ASSESSMENT AND PREDICTION OF NUTRIENT LOADS CONTRIBUTED BY MUSI RIVER BASIN

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ABSTRACT

Water quality management in developing countries including India, is still confronted with identification, assessment and control of non-point source pollution. Since, majority of nutrient loads are of diffuse origin, an exact understanding of the loading pattern is a prerequisite to reduce their impacts on receiving waters. The present paper describes a methodology for assessment of nutrient loads from the river basin under study. Musi River is one of the tributaries of River Krishna which drains a very large area in the south India. The basin experiences rainfall in one of the three seasons of the year and hence the non-point source contribution is considerable during the rainy season. The rainfall in the non-monsoon period is insignificant. The model consists of three modules for studying the behaviour of pollutants from point sources, non-point sources in urban areas and non-point sources in rural areas. The study attempts to apportion the nutrient loads to the different sources of pollution in the river basin. The predicted loads are in good agreement with observed loads, with a few deviations due to data constraints. At present, nearly all emphasis of pollution abatement in the basin has been placed on the construction of elaborate wastewater treatment plants to control point source pollution. The results emphasize the need for non-point source controls for effective water quality management.

Keywords

Nutrients, Diffuse pollution, Water quality modelling, River basin planning.

INTRODUCTION

As part of the general concern for environment, water quality became the important water resources issue in the 1970's. Water quality is closely linked to the total water quality in the basin and hence, it becomes imperative that water quality assessment and river basin planning are closely related. For river basin management and planning whether long range/short range, before going into alternative plans for development, it is essential to combine it with water quality problems, hydrology and analysis. Increasingly the water quality of receiving water is suffering enhanced nutrient input and subsequent deterioration of water quality. Monitoring and modelling are two complementary instruments necessary for the assessment of river water quality degradation, often generated by different sources. Monitoring and modelling of diffuse pollution is more complicated than modelling and monitoring point sources of pollution (Sekhar, 2001). One of the important tasks of water quality management is identification, determination and assessment of both and point and non-point sources. Non-point sources are difficult to identify and quantify, making implementation of effluent limitations almost impossible. The non-point sources pollution reflects that amount of elements distributed on the basin and their leaching to watercourse.

The sources of nutrients are generally distinguished in point sources and non-point sources. Effluents from municipal treatment plants, untreated sewage discharged through sewerage systems and industrial effluents are the dominant point sources. At the same time, it is becoming increasingly clear that diffuse sources, notably the leaching from agricultural lands, are probably even more important than the point sources. The principal cause of leaching of nutrients from agricultural areas is dosing of fertilizers in excess of the capacity of the crop uptake for its growth. Possible transport routes are overland flow, subsurface runoff and base flow. The transport phenomena differ from basin to basin depending on soil characteristics, drainage pattern, areal extent, etc. Usually, there is certain capacity for the basin to modify and to reduce the export of nutrients. There may be some irreversible fixation of phosphates on the soil matrix; in the presence of organic matter there is denitrification; there is some accumulation of organic nitrogen and organic phosphate compounds in soil. However, the capacity of these processes to retain nutrients is not infinite. The sorption processes lead to a further reduction in transport rate. The long transport times and the sorption processes together lead to a delayed response to reductions of fertilizer applications. Considering the above processes which lead to nutrient inputs, it is essential to assess nutrients contributed by both point and non-point sources.

DESCRIPTION OF STUDY AREA

Musi river is one of the tributaries of the River Krishna which drains three important states of south India. The drainage area of Musi river is approximately in the shape of 'L' with two tributaries covering an area of 11,500 km^2. The location of the study area and its description are presented in Fig. 1. The terrain is flat to gently undulating except for few hillocks and valleys. Three seasons prevail in the basin: summer (March – May), monsoon/ rainy (June – November) and Winter (December – February). The mean annual rainfall is around 800 mm during the monsoon period. The rainfall in the other seasons is insignificant. The minimum and maximum temperatures vary between 12^0 C and 43^0 C. The predominant soils in the basin are sandy loam, clay loam, black cotton soils and rocky soils. The river bed is mostly deposited with sandy soils (CWC Manual, 1995). The land use activities in the basin as obtained using the maps from National Remote Sensing Agency, Govt. of India are urban (12%), paddy fields (50%) and other crops (36%).

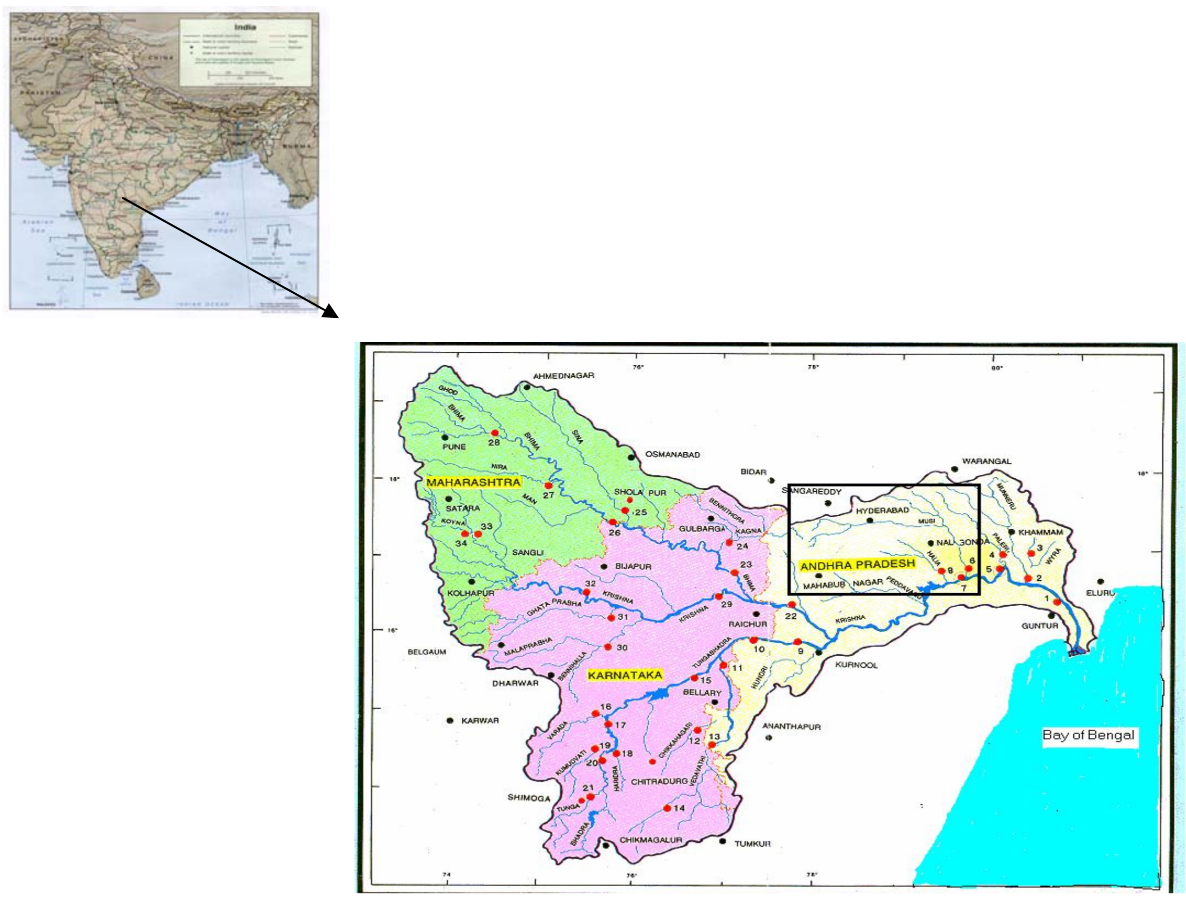

Fig. 1. Study area location and basin description

METHODOLOGY

Behrendt, 1993 demonstrated the relationship between pollutant concentration and river runoff and established the relative importance of different sources. Simplified static pollutant yield models integrated with GIS are used to estimate soil loss, phosphorous and nitrogen loading from watersheds and to delineate critical sub-areas of pollution (Elder, 1985; Feller and Kimmins, 1979). Yamada, et al., (1995) developed a runoff model to showed profiles of pollutants in runoff by simulating the change in runoff load with variation in characteristics of the river basin (i.e., population, urban area, rate of sewerage, land use, etc,.). The model developed by Ichiki, et. al., (1995) forms a basis to simulate generation, accumulation and runoff from the river basin. The model considers the differences in the behaviour of pollutants with rainfall and pollutant sources.

The generated nutrient loads (Lp_{01}, Lp_{02}) in point sources derived from domestic and business activities is estimated respectively using population, production and basic units. These are divided into two categories: one discharged into the drainage system and the other removed by treatment facilities. The removal rate of pollutants from point sources (x) is calculated using

$$Lp_T = (Lp_{01} + Lp_{02})\ (x/100)$$

where Lp_T is the point load removed by treatment plant in kg/day, Lp_{01} is the point source load from domestic activities and Lp_{02} is the point source load from business activities. Further, the nutrients discharged into the drainage system are divided into two classes: one (dS_p/dt) deposited in drainage by the accumulation rate of nutrients from point sources (y) and the other (Lp_s) runoff into receiving water with a basic load from mountainous area (Ln_s). they are estimated using

$$Lp_s = (Lp_{01} + Lp_{02})\ (1 - x/100)\ (1 - y/100)$$

$$dS_p/\,dt = (Lp_{01} + Lp_{02})\ (1 - x/100)\ (y/100 - Lp_r)$$

Runoff nutrient load from point sources during a storm event (Lp_r) is given by

$$Lp_r = k_p\, S_p^{\,a}\, Q_r^{\,b}$$

where k_p is the coefficient of runoff rate, Q_r is discharge in a storm event (m^3/km^2) and a, b are constants.

Runoff nutrient load (kg/day) from non-point sources during a storm event (Ln_r) is formulated as being proportional to the power of the effective discharge in a storm event (Q_r).

$$Ln_r = k_n\ Q_r^{\,b}$$

Water quality data of Musi river were compiled from past investigations 1985 – 94 for modeling purpose. Briefly, water quality data were obtained from the records of Central Water Commission, Govt. of India and from reports, documents and monitoring data collected by various central, state and local agencies. The model parameters are estimated using the data for the years 1985 – 1993 and the models are verified using the two years data 1993 – 94.

RESULTS AND DISCUSSIONS

The water regime of the Musi River is characterized by significant seasonal variations. The peak flow recorded at the monitoring station is 2700 m^3/sec. However, the maximum values of discharges are not more than 1500 m^3/sec on many occasions. The minimum flow is approximately 20 m^3/sec and it occurs at the end of summer season (May), due to long dry spell and high evaporation losses. Some of the tributaries near the Mega City of Hyderabad carry only point source discharges during summer. With respect to water quality management, this is one of the most alarming situations encountered in the river basin. The main water losses from the river are regulated by the intensive use of for water supply, industry and irrigation. Water management (abstraction of fresh water and return of wastewater and irrigation waters) increases the mineralization of the river water, especially during the low flow period in the summer.

Heterogeneity of sources and factors affecting water quality are generally related to imperviousness and potential sources in the basin. In the absence of source inventory data for the basin, broad categories of point and non-point sources are chosen to represent nutrient inputs. Land use, primarily imperviousness, is correlated with water quality and hence land use classification is primarily useful for comparison among various classes, reflective of development in the basin. Using the land use maps during the period 1985 - 94, it is observed that there was marked increase in the growth rate of urban area which is part of Hyderabad city.

The nutrients in the river water are estimated using the model developed during the study and presented in Table 1. The intensive human impact on the river basins leads to considerable inputs of nitrogen and phosphorous. Nutrients are subjected to bio-chemical transformations and partly enter the bottom sediments. However, long term accumulation of nutrients is not foreseen due to flushing effect of wet flows during post-monsoon season. Phosphates are significant when compared with concentrations in the other tributaries of River Krishna. This is attributable to disposal of domestic and industrial wastewaters and other wastes into the river. This state of affairs reflects lack of adequate wastewater treatment for many areas in the basin. Plans are being prepared to upgrade the sewerage and treatment facilities. Disposal of human wastes and other industrial wastes to nullahs, streams and rivers leads to nitrate inputs in the river. Also, number of farmers still uses fertilizers indiscriminately which find way into the river. The loading pattern suggests that problems may still exist, however the regulating agencies do present some evidence of improvement since last two decades.

Table 1 Source Contributions from the River Basin

Year	Nitrates (kg/day)		Phosphates (kg/day)	
	Point Sources	Non-point Sources	Point Sources	Non-point Sources
1985 - 86	168.5	321.2	87.5	458.2
1986 - 87	188.7	324.0	108.8	447.3
1987 - 88	165.6	375.9	109.9	452.6
1988 - 89	220.2	520.9	140.2	457.8
1989 - 90	241.6	554.2	170.5	463.1
1990 - 91	123.0	444.5	154.3	462.4
1991 - 92	128.5	254.8	162.3	457.7
1992 - 93	167.3	260.0	98.5	456.0
1993 - 94	140.5	277.2	102.6	454.5

Domestic and industrial activities are the main point source contributors in the basin. All the business and commercial activities are also included in the industrial source contributions. The nitrates in the period under study from 1985 to 1994 varied from 123 kg/day to 241 kg/day, and Phosphates varied from 87.5 kg/day to 162.3 kg/day. The fluctuations in loading conditions depend on the implementation of point source controls and on the efficiency of the existing domestic and industrial treatment plants. However, there is a general decreasing trend in the nutrient contribution from point sources, which is possibly due to the improved treatment facilities. Despite the higher level of treatment provision, there is still considerable amount of nutrient pollution reaching the river as the conventional treatment plants do not aim at removal of nutrients. As the existing treatment facilities do not aim at removal of nutrients, the nutrients from Point loads also increased during the period. For the same reason, the removal of nitrogen in treatment units (especially Biological treatment, where some nitrogen removal is possible) was 45%. However phosphorus removal is very meagre as it requires some advanced treatment.

The complex models require a large input data consisting of several sub-models, which consider meteorological, geological, physical chemical and management factors including NPS loading. The results obtained by considering the present model are presented in Table 1. From comparison of nutrient loads from point and non-point sources, it is clearly evident that non-point source contribution is much higher. As agriculture is one of the key activities in the catchment, nutrient loads from non-point source are high.

As already described, the potential pollutants from agriculture areas are nutrients and pesticides, runoff draining from large agricultural areas contribute to higher nutrient loading in the river water.

In the Musi river catchment, the identified point sources are domestic and business (which includes industry and commercial). Point source nitrogen contribution is 25 to 35% of total load and non-point source nitrogen contribution is 65 to 75% of total nitrogen load in the river basin under study. The ratio of point and non-point source contributions of Phosphorus is approximately 15:85. The specific load models obtained based on regression for Nitrogen and Phosphorus are given below:

$$Lr/A = 0.000388 \times Qr^{0.727716} \quad \text{for Nitrogen}$$

$$Lr/A = 0.037726 \times Qr^{0.0922} \quad \text{for Phoshporous}$$

where Lr/A is Specific load in a storm event minus the specific load during dry weather period and Qr is the discharge in a storm event minus discharge in dry period.

CONCLUSIONS

The differing sources of nutrients are catchment – area – activity specific. The nutrient inputs are predominantly due to domestic, industrial and agricultural activities. Base flow also represents a source of nutrients to the river. The sources of nutrients themselves variable according to diverse antecedent conditions, seasonal variations and large scale climatological and meteorological conditions covering the river basin. Theses are differentially activated according to rainfall structure and distribution over space and time. The intensity, frequency and amount of rainfall determine the dilution and first flush processes within the river. The mobility of nutrients depends heavily on soil characteristics, plant uptake and agricultural practices. Different sources present changing profiles, however the present study reports only the basic classification of nutrients. Source inventory in the river basin is essential for comprehensive classification and for identification of changing trends in each nutrient source category.

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