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Self-Purification Potential of River Rapti at Gorakhpur, Uttar Pradesh, India

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Abstract

Dissolved oxygen, biochemical oxygen demand (BOD) and hydrological parameters of water samples from the river Rapti were estimated to determine its deoxygenation and reaeration rate coefficients in order to ascertain its natural self purification potential. Deoxygenation rate of 0.15 /day was obtained indicating swift depletion of oxygen in the stream probably due to addition of organic waste due to anthropogenic activities whereas values of 0.11/day to 0.34/day were obtained as reaeration coefficients. These values suggest deep and slow moving streams. The measured DO values indicate high dissolved oxygen concentration in the river at station A,B D and E. FAIR's number (f value = k_2/k_1), the river is under reaeration predominance but deoxygenation rate dominates in the areas where organic waste is directly added to the river. However, the dissolved oxygen profile indicates that after flowing for about 10 to 13 Kms it can reattain its optimum DO level provided there is no further addition of organic waste into it. Hence, an effort should be made to discourage the addition of the organic waste to the surface water bodies and give a chance to the rivers to for self purification.

Key Words: Self-Purification Potential, Deoxygenation, Reaeration, Dissolved Oxygen, Biochemical Oxygen Demand, Stream Velocity.

Introduction

India is rich in water resources, having a network of many 113 rivers and vast alluvial basins to hold plenty of groundwater. India is also blessed with snow-capped peaks in the Himalayan range, which can meet a variety of water requirements of the country. However, with the rapid increase in the population of the country and the need to meet the increasing demands of irrigation, domestic and industrial consumption, the available water resources in many parts of the country are getting depleted and the water quality has deteriorated (www.cpcbenvis.nic.in). India is water-stressed and likely to be water scarce by 2050 due to continuous increase in the demand for water (Gupta and Deshpande, 2004).

Rivers, ponds, and lakes are very important part of our natural heritage. They have been utilized by mankind, over the centuries, to the extent that very few are now in natural conditions (Dube, *et al.*, 2010). Rivers once considered as a life line are now adversely affecting the population by fluvial hazards (Singh, 2007). Rivers are important pathway for the flow of energy matter and organisms through the landscape. A wide range of human activities may lead to environmental deterioration of river water (Iqbal, *et al.*, 2006).

The Rapti river basin in India extends from 26° 12'N 28° N latitude and 81° 39' E- 83° 42' E longitude. It is an integral part of the Saryupar plain, which in turn is a major constituent of the middle Ganga plain. The basin has a catchments area of 19218 Km^2 in India that lies entirely in Uttar Pradesh state. Administrative divisions of Devipatan, Basti, Siddharth Nagar, Sant Kabir Nagar, Gorakhpur, Maharajganj and Deoria districts fall either in full or in parts within the basin. The whole basin is criss-crossed by numerous effluents and a number of oxbow lakes and tals. Important tributaries of the Rapti are Burhi Rapti, Ghonghi, Kain, Rohin, Bhakla, Ami, Taraina and Kakarahiya (Rana and Verma, 2009). River Rapti, a tributary of river Ghaghara drains from Chitwan (inner terai) valley in Nepal joins Narayani (Gandaki), Karnali and Kakahraia River near Gorakhpur. The river is used for dumping untreated sewage through drains and nalas (small channels) resulting in deterioration of the quality of water this leads to physical and chemical changes in water that adversely affect organisms living in it.

Addition of organic matter like sewage and domestic waste into the rivers increases the consumption of dissolved oxygen as microorganisms that flourish on the organic waste increase in population (Fetter 2007). Dissolved oxygen is one of the most important factors in water quality assessment and reflects the physical and biological process prevailing in the natural water. Its presence is essential to maintain all forms of biological life in the water. All the natural water bodies under normal conditions possess capacity or potential to replenish the dissolved oxygen that is continuously consumed by the living organisms for respiration and oxidation of various organic matters. This capacity of water body is defined as self-purification capacity of a water body (Nwankwor and Okpala, 1993). The knowledge of self-purification potential of river can help to design waste treatment plants by the industries and city government that desires to use rivers and other water bodies as disposal channels for their effluent. The pollution problem arises when the rate of assimilation of organic waste into the river exceeds the rate of self purification of a river (Nwankwor and Okpala, 1993). The replenishment of oxygen in river water is dependent on the water flow velocity, water depth and river geometry (Dikeogu, *et al*, 2014). The process and rate of self-purification potential and water quality changes in rivers are dependent on the physical transport processes and biological, chemical, biochemical and physical conversion processes ((Nwankwor and Okpala, 1993, Reichert, *et al.*, 2001)

Hence, an attempt to assess the effect of quantum of pollution in river Rapti due to domestic sewage and waste water from the city on the self-purification potential of the river is made in this paper.

Materials and methods

Collection of water sample

Water samples were collected from five different stations of river Rapti that covered a distance of 15 Kms downstream. The stations were three kilometers apart from each other. On the bank of the river washing of clothes, addition of domestic waste etc could be observed as normal human activity. The samples were collected from just below the surface in plastic bottles. Temperature of the samples at time of collection was recorded and while transportation of samples to the laboratory all necessary precautions were taken. In the laboratory again the temperature of the samples was recorded and within three hours the samples were analyzed. Thirty to thirty two BOD bottles were filled; two were used to determine dissolved oxygen and rest were placed in BOD incubator for timely assessment of dissolved oxygen by Winkler's method (APHA 1976). Two bottles at the end of 1, 2, 3, 4, 5, 7, 9, 11, 13, 15, and 20 days were estimated for dissolved oxygen in order to determine deoxygenation coefficient [(rate) k_1]. The hydrological parameters depth and velocity of the flow of all the sampling stations were measured to determine reaeration coefficient [(rate) k_2] of the river, as reaeration rate of the rivers depends on the condition of the river (Ugbebor *et al* 2012, Clark *et al* 1977). The hydrological parameters water depth, mean flow depth, stream velocity, mean velocity at mean flow depth was measured using a graduated pole at five points along each cross section. There were variations in depth across the channel as determined from the pole and the river velocity was determined using a float. The time taken for the float to move from one point to another was recorded. This technique provided the flow rate of the stream (Dikeogu *et al* 2014).

The deoxygenation rate coefficient k_1, reaeration rate coefficient k_2, and FAIR's number ($f = k_2/k_1$) was the self purification parameters used in the study (Fair 1939). By definition of k_1 and k_2, the value of f expresses the degree of predominance of reaeration over deoxygenation (Nwankwor and Okpala, 1993). The k_2 values were computed for all the river stations using two different methods (equations) developed by Churchil and others (1962).

$$k_2 = 5.026V^{0.769}/H^{1.673} \qquad (1)$$

$$k_2 = 5.23V/H^{1.67} \qquad (2)$$

where H is mean flow depth (m) and V is mean stream velocity (m/s)

Results and Discussion

Dissolved oxygen

Dissolved oxygen profile along the river at different stations is given in table 1. High amount of dissolved oxygen at some stations suggest high atmospheric reaeration or presence of some other source of oxygen in the river. A decreasing trend in the amount of dissolved oxygen from station A to station C indicates depletion of oxygen probably due to the addition of organic matter into the river. Again an increase in DO downstream at station D and E indicates reparation of the river water.

Deoxygenation Rate

The deoxygenation rate constant was computed from BOD test data and the corresponding curves, using Thomas (1950) curve fitting technique. The Deoxygenation coefficient, k_1 (0.15/day) suggest waste of domestic sewage being added to the river. Tebbut (1998) gave the value of 0.17/day at a temperature of 20^o C, as the deoxygenation rate coefficient for domestic sewage. The measured laboratory temperature for the BOD test was 20^o C, and the higher value is very close to 0.17/day characteristic of domestic sewage as given by Tebbut (1998). The k_1 values depict swift depletion of oxygen in the river.

Reaeration Rate

The reaeration coefficient, k_2, determined using two different methods developed by Churchil *et al* (1962) are shown in table 2. The formulae for the two methods are given as equation (1) and (2). Reaeration coefficient, k_2, varies from one station to another, and also with the method used in its calculation. In view of the fact that water velocity and depth are the two major factors that control the degree of reaeration, it is expected that its coefficient varies from one station to another. The k_2 values ranged from 0.11/day to 0.34/day. All the k_2 values were observed to be below 0.35/day. This indicates deep and slow moving river. This is in line with the observed water velocity and depth as measured with a graduated pole.

FAIR'S Number

Based on the definitions of k_1 and k_2, and FAIR'S number ($f = k_2/k_1$), f values less than 1.0 depict predominance of deoxygenation over reaeration whereas values greater than 1.0 depict predominance of reaeration over deoxygenation. Hence, it is expected that at f value of 1.0, the rate of reaeration equals that of deoxygenation. Table 3 shows the f value for different stations. It is apparent from the table that except in station C, reaeration predominates at all the stations.

Reaeration rate decreases downstream from station A and equals deoxygenation reaction at near station B (3.8Kms). Deoxygenation rate begins to increase from this point and peaks at station C where the domestic waste was getting mixed into the river. With flow the deoxygenation rate further decreases and equals reaeration at a station D (9.3Kms) and from this point downstream reaeration increases and peaks at station E. In the downstream direction, the stream begins to recover from pollution problem and this is where FAIR'S number equals 1.0 after the peak of deoxygenation. The f values range from 0.7 to 2.2.

Based on FAIR'S table of values for $f = k_2 / k_1$, the lower value of 0.7 corresponds to the value for sluggish stream of poor reaeration potential whereas the higher value of 2.2 shows flowing streams of normal velocity possessing moderate reaeration potential. We observed that variation in the depth, flow of the river addition of organic waste near station C with f value 0.7 might have been the cause of increase in deoxygenation rate.

CONCLUSION

Dissolved oxygen profiles suggest that the river has capability of self purification as under normal conditions reaeration predominated deoxygenation process. Addition of sewage or other organic wastes into the river increases the oxidative decomposition of the waste and depletion of dissolved oxygen. Further addition of more waste can lead to increase in the deoxygenation rate. The river is capable of reattaining optimum oxygen level within a time period that depends on flow and depth of the river. The flow time suggests that river Rapti has potential of self-purification and discharge of wastes into the river should be discouraged and the government should provide a central sewage disposal system and ensure that domestic or industrial effluents are not disposed into surface waters as they alter the water chemistry.

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Table 1. DO profile along the river at different stations.

Station	Dissolved oxygen (mg/ml)
A	8.7
B	7.1
C	5.9
D	7.2
E	8.2

Table 2. River velocity, depth, and calculated $k_2$values for different stations.

Station	Mean velocity(m/s)	Mean depth(m)	k_2 values (per Day)	
			Equation 1	Equation2
A	0.55	4.2	0.34	0.30
B	0.56	4.1	0.25	0.22
C	0.48	3.9	0.14	0.11
D	0.50	4.0	0.25	0.23
E	0.52	4.2	0.23	0.20

Table 3. Calculated “f” values for different stations.

	FAIR’S number ($f= k_2/ k_1$)	
Station	k_2 of equation 1	k_2 of equation 2
A	2.2	2.1
B	1.6	1.4
C	0.9	0.7
D	1.6	1.5
E	1.3	1.2