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Surface Water Quality Assessment of Panchagnaga River and Development of DO-BOD Relationship Using Empirical Approach

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ABSTRACT

Surface water samples were collected from selected locations along river Panchaganga, from Kolhapur to Narsobawadi during April 2019. Physicochemical parameters were determined in the laboratory and chemical mass balance approach was adopted to estimate the individual ionic loads in the river water. Streeter-Phelps equation was applied to derive a relationship between DO and BOD_5. Model parameters such as De-oxygenation Rate (K_d) and Re-aeration Rates (K_r) were optimized using different empirical methods. The result of chemical mass balance showed an increase in the loading of various ions from upstream to downstream which could be attributed to agricultural and industrial wastes that enter the main stream. De-oxygenation rate and re-aeration constants were calculated using various empirical methods. DO sag curve was developed using Streeter Phelp's model and compared with the observed parameters which showed a significant correlation. DO-BOD concentration observed along the course of the river indicated that the self-purification capacity of the river is high due to which the river regains the lost DO level at a distance less than 50 meters.

1. Introduction

Water quality of rivers is deteriorating due to rapid growth of population, industrial activity and unscientific agriculture development including, conversion of forest and barren land to habitation and agriculture. Such an unwarranted growth, introduces a large quantity of organic matter into the water bodies in the form of domestic, industrial and agricultural wastes which contain many of the sensitive toxic elements. Therefore, change

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in land use-land covers is an important aspect of water quality management which need immediate attention. The existing free electricity as an incentive to farmers resulted in uncontrolled over use of water. In many of the river basins in India, highly water intensive crops are being grown using conventional approaches rather than with a scientific understanding. Fertilizers and pesticides were used intermittently to obtain high crop yields which ultimately resulted in the accretion of inorganic chemicals thereby forming a threat to the adjacent riparian community and may lead to adverse impacts on ecology, crop growth, food security and health aspects. Though the situation is in highly alarming status all over the country, it is necessary to understand the riverine processes and water quality variations in river basins which flows through urban settlements and industrial zones. Globally, more than 80% of residual waters are released into the environment without any adequate treatment [1]. It has been reported that, worldwide, around two million people die annually due to water-related diseases [2]. In recent days, CPCB reported pollution of river Krishna due to various man made disturbances. One of the major tributaries of river Krishna is river Panchaganga.Panchganga river (flows through south western part of Maharashtra) receive large quantity of industrial wastes from City of Kolhapur and also from Ichalkaranji, a textile town of Sangli district. Waterborne diseases, and associated health hazards among the population in Panchganga basin have been reported for some time. The high concentrations of ions such as sodium, chloride, fluoride and ammonium may harm the surrounding environment including plants, animals and mankind. Further, the assimilation of certain ions by plants may lead to absorption of ammonia and ammonium ions. It is also important to note that the high concentrations of ammonium in water bodies can cause harm to humans when converted to nitrate [3].

Both point and non-point sources of pollution are equally sensitive and need proper assessment with respect to the load which passes through the stream at any given point of time. Application of mass balance equation for a river stretch can be very useful means to understand the contributions (point and non-point source) of various ions during dry and wet seasons. This approach is based on flow and chemical concentrations of both anions and cations along the identified river reaches [4]. The differential loads of chemical ions during the wet and dry periods can be considered as good indicators to understand the contribution of point and non-point sources. Jain (1996) [5] carried out chemical mass balance studies for river Kali, Western Uttar Pradesh (India), and concluded that the river is subjected to a varying degree of metal contamination due to numerous outfalls of untreated municipal and industrial wastes of the region. According to the study, the percentage increase in point sources from 61.5 % to 66.9 % (Fe), 57.1% to 77.8% (Zn) and 65.2% to 78.3 (Cu) during the period of study from (October 1993 to December, 1993). Jayashree (2000) [6], found a good correlation between ionic concentrations of upstream and downstream of Bellary nala which receive large quantities of waste from Belagavi city. However, in post-monsoon samples, large variations in ionic concentration were attributed to the addition of non-point sources. Madhurima (2000) [7] carried out a mass balance study for Ghataprabha river, a tributary of river Krishna (India) and observed the variation in ionic concentration to a tune of 1.5 times, between upstream and downstream indicating the impact of agricultural activities in the catchment. Similar study has been carried out by Hiremath (2001) [8] for Ghataprabha during pre-monsoon and post-monsoon period. Malaprabha and Ghataprabha are the two major tributaries of river Krishna (India). A chemical mass balance study of Malaprabha river (a tributary of river Krishna) conducted by Purandara et al., (2004) [9], showed the contribution of groundwater quality on river water characteristics, particularly in parts of M K Hubli, Hoelhosur and Bailahongal taluk.

Therefore, in the present study, surface water quality assessment of Panchaganga river at selected stretches has been carried out during the pre-monsoon season of 2019. Major anions and cations were determined and chemical mass balance approach was adopted to understand the contribution of various ions to river water quality variations. Further, highly sensitive water quality parameters such as DO (Dissolved Oxygen) and BOD (Biochemical Oxygen Demand) were also analysed which is highly essential for the survival of aquatic life. The variation of DO is directly dependent on BOD and is a measure of polluting effect of domestic waste which is responsible for the reduction of DO level in the river. Major anions and cations were also determined along with physical parameters. Such observations will help to assesses and predict contamination status, degradation of the waste discharge and self purifying capacity of the river [10].

In order to understand the water quality variation with respect to river dynamics, Streeter Phelps model which is considered as a classical model has been adopted. The model will predict the longitudinal oxygen profile in flowing waters which works on basic principle of BOD-DO interaction in stream by mass balance phenomenon i.e. de-oxygenation and re-aeration processes.

2. Study Area

The Panchaganga river basin lies between 16º44´4´to 16º31´22´ North latitudes and 74º10´33´to 74º36´3´to east longitude (Figure 1). Five small rivers viz. Bhogavati (83 km), Tulsi (30 km), Kasari (69 km), Kumbi (48 km) and Dhamani (41 km) confluence at Prayag Chikhali and it is renamed as Panchaganga. The river flows and meets Krishna River at Narsobawadi in Shirol taluka of Kolhapur district. There are 174 villages, two municipal towns (Ichalkaranji and Kurundwad), and a city (Kolhapur) are situated on the bank of the river [11].

3. Methodology

In the present study, the Panchaganga River between Shiroli and Narsobawadi was divided into seven reaches by considering parameters such as population density, agriculture activity and industrial development. Station-5 and Staion-6 are located near the industries that include steel, oil, sugar and textiles with an urban-agricultural interface. Samples were collected from the river Panchganga at particular locations which are shown in Figure 1. The latitude-longitude of sampling locations is shown in Table 1. One litre of water using grab sampling method was collected from seven locations (from the middle of the stream) during pre-monsoon season (April) and transferred to clean air-tight plastic containers. During sampling, temperature, pH, DO, EC and TDS were measured on site using Hach water quality samplers. Further, river cross sections and velocity were also determined using standard procedures. In the laboratory turbidity, acidity, alkalinity, chlorides, total hardness, calcium, sodium and potassium were analyzed as per procedure prescribed by American Public Health Association (APHA 2005) [12].

Table 1. Sampling locationsalong the Panchaganga river (between Shiroli and Narsobawadi)

Sl.No	Sites with code	Distance (km)	Location		Elevation from mean sea level (m)
			Latitude	Longitude	
1	P1- Nagadev wadi	0.0	16.6917568	74.1654932	543.0
2	P2- Pancgaganga Ghat	07.72	16.7615540	74.2621537	538.0
3	P3-Kasaba Bawadi	21.88	16.7121682	74.2805517	536.9
4	P4-NH-4highway Bridge	29.77	16.6660892	74.4757330	535.8
5	P5-Ichalkaranji	03.37	16.6810911	74.5082206	534.0
6	P6-Kurandwadi	17.70	16.6818394	74.5759011	531.9
7	P7-Narasoba Wadi	14.80	16.6918400	74.5965658	531.0

4. Streeter-Phelps Methods

One of the primary factors which indicate the pollution status of any flowing stream is the dissolved oxygen content. Though the replenishment of oxygen depend on hydraulic characteristics of the stream and oxidizable pollution load. All biochemical reactions, dependent

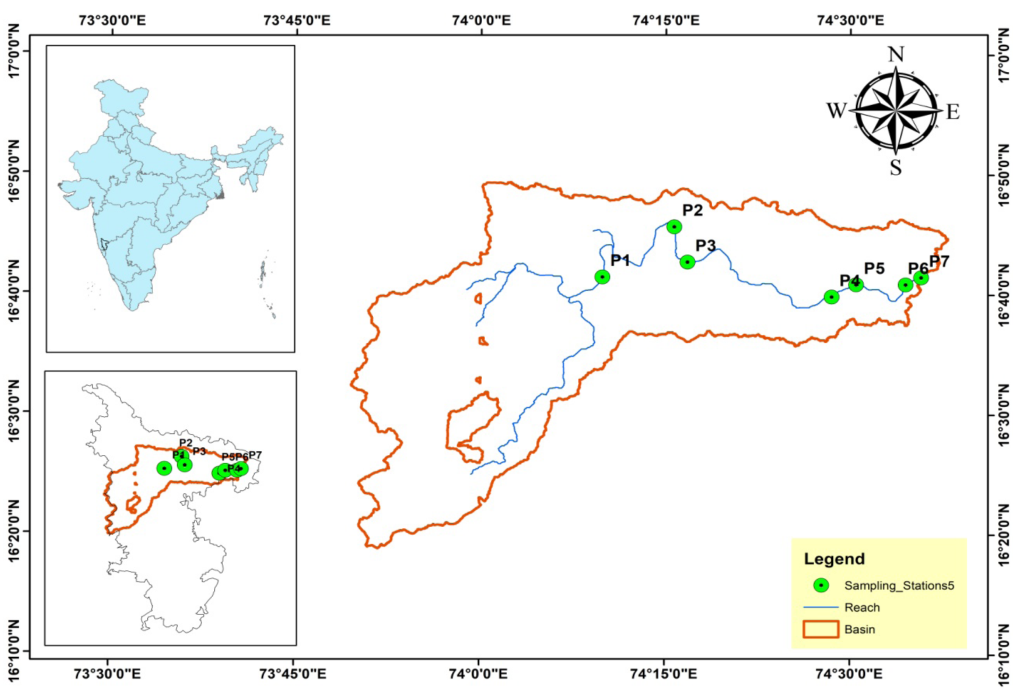

Figure 1. Water sampling points of Panchaganga River

basically on the density of micro-organisms which act as the sinks that depletes oxygen. Phytoplanktons and other pigmented aquatic organisms undergo the process of photosynthesis and provide support to the physical forces of re-aeration. Sludge deposits which form as a result of fine particles carried through streams influence heavily on the forces of oxygen depletion. Other physical parameters which impact the oxygen depletion are temperature, dissolved oxygen saturation percentage and stream morphological characters including sediment particles. One of the most significant parameters which affect the dissolved oxygen content is the waste load received by the stream at various locations. Therefore, in order to assess the waste assimilative capacity, it is important to develop the oxygen sag curves. Accordingly, in the present investigation,

Streeter-Phelps [13] oxygen-sag equation (established for use on the Ohio River) was applied in the study of water contamination as a water quality modelling device. The model explains how dissolved oxygen decreases in a river or stream along a certain distance by degradation of biochemical oxygen demand (BOD).This model foresees deviations in the dissolved oxygen deficit as a function of BOD exertion and stream re-aeration. The major sources of pollution and water inflows to the River Panchaganga occur at number of locations along the selected river stretch between Nagdev wadi and Shiroli MIDC (Kolhapur district) and also between Kasabawadi and Ichalkaranji (Sangli district) (Figure 2). The entire length of the river (under study) is further subdivided into seven reaches based on the location of wastewater outfalls, surface drains, and freshwater tributaries.

5. Model Parameters

5.1 Determination of De-oxygenation Rate

The De-oxygenation rate was determined by conducting laboratory measurements of DO uptake checking daily. Water samples were taken to the laboratory with appropriate procedures and incubated at 20 deg C using BOD bottles in the procedure carried out for 5 days. The data obtained from this method was calculated using Thomas method (Thomas, H. A., 1950) [14]. It is also known as slope method which was used to determine De-oxygenation rate. The Thomas slope equation is expressed as

$$\left(\frac{t}{BOD_t}\right)^{1/3} = (KBOD_U)^{-1/3} + \frac{K^{2/3}}{6BOD_u^{1/3}}t \qquad (1)$$

Where t = time at sample stations (day)

$BOD_{t=}$ BOD that has been exerted in time t (mgL^{-1})

K = BOD deoxygenation rate in base 10 (day)

BOD_u = Ultimate BOD (mgL^{-1})

$\left(\frac{t}{BOD_t}\right)^{1/3}$ = It is plotted as a function of t, with the slope $\frac{K^{2/3}}{6BOD_u^{1/3}}t$

$(KBOD_U)^{-1/3}$ = Gives K and BOD_u

5.2 Empirical Method of De-oxygenation Rate Determination

The de-oxygenation rate was obtained by using an empirical method [15] which is based on physical condition of the river and depth of water. The empirical equation is

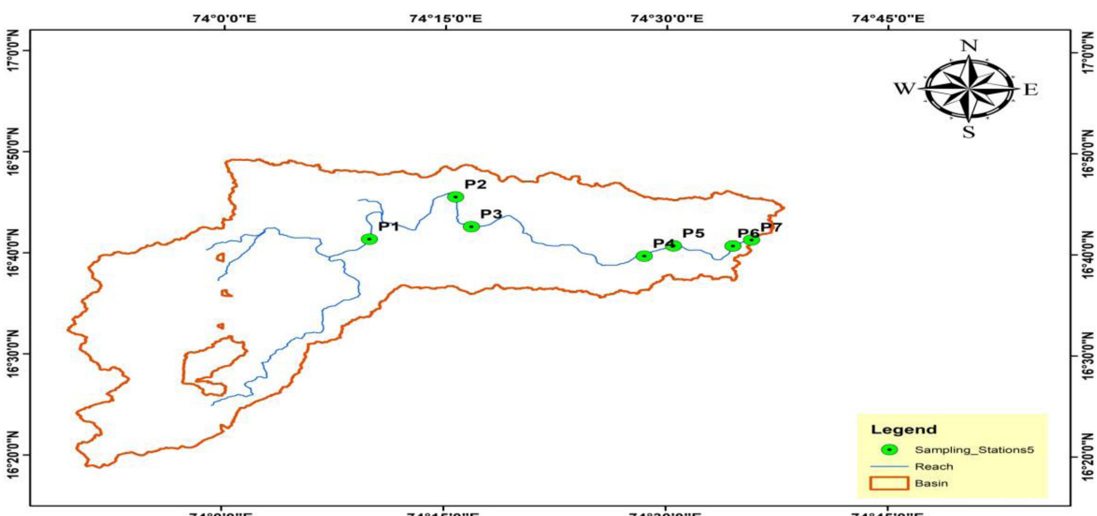

Figure 2. DO-BOD analysed stations:

shown below (Equation 2).

$$kd = 0.3(\frac{H}{8})^{-0.434} \quad (2)$$

Where, Kd = de-oxygenation rate $(day)^{-1}$
H = water depth (ft). $0 < H < 8$

5.3 Re-aeration Rates

Atmospheric re-aeration constant K_a was estimated using the following equation

$$(K_a)_r = (K_d)_{20}(\theta)^{r-20} \quad (3)$$

$(K_d)_{20}$ and $(K_a)_r$ are the reaeration rate constants at 20°C and at any temperature "T" respectively. For the constant "θ", a value of 1.024 is used [16]. Many works have been carried out on mechanism of re-aeration as influenced by temperature, river geometry and hydrodynamics factors such as Connor et al [17], Churchill et al [18], Owens et al [19], Landgbein and Durum [20] and Jha et al [21].

1) O Connor-Dobbins Equation:

$$(Ka) = \frac{3.9V^{\frac{1}{2}}}{H^{\frac{3}{2}}} \quad (4)$$

2) Churchill et al Equation:

$$(Ka) = \frac{5.06V^{0.919}}{H^{1.673}} 1.024^{(T-20)} \quad (5)$$

Where T = Temperature.

3) Owens et al Equation:

$$(Ka) = \frac{5.32V^{0.67}}{H^{1.85}} \quad (6)$$

4) Langbein WB and Durum WH Equation:

$$(Ka) = \frac{5.14V}{H^{1.33}} \quad (7)$$

5) Jha et al Equation:

$$(Ka) = \frac{5.791V^{0.5}}{H^{0.25}} \quad (8)$$

Where Ka = re-areation coefficient at 20° (day^{-1}), V = Average stream velocity (m/s), H = average stream depth (m).

6. Streeter Phelp's Model

The Streeter-Phelps equation was widely applied for the evaluating the waste assimilative capacity of the river. The model elucidates how dissolved oxygen declines in a river or stream along a certain distance by decomposition of biological oxygen demand (BOD).

The model explains the decrease in the oxygen content of river water by the decomposition of the organic load (BOD) along the definite distance present in the river (Figure 3) and it calculate variations in the dissolved oxygen shortfall as a function of BOD exertion and stream re-aeration.

The classic Streeter -Phelps equation

$$D(t) = \frac{k_d L_0}{K_r - k_d} (\exp(-k_d t) - \exp(-K_r t)) + D_0 \exp(-K_r t) \quad (9)$$

Where;

K_r is re-aeration constant $(day)^{-1}$,

K_d is de-oxygenation constant $(day)^{-1}$,

t is the time of travel of wastewater discharge downstream(days)

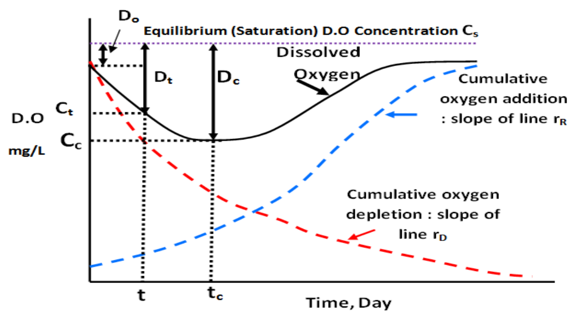

Figure 3. Streeter Phelp Oxygen Sag

7. Chemical Mass Balance

The law of conservation of mass states that "when chemical reactions take place, matter is neither created nor destroyed". This is also applicable to pollutants moving between two sections. A substance that enters the region has three possible outcomes. Part of it may leave the region without any change; part of it may collect within the periphery and part of it may be recovered from other substances. The equation for mass balance can be written for each substance,

Input rate = Output rate + Accumulation Rate + Decay rate (10)

The basic principle in defining the release of materials into a stream is to express a mass balance equation for different lengths of the river. The principal equation for mass balance supposing thorough mixing is,

Load of material upstream + Load added by outfalls = Load of material immediately downstream from outfall

Recalling that the load is the product of concentration and flow, the mass balance is given by

$$QuCu + \sum_{i=1}^{n} L_i = Q_D C_D \quad (11)$$

Where the flows of upstream and downstream are Qu and Q_D, concentration in the receiving water at upstream and downstream are Cu and C_D, and is the sum of all individual loading to the receiving water. Mass balance for certain water constituents is determined to find the association between the water quality estimated and contamination due to natural process due to human activity, i.e. the weight of the substance transported through a cross-section of the river bed per second. When two or more rivers come together at one point, the sum of the loads carried by the streams above the confluence must be equal to the load of the river downstream of this point.

8. Results and Discussion

8.1 Physico-chemical Characteristics of Panchaganga River

The physico-chemical parameters were determined in the laboratory for the samples collected during pre-monsoon season of 2019. The results are presented in Table 2.

From Table 2, it is noticed that, pH vary from 7.14 to 7.78 and lies within the permissible limit and found to be steady from upstream Nagdevwadi to Narasobawadi in the downstream. Turbidity ranges between 1.4 and 6.3 (NTU) indicating that all values are within permissible limit except the one at station Kasaba Bawadi (P-3, the confluence of Jayanti nallah). During the field investigation, it is observed that, large quantity of sediments is transported into the stream and remain in suspension for certain distance. EC of Panchaganga River varies from 202.9 to 952.8 µS/cm. The relatively higher EC and TDS towards the downstream could be attributed to the large quantity of discharge of wastewater from local habitations and also from industries such as textiles which is widely spread over the downstream part of the river. The TDS content ranges from 100 to 500mg/L. Parameters like acidity, alkalinity, chlorides and Total hardness were found to be within the permissible limits. However, a significant change in the concentration of chloride (193 mg/L) was noticed at station P-5 which receives large quantity of liquid waste from textile industries located in the area. Further, cations such as calcium, magnesium, sodium and potassium were also remained within the permissible limits.

8.2 Chemical Mass Balance

The concentrations of major anions and cations were converted to chemical load by multiplying with river cross sectional area and velocity at each station in Table 3. Flow varies between 89.81 m^3/s and 192.014 m^3/s during non-monsoon. The increase in stream flow between stations P1 and P7 (upstream and downstream) was caused by the outfalls of municipal and industrial wastes incoming from various towns located on the catchments. The estimated load of both anions and cations showed a general trend of increase towards the downstream.

Alkalinity is one of the key parameters which is distributed widely all along the course of the river stretch. Maximum load was recorded at Downstream (P7). The increased concentration of alkalinity could be due to the combined effect of agricultural waste and industrial effluents received from the riparian belt covering Ichalkaranji and adjoining areas. Chloride load in upstream estimated was 1673.717 kg/day and an increase was noticed in the immediate downstream location (13177.44 kg/day) which could be due to the inflow of huge quantity of domestic waste enter the river in the downstream Figure 4, particularly from the township of Ichalkaranji which include industrial, domestic and agriculture wastes.

In the case of sodium the increase was gradual with a highest load of (10348.84 kg/day) in the downstream of Ichalkaranji (P7). Similar observation was found in the distribution of potassium where the maximum load increased from 14.45 kg/day upstream to 39.7 kg/day in the downstream. However, potassium load was minimum at Ichalkaranji which could be due to the source area variation and also due to the hydrodynamic conditions and hydrochemical characteristics of the chemical load discharged from the industries. Further, it is noticed that both calcium and magnesium load are very high due to the mixing of industrial wastes. Higher loads are observed towards the downstream of Ichalkaranji (Ca= 16258.209 kg/day; Mg = 9290.40 kg/day). Therefore, it is evident that the excess load is added through effluents discharged from the textile industries. Figure 4 represents the variation of chemical load along the course of the river. It is found that there is a gradual increase in the load from upstream part of the study area to the downstream. The increase in the load of each parameter further substantiated the role of agriculture and industrial wastes into the river all along the river basin. It is also noticed that, due to the sanctity of the Narsobawdi temple located on the Panchganga river, receive large number of devotees on daily basis and use the river water for temple activities and also for swimming, bathing and cleaning of clothes. Therefore, the man made disturbances also causes significant damage to water quality of Panchaganga river. This was evident from the observations on DO and BOD concentrations monitored during the study period.

Table 2. Physico- chemical parameters of Panchaganga river between Shiroli and Narsobawadi (Pre- monsoon, 2019)

Location	pH	Turbidity (NTU)	EC µS/cm	TDS mg/L	Acidity mg/L	HCO_3 mg/L	Cl mg/L	TH mg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L
P1	7.18	2.8	202.9	100	6	86	20.85	70	50	20	18.58	0.18
P2	7.14	4.2	486	200	10	112	22.83	94	76	18	25.66	0.35
P3	7.42	6.3	238.5	100	8	94	24.82	84	66	18	13.42	0.23
P4	7.18	4.5	617	300	12	116	36.73	90	84	6	55.84	0.18
P5	7.27	1.4	952.8	500	10	202	193.61	182	136	46	87.48	0.09
P6	7.33	4.3	836.2	400	12	196	64.53	130	120	10	47.89	0.41
P7	7.78	5.1	807.5	400	14	232	79.43	154	98	56	62.38	0.24

Table 3. Estimated Chemical load in Panchaganga river during Pre-monsoon (2019)

Source	Loads Kg/day					
	Cl	HCO_3	Na	K	Ca	Mg
1 Shiroli Section			**Pre-Monsoon**			
U/S	1673.717	6903.58	1491.49	14.449	4013.712	1605.484
D/S	1925.993	7294.25	1041.37	117.847	5121.49	1396.77
2 Ichalakaranji Section						
U/S	2948.47	9311.811	4482.513	14.449	6743.036	481.645
D/S	13177.44	38488.82	10348.84	39.816	16258.209	9290.40

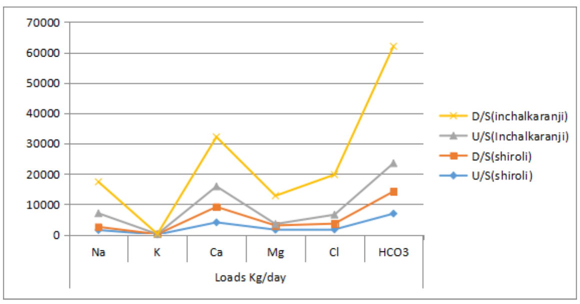

Figure 4. Variation of chemical load in Panchaganga river during Pre-monsoon (2019)

Figure 4 shows the concentrations of major anions and cations along the different stretches of Panchaganga river from Shiroli (Kolhapur) to Narsobawadi. The differential loading between upstream (P1) and downstream (P7) sections varies considerably high (from less than 6 times in the case of bicarbonate and more than 8 times in the case of chloride and 2 times in case of potassium) during non-monsoon period The higher concentration of anions and cations during pre-monsoon season could be attributed to base-flow components (supplied from adjoining aquifer) and also due to the drying of reservoir during non-monsoon period (dilution effect becomes negligible). It is further noticed that, along the stretch of river Panchaganga intensive agriculture activities are ongoing all over the year which plays a significant role in contributing chemical loads both during pre-monsoon and post-monsoon seasons. The present observations as well as the discussions held with the locals also indicated the possible means of contamination from intensive agriculture activities and domestic wastes in addition to industrial loads. One of the important observations found during the study period is with regard to contribution of non-point source of pollution which is significant and need further investigations to quantify the load individually from point and non-point sources.

8.3 Determination of De-oxygenation Rate

The presence of dissolved oxygen in the flowing water depends on de-oxygenation and re-aeration coefficient. Both the coefficients indicate the hydraulic conditions, geomorphological characteristics and the organic matter content in water and sediments of the river. Various methods have been devised for the estimation coefficients. In the present study, de-oxygenation rate was determined using Thomas and Hydroscience methods and presented in Table 4.

Variation of de-oxygenation coefficient showed only marginal variation indicating that the river health is considerably good all along the river stretch under study. It is found that the average de-oxygenation coefficient was higher in the case of Hydroscience method as compared to Thomas. The values were compared with other tributaries of Krishna (Tungabhadra, Ghataprabha and Malaprabha) and it is found to be closer to the one estimated by Hydroscience methods. Similar observations were made by the studies carried out for river tributaries of river Krishna by National Institute of Hydrology, Belagavi (unpublished), Highest de-oxygenation coefficient is noticed at Kasaba Bawadi and lowest in Narsobawadi. The highest value could be attributed to the higher concentration of organic matter carried from the effluent stream flowing through the Kolhapur city (Shiroli MIDC). However, there is a considerable reduction in the de-oxygenation rate towards the downstream. The wide variations observed in the downstream region could be due to the variation in the effluent supply and river hydraulics of the region. Further, as the agriculture activities are intensive in the region, large quantity of water is used for agriculture and such water re-enters the river as irrigation return flow. The reduced de-oxygenation coefficient observed at Kurandawadi and Narasobawadi could be due to the increased self-purification capacity and also due to the mixing of Krishna water with Panchganga at the confluence (Narsobawadi). This is evident from the observations taken during the study period.

Table 4. De-oxygenation coefficients calculated by Thomas and Hydroscience methods

Stations	De-oxygenation constants K_d $(day)^{-1}$	
	Thomas method	Hydroscience Equation Method
P1	0.216	0.256
P2	0.152	0.226
P3	0.1	0.274
P4	0.126	0.215
P5	0.051	0.223
P6	0.058	0.184
P7	0.035	0.182

8.4 Estimation of Re-aeration Rate

Re-aeration coefficients estimated for different stations of Panchaganga river, using different methods viz., Connor et al (1956), Churchill et al (1962), Owens et al (1964), Langbein and Durum and Jha et al (2003).

The estimated values of re-aeration coefficient by different empirical methods were compared with the one suggested by NIH (based on unpublished data) and it showed relatively closer resemblance with the method estimated by O'connor and William. Therefore, re-aeration coefficient values obtained from Connor and William method were considered for of Panchaganga River. The highest re-aeration coefficient is observed at Nagadevwadi (0.158/day) and lowest for Narsobawadi (0.058/day), which could be due to multiple factors such as the low flow conditions, geomorphological characteristics and depth of the stream. It is also found that the shallow water showed higher coefficient of re-aeration, due to ease of mixing across the depth profile and greater surface turbulence. Variation of re-aeration is significantly associated with the hydrodynamic conditions of the river. BOD_5, 20 °C showed marginal variations in all sections of the study area (in none of the cases, it exceeded the permissible limit). This could be attributed to the self purification capacity of the river. The summary of the estimated parameters and experimental observations Table 5 indicate that though the re-aeration coefficients are slightly lower than the de-oxygenation coefficient however, DO remained steady and also within the desirable limits.

The higher DO observed in majority of the locations reflect the higher primary productivity levels and eutrophication process taking place in the riverine environment. The presence of BOD (variation is between 0.9 mg/L and 1.88 mg/L) could be the result of accumulation of organic particles received from agriculture and industrial effluents. It is very important to observe that, as the river passes through rural habitations, due to lack of proper sewage systems, the untreated sewage enter the riverine environment from septic tanks and illegal piping connections. This kind of processes resulted in an increase of organic matter and increase in de-oxygenation coefficients (K_d) [22]. Such changes in K_d could be due to variation in temperature which ultimately influence the metabolic activities of the microorganisms. Further, [23] opined that the significance of K_d and BOD lies when two different samples have the same value as BOD_5, as it indicates the uptake of dissolved oxygen under similar conditions.

8.5 Streeter Phelp's Model

According to Streeter-Phelps model, the Oxygen sag

Table 5. Re-aeration coefficients calculated by different methods

Panchaganga basin	Re-aeration constant $(day)^{-1}$ by different methods				
Stations	Connor & William Dobbins method	Churchill et al	Owens et al	Langbein& Durum	Jha et al
P1	0.158	0.047	0.088	0.067	1.120
P2	0.107	0.031	0.054	0.049	1.079
P3	0.200	0.061	0.117	0.083	1.164
P4	0.126	0.050	0.069	0.084	1.481
P5	0.138	0.054	0.078	0.089	1.463
P6	0.050	0.013	0.021	0.024	0.925
P7	0.058	0.018	0.0263	0.034	1.101

curve is one of the best tools to understand the oxygen deficit with respect to de-oxygenation (K_d) and re-aeration (K_r) at any time" [23-25].Self-purification capacity of a flowing stream decides the natural health of a river as it involves physical, chemical and biological processes and help to retain the original water quality characteristics of the stream. Therefore, the basic parameters of concern are de-oxygenation and re-aeration coefficients which were estimated by using simple empirical equations. Based on the above parameters, the DO sag curves were developed using Streeter Phelp' s equation for two sections of the river (Shiroli in the upstream and Narsobawadi in the downstream). Dissolved oxygen Sag curve for Shiroli (Figure 5) shows three distinctive zones of degradation, decomposition and the recovery along the river course. Initially observed DO at the confluence point of river and effluents (Shiroli MIDC) showed a sharp decline to less than 1 mg/L, whereas, in the flowing stream DO showed a normal value of 6 mg/L prior to the entry of waste water and the river mixed with effluents indicated a drop in the DO to 5 mg/L. It is very significant to note that the self purification capacity is so high that the DO attains almost a normal status within a distance of 15 m to 20 m. Therefore, the study implies that the impact of waste water mixing does not cause significant pollution at Shiroli. This kind of observation indicates that the industries may be discharging the water after primary and secondary treatments.

The above observation was done for a small stretch in the downstream of Ichalkaranji and Narsobawadi (Figure 6). The observations were similar, but need further evaluation. At Ichalkaranji, large quantity of waste enters the system, however, the flow pattern suggest that, the river maintain the DO to the normal due to the confluence of number of tributaries which supply comparatively large quantity of fresh water from the catchment.

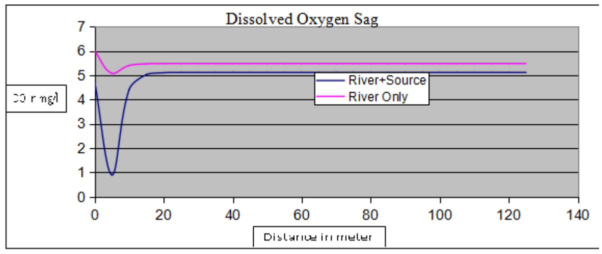

Figure 5. DO sag curve developed using Streeter Phelp's model (Shiroli MIDC)

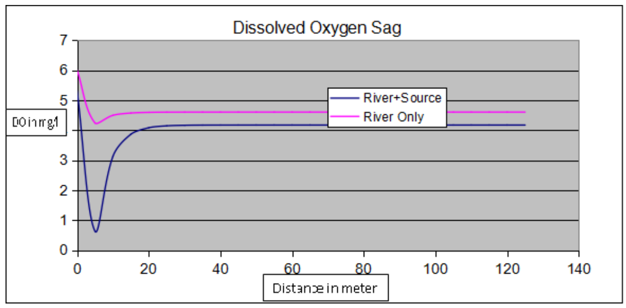

Figure 6. DO sag curve developed by Streeter Phelp's model (Narsobawadi)

9. Conclusions

The primary objective of the present observation is to evaluate the water quality parameters to understand the impact of both agriculture and industrial wastes received by the river particularly between Shiroli and Narsobawadi.

(1) The water quality parameters during study period showed considerable variation from upstream to downstream. However, it is noticed that the variation in both physical and chemical ions are marginal. Turbidity was within permissible limit in all stations except in station P-3 where the Jayanti nallah confluences with Panchaganga.

(2) The estimated loads of major cations and anions during study period showed gradual increase in the load from upstream to downstream which is mainly due to agriculture and industrial wastes entering the

river. Therefore chemical mass Balance study showed contribution of non-point source of pollution is significant.

(3) The estimated De-oxygenation and re-aeration coefficient showed marginal variations and a considerable balance between the two parameters which clearly indicate the good health of the river stretch under investigation. The de-oxygenation coefficient value was slightly higher at Kasaba Bawadi due to discharge of domestic waste and industrial effluent near to it.

(4) Application of Streeter Phelp's model showed that the self purification capacity of the river is very high and the accumulation of organic load is significantly low due to geomorphologic and existed flow conditions. However, a critical assessment of the Panchaganga river is highly essential as the present study is limited to a particular period and time. It is also pertinent to understand the sediment water interaction process in the river as the organic pollutants can adsorb on to fine sediments and lead to intermittent issues of water quality hazard.

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