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ABSTRACT

This article presents physico-chemical parameters of Panchganga River, Maharashtra, India. The river receives varieties of domestic, industrial and agricultural wastes located around the river. The samples are collected from seven different locations P1 to P7 along Panchganga River. Parameters such as pH, turbidity, electrical conductivity (EC), total dissolved solids (TDS), acidity, alkalinity, chlorides, total hardness, calcium sodium and potassium were determined. Dissolved oxygen (DO) deficit assessed using Streeter-Phelps equation from March to May 2019 on monthly basis. Results showed turbidity was out of desirable limit at all sampling locations. Most of parameters showed increase in value as river flows downstream. Calcium and alkalinity showed higher values than desirable limit as per IS 10500-2012 at last four sampling points. From results it is concluded that water quality is getting polluted moderately as river flows from Kolhapur to Ichalkaranji. And there is decrease in DO content of water as river flows downstream; critical DO ranging between 2.66-4.14mg/L is observed at distance of 3396-4475m from discharge point. Finally the attempt has been made to study the water quality index(WQI) of the river flow and the results showed that variation in quality of water from the upstreamto to the downstream.

INTRODUCTION

Water is about 71% of the earth's surface and yet it is one of the scarcest resources.Water is abundant earth as a whole but clean and safe water for consumption is very less in ecosystem (Karikari and Ansa-Ansare 2009).Rivers are the most important resources of drinking water in different countries of the world. As mankind is growing, changes occurred in land and water usage, and hydrological conditions due to coarser use of water. There is an increasing measure of water pollution throughout the world. There are mainly two types of sources of pollution namely point and non-point source pollution(Malik et al, 2011).In India the rivers are getting polluted day by day. Today intense pollution is superior in many rivers such as Krishna, Bramhaputra, Tapti, Hoogly, Ganga and Narmada etc. As the water flows, it collects minerals, salts and silt from the soil and rock in the river bed and river bank. Numerous different pollutants enter stream as it flows downstream, including human waste, animalwaste, agricultural runoff, urban runoff, industrial effluents, and mining waste, because of which most of the rivers are confronting pollution problem or under danger of pollution (Thorvat et al. 2012).

Self-purification is a process by which a stream is partially or totally restored after insertion of foreign substances in quantity and quality, by wayof natural processes, to cause a distinctive change in the physical, chemical and/or biological properties of

the stream. The introduction of foreign matter to the environment is usually through manmade activities (Meenakshi 2012).

The process of self purification can be divided into four zones; “zone of degradation” is characterized by dark and turbid water and DO is as low as 40% of saturation value. Anaerobic decomposition takes place here. “Zone of active decomposition” is marked by heavy pollution. Water in this zone is gray and no fishes are found in this zone because DO decreases to lowest value. The recovery process starts within the “Zone of recovery”. DO again reach 40% of saturation. Close to the end of the zone, microscopic aquatic life reappears. In “clear water zone” becomes clean and more aesthetically pleasant as DO reaches saturation value and fishes reappear. There are many factors affecting the process of self-purification including dilution, current, temperature, sunlight and rate of oxidation (Klien 1962).

The oxygen deficit at any point in the stream is equal to the difference between saturation dissolved oxygen and actual dissolved oxygen at particular time. The resulting oxygen deficiency can be obtained by addition of the oxygenation and reaeration curves algebraically and the obtained curve is called the oxygen sag curve (Jadhav et al., 2013) .

The WQI theory was first proposed by by Horton (1965) and which compares of water quality of the rivers with any statutory standards given by the various organization. It gives different weights to the different parameters based on the limits of the standards and it is very is for us to determine the quality of water of the river (Vasant 2016). Many researchers are developed WQI models successfully and applied to check the quality of water. (Selvam 2014; Guettaf2017;Wagh 2017).

The Panchaganga river basinis situated on the eastern side of the Sahyadriranges. It is in the northern part of Kolhapur districtof Maharashtra, located at $15^{0}43'$ and 17^{0} 17’ North latitude and $73^{0}40'$ and $74^{0}42'$ East longitude and is constituted of five northeast flowing streams, namely Bhogavati (83km), Tulsi (30km), Kasari (69km), Kumbi (48km) and Dhamani (41km). The Bhogawati River is renamed Panchaganga from Prayag Chikhali. The river flows and meets Krishna River at Narsinhwadi, Tal: Shirol, Dist: Kolhapur.There are 174 villages, 2 municipal towns (Ichalkarnji and Kurundwad) and one city (Kolhapur) situated on the bank of the river (Gaikwad, (2014).

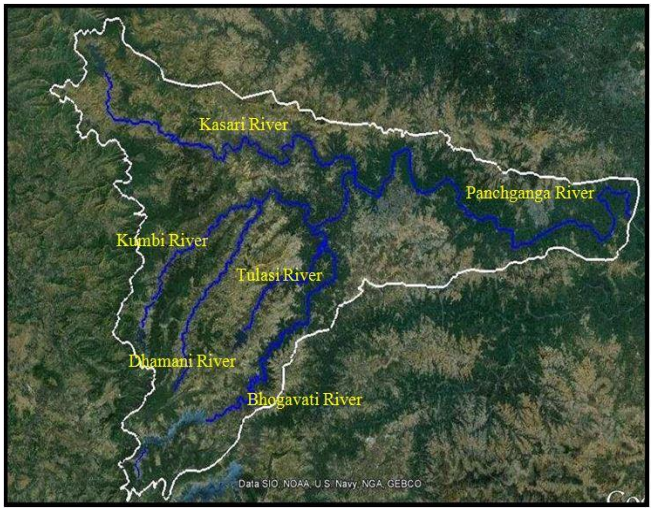


Fig.1. Satellite image of Panchganga river basin

Kolhapur and Ichalkaranji cities are situated on the bank of Panchganga River, which is the main water source for many purposes. Increase in industrial activities and rapid urbanization is polluting river water. The wastewater from MIDC Shiroli, Kolhapur and textile mills of Ichalkaranji is reaching the river without any treatment. Due to this man made activities there is

problem in drinking water supply to surrounding areas. Water pollution created severe health impact on human life. Hence, it is most important to assess the quality of river Panchganga. The main objective of this work is to assess and analyze the water quality of the Panchganga River by analyzing WQI and the attempts has been made to establish the dissolved oxygen sag curve for Panchganga River.

Samples are collected from the river Panchganga at particular locations which are shown in the fig.1 and 2. One liter of samples was collected from each location in the study area. The samples were collected in the middle of river from 7 different locations for the months of March, April and May 2019. Samples are collected in new clean air-tight plastic containers marked with numbers. Grab sampling method is used for the collection of sample.

STUDY AREA

Table 1.Details of sampling points

Si. No.	Site Code	Distance (km)	Location		Elevation from mean sea level(m)
			Latitude	Longitude	
1	P1	0.0	16.6917568	74.1654932	543.0
2	P2	07.72	16.7615540	74.2621537	538.0
3	P3	21.88	16.7121682	74.2805517	536.9
4	P4	29.77	16.6660892	74.4757330	535.8
5	P5	03.37	16.6810911	74.5082206	534.0
6	P6	17.70	16.6818394	74.5759011	531.9
7	P7	14.80	16.6918400	74.5965658	531.0

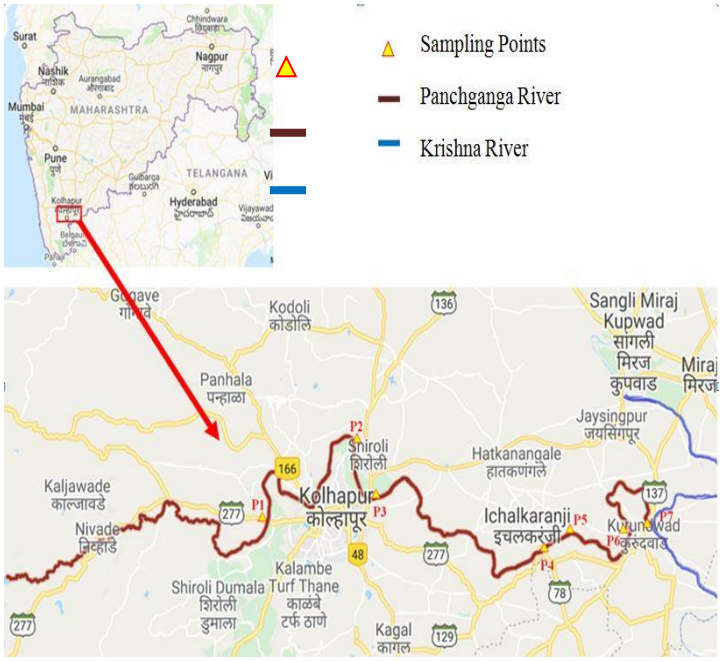


Fig.2. Water sampling points

MATERIALS AND METHODOLOGY

The parameters pH, turbidity, electrical conductivity (EC), total dissolved solids (TDS), acidity, alkalinity, chlorides, total hardness, calcium, sodium and potassiumwere analyzed as perprocedure prescribed by APHA 2005.

Oxygen sag curve

Assume the river is completely mixed and the concentration of water and waste at x = 0 is [Dunnivant 2004]:

$$C_o = \frac{Q_r C_r + Q_w C_w}{Q_r + Q_w} \quad (3.1)$$

Where,

C_o = initial strength at the starting point after mixing (mg /l)

Q_r = Discharge (m^3/sec) of the stream

C_r = Before mixing (mg/L)

C_w = wastewater strength (mg/L)

The saturated oxygen is equal to

$$D_S = \frac{475}{33.3+T} \quad (3.2)$$

Where,

Ds = DO Saturation

T = Temperature in ^{0}C

The deoxygenation constant is obtained by the equation .

$$K_{20} = 0.3\left(\frac{H}{8}\right)^{-0.434} \quad (3.3)$$

$$K_T = K_{20^0} \times 1.047^{(T-20)} \quad (3.4)$$

Where,

H = average depth of river (m)

U = average velocity of river flow (m/s)

The reaeration constant was determined (Churun Ain et al. 2019):

$$R = \frac{294(D_L U)^{0.5}}{H^{1.5}} \quad (3.5)$$

$$D_L = 1.760 \times 10^{-4} m^2/ d \times 1.037^{(T-20)} \quad (3.6)$$

Where,

R = reaeration constant

H = average depth of river (m)

U = average flowvelocity (m/s)

D_L = diffusion coefficient (m^2/day)

Several assumptions have been made to for the calculation of dissolved oxygen. We assumed that the mixed one is evenly across the width of the river and is rapidly mixed with the stream water. The two necessary parameters are the rate of deoxygenation(K) and the rate of reaeration (R). And the term x indicates the distance of downstream from the waste discharge point and uin the equation indicates the velocity of the river water respectively (Dunnivant 2004).

$$D_t = \frac{KL_0}{R-K}(e^{-K(x/u)} - e^{-R(x/u)}) + D_0 e^{-R(x/u)} \quad (3.7)$$

Where,

D_t = DO deficit at anytime t

L_o = BOD remaining at time t=0

K = deoxygenation rate

R = reoxygenation rate

x = downstream distance from the waste discharge point

u = velocity of the river water

RESULTS AND DISCUSSION

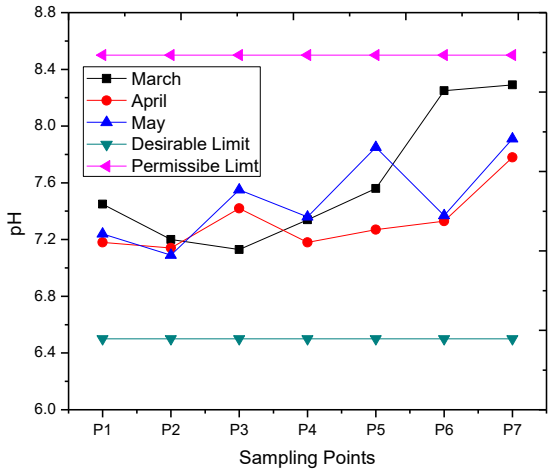
Physico-chemical parameters

The pH, turbidity, electrical conductivity (EC), total dissolved solids (TDS), acidity, alkalinity, chlorides, total hardness, calcium, sodium and potassium of the river water samples collected during March to May 2019 are explained below.

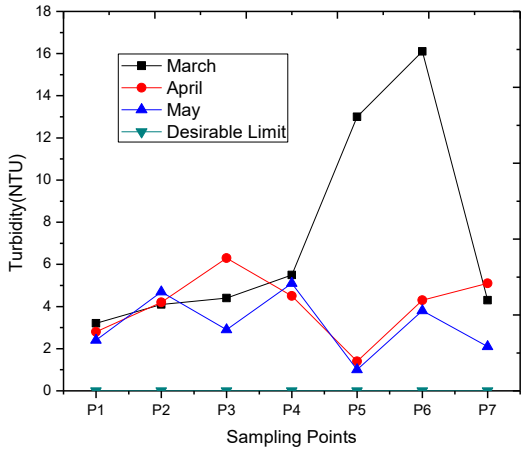
Table 2. Variation of physico-chemical parameters at sampling locations

Location	pH	Turbidity (NTU)	EC µS/cm	TDS mg/L	Acidity mg/L	Alkalinity mg/L	Chlorides mg/L	Total hardness mg/L	Calcium mg/L	Sodium mg/L	Potassium mg/L
						March 2019					
P1	7.45	3.2	72.5	40	5	68	16	84	28	3.19	0.8
P2	7.2	4.1	241.1	100	8	134	26	90	60	11.92	1.18
P3	7.13	4.4	167.7	80	12	98	23	88	78	7.54	1.21
P4	7.34	5.5	621.3	300	18	244	78	156	60	58.01	1.65
P5	7.56	13	832.2	400	12	252	109	232	102	84.55	1.28
P6	8.25	16.1	505	200	14	170	68	134	72	46.09	1.46
P7	8.29	4.3	599	300	8	198	64	186	112	52.33	1.26
						April 2019					
P1	7.18	2.8	202.9	100	6	86	20.85	70	50	18.58	0.18
P2	7.14	4.2	486	200	10	112	22.83	94	76	25.66	0.35
P3	7.42	6.3	238.5	100	8	94	24.82	84	66	13.42	0.23
P4	7.18	4.5	617	300	12	116	36.73	90	84	55.84	0.18
P5	7.27	1.4	952.8	500	10	202	193.61	182	136	87.48	0.09
P6	7.33	4.3	836.2	400	12	196	64.53	130	120	47.89	0.41
P7	7.78	5.1	807.5	400	14	232	79.43	154	98	62.38	0.24
						May 2019					
P1	7.24	2.4	215.3	100	4	78	15.88	60	32	21.72	0.1
P2	7.09	4.7	472.5	200	6	90	21.84	68	58	23.72	0.17
P3	7.55	2.9	236.8	100	8	86	25.81	52	46	23.91	0.23
P4	7.36	5.1	294.1	100	8	102	61.55	96	80	53.77	0.43
P5	7.85	1	798.4	400	10	178	113.18	164	118	89.77	0.61
P6	7.37	3.8	854.7	400	12	182	57.58	156	106	47.45	0.18
P7	7.91	2.1	958.2	500	10	204	83.4	192	104	80.44	0.33

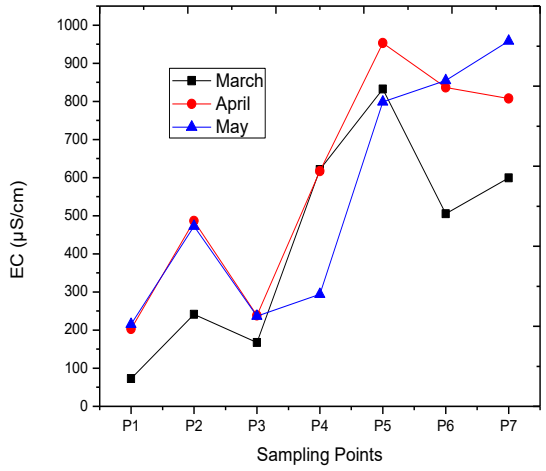
(a)


March
April
May
Desirable Limit
Permissibe Limt
pH
Sampling Points
P1
P2
P3
P4
P5
P6
P7

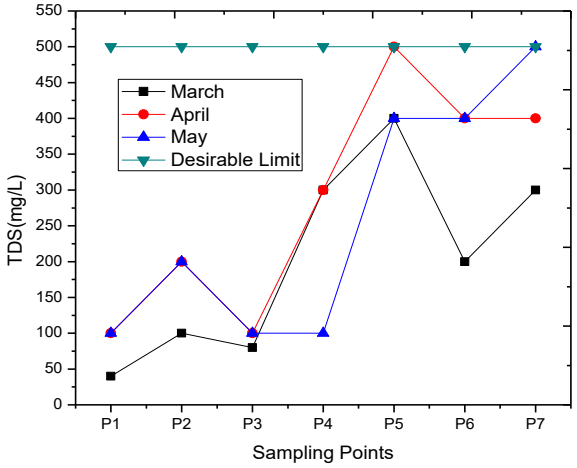
(b)


March
April
May
Desirable Limit
Turbidity(NTU)
Sampling Points
P1
P2
P3
P4
P5
P6
P7

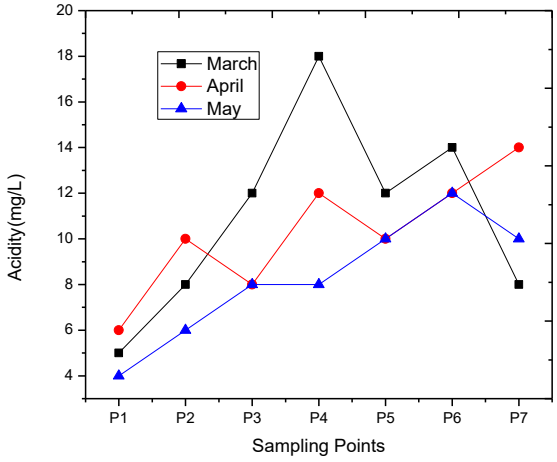
(c)


March
April
May
EC (µS/cm)
Sampling Points
P1
P2
P3
P4
P5
P6
P7

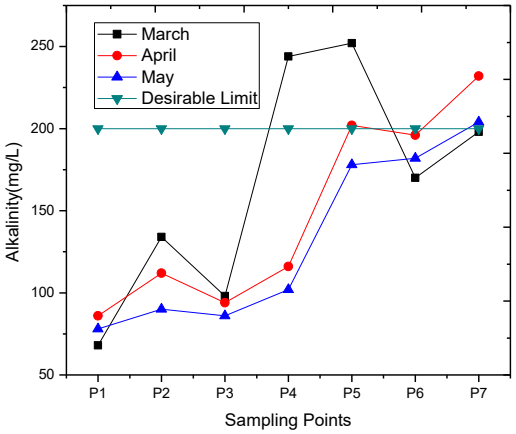
(d)


March
April
May
Desirable Limit
TDS(mg/L)
Sampling Points
P1
P2
P3
P4
P5
P6
P7

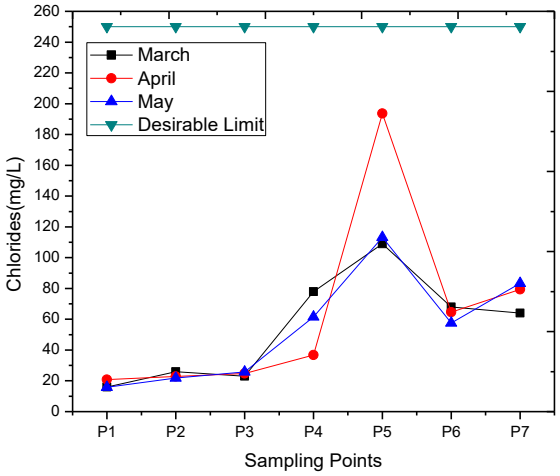
(e)


March
April
May
Acidity(mg/L)
Sampling Points
P1
P2
P3
P4
P5
P6
P7

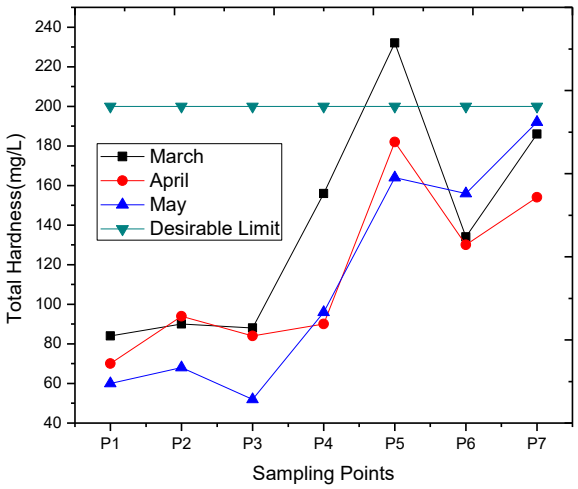
(f)


March
April
May
Desirable Limit
Alkalinity(mg/L)
Sampling Points
P1
P2
P3
P4
P5
P6
P7

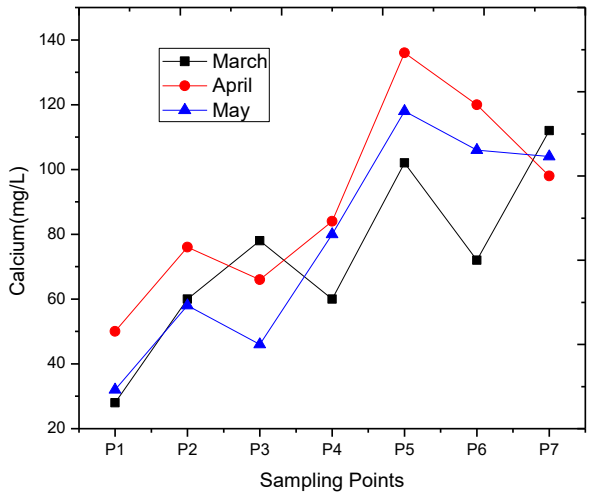
(g)


March
April
May
Desirable Limit
Chlorides(mg/L)
Sampling Points
P1
P2
P3
P4
P5
P6
P7

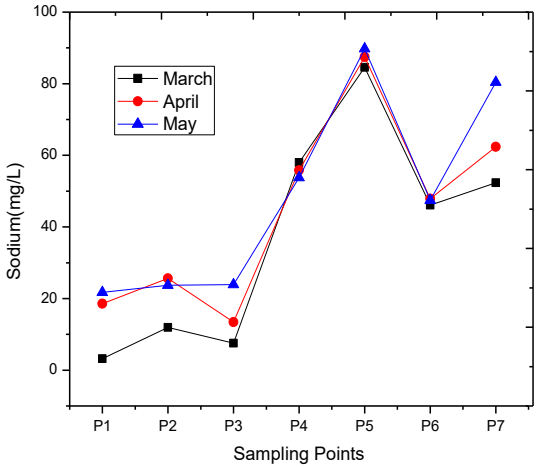
(h)


March
April
May
Desirable Limit
Total Hardness(mg/L)
Sampling Points
P1
P2
P3
P4
P5
P6
P7

(i)


March
April
May
Calcium(mg/L)
Sampling Points
P1
P2
P3
P4
P5
P6
P7

(j)


March
April
May
Sodium(mg/L)
Sampling Points
P1
P2
P3
P4
P5
P6
P7

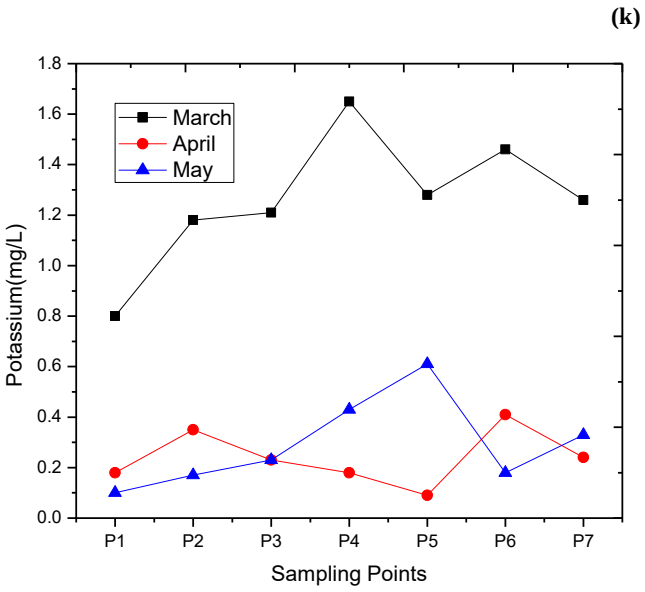


Fig.3. Variation of physico-chemical parameters at sampling locations (a)pH,(b) turbidity, (c)electrical conductivity (EC), (d)total dissolved solids (TDS), (e)acidity, (f)alkalinity, (g)chlorides, (h)total hardness, (i)calcium, (j)sodium, (k)potassium.

pH

In the present study the pH of water is in the range of 7.09 to 8.29. From the Table 2 it is noticed that the pH is well within the permissible range.There is no much variation pH at different locations as shown in fig.3.(a). In majority of the cases, the water is nearer to neutral range. The minimum pH is recorded at P2 (7.09) in May and maximum pH is recorded at P7 (8.29) in 1st March. pH is slightly increased at end points due to the mixing of untreated sewage discharge from Ichalkaranji Nallah.

Turbidity

However, turbidity observed in the river waster varies from 1.0 to 16.1 NTU. The values of turbidity obtained are given in Table .2.The fig.3.(b) represents the variation of turbidity along the Panchganga River. The turbidity is maximum at P6 (16.1 NTU) in March and sharp decline in turbidity is obtained at P5 (1.0 NTU) in May. This is attributed to the sudden deposition of relatively coarser particles derived from the upstream area and further finer sediments are carried away and remain in suspension.

Electrical Conductivity

Conductivity of water is its ability to conduct an electric current. In the present study, the Electrical Conductivity of waster varies from 72.5 to 958.2µS/cm. Maximum was recorded at P7 in the month of May 2019. As the sampling was done in summer season, significantly high EC was recorded in the downstream. The values of EC are as given in table 2. The variation of EC along the course of the river from Kolhapur to Ichalkaranji is shown in fig 3.(c). From the figure it is evident that there is a considerable increase in conductivity from upstream to downstream of the study area because of discharge of domestic waste and agricultural runoff. Maximum value was obtained at P5.

Total Dissolved Solids

It is the amount ionised and non-ionised matter in water. The desirable limit of total dissolved solids in drinking water as per BIS (IS 10500-2012) is 500mg/L. The variation of TDS along the river is shown in fig.3.(d). Evaporation and lower flow volume might be reason for higher TDS at downstream. But, the values are within the desirable limits. The recorded TDS value is low at upstream of Kolhapur (P1) in March and high at P5 and P7 in April and May respectively.

Acidity

Acidity is caused by the presence of organic and inorganic acids and salts. Carbon dioxide which is dissolved is usually the main reason for acidity in unpolluted surface waters. The acidity of sample varies from 5 to 18 mg/L. Maximum acidity was recorded at P4 in the month of March 2019. The values of acidity are as given in table 2.

Alkalinity

The BIS (IS 10500:2012) specified desirable limit of alkalinity in drinking water is 200 mg/L (as CaCO3). In the present study area, there is a wide variation in alkalinity. It varies between 68 and 252 mg/L. Table 2 shows the alkalinity variation with respect of time and space.The variation of alkalinity along the course of the river from Kolhapur to Ichalkaranji is shown in fig.3.(g). From the figure it is evident that there is a significant increase in alkalinity at P5 is 252 mg/L in March is may be due to weathering of carbonate minerals in rocks and soil.

Chloride

Chloride irons are essential for life. However, above a concentration of 250 mg/L chloride, the water may taste salty. The BIS (IS 10500:2012) standard of chloride is 250mg/L. The concentration of the chloride showed variation both spatially and temporally. This may be an indication of the transported soil and solute particles which reaches the river water as nonpoint sources.The graphical representation of chloride distribution is shown in fig.3.(h).This shows that the chloride content is within desirable limit. The higher concentrations at P5, P6 and P7 may indicate pollution by sewage and industrial waste.

Total Hardness

The concentrations of total hardness obtained during the study period are given in table 2.The variation of total hardness in the study area is shown in fig.3.(i). It is quite evident that there is a significant increase in the total hardness in the downstream area which could be due to the nature and composition of soil particles suspended in the water. Total hardness is low at P1 (60 mg/L) in May and maximum at P5 (232 mg/L) in the March.

Calcium

The concentration of the calcium showed variation both spatially and temporally. This is caused due to the deposition of minerals.The variation of calcium along the course of the river from Kolhapur to Ichalkaranji is shown in fig.3.(j). From the figure it is evident that from sampling point P4 to P7 values exceeds desirable limit. This may be due to deposition of minerals due to industrial, residential and agricultural discharges.

Sodium

Sodium is always present in natural waters. It is also an essential dietary requirement in very small quantity. The sodium concentration along the river is shown in table 2. It ranges from 3.19 to 89.77mg/L. This sudden increase and decline of sodium content is referred to hydrological changes resulted from rainfall and discharge characteristics. The variation of sodium along the course of the river is shown in fig.3.(j). The peak of sodium concentration observed at P5 in March, April and May months could be due to sewage and runoff characteristic which indirectly influences the water quality parameters.

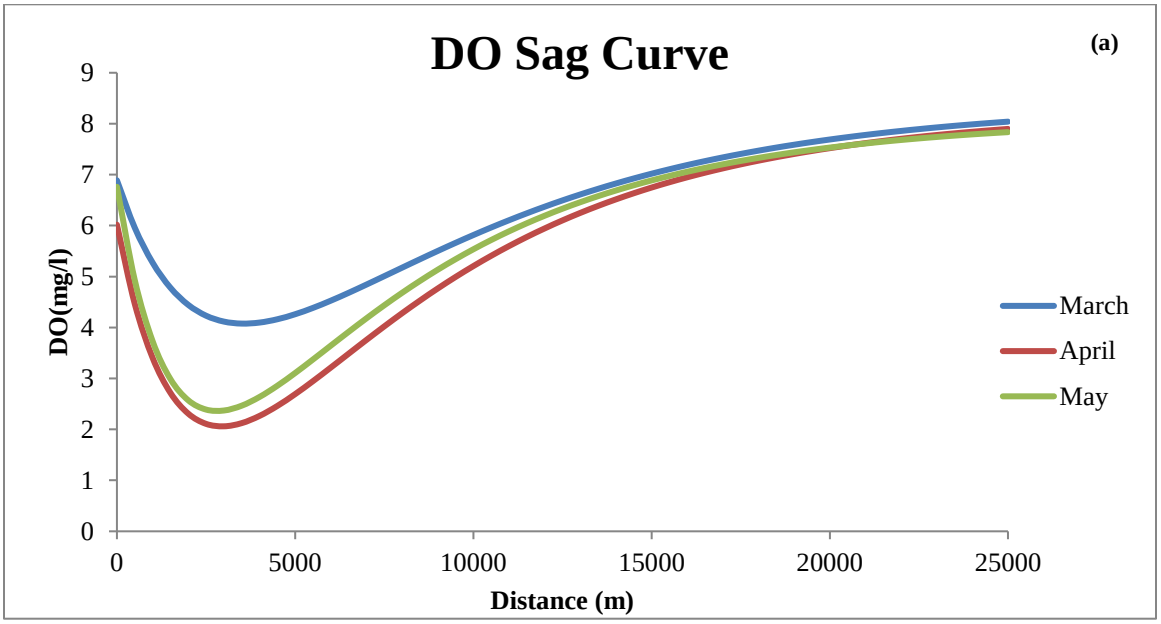
Potassium

Potassium is present in geological formations. In spite of high concentration of sodium in the river water, it is recorded that the potassium content is found to be very low in all months. This kind of character of ions indicates the source of sodium as natural rocks and soil type whereas potassium is contributed mainly through non-point sources, particularly from agricultural lands. High concentration is observed in March. The lowest potassium content is recorded at P5 in April and highest content is recorded at P4 in March. Leaching of artificial fertilizer is may be the reason higher concentrations(fig.3.(k) of potassium.

DO sag curve

The DO sag curves were developed for Panchganga River where the industrial wastes discharges into the main stream. There was

discharge of 2 MLD of wastewater from MIDC Shiroli, Kolhapur(P3). The observed BOD discharge is of wastewater found to be 900, 932 and 998mg/Lfor the months March, April and May 2019 Respectively. And from Ichalkaranji Nallah (P5) 1.5 MLD of wastewater is discharged into the river and BOD load of 810, 865 and 912mg/L for the months March, April and May 2019 Respectively. The observed values are abnormally high. Once they joined the main stream, the DO showed significant fallwhich is shown below(Fig4).



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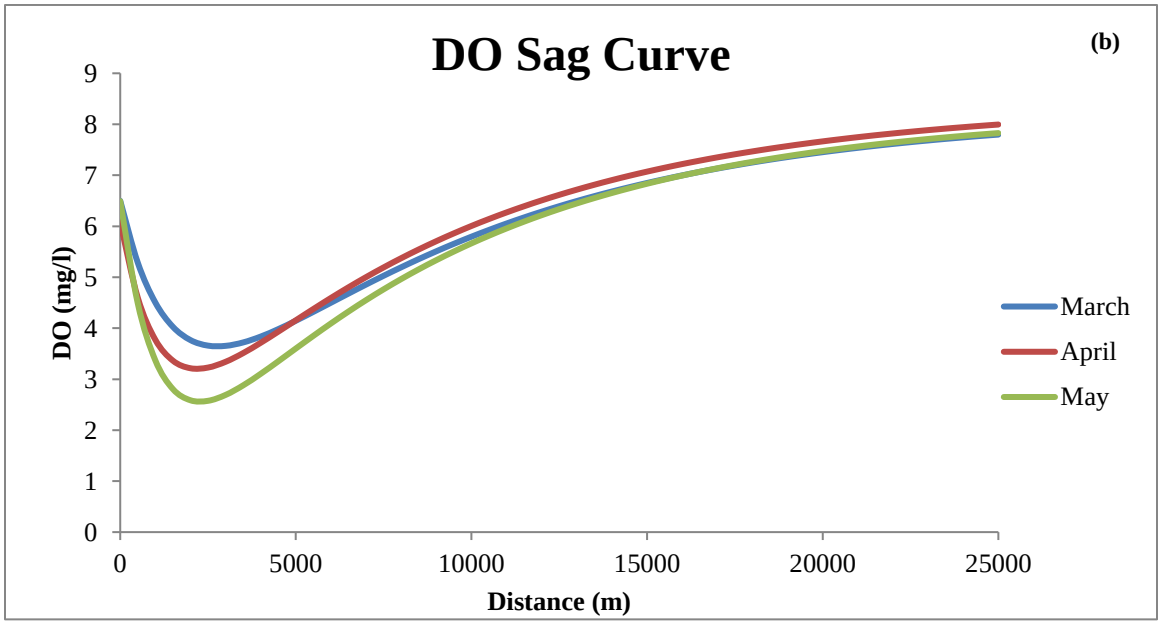

Fig.4: DO sag curve for (a)MIDC Shiroli, Kolhapur, (b)Ichalkaranji Nalla.

Table3: Desirable limit as per IS10500-2012

Parameters	**IS10500-2012(Desirable limt)**
pH	6.5-8.5
Turbidity(NTU)	5
TDS(mgL^{-1})	500
Chlorides(mgL^{-1}) as Cl	250
Total hardness(mgL^{-1}) as $CaCO_3$	300
Calcium (mgL^{-1})	75
DO(mgL^{-1})	Should not be less than 4
Potassium(mgL^{-1})	

Table 4 Water quality criteria based on Bhargava Water Quality Index

Criteria	**Range of values**
91-100	Excellent
71-90	Good
51-70	Fair
41-50	Marginal
<40	Poor

Table 5: Water quality Index

Month	Sampling Points						
	P1	P2	P3	P4	P5	P6	P7
March	84	83	68	56	45	61	63
April	86	81	65	58	46	63	58
MAY	76	78	70	50	41	56	67

The DO concentrations 500 m upstream from the point of discharge of Kolhapur MIDC effluent were 6.89, 6.02 and 6.76mg/L. At the point of discharge of waste, the DO concentrations were 6.15, 4.98 and 5.62 mg/L months March, April and May respectively. The critical DO concentrations of 4.14, 2.66 and 3.03mg/Lwere observed at critical distances4475, 3773 and 3924 m downstream from the discharge point respectively.

The DO concentrations 500 m upstream from the point of discharge of Ichalkaranji Nallah were 6.50, 6.07 and 6.57mg/L. At the point of discharge of waste, the DO concentrations were 5.72, 5.18 and 5.38 mg/L months March, April and May 2019 respectively. The DO concentrations decreased to critical value of 3.94, 3.68and 3.23mg/L at 4019, 3122 and 3396 m which is the critical distance downstream from the discharge point. The DO concentration increases as flow takes along the distance.

4.13 Water Quality Index(WQI)

Water Quality Index (WQI) is going decide the suitability of the water for different purpose. It is very important to specify the purpose before the analysis. In the present study WQI is calculated based on the 8 water quality parameters namely pH, turbidity, total dissolved solids (TDS), , chlorides, total hardness,

calcium, DO, potassium. The weights are assigned based on the important parameter for the particular use. The desirable limit for the drinking purpose is shown in Table 3. The Bargavas (Bhargava 1983) method is used for the calculation of water quality index as it is very simple and more easy towards analyzing water quality for various purpose. The water quality criteria for drinking purpose is shown Table 4 and the calculated water quality Index is shown in Table 5. It is observed that water quality at P4, P5 and P6 are not acceptable with the some parameters. This may be due to the industrial discharge points and also during the may month the water quality is not acceptable, due to the heavy rain fall before the sampling.

CONCLUSIONS

This study investigated the physico-chemical and dissolved oxygen sag of Panchganga River which is polluted by various sources. The discharge of industries, agricultural chemicals and domestic sewage are the main sources of pollution.

From the study, the following conclusions were drawn:

- The water quality parameters have been observed during study period of March, April and May 2019. Turbidity, calcium and alkalinity showed very higher values at P4, P5, P6 and P7, which are more than desirable limit in all three months at downstream. Whereas total hardness exceeded desirable limit only at P5 in the month of March.
- It is noticed that there is a significant change in water characteristics as the river flows from Kolhapur to Ichalkaranji. Water pollution increases in Ichalkaranji area due to sewage and textile mill waste disposal in river without treatment.
- The DO concentrations of Panchganga River in upstream area of Kolhapur (P3) were 6.89, 6.02 and 6.76mg/L and in upstream of Ichalkaranji (P5) were 6.50, 6.07 and 6.57mg/L for months March, April and May 2019 Respectively. These concentrations were fit for survival of aquatic life.
- The critical DO concentrations for MIDC Shiroli, Kolhapur were 4.14, 2.66 and 3.03mg/L at critical distances of 4475, 3773 and 3924 mand for Ichalkaranji Nallah critical DO were 3.94, 3.68 and 3.23 mg/L at 4019, 3122 and 3396 m respectively.
- Finally, the WQI confirms the zone of pollution and are P4, P5, P6 respectively.

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