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Research Article

STUDY OF WATER QUALITY INDEX OF HINDON RIVER OF WESTERN UP, INDIA: A COMPARATIVE INVESTIGATION

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ABSTRACT
In this paper water quality of river Hindon has been investigated using different model of water quality index and the quality of river Hindon was assessed. Eight physico-chemical parameters, such as pH, conductivity, TDS, alkalinity, DO, TH, Ca, Mg as variable were used for measuring water quality index. The level of quality of water and pollution in the river of twelve sampling stations namely S-I (Paragpur), S-II (Lakhnaur), S-III (Bhaghanpur) of Saharanpur district, S-IV (Anechh), S-V (Titawi), S-VI (BHL Budhana) of Muzzafar Nagar district, S-VII (Barnava), S-VIII (Pura Mahadev), S-IX (Ahmad)of Bagpat district, S-X (Daluhera) of Meerut, S-XI (Surana), S-XII (Nagar) of Ghaziabad district, UP during pre-monsoon (March to May), monsoon (June to September) and post-monsoon period (October to February) were observed and found in the ranges of 163.89-487.89 and 33-51.796 evaluated by Tiwari and Mishra and Akkaraboyina and Raju methods. The results infer bad quality of water all over the sampling stations of Hindon River. Most of the sites were found to be severally polluted and water is not fit even for industrial purposes. This may be due to untreated or partially treated waste inputs of municipal and industrial effluents joining the river. Thus there is an urgent need to preserve water quality and control and manage the way to control the contamination throwing in the river. The most popular model for WQI includes a value of 100 is the best possible index score and a value of 0 is the worst possible. For the evaluation of WQI of rivers water, atleast 30 water quality Indices are being used over the world, with the number of variables ranging from 3 upto 72. In the present paper, WQI based on eight different parameters contributing river Hindon is discussed and water quality of river Hindon is characterized and assessed.

Keywords: *Hindon River, WQI, Physico-Chemical Parameters, Contamination*

INTRODUCTION
Study Area
The river Hindon is among one of the important rivers in western Uttar Pradesh (India) having a basin area of about 7000 km2 (Figure 1). The study area is a part of Indo-gangetic Plains, composed of Pleistocene and sub recent alluvium. The catchment area of the river lies between latitude 28o 30’ to 30o 15’ N and longitude 77o 20’ to 77o 50’ E. The main sources of pollution in river Hindon include municipal wastes from Saharanpur, Muzaffarnagar, Bagpat, Meerut and Ghaziabad urban areas and industrial effluents of sugar, pulp and paper, distilleries and other miscellaneous industries through tributaries as well as direct outfalls. In summer months the river is completely dry from its origin upto Saharanpur town. The map of river Hindon from which twelve sites were undertaken for physico-chemical investigation and WQI was shown in figure 1.
Water pollution is one of the crucial environmental problems of the world and is hoped the situation would be worse in the future unless proper measures undertaken. The world’s great rivers are drying up at an alarming rate, with devastating consequences for humanity, animals and the future of the planet. More than half the world’s 500 mightiest rivers have been seriously depleted (Symons, 1995; Dix, 1981; Sharma *et al.,* 2001, 2005). Both the surface and ground water sources all over the world are severely polluted (Chugh, 2009; CPHEEO, 1991; Bharagava, 2006) at present. The major causes of water resource deterioration and water pollution all over the world (Ajmal *et al.,* 1987; Malic, 2013; Raghunath *et al.,* 2001) include the rapid expansion of population and commercial and industrial growth with their increasing demands for water use, disposal of untreated or partially treated sewage, run off carrying nutrients from fertilizers, pesticides, disposal of industrial effluents, oil and gasoling, sedimentation due

to deforestation, mining activities, and a variety of other causes. For better understanding and managing of water resources, the quality of water in an area of interest should be determined in terms of either its physical, chemical, or biological parameters, or all of these factors. Additionally, the integrated situation of water in a study area should be evaluated using an appropriate technique, (O'connor, 1970; Ouyang *et al.*, 2006; Schiff, 2001; Shriadah *et al.*, 1999) such as the water quality index WQI. WQI combines large amounts of water quality data and represents into simple terms for reporting to management and the public in a consistent manner. The overall quality of water bodies is highlighted by WQI and censes us towards the potential threat to various uses of water. A WQI also allows for comparison of pollution status made among different rivers of the world. This index allows for a general analysis of water quality on many levels that affect a stream's ability to host life. Different WQI models were suggested by a number of groups of water scientists of the world to give real picture of surface water source. Actually water quality data is multivariate in nature. One possible solution for the reduction of multivariate nature of water quality data is to employ an index which could meet all water quality measures and provide a general and readily understood description of water. This way the index is used to assess water quality relative to its desirable state and to provide insight into the degree to which water quality is affected by human activity. An index is a useful tool for describing the state of the water column, sediments and aquatic life and for ranking the suitability of water for use by humans, aquatic life, wildlinfe, etc. The index result represents the level of water quality in a given water basin, such as lake, river or stream. The index imbibes all key components of water quality, is easily calculated, and is sufficiently flexible that it can be applied in a variety of situations. The index can be very useful in tracking water quality changes at a given site over time and can also be used to compare directly among sites that employ the same variables and objectives. A number of workers (Symons, 1995; Walling *et al.*, 1983; Saksena, 2008; Panday, 2001) all over the world developed WQI based on rating of different water quality parameters. Basically a WQI attempts to provide a mechanism for presenting a cumulatively derived, numerical expression defining a certain level of water quality.

Figure 1: Location Map of sampling station of Hindon river

The WQI was first developed in 1965. Since then, it has been widely applied for generating trends, evaluating, and communicating the overall quality of water for the public to be able to understand, and for allowing comparisons among different watercourses or different locations in the same watercourse (Hortan, 1965; Bolton, 1978; Cude, 2001; De, 1983; Gupta, 2012, 2013). The WQI concept integrates magnitudes of all water quality parameters of interest into scores that can assess water quality for multiple purposes (UPPCB, 2007; WHO, 2011). Four steps for developing WQI were (Massoud, 2012) selecting (i) a set of water quality parameters of interest, (ii) developing sub-indices-transforming the different units and dimensions of water quality parameters to a common scale, (iii) assigning weights to the water quality parameters based on their relative importance to overall water quality, and (iv) aggregating sub-indices to produce an overall index. In Thailand, the Pollution Control Department (PCD) has modified the WQI (Miller, 1986). This WQI is considered to be the basis of opinion research in this field (Singnkaran, 2010) for evaluating the overall water quality in Thailand's rivers since 1995. Following the suggestions (Nasiri, 2007) an unweighted WQI is applied for evaluating the overall water quality by the PCD in which all water quality parameters of interest are assumed to have equal importance. Before determining the WQI in each area, the values of each water quality parameter included in the WQI model have to be converted into sub-index scores between 0 and 100 using the rating curve technique developed for Thailand's rivers. In this study, a set of time series models in was used to determine the changing patterns of six important water quality parameters, including dissolved oxygen, biochemical oxygen demand, nitrate-nitrogen, total phosphorus, fecal coliform bacteria, and suspended solids in five rivers located in the Northeast of Thailand. A time series method is simple and efficient for analyzing the past behavior of a time series variable in order to predict its future behavior when causal independent variables influencing the time series variable are unknown or cannot be determined (Kannel, 2007). This modeling technique requires uncomplicated data sets (only the time series data for each water quality parameter of interest) and less time needed for computation. Other factors influencing water quality (e.g., changes in land use and population growth) are assumed to indirectly reflect the changing patterns of the six water quality parameters in each study river. The unweighted WQI (Tiwari, 1985; Saha, 2010) was then used to estimate the overall water quality in the study river and categorize its conditions into classes. The objectives of this study were, thus, to (i) determine the present and future situations of the six water quality parameters in five rivers located in the Northeast of Thailand using a set of time series models, (ii) determine the overall water quality for each river using the unweighted WQI, and (iii) categorize the conditions of water quality for each river into classes.

The sub-index scores for all water quality parameters from both observation and prediction at each station in each river were then used to evaluate the overall water quality in the associated river using the unweighted geometric mean WQI. The sub-index scores of a water quality parameter in past study (i.e., DO, BOD, NO3–N, TP, FCB, and SS) were taken. The total number of the selected water quality parameters was six. To obtain the WQI between 0 and 100 at each station in each river, the product of all Six was normalized. The WQI scores for all stations in each river were used to categorize the overall water quality into classes. The five surface water quality classes with specific characteristics are as follows: • Class I: Very good condition, without any pollutant contamination, suitable for (1) consumption after customary disinfection process and (2) the natural breeding of living organisms and ecosystem conservation. The WQI scores for this water class are 91–100. • Class II: Good condition, with some pollutant contamination, suitable for (1) consumption after customary water treatment and disinfection processes, (2) aquatic organism conservation, (3) fisheries, and (4) swimming, water sport, and other forms of recreation. The WQI scores for this water class are 71–90. • Class III: Fair condition, with some pollutant contamination, suitable for (1) consumption after customary water treatment and disinfection processes and (2) agriculture. The WQI scores for this water class are 61–70. • Class IV: Poor condition, with some pollutant contamination, suitable for (1) consumption after customary water treatment and disinfection processes and (2) industry. The WQI scores for this water class are 31–60. • Class V: Very poor, with some pollutant contamination, suitable for navigation only. The WQI scores for this water class are 0–30.

MATERIALS AND METHODS

For physico-chemical studies of Hindon river water, the samples from twelve sampling station namely S-I (Paragpur), S-II (Lakhnaur), S-III (Bhaghanpur) of Saharanpur district, S-IV (Anechh), S-V (Titawi), S-VI (BHL Budhana) of Muzzafar Nagar district, S-VII (Barnava), S-VIII (Pura Mahadev), S-IX Ahmad)of Bagpat district, S-X (Daluhera) of Meerut, S-XI (Surana), S-XII (Nagar) of Ghaziabad district, UP, India were collected and analyzed as per the standard methods (Shahnawaz *et al.,* 2009; APHA, 2005). A total of 108 samples including 500 m up and down streams off all twelve sites were collected in pre-monsoon, monsoon and post-monsoon season. All the samples were collecting in polypropylene bottles. Before collecting the samples, bottles were through cleaned by 8M HNO_3, followed by repeated washing with deionized water. Total hardness (TH) and Alkalinity of the samples were determined by titration method (APHA, 2005; Shanawaj *et al.*, 2009; Verma *et al.*, 1980; OJha *et al.*, 2012). The analysis of magnesium and calcium were determined by the method of titration. The pH and electrical conductivity (EC) were measured with the help of recalibrated portable pH and meter, conductivity meter respectively. Total dissolved solid (TDS) was determined on Glass fibre filter by gravimetric method. Dissolved oxygen (DO) was measured by modified Winkler- Azide (iodometric) method.

RESULTS AND DISCUSSION

Discussion

The evaluation of overall water quality is not an easy task (Jain *et al.*, 2001, 2002, 2004, 1980), especially when it is applied to a water source with complex physicochemical processes and the influence of human activities. This study showed that the water quality in the five tributary rivers decreased downstream before emptying into the main associated rivers. Although temporal changes in amounts of the pollution indicators (e.g., DO, BOD, nutrients, and fecal coliform bacteria), which are the results of changes in human activities over time, were not directly estimated for each river, their trends in the near future were predicted using time series forecasting models. Since time series data can vary in nature over space and time (e.g., with or without trend, with or without seasonal effect), water quality modelers or water resources managers should be aware of different forecasting techniques and the types of problems they need to investigate (Horton, 1965).

Furthermore, in modeling time series data, it is often useful to try several types of time series models and compare their accuracy of prediction using statistical methods and a graphical inspection of how well the model fits the historical data (Horton, 1965). To cope with the complexity for developing and simulating several models were adopted at the same time and obtained good results. Using the unweighted WQI to evaluate comprehensive water quality in each river was helpful for alleviating ambiguous interpretation of the results when changes in the values of several water quality parameters were considered. PCD, which has used the unweighted WQI (Gupta *et al.,* 2003) since 1995, reported that the results obtained from the index provided a better understanding of the water conditions in a river than the results obtained from a comparison between the observed values and those stated in Thailand's surface water quality standard. However, the major drawback of the unweighted WQI is the eclipsing effect that may occur when at least one sub-index parameter exhibits poor environmental quality (Sharma *et al.*, 2010, 2011, and 2014). Practically, a WQI should be developed using certain techniques that are appropriate for explaining the characteristics of water quality parameters in an area of interest. In general, water quality parameters considered in developing a WQI are of local importance (Jain *et al.*, 2003).

In this study, each of the selected six water quality parameters was assumed to have equal importance in each river where no extremely poor water quality was observed. Consequently, the unweighted WQI seemed to be appropriate for estimating the overall water quality in the associated river. Nevertheless, different weights can be assigned to the water quality parameters in the WQI model as appropriate for evaluating the water quality in an area with extreme changes in the patterns of one or all of the considered water quality parameters. As a result, the application of a WQI may be limited to the aquatic ecoregion/ watershed for which it has been developed. In other words, a WQI should not be used unrestrictedly without consideration of its characteristics and limitations (Janhit, 2007). Meanwhile, for better evaluating water quality influenced by human activities, rating curves for converting the values of biotic parameters and the effects of changes in land use along the riversides into subindex scores should be conducted for including in the WQI model estimation.

Water Qualiaty Index

Water quality index (WQI) was calculated for assessing the water quality of river Hindon at different sites in per- and post-monsoon seasons 2012. WQI of River Hindon was calculated as proposed by Tiwari and Mishra (1985).

It was done by considering eight important physicochemical properties using Central Public Health Environmental Enginneering Organisation (CPHEEO), 1991 and Indian Council of Medical Research (ICMR), 1975 standards. In order to calculate WQI eight Important parameters, pH, dissolved oxygen (DO), total dissolved solids (TDS), electrical conductivity (EC), Total Alkalinity (Alk), Total hardness (Hard), calcium (Ca) and magnesium (Mg) were used. These parameters maximum contribute for the quality of river. The steps for WQI are:

Weightage

Factors which have higher permissible limits are less harmful because they can harm quality of river water when they are present in very high quantity.

So weightage of parameters has an inverse relationship with its permissible limits and is given by

$W_i = k/X_i$

Where k is constant of proportionality, W_i is unit weight of various parameters and X_i is world by accepted water quality standard prescribed by WHO/EPA.

$$\sum_1^8 \left(\frac{1}{Xi}\right) = \frac{1}{Xi(pH)} + \frac{1}{Xi(DO)} + \frac{1}{Xi(EC)} + \frac{1}{Xi(TDS)} + \frac{1}{Xi(Alk)} + \frac{1}{Xi(Hard)} + \frac{1}{Xi(Ca)} + \frac{1}{Xi(Mg)}$$

The weightage of all the factors were calculated on the basis of the above equation and given in Table 3

The overall WQI is calculated by taking geometric mean of these sub indices given by

$WQI = \Sigma\ (Q_n)^{Wn}$ Where $Q_n = 100\ X_i/X_s$

Or WQI anti log $[\Sigma\ W_n \log Q_n]$

Quality status is assigned on the basis of calculated values of water quality indices. Following assumptions are made in order to assess the extent of contamination (Tables 4, 5) or the quality of drinking water (Tiwari and Mishra, 1986). WQI < 50:

Fit for human consumption, WQ I < 80: Moderately contaminated, WQI > 80: Excessively contaminated, WQI > 100: Severally contaminated. For all twelve sites under taken during monsoon (June to September) and post-monsoon period (October to February) were observed (Tables 1, 2) and found in the ranges of 163.89-487.89 and 33-51.796 evaluated by Tiwari and Mishra and Akkaraboyina and Raju methods and shown in figures 2 and 3. Hindon River was all most all the sites are severally contaminated.

Table 1: Value of Water Quality Index scaled by Tiwari and Mishra (1985) and Quality of Hindon River water

Site	Location	Pre-monsoon		Monsoon		Post-monsoon	
		WQI	Quality	WQI	Quality	WQI	Quality
S-I	Paragpur	455.36	Bad	430.87	Bad	425.12	Bad
S-II	Lakhnaur	487.89	Bad	450.13	Bad	486.74	Bad
S-III	Bhaghanpur	465.28	Bad	402.52	Bad	453.65	Bad
S-IV	Anechh	233.18	Bad	431.05	Bad	457.84	Bad
S-V	Titawi	483.81	Bad	452.63	Bad	223.66	Bad
S-VI	BHL Budhana	436.23	Bad	417.68	Bad	478.59	Bad
S-VII	Barnava	336.94	Bad	275.67	Bad	391.46	Bad
S-VIII	Pura Mahadev	370.10	Bad	354.58	Bad	388.78	Bad
S-IX	Mohammadpur Ahmad	314.70	Bad	320.15	Bad	353.94	Bad
S-X	Daluhera	336.23	Bad	313.24	Bad	466.40	Bad
S-XI	Surana	285.39	Bad	310.43	Bad	163.89	Bad
S-XII	Atta Peer *Mohan Nagar*	301.37	Bad	348.22	Bad	357.48	Bad

Table 2: Value of Water Quality Index Calculated by Akkaraboyina and Raju (2012) and Quality of Hindon River water

Site	Location	Pre-monsoon		Monsoon		Post-monsoon	
		WQI	Quality	WQI	Quality	WQI	Quality
S-I	Paragpur	36.624	Bad	36.624	Bad	36.624	Bad
S-II	Lakhnaur	33.18	Bad	33.18	Bad	33	Bad
S-III	Bhaghanpur	35.518	Bad	35.554	Bad	35.428	Bad
S-IV	Anechh	33.288	Bad	34.748	Bad	33.108	Bad
S-V	Titawi	34.802	Bad	36.978	Bad	35.464	Bad
S-VI	BHL Budhana	34.802	Bad	36.942	Bad	35.464	Bad
S-VII	Barnava	51.348	Normal	40.668	Bad	40.632	Bad
S-VIII	Pura Mahadev	40.99	Bad	40.99	Bad	41.344	Bad
S-IX	Mohammadpur Ahmad	50.636	Normal	50.636	Normal	41.254	Bad
S-X	Daluhera	51.796	Normal	41.116	Bad	39.208	Bad
S-XI	Surana	50.636	Normal	51.348	Normal	39.208	Bad
S-XII	Atta Peer Mohan Nagar	50.636	Normal	51.348	Normal	39.956	Bad

Table 3: WHO/EPA standards and assigned unit weights

Water Quality Factors	WHO/EPA Standards (X_i)	Unit Weight (W_i)
pH	8	0.3342
DO	5	0.5348
EC	300	0.0089
TDS	1500	0.0018
Alkalinity	100	0.0267
Total Hardness	600	0.0045
Ca	75	0.0356
Mg	50	0.0535

Table 4: Rating Scale for Calculating WQI

Water Quality parameter	Ranges				
pH	8	8.6 – 8.7	8.8 – 8.9	9.0 – 9.2	> 9.2
		6.8 – 6.9	6.7 – 6.8	6.5 – 6.7	< 6.5
DO	7	5.1 – 7.0	4.1 – 5.0	3.1 – 4.0	< 3.0
EC	100	75.1 - 150	150.1- 225	225.1 - 300	> 300
TDS	500	375.1 -750	750.1 - 1125	1125.1 - 1500	> 1500
Alkalinity	50	50.1 – 70	70.1 – 90	90.1 – 120	> 120
Total Hardness	100	150.1 - 300	300.1 - 450	450.1 - 600	> 600
Ca	25	20.1 – 40.0	40.1 – 60.0	60.1 – 75.0	> 75
Mg	15	12.6 – 25.0	25.1 – 37.5	37.6 - 50	> 50
X_r	100	80	60	40	0
Extent of pollution	Clean *pollution*	Slight *pollution*	Moderate *pollution*	Excess *pollution*	Severe *pollution*

Table 5: Rating Scale for Quality of Water

Value of WQI	Quality of Water
90 -100	Excellent
70 – 90	Good
50 – 70	Medium
25 – 50	Bad
0 – 25	Very Bad

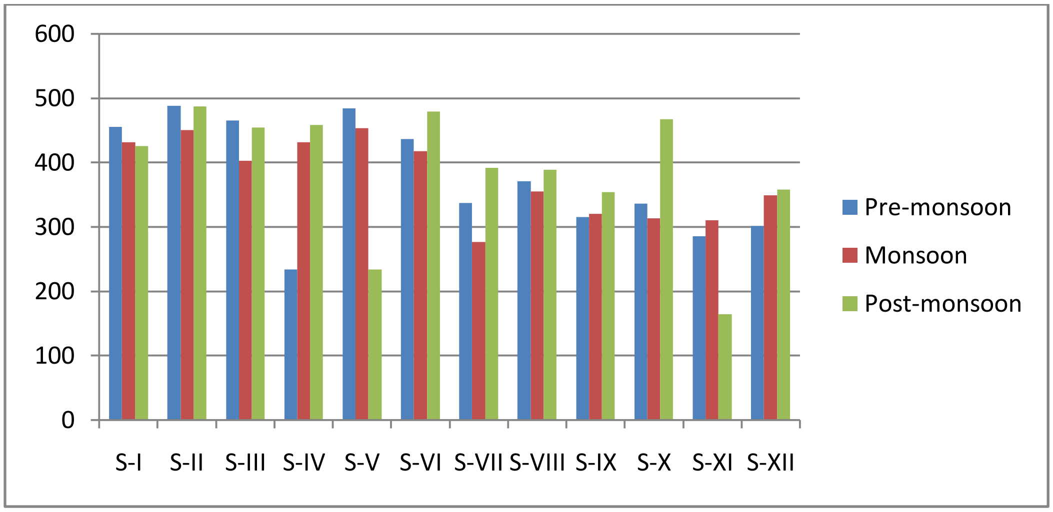

Figure 2: Water quality index Graph Estimated from Tiwari and Mishra method

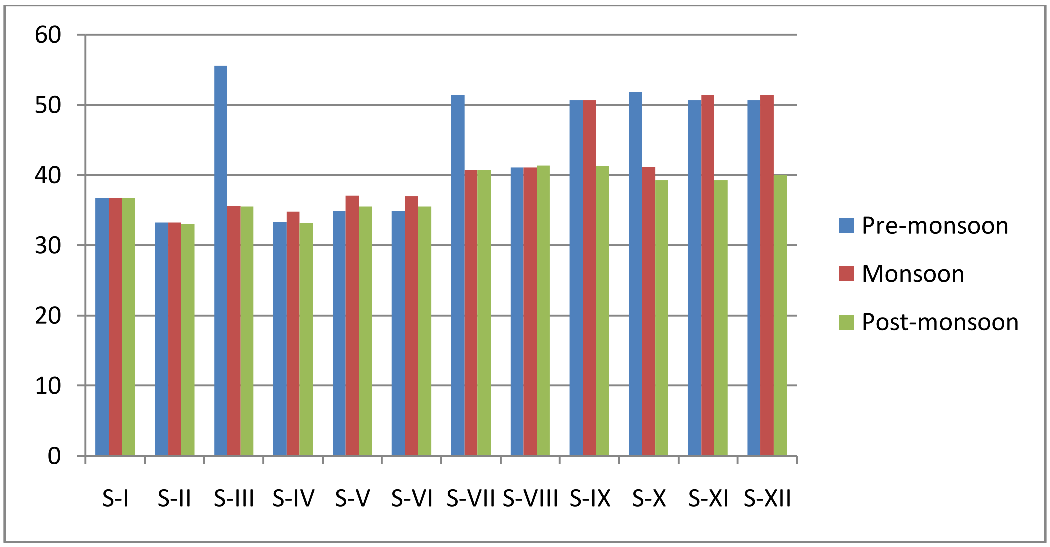

Figure 3: Water quality index Graph Estimated from Akkaraboyina and Raju method

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