td>Alien Species</td>
<td>Outcompete native species and reduce biological diversity. Associated with increased incidence of red tides and other algal blooms. Problem in major ports.</td>
</tr>
<tr>
<td>Persistent Toxins</td>
<td>Poison or cause disease in coastal marine life, especially near major cities or industry. Contaminate seafood. Fat-soluble toxins that bio-accumulate in predators can cause disease and reproductive failure.</td>
</tr>
<tr>
<td>Oil</td>
<td>Low level contamination can kill larvae and cause disease in marine life. Oil slicks kill marine life, especially in coastal habitats. Tar balls from coagulated oil litter beaches and coastal habitat.</td>
</tr>
<tr>
<td>Plastics</td>
<td>Discarded fishing gear continues to catch fish. Other plastic debris entangles marine life or is mistaken for food. Plastics litter beaches and coasts and may persist for 200 to 400 years.</td>
</tr>
<tr>
<td>Radioactive substances</td>
<td>Hot spots of radio activity. Can enter food chain and cause disease in marine life. Concentrate in top predators and shellfish, which are eaten by people.</td>
</tr>
<tr>
<td>Thermal</td>
<td>Kill corals and other temperature sensitive sedentary species. Displace other marine life.</td>
</tr>
<tr>
<td>Noise</td>
<td>Can be heard thousands of kilometers away under water. May stress and disrupt marine life.</td>
</tr>
</tbody>
</table>

Source: World Watch Institute
Municipal and industrial wastewater may cause severe effects on local estuary ecosystems. With the increase of wastewater in estuaries, the coastal ocean is being called upon to assimilate these pollutants indefinitely. Because of that, understanding estuarine-coastal ocean transports is one of the most important challenges in the environmental sciences (Bilgili et al., 2005).

1.4 ESTUARY NUMERICAL MODELING

Most hydrodynamic models are based on two governing partial differential equations: conservation of mass (continuity equation) and conservation of momentum. For water bodies that contain saline water, another equation governing the conservation of salt may also be required if stratification or density driven flows are important. An equation of state is used to relate the salt concentration to water density. The models used to solve the equations differ mainly due to the spatial averaging which are used to simplify the equations and the techniques used to solve the averaged equations. Under many practical conditions, flow and fluid properties (e.g., velocity, density) are approximately uniform in the vertical direction. In these cases, it is appropriate to average the governing equations in the vertical direction, resulting in a two-dimensional set of equations. They are appropriate under a wide range of conditions. Three-dimensional models solve the equations for conservation of mass and momentum without vertical averaging. Three-dimensional models can resolve vertical stratification. But, until recently, they were not extensively used because of the requirement of large computer resources for simulations.

1.4.1 One-Dimensional Modeling

One-dimensional estuary models are capable of simulating hydrodynamics in the longitudinal direction or along the length of the estuary. These models are best suited for estuaries that are long, narrow, and shallow in nature. One-dimensional models employ the use of the conservation of mass and
momentum equations to determine a number of estuary hydraulic characteristics, such as flow rates, depths, velocities, top widths, and cross-sectional areas (Martin and McCutcheon 1999). Typically it is assumed that the density of water remains constant. Therefore, the conservation of mass equation simplifies to the continuity equation. The continuity equation can be written as (Chaudhry 1993),

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} - q_L = 0 \quad \text{... (1.1)}$$

where

- $A$ is the cross-sectional area of the flow ($m^2$)
- $Q$ is the discharge in the channel ($m^3/s$)
- $q_L$ is the lateral flow into the channel ($m^3/s/m$)
- $t$ is the time (s) and
- $x$ is the longitudinal distance (m)

For most one-dimensional estuary models, the lateral inflow or outflow per unit channel length is assumed to be negligible when compared to the main channel inflows or outflows. The Saint Venant continuity equation can be written as:

$$\frac{\partial y}{\partial t} + U \frac{\partial y}{\partial x} + y \frac{\partial U}{\partial x} = 0 \quad \text{... (1.2)}$$

Where

- $y$ – Depth (m)
- $U$ – Average velocity across the cross section in x direction (m/s)

To reproduce the one-dimensional momentum equation, one must apply Newton’s second law, which states that the sum of the forces acting on a control volume is equal to the rate of change of momentum. Assuming that the
lateral inflow or outflow per unit channel length \((q_{L})\) is approximately zero, the well-known dynamic equation can be written as:

\[
\frac{\partial U}{\partial t} + g \frac{\partial}{\partial x} \left( \frac{U^2}{2g} + y \right) = g (S_o - S_f) \quad \ldots (1.3)
\]

where

- \(g\) - Acceleration due to gravity (m/s\(^2\))
- \(S_o\) - Bed slope of the control volume
- \(S_f\) - Energy slope of the control volume.

The Saint Venant momentum equation (1.4) can be obtained from the dynamic equation (1.3) with further manipulation:

\[
\frac{1}{g} \frac{\partial U}{\partial t} + \frac{U}{g} \frac{\partial U}{\partial x} + \frac{\partial y}{\partial x} = S_o - S_f \quad \ldots (1.4)
\]

Equations 1.2 and 1.4 are used to describe one-dimensional open channel flow neglecting lateral inflows or outflows. With the given initial and boundary conditions, one can solve the equations simultaneously to obtain velocity \((U)\) and depth \((y)\) at any distance \((x)\) along the estuary at any time \((t)\).

1.4.2 Two-Dimensional Modeling

Two-dimensional estuarine models are able to simulate hydrodynamics in the longitudinal direction as well as the lateral direction or vertical direction. Depth averaged two-dimensional models (simulation in the longitudinal and lateral directions) are employed when changes in the vertical direction are negligible. They are typically applied to rivers, lakes, reservoirs, and estuaries that are long, wide, and relatively shallow. Laterally averaged two-dimensional models (simulation in the longitudinal and vertical directions) are
used when changes in the lateral (perpendicular to the main direction of flow) direction are negligible, such as a narrow stratified reservoir. They are normally applied to water bodies that are long, narrow, and fairly deep.

**Two-dimensional, depth-averaged flow:**

For two-dimensional, incompressible, depth averaged flow, the continuity equation (1.5) given by Montes (1998) is given below.

\[
\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \tag{1.5}
\]

Where

- \( u \) is the velocity in the \( x \) direction and
- \( v \) is the velocity in the lateral \( y \) direction.

The equations of momentum (1.6 and 1.7) for the corresponding flow regime are provided by Rahman (1988):

**Longitudinal (x) direction:**

\[
\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} = \frac{1}{\rho} \frac{\partial P}{\partial x} + X + \nu \nabla^2 u \tag{1.6}
\]

**Lateral (y) direction:**

\[
\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} = \frac{1}{\rho} \frac{\partial P}{\partial y} + Y + \nu \nabla^2 v \tag{1.7}
\]

Where,

- \( u \) - Velocity in the longitudinal direction
- \( v \) - Velocity in the lateral direction
- \( X \) - Body force per unit mass in longitudinal direction
- \( Y \) - Body force per unit mass in lateral direction
P - Pressure

\( \nu \) - Kinematic viscosity, and

\[ \nabla^2 = \text{Laplacian transform} = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} \]

**Two-Dimensional, laterally-averaged flow:**

For two-dimensional, incompressible, laterally averaged flow, continuity equation is as follows:

\[ \frac{\partial \hat{u}}{\partial \hat{x}} + \frac{\partial \hat{w}}{\partial \hat{z}} = 0 \] \hspace{1cm} \ldots(1.8)

Where,

\[ \frac{\partial \hat{w}}{\partial \hat{z}} \] is the change in the vertical velocity component per unit channel depth.

The equations of momentum (eqn. 1.9 and 1.10) for the corresponding flow regime are given by

**Longitudinal (x) direction**

\[ \frac{\partial \hat{u}}{\partial \hat{t}} + u \frac{\partial \hat{u}}{\partial \hat{x}} + w \frac{\partial \hat{u}}{\partial \hat{z}} = \frac{1}{\rho} \frac{\partial \hat{P}}{\partial \hat{x}} + X + \nu \nabla^2 \hat{u} \] \hspace{1cm} \ldots(1.9)

**Vertical (z) direction:**

\[ \frac{\partial \hat{w}}{\partial \hat{t}} + u \frac{\partial \hat{w}}{\partial \hat{x}} + w \frac{\partial \hat{w}}{\partial \hat{z}} = \frac{1}{\rho} \frac{\partial \hat{P}}{\partial \hat{z}} + Z + \nu \nabla^2 \hat{w} \] \hspace{1cm} \ldots(1.10)
Where,

- $w$ - Velocity in the vertical direction
- $Z$ - Body force per unit mass in vertical direction

### 1.4.3 Three-Dimensional Modeling

Three-dimensional estuary models facilitate the simulation of hydrodynamics in the longitudinal, lateral, and vertical directions. As a result, they can be applied to all flow situations (one, two and three dimensional) and generally produce fairly accurate results. Since there are no dimensional limitations, three dimensional models can be used to simulate hydrodynamics in waterbodies of all types. However, the time, effort, and resources required to set up, calibrate, and validate three dimensional models is quite extensive as compared to one or two dimensional estuary models. Therefore, a decision must be taken before model selection and implementation. For a three-dimensional, incompressible flow, the continuity equation can be given as follows,

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \quad \ldots (1.11)$$

The equations of momentum for three-dimensional flow are similar to those for two-dimensional flow. The main difference between the two is that the three-dimensional equations contain terms for all flow directions (eqns 1.12 to 1.14)

**Longitudinal (x) direction:**

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} + w \frac{\partial u}{\partial z} - \frac{1}{\rho} \frac{\partial P}{\partial x} + X + \nu \nabla^2 u \quad (1.12)$$
Lateral (y) direction:

\[
\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} + w \frac{\partial v}{\partial z} = \frac{1}{\rho} \frac{\partial p}{\partial y} + Y + \nu \nabla^2 v
\]  

(1.13)

Vertical (z) direction:

\[
\frac{\partial w}{\partial t} + u \frac{\partial w}{\partial x} + v \frac{\partial w}{\partial y} + w \frac{\partial w}{\partial z} = \frac{1}{\rho} \frac{\partial p}{\partial z} + Z + \nu \nabla^2 w
\]  

(1.14)

Where:

\[\nabla^2 = \text{Laplacian transform} = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}.\]

It should be noted that the complete three-dimensional equations of motion (1.11 through 1.14) could be simplified in order to represent two-dimensional or one-dimensional flow patterns. They are an extremely powerful set of equations which can be applied to different water bodies (Andrew 2004).

1.5 STUDY AREA

The study area Uppanar estuary is situated in Cuddalore, Tamilnadu at 11° 42'N Latitude and 79° 46'E Longitude (Figure 1.2) on the East Coast of India. The Gadilam river originates from the northeastern part of the Shervaroyan foothills, Salem District of Tamilnadu and runs for a distance of about 250 km. Before it confluences with the Bay of Bengal at Cuddalore, it meets Paravanar river which originates at Perumal tank and forms the Gadilam – Uppanar (Paravanar) estuarine complex which is called as the Uppanar estuary.
Figure 1.2 Uppanar Estuary in Cuddalore

1.5.1 Physiography

Cuddalore is located 200 km south of Chennai, and less than 25 km south of Pondicherry. It is a port town from ancient times with historical trade ties to the Occident and Orient. The 27 sq. km District comprises 6 Taluks and 136 Panchayat villages. The monthly average rainfall of the district is 102.13mm. From August to December, the district receives a rainfall, which is more than the annual average rainfall due to Northeast monsoons. The average
maximum and minimum temperatures have been 36.6 °C in May and 20.5°C in January, respectively. Cuddalore District is predominantly a flood and cyclone prone district. The major part of the district is a flat plain sloping gently from the west to the sea on the east and also from the north to the south.

Cropped area accounts for about 65% of the total area. Forest cover is very minimum accounting for only about 3% of the land. A significant portion of the land falls under the category of ‘non available for cultivation’ and ‘fallow lands’. Black soil is the predominant soil type in this district accounting for 45.2% of the total area under agriculture. Red Loam and red sandy soil are the other types of soil prevalent in the district. Sandy coastal alluvium soil occupies the coastal stretches of the district. About 3.83% of the land available for cultivation suffers from salinity/alkalinity and another 3.49% are prone to floods. About 5.23% of the soil comprises sand and hardest characteristics. In all, about 15% of the land presently available for cultivation is subject to problems arising from poor soil conditions.

Both groundwater and surface water are abundantly available in the region, rivers and estuaries are fed by streams and tank overflows. Agriculture is the mainstay of the district and is dependent on the availability of subsurface water harvested through tube wells and bore wells. The primary crops are paddy, sugarcane, groundnut, gingelly (sesame oilseeds), coconut and millets (kambu, varagu); pulses like red, green and black gram; and fruits like bananas, cashew, mango and jackfruits. The Census (2001) lists more than 80% of the "total workers" in rural Cuddalore as "farmers" (24%) and "agricultural labour" (57%).

The Cuddalore district has a coastal line of 54 km. The Inland fresh water area spreads about, 81.13 sq.km, and estuaries and brackish water area occupy 80.72 sq.km. Given its proximity to the sea and the numerous estuaries and rivers running through the area, fishing too is an important activity. Marine fishing, the more lucrative trade, is exclusively practiced by those living on the
coast. Inland fishing, particularly in the Uppanar river forms the sole livelihood activity for several villages.

1.5.2 SIPCOT Industrial Complex

State Industries Promotion Corporation of Tamilnadu (SIPCOT) Chemical Industrial Estate is located at 8 km from Cuddalore on the seaward side of the Cuddalore-Chidambaram Road, stretching from Pachaiyankuppam in the North to Semmankuppam in the South. The Industrial Estate was set up in 1982. Phase-I of the industrial complex spreads over 200 sq.km, and is set up to house 53 units. Phase-II covers 50 sq.km, around 29 functional units lie within Phase-I of the industrial estate on the western bank of the Uppanar river. A few companies such as Rallis, EID Parry, Elf Atofina, Vanavil Dyes and Bayer operate outside the SIPCOT limits but in the vicinity of the Estate. These companies manufacture pesticides and intermediates, pharmaceuticals and intermediates, chemicals, plastics and plastic additives, dyes and intermediates and textiles.

Less than 4 units in the region are categorised as non-polluting, while 24 companies fall under "Red" category of highly polluting industries. Seven out of nine industries proposed for SIPCOT are "Red" category industries. Several villages, including Pachaiyankuppam, Thaikal, Thiyagavelli, Eacchangadu, Kudikadu, Karaikadu, Sonnanchavadi, Sangolikuppam, Nellikuppam, Poondiyankuppam lie within or in the vicinity of the industrial complex.

SIPCOT industries are manufacturing fluoride, dyes, drugs, antibiotics, pulps, pesticides and other chemicals. Most of these industries are wet process industries and consume large quantity of water. There are six plants discharging effluents throughout the year to the Uppanar estuary (Srinivasan, 1992). The total effluent generated by 22 of 26 functional industries in SIPCOT is 17.7 MLD. Until 1999, 7 industries generated more than 95% of the total trade
effluents all of which was discharged into the Uppanar (Table 1.3). The rest was dumped either at the sea or in the SIPCOT sewer, and about 1% is recycled or introduced into the solar evaporation ponds.

**Table 1.3 Trade Effluents Generated by Major Industries**

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Name of the Industry</th>
<th>Total effluent generated (%)</th>
<th>Effluent discharge in Uppanar river (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SPIC</td>
<td>20.1</td>
<td>20.1</td>
</tr>
<tr>
<td>2</td>
<td>J.K. Pharmachem</td>
<td>13.6</td>
<td>13.6</td>
</tr>
<tr>
<td>3</td>
<td>D.S.Q. Biotech</td>
<td>5.7</td>
<td>5.7</td>
</tr>
<tr>
<td>4</td>
<td>Tanfac (Alf3)</td>
<td>25.2</td>
<td>25.2</td>
</tr>
<tr>
<td>5</td>
<td>Tanfac (Cryolite)</td>
<td>29.9</td>
<td>29.9</td>
</tr>
<tr>
<td>6</td>
<td>Other 17 Industries</td>
<td>4.9</td>
<td>Nil</td>
</tr>
</tbody>
</table>

(Source: NEERI 1999)

Most of the SIPCOT industrial effluents are discharged into Uppanar River. Up to 1999, small quantities are discharged in to public sewer. In 1999, SIPCOT Industries Common Utilities Ltd (CUSECS) commissioned a Common Effluent Treatment Plant (CETP). The CETP claims to collect effluent from 20 member companies, and discharges it at sea through a 2.6 km pipeline after secondary and tertiary treatment.

According to CUSECS, the CETP only receives effluents that have undergone onsite primary treatment by the company that generates it. Until 2000, industries discharged untreated effluents through pipes and ground channels directly into the Uppanar river. Given that the industrial effluent from chemical industries manufacturing or processing persistent environment toxin have been discharged for nearly two decades into the river, it is expected that the
river sediments will remain polluted in the long-term in the absence of appropriate clean-up.

1.6 NEED FOR THE STUDY

Estuaries have been the focal point of the maritime research and activities. As they are semi-enclosed water bodies and have free connection with ocean, they provide natural harbour for trade and commerce. They are also effective nutrient traps and provide a vital source of natural resources to man and are used for commercial, industrial and recreational purposes. Biodiversity in this ecosystem is very impressive. They are the best settling places for clams and oysters. They also act as nursery ground for a variety of shrimps, fin fishes and other marine organisms.

The health status and biological diversity of the estuarine ecosystem are deteriorating day by day through numerous man-made activities including dumping of enormous quantities of sewage and industrial effluents into the estuary, resulting in drastic reduction of dissolved oxygen level. If DO level of water is reduced to less than 4 mg/l, the organisms in the estuary are gravely affected. Industrial effluent disposal causes heavy metal pollution which gets biomagnified and even reaches man through the food-chain.

Most of SIPCOT industries are situated on the banks of Uppanar river. Cuddalore port, an important minor port of Tamilnadu on the East coast of India, is located on Gadilam river of Uppanar estuary. The estuary and seawater qualities are very much affected by the discharges from SIPCOT complex, which includes major units like pharmaceutical, dyes, pesticides, organic and inorganic chemical manufacturing units, etc. Currently, the effluent from SIPCOT industrial estate is discharged into the sea through a marine outfall that releases the effluent near Rajapettai village. The effluents stain the sea red to a
distance of more than 200 m from the point of discharge. The pollution incidents occurred in Uppanar estuary during 2004 and 2005 are listed in Table 1.4.

The fishermen in Rajapettai village complaint about the intense foul odour during the sea breeze. Authorities of SIPCOT and the Tamilnadu Pollution Control Board repeatedly point out that the effluent from SIPCOT industries are to be discharged into sea by marine outfall system, and the Uppanar river should be flowing clean. However, data based on monitoring information indicates that this is not practised. Illegal discharge of effluents into the Uppanar River has been resumed on a regular basis and that river water quality has degraded much. Inland fishermen are getting the bad health effects due to their contact with contaminated water. Skin rashes and itching are commonly reported. Communities living in and around the industrial estate find fault that the pollution from the industries has damaged their environment, livelihood and health.

As estuaries are an integral part of a marine ecosystem, an understanding of the parameters affecting the estuarine system needs to be established. The tidal level and the water current play a major role on estuary sediment and pollutant transport etc. The development of hydrodynamics and advection dispersion model for Uppanar estuary will be helpful to understand the fate of pollutant transport and dispersion, coastal zone management and future developmental activities.
Table 1.4 Pollution Incidents occurred in Uppanar River

<table>
<thead>
<tr>
<th>Date</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>03.10.2004</td>
<td>Effluent was discharged in the river Uppanar</td>
</tr>
<tr>
<td>13.10.2004</td>
<td>Biscuit colour effluent discharge from Asian paints penta division</td>
</tr>
<tr>
<td>18.11.2004</td>
<td>Biscuit colour effluent was discharged reportedly by Pioneer Miyagi into the river Uppanar</td>
</tr>
<tr>
<td>17.12.2004</td>
<td>At about 3:00 am there was brick red colour effluent discharge was noticed in the Uppanar from the northern side of SPIC.</td>
</tr>
<tr>
<td>05.1.2005</td>
<td>Following damages were noticed post tsunami:</td>
</tr>
<tr>
<td></td>
<td>a) the toxic sludge from behind SPIC unit was washed out in the river</td>
</tr>
<tr>
<td></td>
<td>b) Mountain of toxic waste from behind Victory Chemicals washed out in the river</td>
</tr>
<tr>
<td></td>
<td>c) CUSECS submarine effluent outfall was reportedly damaged.</td>
</tr>
<tr>
<td></td>
<td>The incident occurred at about 3 am in the morning, there was an oily layer on the water observed in the area where effluents were discharged into the river. No colour or odour was reported. The fisherfolk who came in contact with the contaminated water reported itching sensation on the skin.</td>
</tr>
<tr>
<td>7.9.2005</td>
<td>The incident occurred at about 3 pm in the evening, similar to the previous incident.</td>
</tr>
<tr>
<td>24.9.2005</td>
<td>The effluents had a strong pesticides odour. Fish kill was noticed only after sunrise, though the effluent was reportedly discharged at around 4 am. Before the fish kill, the fishermen had reported better catch than usual leading to speculations that the poisons may have something to do with larger fish catch.</td>
</tr>
</tbody>
</table>

Source: SIPCOT Area Community Environmental Monitoring (2005)
1.7 OBJECTIVES OF THE STUDY

The core objectives of the study are as follows:

i) to assess the seasonal variation in water quality during high tide and low tide;

ii) to develop the water quality index (WQI) for Uppanar estuary;

iii) to assess the hydrodynamic and advection-dispersion conditions of Uppanar estuary using numerical model; and

iv) to simulate the dispersion of the pollutant in Uppanar estuary and marine outfall into the coastal waters of Cuddalore.

1.8 ORGANIZATION OF THE THESIS

Thesis has been presented in seven Chapters. This Chapter provides the introduction, brief description of marine and estuary pollution, details about the study area and objectives of the study. Chapter 2 provides an extensive literature review performed to provide background information on the sources of estuary and marine pollution, estuary water quality, numerical modeling of estuary and similar studies around the world. Chapter 3 describes the study area and explains the protocol followed in model selection, description of MIKE 21 model, data required for hydrodynamics and advection dispersion model.

Based on the water sample collected and detailed analysis, the seasonal variations of the physio-chemical parameters of estuary and heavy metal concentration were documented and also explained water quality index in detail through Chapter 4. Chapter 5 discusses about the model setup to analyse
the hydrodynamic and advection-dispersion. The pollutant dispersion from estuary and marine outfall field data are elaborated in Chapter 6. Concluding Chapter 7 presents the conclusion obtained from this research and also provides the recommendations for further research.