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WATER QUALITY ASSESSMENT OF TUNGA RIVER USING FACTOR ANALYSIS

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ABSTRACT

The paper presents a factor analysis method which can help in assessing of river water quality. Variations in land-use by the human activity can have profound effects on river water quality. The water quality data collected for Tunga river is analysed in this study by using the factor analysis technique. It is observed that the water quality of this river is much affected by the agricultural pollutants and by urban wastes. In the study, variations in the quality of water in different locations has been observed. The river water quality was strongly affected by non-point sources from agricultural activities and by the urban wastes on the banks as well as along the river bed.

INTRODUCTION

The importance of rivers around human habitations is well known. In olden days man was content to survive and exist with the basic needs. However, as civilisations progressed his needs also increased. He began to crave for more luxuries and comforts and in his greed for these, he began to destroy his surroundings indiscriminately. It is observed that the quality of rivers in India are much affected by the agricultural pollutants and by urban wastes.

The main goal of the present research paper was to develop and test a method to separate the relative impact of human activities on the quality of river water. We have limited ourselves to studying the impacts of increasing water consumption for agricultural activities and urban utilization by using factor analysis. Surface water and environmental research employing multi-component techniques are described in the literature (Praus 2005). Multivariate statistical approaches allow deriving hidden information from the data about the possible influences of the environment on water quality (Spanos et al. 2003). Factor analysis attempts to explain the correlation between the observations in terms of the underlying factors, which are not directly observable (Yu et al. 2003). It presents a methodology for limiting the variability of natural landscape characteristics in the river basins and for ranking the magnitude of human influence or urbanization, based on land cover, infrastructure, and socioeconomic data in river basins (McMahon & Thomas 2000).

The global amount of water consumed for agriculture has been estimated to have roughly doubled between 1900 and 1980 (Falkenmark & Lannerstad 2005). Water has, therefore, been identified a critical factor for reaching the millennium development goals (Rockstrom et al. 2005), and further assessment of water quality is needed. Several studies have been devoted to either the impact of climatic conditions or environmental and human use of water availability. Using hydrological models, it is possible to make a distinction between pristine catchment conditions and the effects of environmental changes (Letcher et al. 2001). Recent global studies on the effects of water storage and consumption have shown dramatic effects on water quality (Syvitski et al. 2005). It has, thus, been argued that natural processes no longer have the sole influence on river systems; anthropogenic influences currently dominate (Meybeck 2003).

MATERIALS AND METHODS

Study Area

The Tunga river originates in the Western Ghats, on a hill known as Varaha Parvata, at a place called Ganga Moola of Chikmaglur district in Karnataka state. The Gangamoola hill is surrounded by thick forests called as Bhagavathi forest. Three important rivers, the Tunga, the Bhadra and the Nethravathi have their origin here. From here, the river flows 147 km long through four districts in Karnataka, Dakshina Kannada, Udupi, Chikmagalur and Shimoga. The River Tunga merges with the Bhadra river at Koodli, a small village near Shimoga. The river is given the compound name Tungabhadra from this point onwards. The Tungabhadra flows eastwards and merges with the Krishna river in Andhra Pradesh. Rivers Tunga and Bhadra are the principal tributaries of Krishna in Karnataka along with other tributaries like Ghataprabha, Malaprabha and Bhima.

The Krishna river basin is the second largest river basin in peninsular India and stretches over an area of 258948 km^2. The basin is located in the states of Karnataka (113271 km^2), Andhra Pradesh (76252 km^2) and Maharashtra (69425 km^2). The basin represents almost 8% of surface area of the country of India and is currently inhabited by 67 million people. The major tributaries of the river include the Bhima river in the north and the Tungabhadra river in the south. The river terminates at the Krishna delta in the Bay of Bengal.

The climate in the basin is characterised by sub-tropical conditions with considerable rainfall in the mountains of the Western Ghats and arid conditions in the basin interior. The climate of the study area is classed as dry season with clear bright weather from December to February with summer from March to May, followed by the southwest monsoon season from June to September. October and November constitute the post-monsoon or retreating monsoon season. The mean annual rainfall is 1400 mm, with different rainy periods covering eight months of the year. Total annual rainfall today averages 835 mm, while the annual average temperature reaches 26.7°C. Rainfall over India is highly variable due to the intra-seasonal and inter-annual variability of the south-west monsoon (June to September) and the north-east monsoon (October to November), leading to alternating drier and wetter conditions on the Indian subcontinent (Krishnamurthy & Shukla 2000, Munot & Kothawale 2000).

Methods

A series of sampling sites along the Tunga river were chosen to provide a range in water composition. Water quality monitoring was conducted at 18 stations along the Tunga river during January 2003 to December 2005 at an interval of 30 days. Every month, a single 5-L sample was collected per location in a plastic bottle thoroughly cleaned by detergent, hypochlorous acid, distilled water and finally rinsed with deionised water. The samples were stored at 4°C until analysis was carried out. All the samples were collected by grab method. The parameters, biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), electrical conductivity (EC), total dissolved solids (TDS), sodium (Na^+), potassium (K^+), calcium (Ca^{++}), magnesium (Mg^{++}), sulphate (SO_4^{2-}), nitrate-nitrogen (NO_3-N) and Kjeldahl nitrogen were determined to evaluate the influence of anthropogenic sources on water quality.

In this study, the statistical package for the Social Sciences Software-SPSS 14.0 evaluation version for Windows was used. Initially, a correlation matrix for all the variables is generated and factors are extracted from the correlation matrix based on the correlation coefficients of the variables. Gupta et al. (2005) adopted three stages of factor analysis model to facilitate simple interpretation of variables. The factors were rotated to maximise the relationship between some of the factors and variables (Zeng & Rasmussen 2005).

RESULTS

Descriptive statistics of the data are presented in Table 1. The correlation matrix of variables was generated and factors extracted by the centroid method and rotated by Varimax rotation (Ahmed et al. 2005). Calculated eigen values, per cent total variance, factor loadings and cumulative variance are given in Table 2. The factor analysis generated three important set of factors which explained 85.9% of the variance in data. The parameters, calcium, magnesium and sulphate were selected as first set of factors (F_1), the sodium and potassium as second set of factors (F_2) and chemical oxygen demand, Kjeldahl nitrogen, nitrate-N and biochemical oxygen demand as third set of factors (F_3). Agricultural runoff generally includes carbonates and bicarbonates of calcium and magnesium along with sulphates and chlorides. Hence, the first set of factors (F_1), i.e., calcium, magnesium and sulphate were indicated as agricultural originated sources. Urban discharges usually contain sodium and potassium. Hence, these factors (F_2) were considered as urban pollutants. The third set factors (F_3) which include chemical oxygen demand, Kjeldahl nitrogen, nitrate-N and biochemical oxygen demand were denoted as organic load.

DISCUSSION

The study focused on relationship between anthropogenic activities and quality of Tunga river by using factor analysis technique with a few important parameters. Some researchers have approached these anthropogenic sources of pollution by using the green-blue water concept. Green water refers to the amount of available freshwater which is used for evaporation in natural or agricultural vegetation, which is consumptive use, whereas blue water refers to the amount of water which is unaffected or remains as return flow. The blue water flow is important for downstream water quality, and it has been proposed that a certain requirement for minimum flow exists for ecological sustainability (Tharme 2003). However, while an assessment of 'green' and 'blue' water flows is important for proper decisions in water resources management, the total amount of available freshwater from which allocations can be made is not constant over time, mostly because of variations in climate. It appears, however, that very few studies pay attention to the combined effect of natural climate variability, climate change and anthropogenic impacts (Changnon & Demissie 1996). Vorosmarty et al. (2000) compared the impacts from climate change and population growth and concluded that average climate change is likely to have a minor impact on water resources. In this study factor analysis shows that major pollution threats of Tunga river were non-point agricultural and urban sources.

Based on the results of the factor analysis and typical sources of water pollutants, it is concluded that, the water quality of Tunga river was mainly affected by the agricultural pollutants as F_2 is strongly correlated with Na^+ and K^+ with the factor loading 0.94 and 0.97 respectively. The first set of factors (F_1) expressed high positive loading in Ca^{++}, Mg^{++} and SO_4^{2-} (0.94, 0.90 and 0.91 respectively) with 38.21% of total variance. Eigenvalues correspond to an eigenfactor, which identifies the groups of variables which are highly correlated among them. Lower eigenvalues of the second set factors (F_2) and third set of factors (F_3) contribute little to the explanatory ability of the data.

Table 1: Descriptive statistics of water quality of Tunga river.

Variable	Unit	Mean	Median	Std. deviation	Variance	Coeff. of variance	Min.	Max.
BOD	mg/L	6.42	5.50	3.97	15.74	0.62	2.10	17.60
COD	mg/L	31.12	32.00	16.68	278.11	0.54	6.00	68.00
EC	µS/cm	1027.06	660.00	831.95	692147.10	0.81	160.0	2750.00
TDS	mg/L	663.53	420.00	531.99	283011.80	0.80	100.0	1760.00
Na^+	mg/L	85.24	24.80	129.66	16810.57	1.52	3.60	434.00
K^+	mg/L	8.94	4.40	11.96	143.16	1.34	1.30	52.40
Ca^{++}	mg/L	68.49	56.10	39.61	1568.79	0.58	20.00	190.40
Mg^{++}	mg/L	46.00	43.60	38.82	1506.75	0.84	1.20	147.10
SO_4^{2-}	mg/L	163.02	81.20	212.34	45089.62	1.30	24.00	710.60
NO_3-N	mg/L	2.29	2.26	1.75	3.06	0.76	0.00	5.25
Kjeldahl-N	mg/L	0.83	0.60	0.54	0.29	0.65	0.30	1.80

Table 2: Total variance, factor loading and cumulative variance.

Variable	Factor set-1	Factor set-2	Factor set-3
BOD_5	0.60	-0.12	0.67
COD	0.13	-0.02	0.81
EC	0.72	0.67	0.08
TDS	0.73	0.67	0.06
Na^+	0.28	0.94	-0.02
K^+	0.04	0.97	0.04
Ca^{++}	0.94	0.0054	0.12
Mg^{++}	0.91	0.28	0.09
SO_4^{2-}	0.90	0.285	0.03
NO_3-N	0.41	0.43	-0.60
Kjeldahl-N	0.06	0.24	0.77
Eigenvalue	4.20	3.14	2.11
Total variance(%)	38.21	28.54	19.13
Cumulative (%)	38.21	66.75	85.9

Chemical oxygen demand, biochemical oxygen demand and Kjeldahl-N, which were correlated with F_3, decreased with increasing NO_3-N concentration caused by the nitrification process in water. The organic load was found to be constant at all the stations. The present factor analysis technique showed that the water quality of Tunga river is mainly affected by agricultural activities and urban settlements along the river. Therefore, priority should be given to reduce these non-point pollution sources to maintain the water quality of the river. The factor analysis method can be utilised as an effective water quality assessing tool.

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