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Estimation of waste water generation in a growing city using spatial techniques – a case study of Nagpur, Maharashtra

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Abstract: Settlement of rural migrated population in urban area is always one of the major concerns to the local civic authorities. Today, due to the growing population pressures and improper management of urban streams, rivers have transformed into sewer systems.

Nag River in Nagpur city, India offers a typical case of over exploited water resource for dumping wastewater and solid waste exceeding its carrying capacity. Today, 100% of Nagpur city sewage is pumped into Nag River resulting in degraded environment. The polluting parameters mainly present in the Nag River are Total suspended solids (TSS), total dissolved solids (TDS), turbidity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), kjeldahl Nitrogen (kNitro). The above parameters revealed the overall health condition of river, which requires much attention and emphasis towards the quantification of wastewater generation, its prevention from mixing directly to river and partial biological treatment.

In this study, estimation of wastewater generation by various socio-economic classes was carried out using remote sensing & GIS techniques. It was observed that various habitat classes contribute the maximum wastewater.

Keywords: Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), kNitro, Land use, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), urban watershed

I. Introduction

As per 2001 census, almost twenty eight percent (28%) of India's population resides in urban areas. It is assumed that within the next few decades, more than 50% of India's population would be living in urban areas. Quality of life of majority of Indian population depends on the existing environment within the cities [5].

The rate of urbanization is highest in Maharashtra state with Nagpur city as fastest growing urban centers. Rural watersheds studies have been always focused in India, but very less work has been carried out on "urban watershed" in the Indian context [3]. Nag river urban watershed has been selected, keeping in view its characteristics of "urban watershed". Severity of the problem can be understood by the fact that growing urbanization has changed the morphometry of Nag River. It offers a typical case of over exploited water resource for dumping wastewater and solid waste exceeding its carrying capacity [1]. In this case study, potential of remote sensing & GIS technologies has been utilized to estimate wastewater generation in Nag River urban watershed by various socio-economic classes.

II. Methodology

In order to analyze the health status of Nag river urban watershed & the impacts of various socio-economic classes, the land use pattern was studied. The studies were carried out to estimate grey water and black water generation [2].

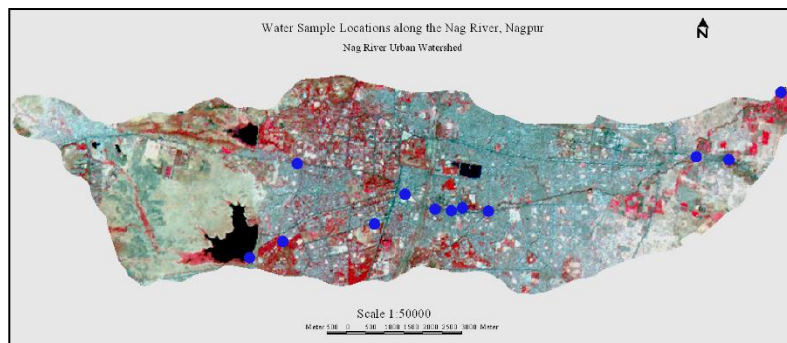
Since the study involved generation of land use / land cover maps, False Color Composites (FCC) images were developed on Indian Remote Sensing (IRS-1C LISS III) satellite data of January 2003. This data was used for visual as well as digital interpretation and analysis. Restricted ground checks were carried out to cross-check the results. Nag river urban watershed area was classified into eleven urban categories and further analysis was carried out in GIS environment. The classified eleven urban categories are as following:

- Commercial area
- Public utility
- Open land
- Vegetation
- Water body
- Dense slum
- Slums

- LIG (Lower Income Group)
- MIG (Middle Income Group)
- HIG (Higher Income Group)
- Institutions / Organizations

Water quality parameters are means to describe the chemical, physical and biological characteristics of water usually in respect to its suitability for particular purposes [4]. The qualitative parameters derived from water samples were collected at various locations along the urban stretch of Nag River (approx. about 16.4 Km). Twelve (12) sampling stations were fixed starting from Ambazari Lake to Bharatwada (before confluence of Nag and Pioli River) (**Fig. 1**). Selection of sampling locations required consideration of the monitoring objectives and some knowledge of the physical features of the river water course system, as well as of water and of any discharges of wastes into it. The field work also helped in assessing & cross-checking the demographic / habitat structure within the watershed. The water samples were tested in the laboratory for different physical, chemical and bacteriological parameters.

Fig. 1 – Location Map for Nag Urban Watershed, Nagpur



Wastewater is any water that has been adversely affected in quality by anthropogenic influence. It comprises liquid waste discharged by domestic residences, commercial properties, industry, and agriculture and can encompass a wide range of potential contaminants and concentrations. In the most common usage, it refers to the municipal wastewater that contains a broad spectrum of contaminants resulting from the mixing of wastewaters from different sources. Here, the combined contribution of grey water and black water together constitutes waste water.

Following studies were carried out based on *veenstra*, who has given an innovative approach to estimate the potential per capita contribution of waste water qualitative parameters such as Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), kjeldahl Nitrogen (kNitro) [6] (**Table 1**):

Table 1 Variations in domestic wastewater composition (Source: Veenstra et al., 1997)

Parameter	Specific production (g c-1 d-1)2	Concentration1 (mg l-1)2
TDS (total dissolved solids)	100-150	400 – 2,500
TSS (total suspended solids)	40-80	160 – 1,350
BOD (biochemical oxygen demand)	30-60	120 – 1,000
COD (chemical oxygen demand)	70-150	280 – 2,500
Kjeldahl-N	8-12	30 – 200
Total-P	1-3	4 – 50
Faecal coliforms(No per 100 mL)	108 – 109	104 - 106/100 ml

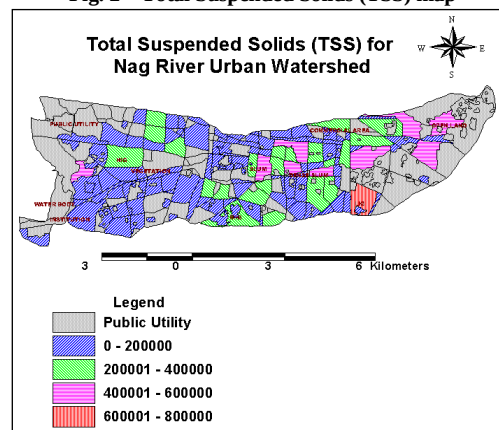
- Assuming water consumption rate of 60 & 250 L c-1d-1

Total Suspended Solids (TSS)

Total Suspended Solids (TSS) represents the total suspended solids / undissolved in water. Total suspended solids (TSS) include all particles suspended in water which will not pass through a filter. Suspended solids are present in sanitary wastewater and many types of industrial wastewater. There are also non-point sources of suspended solids, such as soil erosion from agricultural and construction sites.

As levels of TSS increase, a water body begins to lose its ability to support a diversity of aquatic life. Suspended solids absorb heat from sunlight, which increases water temperature and subsequently decreases levels of dissolved oxygen (warmer water holds less oxygen than cooler water). Total Suspended Solids (TSS) maps were derived from random samples collected from Nag River. (**Fig. 2**)

Fig. 2 – Total Suspended Solids (TSS) map

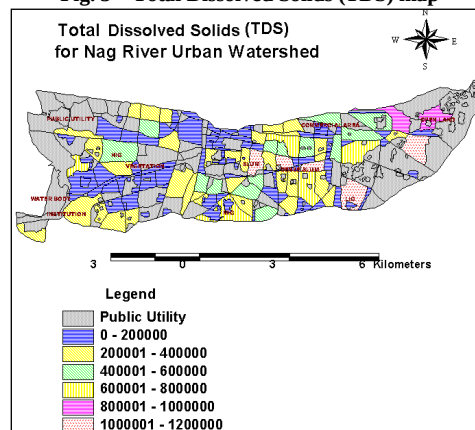


Total Dissolved Solids (TDS)

TDS means the total concentration of dissolved minerals (or salts) in water. Total dissolved solids (TDS) are a measure of dissolved matter (salts, organic matter, minerals, etc.) in water. Inorganic constituents comprise most of the total concentration of TDS.

TDS can be naturally present in water or due to some industrial or municipal treatment of water. TDS can be toxic to aquatic life through increases in salinity or changes in the composition of the water, or it may include substances that are toxic to people or aquatic life. Total Dissolved Solids (TDS) maps were derived from random samples collected from Nag River. **(Fig. 3)**

Fig. 3 – Total Dissolved Solids (TDS) map

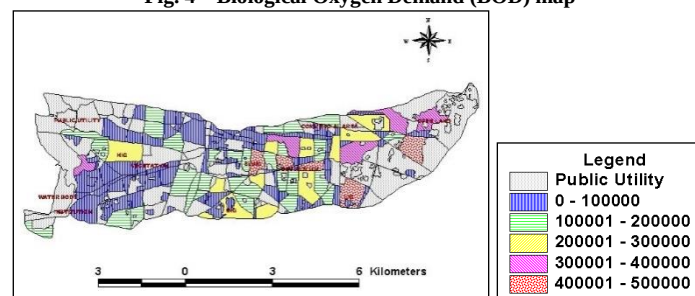


Biological Oxygen Demand (BOD)

If sufficient oxygen is present in water, the useful aerobic bacteria production will flourish, which causes the biological decomposition of waste and organic matter and thus reducing the carbonaceous material from the water. The amount of oxygen required in the process, until oxidation gets completed is known as Biochemical Oxygen Demand (BOD).

Polluted water will continue to absorb oxygen for many months and it is not possible to determine this ultimate oxygen demand. Hence the BOD of water during five days at 25° C is generally taken as the standard demand. If BOD of water is zero, it means that no oxygen is required and thus no organic matter is present **(Fig. 4)**

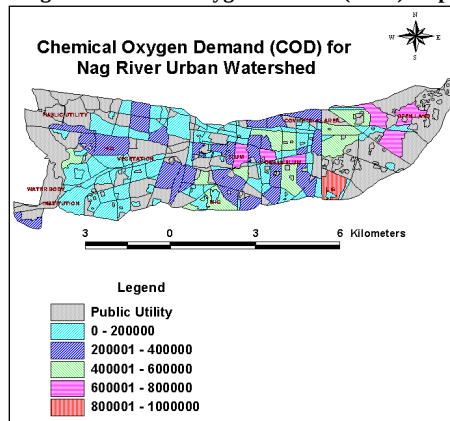
Fig. 4 – Biological Oxygen Demand (BOD) map



Chemical Oxygen Demand (COD)

Chemical oxygen demand (COD) is a measure of the oxygen equivalent to that portion of organic matter present in the waste water sample that is susceptible to oxidation by potassium dichromate. This is an important and quickly measured parameter for the streams, sewage and industrial waste samples to determine their pollution strengths. (Fig. 5)

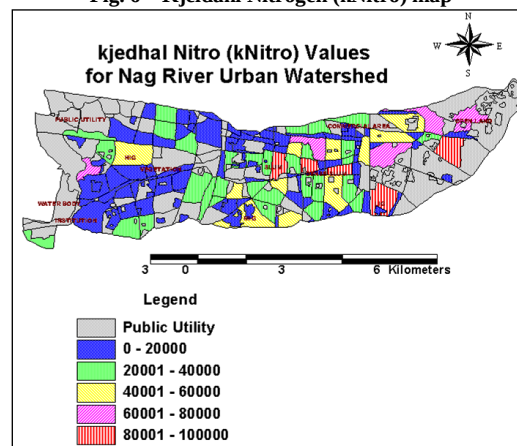
Fig. 5 – Chemical Oxygen Demand (COD) map



Kjeldahl Nitrogen (kNitro)

This parameter is responsible for increase of organic nitrogen and ammonia nitrogen. The leaf, vegetable and kitchen wastes and other decomposed dead bodies are the cause of kjeldahl Nitrogen parameter. The undigested fertilizer from the vegetation activities on the watershed also increases this parameter. This promotes unwanted aquatic plant growth resulting deficiency of dissolved oxygen. (Fig. 6)

Fig. 6 – Kjeldahl Nitrogen (kNitro) map



IV. Results & Conclusions

From the above study carried out, it can be derived that the urban classes which contributes maximum wastewater are mainly habitat groups and partially from institutions. Habitat groups contributing the maximum wastewater include dense slums, slum, Lower Income Group (LIG), Middle Income Group (MIG), Higher Income Group (HIG) and institutions.

These types of habitat groups are generating and contributing the maximum domestic wastewater and various other wastewater components. Wastewater generated from the respective habitat groups is deteriorating the overall quality of Nag River especially in urban areas. Hence, while calculating the wastewater generation, within the watershed, only urban area is been taken into the account.

It has been established through the present study that the remote sensing and GIS technology are effective tools to study, analysis, planning and effective management of urban watershed. The results present encouraging state, wherein further studies may be taken up to demonstrate the potential of this technology with advent of advanced technological tools to estimate wastewater generation in urban areas. The case study will be beneficial in better planning for assessing the potential contribution of wastewater from urban population to the system and may help in minimizing the damage to some extent for similar urban cities of developing countries.

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