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Mapping and Analysis of Marine Pollution in Tuticorin Coastal Area Using Remote Sensing and GIS

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Abstract In this project, the Marine Pollution Information System has been suggested with the help of Remote Sensing and GIS. This system provides pollution hot spot area and spread rate of the Tuticorin coastal area in Tamilnadu, India. The spread rate and hot spot analysis has been analyzed with the aid of various chemical, biological and physical parameters such as pH, Temperature, Total Suspended Sediments (TSS), Salinity, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Nitrate, Nitrite, Phosphorus as Phosphate PO4, Chlorophyll-a, Silicate, primary productivity and Ammonia. The Remote Sensing data plays vital role in pollution monitoring and analysis. The Geographic Information System and Remote Sensing facilitate to scrutinize various marine pollution such Industrial pollution, sewage pollution and anthropogenic pollution. The various pollution parameters are examined with the allusion of “General Coastal Cater Quality Standard”. The preliminary investigations of pollution spots were identified on the remote sensing data (IRS P6) through the visual interpretation techniques. From the visually interpreted data the major polluted spots were identified on the ground by ground survey method. The water samples were collected from the polluted spots. The various samples had undergone with diverse laboratory analysis and readings were stored in GIS database. The various pollution parameters reading are compared with General Coastal Cater Quality Standard values in GIS environment. The various parameters Map, Hot Spot Map and Spread Rate Map are generated with the assist of Weighted Overlay Analysis and Statistical Analysis in ARC-GIS.

Keywords *Remote Sensing, Geographic Information System, Marine Pollution, Digital Image Processing, Field Survey, Statistical and Overlay Analysis*

1. Introduction

Coastal environment plays a main role in nation's wealth by asset of the resources, productive habitats and rich biodiversity. The term 'pollution' describes the foreword of harmful or artificial substances or product into the environment. Pollution is human activity or natural disasters cause the environment to

become contaminated or unclean [1]. Pollution is the introduction by man, directly or indirectly, of substances or energy into the marine environment resulting in deleterious effects of such nature as to endanger human health, harm to living resources ecosystems and hinder marine activities quality of seawater. The marine environment mainly contaminated by waste disposal. The wastes of society can be placed on land or in the water. It also penetrates directly to the marine environments [2].

The coastal areas of Tuticorin are assuming greater importance owing to increasing human population, urbanization and accelerated industrial activities. These anthropogenic activities have put tremendous pressure on the fragile coastal environments [3]. In general, the near shore regions are of great concern now. Coastal pollution in Tuticorin has seriously affected the exploitable living resources, recreational and commercial uses of coastal areas and the overall integrity of the marine and coastal ecosystems. Hence protection of the coastal and marine regions from continuing pollution becomes the most essential in coastal resources management [4]. Effective planning for controlling and combating coastal pollution requires knowledge about the magnitude of the pollution, the entry, transport and the state of pollutants in the marine environment and their effects on marine ecosystems [5].

2. Study Area and Description

Tuticorin coast has a major port and it is rapidly developing area. The study area falls in the latitudinal and longitudinal extensions of 8°40'- 8°55' N and 78°0' -78°15' E on the Tamil Nadu; India has a coastline of about 7,500 kms. The coastline of Tuticorin has a length of about 163.5 kms. Tuticorin is port town with several industries and saltpan activity, its population is around 0.4 million. The town generates an estimated 17.5 MLD of sewage. There are no treatment facilities for the sewage; all of it is disposed of in canals that eventually reach the sea. Industries around Tuticorin include a refinery, aquaculture, chemicals and fertilizers, caustic soda and a thermal power plant. The total volume of waste discharge from these industries, other than aquaculture is about 10.4 MLD [1]. The effluent characteristics from these industries include suspended solids, ammonia, nitrate, BOD compounds, oil and grease, and trace quantities of heavy metals such as chromium. Municipal waste contains high BOD compounds (putrefied organic matter), nutrients and bacteria. Aquaculture generates about 91.2 MLD [6]. Major Industries such as Southern Petrochemical Industrial Corporation, Thermal Power Plant, Tuticorin Alkali Chemicals and Heavy Water Plant are also present in this area. Due to the accelerated development activities the coastal area experience significant changes [3].

3. Methodology

Remote Sensing & Geographical Information System (GIS) is the backbone for marine pollution mapping and analysis [7]. It integrate a large range of spatial and non spatial information with respect to topography & other spatial information including existing data of physical, chemical and biological [8]. With the help of satellite based map and digital information all the required information are integrated in the GIS based pollution mapping system [9]. It has four steps for mapping and analysis spatial variations of marine pollution; they are Data collection, Digital Image Processing, Laboratory Analysis Geographic Information Systems (GIS) Analyzing and Map generation. The figure 1 shows the work flow of Mapping and Analysis of Marine Pollution.

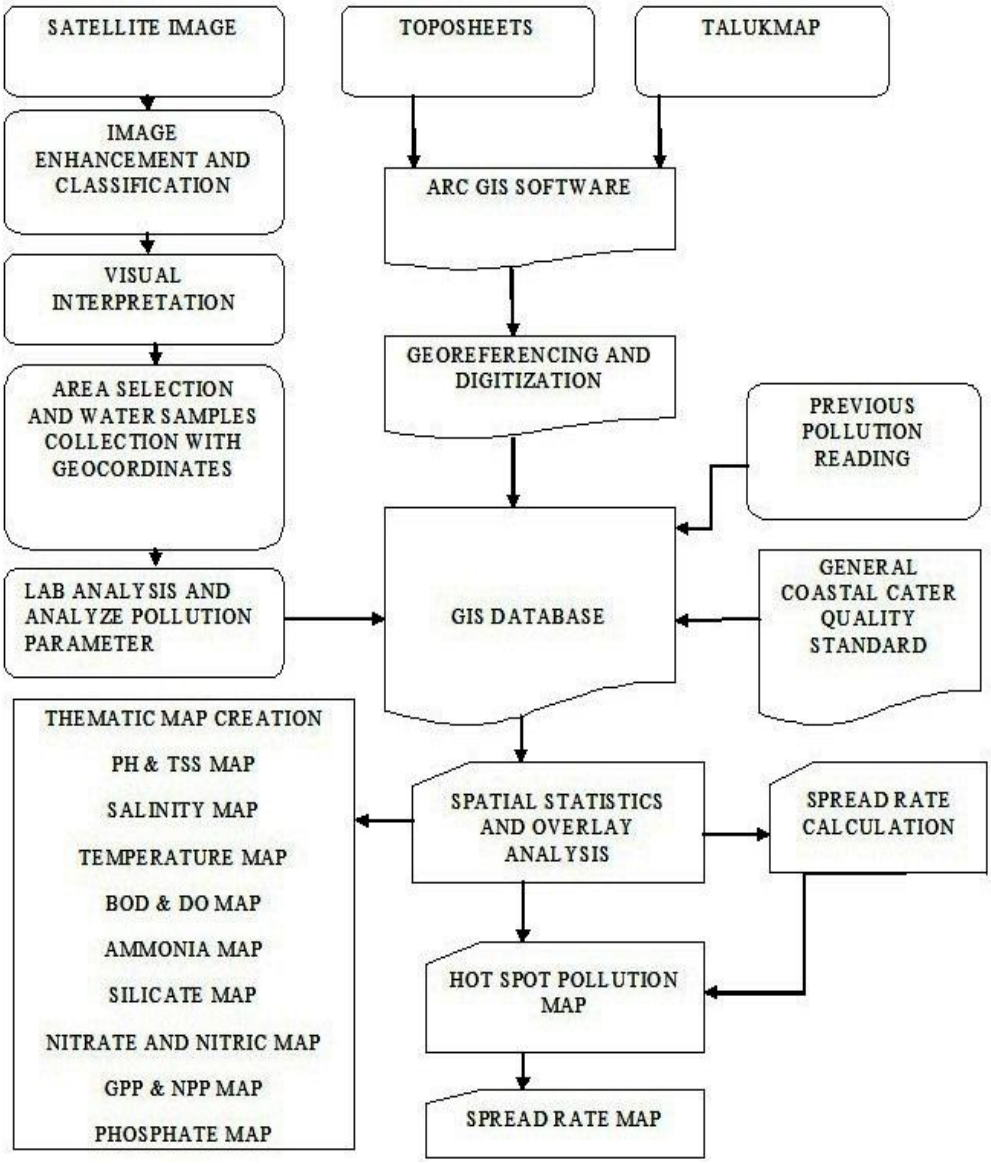

Figure 1: *Flow Chart for Mapping and Analysis of Marine Pollution*

A. Data Collection

The data required for the mapping and analysis of marine pollution obtained from remote sensing satellite image, toposheets and existing water quality values. The satellite data used to geo-referencing the toposheet to the real world coordinate system and identify the area of pollution point source like thermal power plant, harbor, fishing harbor, chemical factory, outlet of sewage and tourism and urbanization area through the visual interpretation. Toposheet furnish the reference map for the pollution mapping. The existing water quality value used for finding the spread rate of pollution.

B. Digital Image Processing

It is software based image classification technique which involves automated information extraction and subsequent classification of multispectral satellite images [10]. These are statistical decision rules which groups pixels in different feature classes [11]. Digital classification techniques are less time consuming than visual techniques.

C. Visual Interpretation

Interpretation is the processes of detection, identification, description and assessment of significant of an object and pattern imaged. The method of interpretation may be either visual or digital or combination of both. Both the interpretation techniques analysis the output is also visually analyzed. The ability to recognize objects in aerial and satellite photographs [12]. From knowledge of a landscape and its interpretation keys, the interpretation rules keys such as color, form, size, texture or context.

D. Identify the Area to Be Measured

The area of point and non-point source of pollution like thermal power plant, harbor, fishing harbor, chemical factory, outlet of sewage and tourism and urbanization area identified and fixing the pollution station on area through the visual interpretation.

E. Taking GPS Reading on Station

The area identified for pollution station through the visual interpretation on satellite image and ground truthing. In ground truthing taking the GPS points on each pollution stations like thermal power plant, harbor, fishing harbor, chemical factory and outlet of sewage. That GPS data is used as input for the Georeferencing and Rectification.

F. Collecting Water Samples

Collecting Water Samples in each pollution station like thermal power plant, harbor, fishing harbor, chemical factory and outlet of sewage. Water samples are collected through the field survey with the GPS instrument.

G. Measure Pollution Parameters

After the collection of the water sample the following parameters are measured with the aid of Laboratory analysis, pH, Temperature, Total Suspended Sediments (TSS), Salinity, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Nitrate, Nitrite, Phosphorus as Phosphate PO4, Chlorophyll-a, Silicate, primary productivity and Ammonia [1]. The measured qualities are stored in GIS database.

H. Layer Creation

For each water samples physical, chemical, biological parameters spatial layers are created using GIS software and they are pH, Temperature, Total Suspended Sediments (TSS), Salinity, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Nitrate, Nitrite, Phosphorus as Phosphate PO4, Chlorophyll-a, Silicate, primary productivity and Ammonia.

I. General Coastal Cater Quality Standards

The general coastal water quality standards for several parameters of National Environmental Board report, 1994. It has standard value for various physical, chemical and biological parameters from the water. The water quality value exceed the limits mean the pollution present in the water [1]. The table 1 shows the Coastal Cater Quality Standard value for various parameters.

Table 1: *Coastal Cater Quality Standard Value Table*

Parameters	Standards
pH	7.8 – 8.3
Temperature (◦C)	30
Total Suspended Sediments (TSS)	25 mg L^{-1} or less
Dissolved Oxygen (DO)	4mg L^{-1} or more
Biochemical Oxygen Demand (BOD)	30 mg L^{-1} or less
Nitrate	10 mg L^{-1} or less
Total Nitrogen	1 mg L^{-1} or less
Phosphorus as Phosphate PO4	0.1 mg L^{-1} or less
Chlorophyll-a	15 mg L^{-1} or less

J. Calculate Spread Rate

Spread rate can be found from the existing water quality value of successive measurements. Standard deviations of water quality value were calculated. This is used for generate the future spread rate map (8).

K. Spatial Statistics / Overlay Analysis

One basic way to create or identify spatial relationships is through the process of spatial overlay [13]. Spatial overlay is accomplished by joining and viewing together separate data sets that share all or part of the same area. The result of this combination is a new data set that identifies the spatial relationships. Finally a hot spot pollution area was determined by performing a weighted average of the all separate layer of parameter to create the hot spot pollution map of Tuticorin coastal area.

4. Results

In this project different Maps have been prepared for various analysis and parameters such as pH Map, Atmospheric Temperature Map, Surface Temperature Map, Total Suspended Sediments Map, Chlorophyll 'a' Map, Dissolved Oxygen Map, Biochemical Oxygen Demand Map, Net primary productivity Map, Grass primary productivity Map, Nitrate Map, Nitrite Map, Phosphate Map, Silicate Map, and Ammonia Map. The figure 2 to 15 shows the various parameters map and figure 16 and 17 shows the Pollution Hot Spot Map and Spread Rate Map respectively. The figure 18 and 19 illustrate Marine Pollution Information System portal.

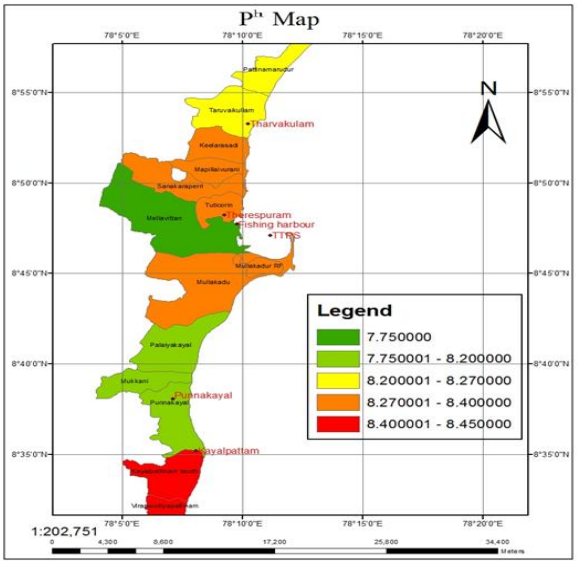

***Figure 2**: pH Map*

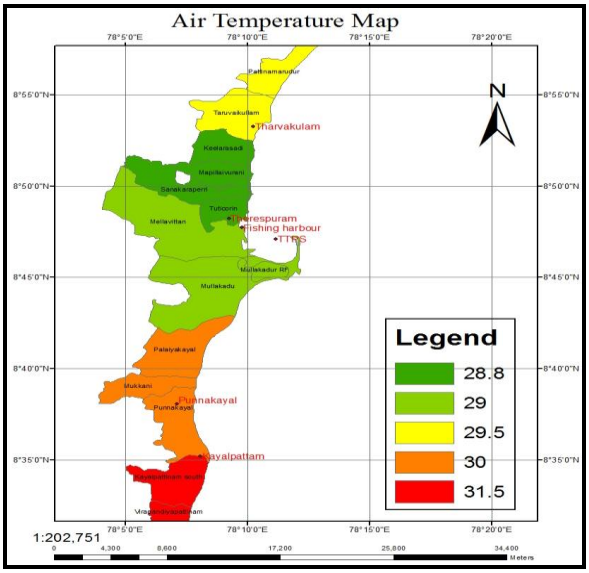

***Figure 3:** Air Temperature Map*

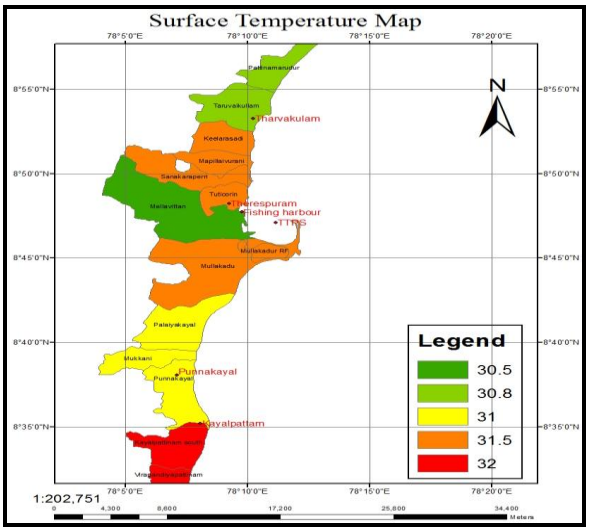

***Figure 4**: Surface Temperature Map*

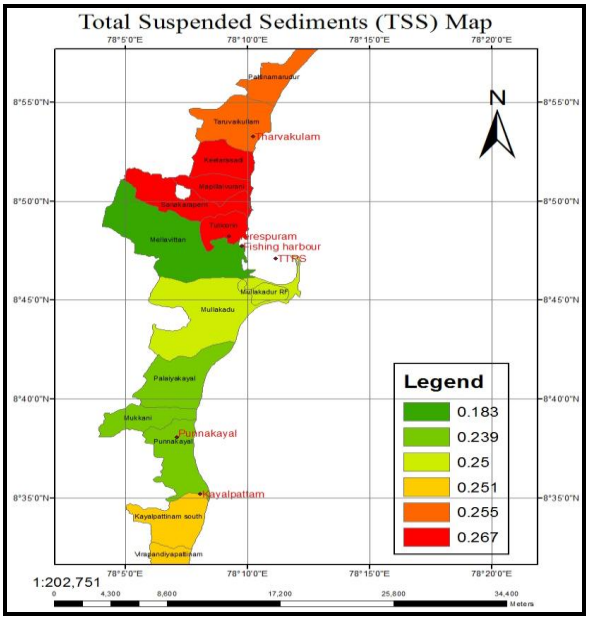

***Figure 5:** Total Suspended Sediments Map*

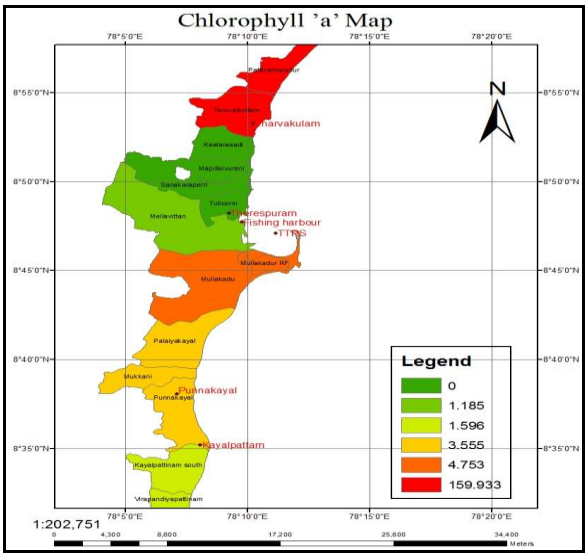

Figure 6: *Chlorophyll 'a' Map*

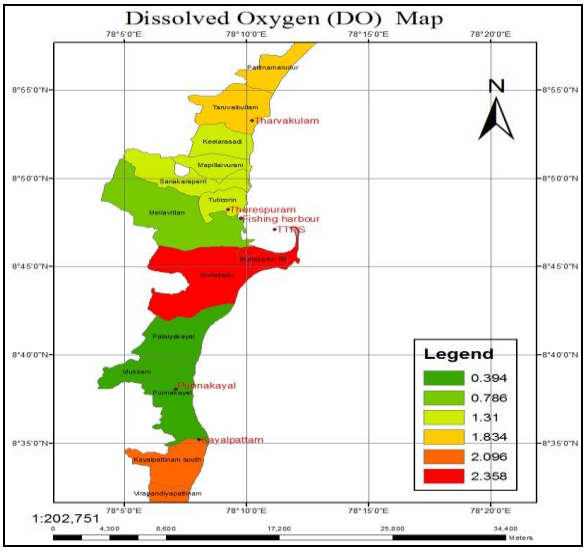

Figure 7: *Dissolved Oxygen Map*

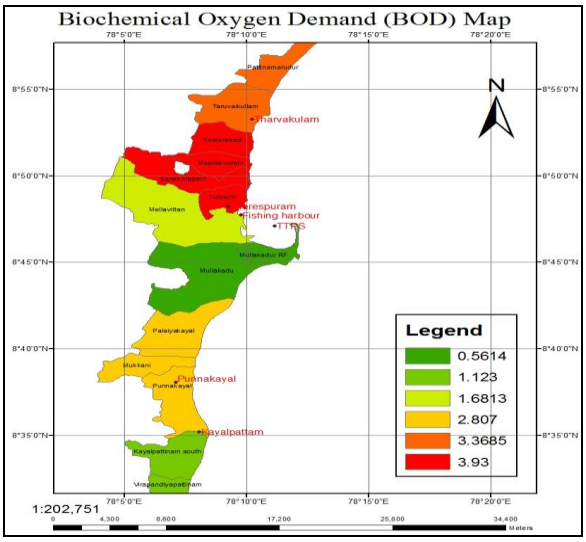

Figure 8: *Biochemical Oxygen Demand Map*

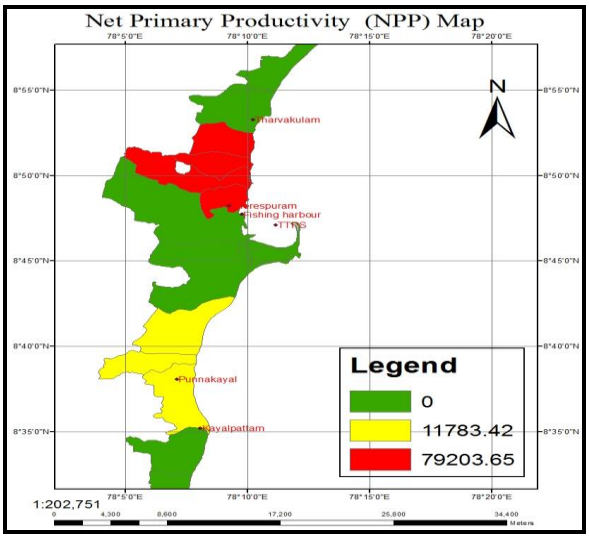

Figure 9: *Net Primary Productivity Map*

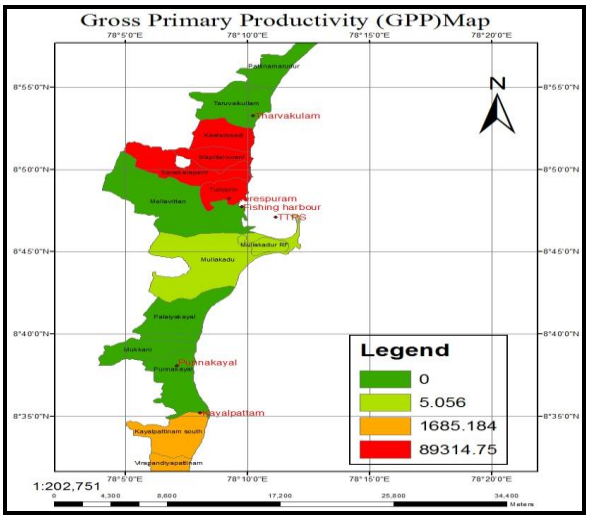

Figure 10: *Gross Primary Productivity Map*

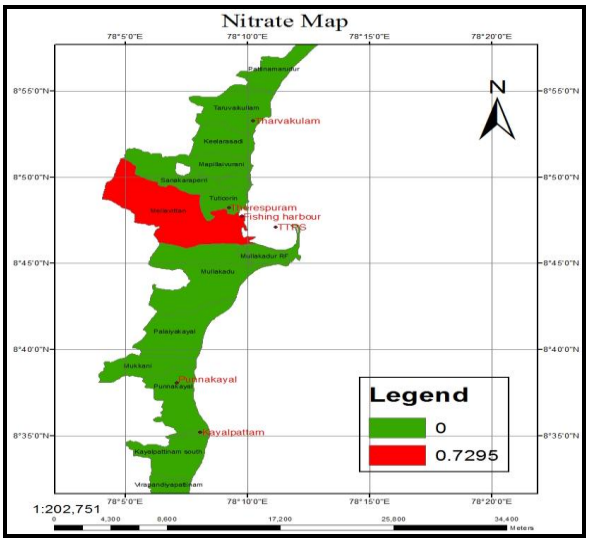

Figure 11: *Nitrate Map*

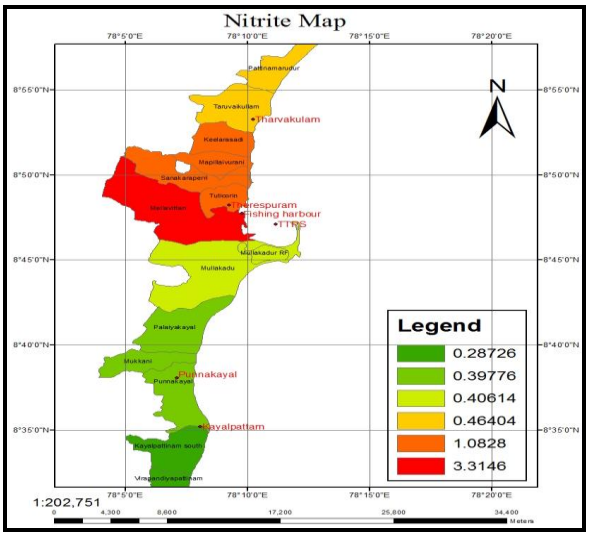

Figure 12: *Nitrite Map*

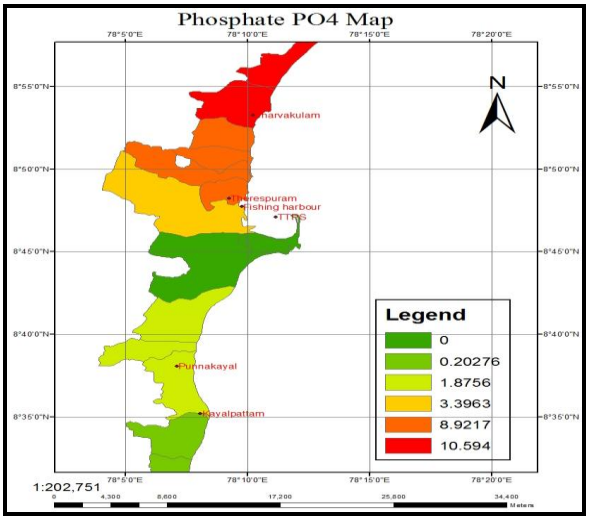

Figure 13: *Phosphate Map*

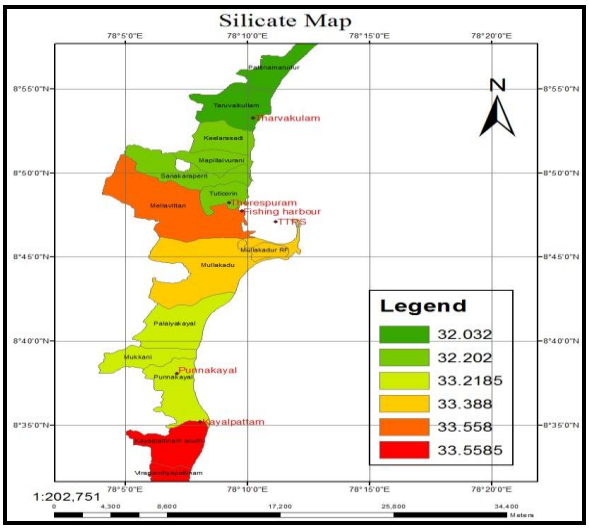

Figure 14: *Silicate Map*

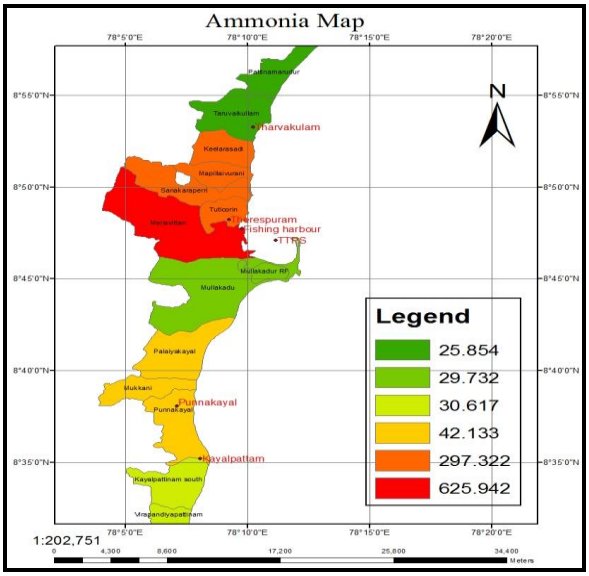

Figure 15*: Ammonia Map*

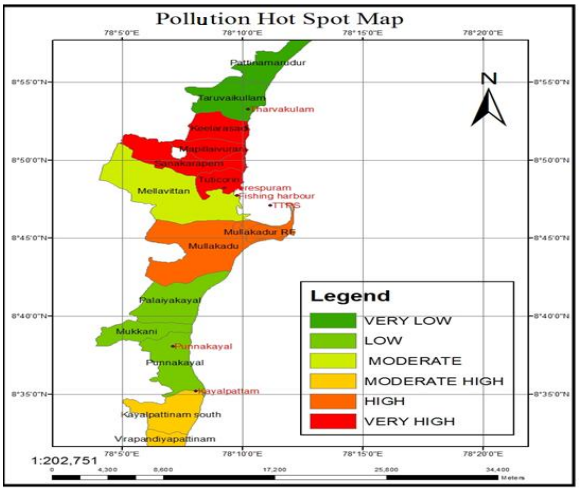

Figure 16: *Pollution Hot Spot Map*

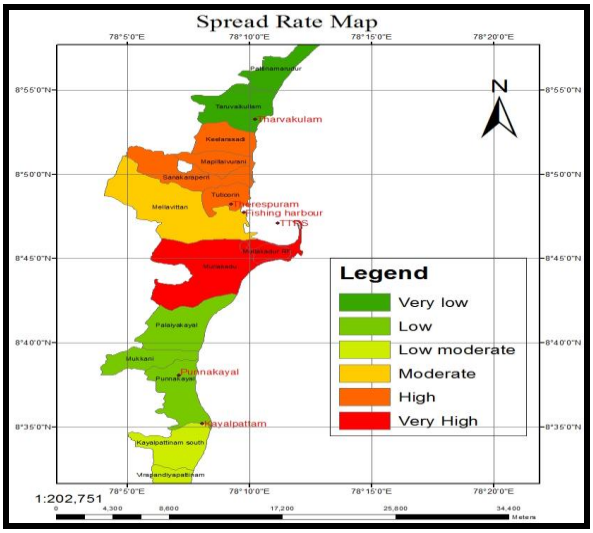

Figure 17: *Spread Rate Map*

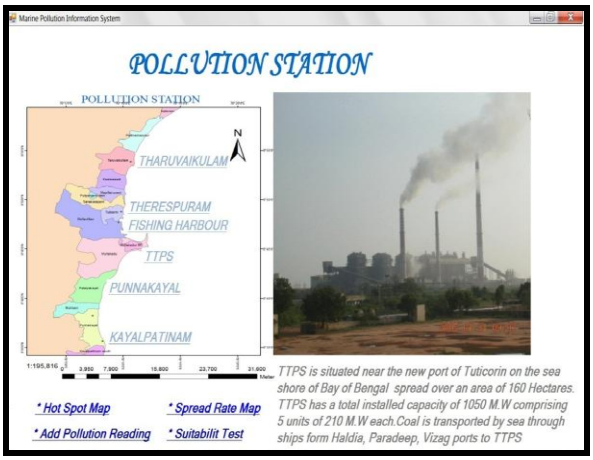

Figure 18: *Marine Pollution Information System Portal Snap shot*

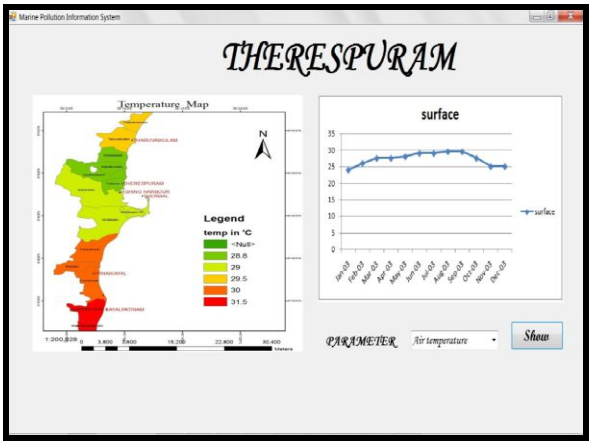

Figure 19: *Marine Pollution Information System Portal Snap shot*

5. Conclusion

This project provides Marine pollution information at a provincial level that could be used by Research people, Local community and fisher folks. It gives the warning system for marine pollution in different coastal areas in Tuticorin. For the hot spot analysis based on various Physical, chemical and biological parameter maps are prepared using the statistical data and Remote Sensing data with the help of GIS environment. Using the General Coastal Cater Quality Standards approach on all the layers of thematic maps has undergone weighted overlay analysis.

Hot spot map and Spread rate map were derived with the assist of GIS analysis. In that Therespuram and Tuticorin thermal power station (TTPS) have high rate of pollution and it seems that polluted area are not suitable for living organisms. Kayalpatinam have reasonable value of pollution. Fishing harbor and Punnakayal have highly moderate rate of pollution and these areas are quite suitable for living organisms. Finally Tharuvaikulam has low pollution value and it clearly shows that the area is greatly suitable for living organisms.

From Spread rate map, Tuticorin thermal power station (TTPS) has very elevated spread rate of pollution hence the control measure should be taken by introducing chimney (flue-gas stack) of height upto 400 meters or more and proper air filter mechanism should be installed and suggested to increase the cooling tower efficiency. Therespuram has high spread rate of pollution and it has been recommended to remove the wastage from anthropogenic activity and link the sewage into deep sea minimum depth of 20 m and above through pipe line after primary treatment. Kayalpatinam has sensible spread rate of pollution for the reason that DCW chemical factory influenced; the wastage from the chemical factory should dispose into deep sea (20 m) through pipe line after most important treatment is advisable.

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