e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

PANCHGANGA RIVER POLLUTION: A CASE STUDY

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ABSTRACT

The Panchganga River is a lifeline for the residents of Kolhapur, Ichalkaranji, and numerous villages. This paper is a case study on Panchganga River pollution, which was researched by various authors from 2009 to 2020. The authors looked at a variety of physicochemical, nutritional, gravimetric, titrimetric, and microbiological characteristics during the study, which revealed that two of largest cities Kolhapur and Ichalkaranji beside the river, are the point sources of pollution. The presence of very low to high DO, as well as a wide range of BOD, high COD, turbidity, and TDS, as well as MPN, Faecal Coliforms, and Total Coliforms, indicates water contamination as the values exceeds BIS, MPCB, CPCB and WHO Standards. Lead (BDL), Cadmium (0.018 to 0.021 mg/L), Zinc (0.042 to 0.078 mg/L), Nickel (0.337 to 0.366 mg/L), Chromium (2.21 to 2.27 mg/L), Manganese (0.190 to 0.212 mg/L), and Iron (0.578 to 0.597 mg/L) were analyzed using Atomic Absorption Spectrophotometer (AAS) in 2015. Cadmium, Nickel, Chromium and Iron were higher than the BIS surface water standards (IS 22296) and BIS Drinking water standards (10500:2012) while Manganese levels were found to be greater than BIS drinking water standards (10500:2012) but below acceptable limits for surface water standards (IS 22296).

Keywords: Panchganga River Pollution, Heavy Metals, Physico-Chemical Parameters, Industrial Effluent Discharge.

I. INTRODUCTION

Water is an essential resource for life's long-term survival. Although the Earth holds a vast amount of water, the percentage of potable water is extremely low [9]. The amount of drinkable water required for human survival is only 1%. In several countries around the world, the riverine system is one of the most important sources of water supply. It serves drinking, agricultural, industrial, and other uses with water [41]. Water is required for a variety of purposes, the most important of which is drinking [42]. As it moves downstream from a river's source, the water is generally pure. The riverine systems in India are becoming increasingly polluted, which is a severe concern. Yohannes. H [53] stated the rivers around the world have become contaminated as a result of sewage, domestic waste, industrial, and agricultural effluents. Aquatic pollution is a primary cause of the Industrial Revolution, and it has a direct or indirect impact on floral and faunal incapacitation and utter degeneration. Any alteration in the physical, chemical, or biological qualities of water that has a deleterious effect on living organisms is referred to as water pollution [54]. Water contamination is the leading cause of a variety of waterborne diseases around the world, especially in underdeveloped countries. Because of its long-term repercussions, polluted water not only affects the lives of current and future generations.

The Fig 1 depicts the various sources that leads to the river pollution. It is due to the rapid urbanization, industrialization that leads to the generation of the waste. The various anthropogenic activities like washing clothes, agricultural runoff, domestic waste discharge, discharge of effluent from industries and wastewater treatment plants in the rivers that leads to the river pollution.

India is known for its culture, values, and traditions. The country is famed for its rich legacy and is on the road to becoming a developed nation. There are eight major rivers in India: The Indus, Brahmaputra, Ganga, Yamuna, Narmada, Tapi, Godavari, and Krishna, as well as numerous minor rivers that flow throughout India [44]. The river is referred as "Mata," or Mother, and hence holds a special place in people's minds and hearts. Because the water is regarded as clean, it is used for a variety of religious purposes. Water is also used for drinking, cleaning, electrical generation, industrial and agricultural purposes [19].

Maharashtra is the third-largest state by area and the second-largest by population. Maharashtra is home to three main rivers: The Krishna, Godavari, and Tapi. According to the CPCB (Central Pollution Control Board) Report for the studies of impact of lockdown on the major rivers, Many industries, such as leather, thermal, chemical, and fertilizer plants, are located along the Krishna River's bank [13]. The Krishna Basin contains a

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variety of significant minerals such as gold, diamonds, coal, iron, laterite, uranium, granite, dolomite, limestone, and oil and gas. The right bank tributaries of the Krishna River include Panchganga, Kundali, Venna, Koyna, Dudhganga, Ghataprabha, Mataprabha, and Tungabhadra, while the left bank tributaries are Bhima, Dindi, Peddavagu, Musi, Paleru, and Munneru [13].

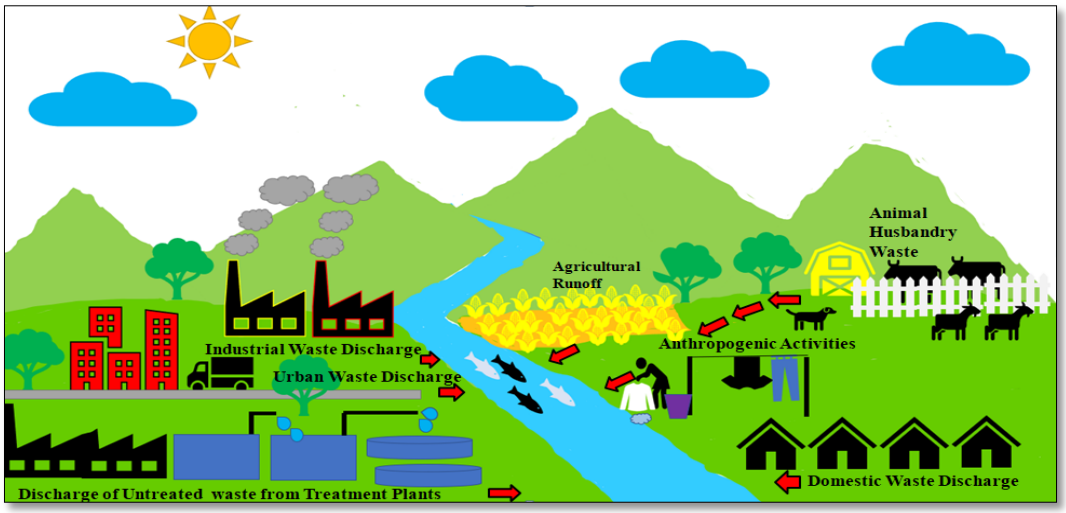

Fig 1: Sources of River water pollution

The Panchganga River in Kolhapur is the primary river, flowing 136 kilometres across the district until meeting the Krishna River near Narasobawadi. The Panchganga river has its source in Prayag Chikhli, Kolhapur, Maharashtra, India, between 16°31'N and 74°36'E as per studies by Panhalakr. S [37]. The Panchganga River is formed by the confluence of four rivers: The Kasari, Kumbhi, Tulsi and Bhogawati [17]. The river flows for 81 kilometres (30 miles), continuing in a vast pattern till it reaches Kurundwad, where it joins the Krishna River. The discharge of home sewage and industrial effluents has polluted the river. According to the MPCB Report for the clean-up of polluted Panchganga River [35] , the River has 21 drains, 12 of which are from Kolhapur Municipal Corporation (Lakshtirthvasahat, near Khanvilkar Petrol Pump, Dudhali, Near Mahadev Temple, Juna BudhwarPeth, near CPR Hospital, Backside of Tarabai Park, New Palace area, near Ramanmala Javedkar Scheme, Line Bazaar, GolibarMaidan, and Bapat Campus), 2 from Ichalkaranji Municipal while the remaining drains are from Gadhinglaj, BirdevMandir, Tilawani, Kabnur, Hupri, Shirdon, and Shirol (Gadhinglaj, BirdevMandir, Tilawani, Kabnur, Hupri, Shirdon, and Shirol).

The current state of the Panchganga River can be attributed to a number of reasons, such as industrialization near river, particularly sugar, textile, and sizing industries, and discharge of untreated effluents into river, which contain toxic chemicals and pose a risk when mixed with water [38]. Simultaneously, human inclinations such as depositing waste in rivers or on riverbanks in rural regions contribute to pollution [20]. Furthermore, washing clothing beside riverbanks is a regular problem, as detergents containing dangerous chemicals mix with the water and damage the river. Sewage discharges from several hospitals, as well as pathological laboratories. Vaishvadham Crematorium, near Prince Shivaji Bridge, and Bapat Camp Crematorium are the two crematoriums that have the most impact on river water quality [17]. The ash is thrown into the river water after the deceased bodies are burned as a ritual, forming a layer on the water surface. Rivers are also used to dispose of Nirmanlaya and idols. The quality of the water changes due to oil and grease content, as well as various petrochemical colours, which come from slaughterhouses, fish markets, and 2 and 4 wheeler service stations with high organic loads that are directly discharged into the nearby sewer, which eventually ends up in the river via nullahs. According to Tambekar. H [45], water contamination is also caused by sources such as hotels and restaurants.

Kamble. S [24] stated the other sources of pollution, such as industrial effluent from various small industrial facilities, foundries spray painting units in Udyamnagar, and tanneries from Jawahar Nagar, affect the river water quality. The quality of ground water is also affected by industrial wastewater. Farmers use chemical fertilizers, pesticides, fungicides, and herbicides for agriculture, and these chemicals, which contain strong

chemicals, slowly enter the river by running along with surface runoff water, polluting the water. Farmers are increasingly using chemical fertilizers, herbicides, and insecticides to boost sugarcane growth and revenue, which can contaminate river water during runoff [26]. This is taking place near the Panchganga River in order to quickly harvest cash crops. Excessive use, flooding, high rains, increased irrigation, and other factors cause chemical residues to mix into the river. Many pesticides and chemicals enter the food chain when they dissolve in river water. Excess and improper use of the pesticides have impact on environment and ecology [33]. Many vegetables and fruits have been shown to have dangerous pesticide residues. [18]. Fazal-ur-Rehman. M [16] stated the pollution has a greater impact on the spread of waterborne diseases such as jaundice, diarrhea, gastroenteritis, and other diseases, as well as human health. Even though the pesticides and insecticides are used regularly as they helps to keep crops, protect from pests and insects attack but in long term contact and use of pesticides, insecticides by humans have adverse effects on them as they are carcinogenic in nature which leads to various health issues in humans [32]

Heavy metals in the water, soil, sediment, and air are also a source of concern for living things because they are non-degradable and extremely stable in nature, which is a huge cause for concern because they can create serious health problems [10]. Their existence in living bodies is advantageous up to a point until they reach the limit set by national and international bodies, at which point they cause significant damage. Heavy metals enter the environment via a variety of sources, including sewage, agricultural runoff, industrial waste, and others [31]. Human activities and natural sources are responsible for the addition of heavy metals to the river body, which occurs as water pollution [2].

After a river body has been contaminated, it requires treatment, which might be natural or rely on contemporary technology. According to the Ramalho S.R [43], the natural way contains four zones of self-purification processes: "zone of degradation," "zone of active decomposition," "zone of recovery," and "clean water zone," whereas modern technology requires water treatment at the primary, secondary, and tertiary levels.

According to the Ghatage. R and Patil. B [17,40], the Kolhapur Municipal Corporation (KMC) has established 4 water treatment plants in and around the Kolhapur to treat the Panchganga river to provide water for drinking purpose for the people and their name are as Kalamba Water Treatment Plant which is having the capacity of 8 MLD that provide water to B ward of the city, Puikhadi Water Treatment Plant which is 14 km. away from the Shingnapur pumping station having the capacity of 50 MLD capacity to treat the water. Bawadais Water Treatment Plant that provides water to E ward and to 6 villages of eastern outskirts of city which was having the capacity of 36 MLD and Balinga Water Treatment Plant is provide the water from Bhogawati River by treating capacity of 41 MLD .

The Panchganga river is a key source of drinkable and agricultural water for Kolhapur and Ichalkaranji, as well as nearby villages, hence river pollution levels must be determined. May be due to untreated discharge of effluent in the river body, from the cities like Kolhapur and Itchalkaranji city, as per the review study by Jadhav. R [21]. Similar study by Devkar. P [14] revealed the major two cities as of Kolhapur and Ichalkaranji cities having various industries like sugar, textiles are responsible for river pollution. Industrial wastes, domestic sewage, and agricultural wastes all contribute to pollution, which affects not only people's health but also their lives [1]. As a result, the current review study is being carried out to determine the pollution state of the Panchganga River during a ten-year period from 2009 to 2020, which involves a detailed examination of several factors.

II. STUDY AREA

The samples were gathered by the authors from the Panchganga River from upstream, midstream, and downstream. The sampling location from 2009 to 2020 is included in the publication as Piral, Kolhapur-PanchgangaGhat, Kasaba Bawada, Shiroli, Rukdi, RuiIchalkaranji, Narsobawadi, and other areas were investigated.

III. SAMPLING SITES OF PANCHGANGA RIVER

Researchers, Private and Governmental agencies gathered samples from the Panchganga River from upstream, midstream, and downstream throughout the year from 2009 to 2020, with varying months and sampling

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durations as pre-monsoon, monsoon, and post-monsoon. Because the majority of the samples are collected from the same sampling location, the sampling locations are labelled with a "A" code on Google Map to avoid confusion and to aid in preparation and research. The sampling locations' latitude and longitude are listed in Table 1.

Table 1: Code with latitude and longitude of sampling location

Code	Sampling Location	Code	Sampling Location
A1	16°41'30.32"N, 74° 9'55.78"E	A9	16°43'2.66"N, 74°11'1.24"E
A2	16°45'41.59"N, 74°15'43.75"E	A10	16°44'10.05"N, 74°14'7.69"E
A3	16°42'43.81"N, 74°16'49.98"E	A11	16°36'26.38"N, 74° 6'50.61"E
A4	16°39'57.92"N, 74°28'32.64"E	A12	16°42'50.93"N, 74°20'16.00"E
A5	16°40'51.93"N, 74°30'29.59"E	A13	16°40'52.98"N, 74°23'39.00"E
A6	16°40'54.62"N, 74°34'33.24"E	A14	16°25'38.42"N, 74° 0'14.74"E
A7	16°41'30.62"N, 74°35'47.64"E	A15	16°40'22.79"N, 74°31'28.28"E
A8	16°42'24.07"N, 74°13'1.90"E	A16	16°43'17.70"N, 74°35'40.30"E

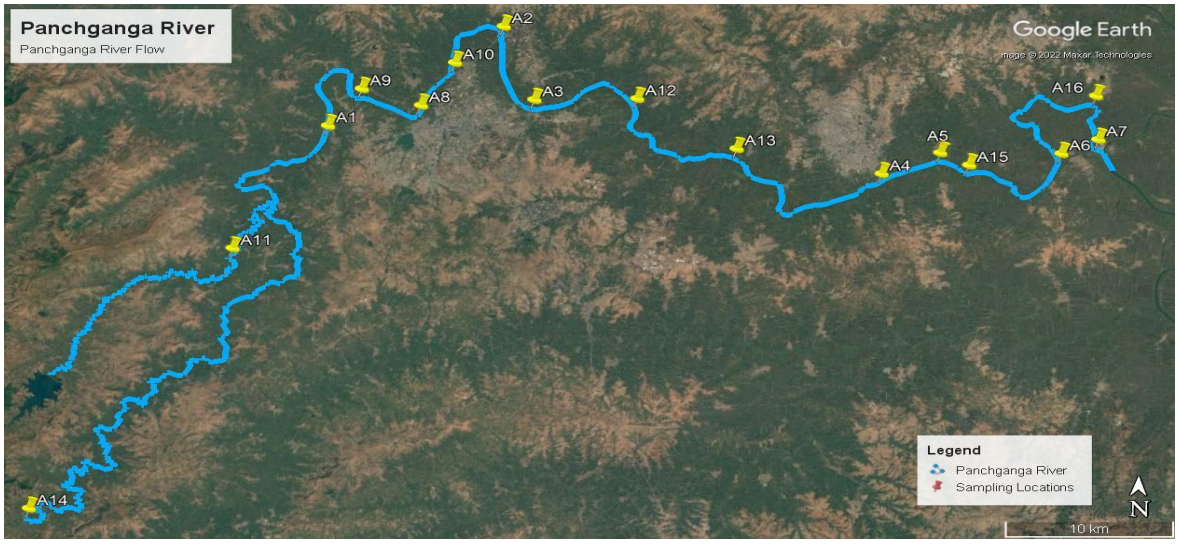

Fig 2: Sampling Locations during study of 2009 to 2020

Kolhapur and Ichalkaranji are the two cities that contribute the most pollution to the Panchganga River as per Jadhav. R [21]. The sampling at A8 and A13 showed that metrics like Turbidity, TDS, MPN, DO, and BOD exceed the BIS [6, 7 & 11], WHO [51,52] and CPCB [12] Standards limit. The pollution of various other parameters at the remaining locations varies because different authors conducted studies during different years and seasons, some of them exceed the limit while some are within the limit. Kolhapur and Ichalkaranji contribute to the river pollution. The pollution load decreases as it flows from the A8 and A13, which are near the Kolhapur and Ichalkaranji as shown in Fig 2. which are described further in result and discussion which was also reviewed by Jadhav. R [21]

The Fig 3 depicts the results of a study conducted by the researchers from 2009 to 2020. The 'B' code designates the pollutant-heaviest sampling site of the year. The sampling sites B-7, B-1, B-2, and B-12 are located near the Kolhapur location and are drained by effluent and sewage samples. Because most of India's textile industries are located in Ichalkaranji, it is known as the "Manchester of India." The main source of pollution in B-3, B-4, B-5, B-6, B-8, and B-11 is effluent discharge from textile industries. B-9 and B-10 are near Shirol, and Shiradawad is contaminated by sewer pollution.

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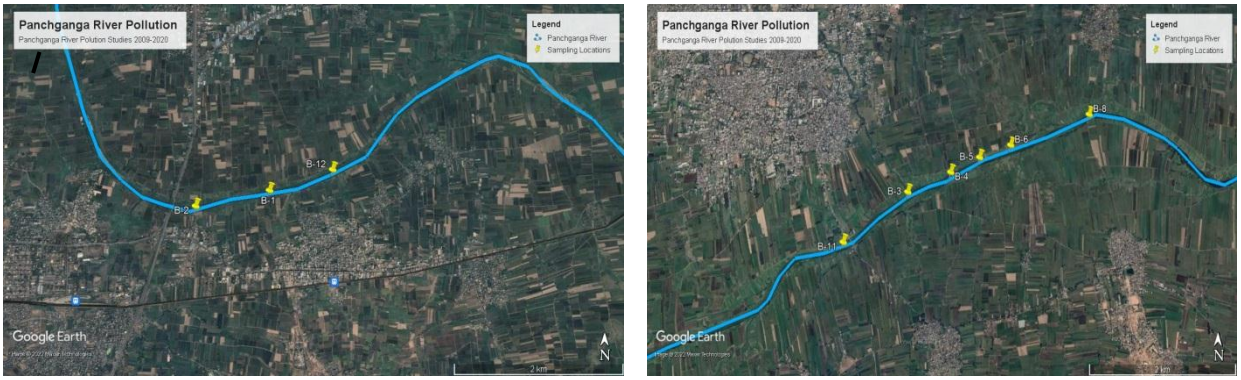
Fig 3: Sampling Location from upstream to downstream of Panchganga River for the study from 2009 to 2020



a b

Fig 4: (a) and 4 (b) represents the zoomed sampling locations from fig 3

IV. MATERIAL AND METHODOLOGY

For the years 2009 to 2020, water samples were collected from upstream, midstream, and downstream of the Panchganga River during pre-monsoon, monsoon, and post-monsoon. The authors measured pH with a pH metre, EC with a conductivity metre, TDS and TSS with a gravimetric method, DO with a Wrinkler's idometric method, Total Hardness with an EDTA method, Total Alkalinity with a Simple Titration method, Free CO2 with a Simple Titration method, Phosphate with a Molybdophosphoric Blue Color Method, Nitrate Brucine method, For their analysis, the writers consulted several APHA Editions as 1998[3], 2005 [5] , 2012 [4], Trivedi and Goel (1984) [47] and Kodarkar (1992) [27].

Table 2: Parameters studied by the Authors, National and State agencies from 2009 to 2020

Sr. No.	Sample Code	Parameters	Authors
1	B1	pH, EC, TDS, Turbidity, DO, BOD, COD and WQI	Thorvat. R [46]
2	B2	Water Quality Index (WQI)	Mangalekar. S [29]
3	B3	Temperature, pH, TS, TDS, Free CO_2, T. Alkalinity, Hardness, PO_4, DO, NO_3 and Chlorides	Kamble. N [23]
4	B4	Temperature, pH, TSS, TDS, Free CO_2, T. Alkalinity, Hardness, PO_4, DO, NO3 and Chlorides	Kamble N A. [23]
5	B5	Temperature, pH, EC, TDS, Turbidity, DO, BOD, COD, Hardness, MPN, CO_2, T. Alkalinity, Chlorides and SO_4	Sunil Kamble [22]
6	B6	Temperature, pH, EC, TDS, Turbidity, DO, BOD, COD, Hardness, MPN, CO_2, T.	Sunil Kamble

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		Alkalinity, Chlorides, and SO_4	[22]
7	B7	pH, EC, TDS, DO, BOD, COD and Heavy metals	Dhawal J S. [15]
8	B8	pH, DO, BOD, COD, FC and TC	MPCB Report [35]
9	B9	Temperature, pH, TDS, Acidity, DO, BOD, COD, CO_2, T. Alkalinity, PO4, NO_3 and Chlorides	Kamble S P. [23]
10	B10	pH, DO, BOD, COD, FC and TC	CPCB Report [13]
11	B11	pH, EC, TDS, Acidity, Turbidity, Alkalinity, Chlorides, Total Hardness, Cal, Na, K and WQI	Patil. C [39]
12	B12	Temperature, DO, pH, EC, BOD, N-NO3, N-NH3, TC, FC, COD, TKN, TDS, TFS, TSS, Turbidity, Hardness, Fluoride, B, Chlorides, SO4, T. Alkalinity, P. Alkalinity, Na, K, Cal, Mg, PO4 and Faecal Streptococci	MPCB Report [34]

V. RESULT & DISCUSSION

Table 3 depicts the Karl Pearson Correlation of various physicochemical, gravimetric, nutritional, inorganic parameters with four sampling station in 2020. The sampling locations are chosen by the MPCB in 2020. Temperature has a strong positive correlation with pH, Nitrate, and COD, while with Calcium just have positive correlation. Demand parameters such as DO have a positive correlation with N-Ammonia. pH was found to have a strong positive correlation with COD. Electrical conductivity (EC) has a strong positive correlation with Nitrate, as well as gravimetric and inorganic parameters such as TDS, TFS, Hardness, Chloride, Sulphate, Total Alkalinity, Sodium, Potassium, Calcium, and Magnesium. Faecal Coliforms have a positive correlation with microbial analysis such as MPN. Nitrate was shown to have a strong positive correlation with Total Hardness and Calcium, as well as positive correlation with COD, TDS, TFS, Nitrate, Magnesium, and Sulphates. It was discovered that Nitrate and Chlorides have the best positive association. Ammonia is one of the form of nitrogen where TKN represents the all the forms of the nitrogen which is having strong positive association. Total coliforms and faecal coliforms were found to have a positive correlation. Fluoride has the strongest positive correlation with the TKN.

Parameters like Total Hardness, Chloride, Sulphates, Alkalinity, Sodium, Potassium, Calcium, and Magnesium, all had a strong extremely positive correlation with TDS and TFS. TDS was found to have a strong positive connection with TFS. Suspended particles in water samples also contribute to the turbidity that can be measured with a nephlometer. TSS and Turbidity were found to have a strong positive correlation. Hardness is caused by the presence of Calcium and Magnesium Carbonates in the sample, which exhibited a strong positive association with Hardness. Other parameters such as Chlorides, Sulphates, Alkalinity, Sodium, and Potassium also had a strong positive correlation with Hardness.

Due to the very favourable association of Chloride and Sulphates with Sodium, Potassium, Calcium, Magnesium, and Alkalinity, the creation of various salts in water samples can be analysed. Sulphates and Chlorides have a strong positive correlation. Cations such as Sodium, Potassium, Calcium, and Magnesium have a strong positive association with total alkalinity. Cations such as Sodium have a strong positive correlation with other cations such as Potassium, Calcium, and Magnesium, while Potassium has a strong positive correlation with Calcium and Magnesium. Other cations, such as Calcium and Magnesium, have a similar relation to Potassium and Calcium and Magnesium.

Thorvat. R [46] sampled the Panchganga River in 2009-10 and found the pH to be in the range of 5.3 to 8.3. Three of the four sampling stations had pH values that were within the BIS requirements (10500:1991) [7], however the pH ranged from acidic to alkaline. The average pH concentrations at sampling stations I, II, III, and IV were 6.38, 7.29, 7.36, and 7.44, respectively. The electrical conductivity (EC) was found to be high, ranging from 140 to 772 mhos/cm. EC concentrations were 436.70 mhos/cm on an average. Temperatures in the research ranged from 29 to 39^{o}C. When compared to the BIS standard (10500:1991) [7], total dissolved solids as TDS in mg/L ranged from 46 to 476 mg/L, which was within the limit. TDS levels in the water samples averaged 195.16 mg/L. The turbidity ranged from 4 to 28 NTU, which was determined to be greater than the

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BIS guidelines. DO and BOD are crucial parameters for water bodies because they provide the required oxygen for aquatic biota. They were found to be in the range of 3 to 7.9 mg/L and 2.40 to 11.60 mg/L, respectively, which was greater than the BIS limit for a few stations. The Chemical Oxygen Demand ranged from 13 to 58 mg/L, which was greater above the BIS guidelines. According to the author due to huge number of agricultural, municipal, and industrial wastewater entered the river Panchganga through numerous drains and nallahs which led to the deteriorating the quality of river water due to a lack of suitable land and full-fledged treatment facilities.

Table 3: Karl Pearson Correlation study for the various parameters of sampling location carried out by MPCB during 2020

	Temp	DO	pH	EC	BOD	NO3	NH3	TC	FC	COD	TKN	TDS	TFS	TSS	Turb.	TH	F	Cl	SO4	TA	Na	K	Cal	Mg	PO4
Temp	1																								
DO	0.06	1																							
pH	0.97	0.26	1																						
EC	0.51	0.34	0.48	1																					
BOD	0.43	-0.86	0.22	0.07	1																				
NO3	0.90	-0.01	0.82	0.79	0.51	1																			
NH3	0.01	0.80	0.23	-0.23	-0.80	-0.30	1																		
TC	-0.60	-0.83	0.75	-0.52	0.46	-0.47	-0.67	1																	
FC	-0.21	-0.93	0.43	-0.12	0.78	0.01	-0.94	0.87	1																
COD	0.99	0.20	0.99	0.57	0.30	0.89	0.11	0.71	-0.33	1															
TKN	-0.43	0.70	0.21	-0.42	-0.91	-0.66	0.90	0.35	-0.76	-0.33	1														
TDS	0.54	0.34	0.50	1.00	0.09	0.81	-0.23	0.53	-0.12	0.60	0.43	1													
TFS	0.53	0.33	0.50	1.00	0.09	0.80	-0.23	0.52	-0.12	0.59	0.43	1.00	1												
TSS	-0.72	-0.22	-0.81	0.11	-0.05	-0.34	-0.55	0.60	0.55	-0.72	0.19	0.09	0.10	1											
Turb.	-0.66	-0.41	-0.79	0.06	0.15	-0.29	-0.69	0.73	0.71	-0.69	0.34	0.04	0.04	0.98	1										
TH	0.69	0.23	0.64	0.97	0.24	0.91	-0.26	0.54	-0.08	0.73	0.53	0.98	0.98	0.06	-0.08	1									
F	-0.25	0.16	0.11	-0.83	-0.42	-0.65	0.71	0.04	-0.44	-0.25	0.75	0.83	0.83	0.49	-0.52	-0.80	1								
Cl	0.51	0.37	0.48	1.00	0.04	0.78	-0.20	0.54	-0.15	0.57	0.39	1.00	1.00	0.10	0.04	0.97	-0.82	1							
SO4	0.56	0.35	0.52	1.00	0.08	0.81	-0.21	0.55	-0.14	0.61	0.42	1.00	1.00	0.06	0.01	0.98	-0.82	1.00	1						
TA	0.66	0.28	0.62	0.98	0.18	0.89	-0.23	0.55	-0.11	0.70	0.49	0.99	0.99	0.04	-0.07	1.00	-0.80	0.98	0.99	1					
Na	0.59	0.37	0.57	0.99	0.07	0.83	-0.17	0.59	-0.18	0.65	0.40	1.00	1.00	0.01	-0.05	0.98	-0.78	0.99	1.00	0.99	1				
K	0.44	0.57	0.47	0.97	-0.19	0.67	0.01	0.67	-0.35	0.53	0.17	0.96	0.96	0.06	-0.04	0.90	-0.69	0.97	0.96	0.93	0.97	1			
Cal	0.75	0.16	0.69	0.94	0.32	0.95	-0.29	0.52	-0.04	0.78	0.58	0.95	0.95	0.13	-0.13	0.99	-0.78	0.94	0.95	0.99	0.96	0.86	1		
Mg	0.64	0.41	0.63	0.98	0.05	0.84	-0.10	0.65	-0.25	0.71	0.36	0.99	0.98	0.08	-0.14	0.98	-0.73	0.98	0.99	0.99	1.00	0.96	0.96	1	
PO4	0.10	-0.55	0.07	-0.78	0.40	-0.23	0.06	0.34	0.20	0.00	0.00	0.76	0.77	0.53	-0.39	-0.61	0.66	-0.79	0.75	-0.66	0.73	0.84	0.52	0.69	1

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(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

Mangalekar. S [29] measured the Water Quality Index (WQI) of the Panchganga River water samples in 2010, and found it to be 48.60, indicating low quality. The WQI ranged from 41 to 49, 46 to 54, and 44 to 55 during summer, monsoon, and winter sampling, respectively. Summer, monsoon, and winter average WQIs were 45.80, 50.60, and 49.40, respectively. Only the WQI for river samples was found to be marginally good quality during the monsoon season. The Panchganga River is polluted due to the discharge of untreated sewage and industrial effluents into the river which also led to various water borne diseases.

Mangalekar. S[30] conducted sampling throughout pre-flood and post-flood periods in 2011, with pH ranging from 7.5 to 7.8 in pre-flood and 7.6 to 7.9 in post-flood. The pH was within BIS guidelines (10500:2005) [11]. During pre-flood and post-flood, TDS levels varied from 123 to 199 mg/L and 211 to 300 mg/L, respectively, which was within acceptable limits. The turbidity of pre-flood water samples ranged from 1.2 to 3.3 NTU, while post-flood water samples ranged from 1.8 to 5.5 NTU, which was greater than the limit at a few test sites. Hardness was determined to be 45 to 94 mg/L to 51 to 118 mg/L during pre-flood and post-flood, respectively, which was within the BIS limit. For microbiological analysis, the Most Probable Number was determined to be in the range of 0 to 11/100 ml and 2 to 25/100 ml during pre-flood and post-flood sampling, respectively, and was found to be greater than the BIS Standards during post-flood and at a few sites during pre-flood sampling. Average Pre-flood pH, TDS, Turbidity, Hardness, and MPN were 7.6, 161 mg/L, 74 mg/L, 2.1 NTU, and 4/100 ml, respectively, while post-flood pH, TDS, Turbidity, Hardness, and MPN were 7.8, 258 mg/L, 84 mg/L, 4 NTU, and 9/100 ml, respectively. According to the author, the variation in the studies is due to floods. Mangalekar. S [29] calculated a WQI of 45.67 for the year 2011, indicating poor water quality. Summer, monsoon, and winter WQIs are 40 to 47, 44 to 52, and 42 to 49, respectively. For 2011, the average value for the three seasons is 43.40, 47.80, and 45.80. Mangalekar. S stated the results obtained show the poor quality for the water which is due to the release of sewage and effluent into the river. Similar studies for several physicochemical and nutritional characteristics were carried out by Kamble. N [23] with pH ranging from 7.72 to 8.57, showing that the samples are neutral to alkaline. During the summer, the S5 sample exceeded the WHO Standards. The water samples ranged in temperature from 17.75°C to 28.62°C. The sample's Total Dissolved Solids (TDS) and Total Solids (TS) concentrations were 458 to 643 mg/L and 550 to 877 mg/L, respectively. The TSS have exceeded the WHO's limit. The DO ranged from 1 to 3.31 mg/L, which was below WHO Standards. CO2 levels were within WHO guidelines, while hardness levels ranged from 85 to 202 mg/L which was also within the limit. For a few sites, the total alkalinity used to determine carbonates ranged from 173.7 to 577.5 mg/L, which was beyond WHO criteria. Phosphate and nitrate levels were within the acceptable ranges of 0.26 to 1.10 mg/L and 4.23 to 8.46 mg/L, respectively. The concentrations of chlorides (17.75 to 96.91 mg/L) were found to be within WHO guidelines. The WQI was determined to be between 40 and 120, with an average score of 73.66, suggesting poor water quality. KMC (Kolhapur Municipal Corporation) [28] conducted the same study for WQI, which was prepared by TERI (Tata Energy and Resource Institute), TERI Report for sampling stations 1904 and 1905, which showed "Good to Excellent" water quality.

pH ranges from 7.40 to 8.75, according to a study conducted in 2012-13 by Kamble. N [23]. The pH level has surpassed the WHO standard. The temperatures in the samples ranged from 19.25 to 27.75 °C. The gravimetric parameters such as TDS ranged from 463 to 750 mg/L, which is within the limit, and TS ranged from 622 to 875 mg/L, which is beyond the WHO guideline. The DO demand parameter ranged from 0.60 to 1.88 mg/L, which is well below the limit. Total Hardness, Total Alkalinity, and Total Chlorides titration parameters varied from 40 to 156 mg/L, 61.25 to 215 mg/L, and 11.36 to 56.88 mg/L, respectively, all within the limits. CO2 levels were found to be within the acceptable range, ranging from 6.24 to 21.22 mg/L. The spectrometric parameters of nitrate and phosphorus varied from 3.44 to 5.37 mg/L and 0.24 to 2.06 mg/L, respectively, which were below WHO guidelines. The physicochemical parameters clearly showed that some monitoring locations along the river Panchganga were the least polluted, but were nonetheless classified as a continually polluting zone. Pollution can come from a variety of sources, including direct discharge through a variety of drainage outlets, untreated effluent discharge, agricultural runoff, and home activities. Mangalekar. S [29] calculated a WQI of 42.93 in 2012, indicating low water quality. Summer, monsoon, and winter temperatures range from 37 to 44, 43 to 50 and 39 to 48, respectively. Summer, monsoon, and winter shows average WQIs as 41.00, 44.60, and 43.20, respectively. The TERI report [28] for the WQI of the KMC Report for 2012-13 reveals a "Good to

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

Excellent" range for sample locations 1904 and 1905, which represent upstream and downstream of the Panchganga river, respectively.

Kamble. S [22] sampling and analysis in 2013-14 revealed air and water temperatures ranging from 21.1 to 28.2 °C and 21.6 to 25.8°C, respectively. The pH and EC range from 7.4 to 7.9 and 1640 to 1820 mho/cm, respectively. Alkalinity was found to be in between 133 and 170 mg/L. The turbidity was found to be between 16 and 48 NTU. TDS and Hardness were determined to be between 1014 and 1584 mg/L, with 642 to 702 mg/L being above the limit. The concentrations of chlorides and sulphates were 124 to 286 mg/L and 100 to 144 mg/L, respectively. DO, BOD, COD, and CO2 demand values ranged from 3.2 to 7.6 mg/L, 0.1 to 12.8 mg/L, 6 to 39.2 mg/L, and 0.1 to 0.4 mg/L, respectively. Microbiology studies parameter like MPN was determined as 14 to 65/ 100 ml. The study revealed that the addition of Microbes, human wastes, and pathogens have contaminated the Panchaganga River, making it extremely filthy. Sewage, industrial waste dumping, and other pollutants have also polluted the river. The WQI Report [28] of KMC prepared by TERI for 2013 -14 of Panchganga River WQI for 1904 and 1905 station reveals “Good to Excellent” quality of water throughout.

For the sampling stations of 1904 and 1905, the 2014-15 KMC by TERI report [28] for Panchganga River for WQI reveals "Good to Excellent" water quality standards. According to a study conducted by Kamble. S [22] in 2014-15, the pH and EC were 7.4 to 7.8 and 1648 to 2260 mho/cm, respectively. During 2014-15, titration parameters such as alkalinity, hardness, and chlorides ranged from 134 to 158 mg/L, 644 to 704 mg/L, and 128 to 288 mg/L, respectively. The air and water temperatures were found to be 21.4 to 27.2°C and 22 to 25.9°C, respectively. The turbidity ranged from 19 to 50 NTU. Total Dissolved Solids (TDS) were ranging from 1020 to 1592 mg/L. Sulphates are found in concentrations ranging from 108 to 148 mg/L. DO, BOD, COD, and CO2 levels were found to be 3.4 to 7.9 mg/L, 0.1 to 20 mg/L, 8 to 42.4 mg/L, and 0.1 to 0.4 mg/L, respectively. The MPN for water samples ranged from 15 to 68/100 ml. The study during 2014 shows the Panchganga River is polluted due to the release of the untreated sewage, effluent, human waste and others detritus waste

Dhawal. S [15] studied the analysis in 2015-16. Physical parameters such as pH and EC were found to be 7.08 to 8.28 and 220 to 880 mho/cm, respectively, which are within BIS requirements. BOD, DO, and COD levels were measured in 2015 and ranged from 3 to 31 mg/L, 2.80 to 5 mg/L, and 10 to 41 mg/L, respectively. The DO, BOD, and COD values were not determined to be in the range of the BIS limit (10500:1991) [7]. The variation in the physico-chemical characteristic of the water due to the anthropogenic activities as per the study conducted by Dhawal. S [15]. Heavy metals such as Lead (BDL), Cadmium (0.018 to 0.021 mg/L), Zinc (0.042 to 0.078 mg/L), Nickel (0.337 to 0.366 mg/L), Chromium (2.21 to 2.27 mg/L), Manganese (0.190 to 0.212 mg/L), and Iron (0.578 to 0.597 mg/L) were measured using an Atomic Absorption Spectrophotometer (AAS). Cadmium, Nickel, Chromium and Iron exceeded the limit (IS 22296) [8] and BIS (10500: 2012) [6] while Manganese levels were found to be greater than BIS (10500:2012) [6] but below acceptable limits for surface water (IS 22296) [8]. Mulla. R [36] examined several physicochemical parameters in 2015-16, finding pH and temperature to be in the range of 6.7 to 7.9 and 20^{o}C to 23.4^{o}C. DO, BOD, and COD demand values ranged from 6.7 to 8 mg/L, 6.6 to 8.2 mg/L, and 14.9 to 21.1 mg/L, respectively. The presence of heavy metals in the Panchganga river is due to the human activities like urbanization and industrialization. The value of DO, BOD, and COD in contrast to the standards ranged from low to high. The TDS was found to be between 145 and 215 mg/L. The TERI's WQI Report [28] for KMC reveals "Good to Excellent" water quality for sampling stations in 1904 and 1905.

According to the Action Plan for Clean-up of Polluted Stretch of Panchganga River [35], investigations conducted in 2016 at Kolhapur for Panchganga River found that pH ranged from 6.9 to 8.1, indicating that the samples were neutral to alkaline in character. DO is measured in 4.5 to 7 mg/L; BOD is measured as 2 to 3.2 mg/L and COD as 16 to 40 mg/L. For MPN/100 ml of samples, microbiological analysis as Faecal Coliform (FC) and Total Coliform (TC) as NA. The pH of the Panchganga River in Shirol was 6.8 to 8.3, with DO, BOD, and COD levels ranging from 4.8 mg/L to 7.2 mg/L, 2 to 5.2 mg/L, and 20 to 48 mg/L, respectively. NA for MPN/ 100 ml of samples for Faecal Coliform (FC) and Total Coliform (TC). DO and BOD values ranged from low to high for both sampling locations, whereas COD was over the limit.

Table 4: WQI of Panchganga River in Kolhapur City (2011-2016)

March	**81**	**79**	**Dry**	**Dry**	**78**	**83**	**78**	**Dry**	**Dry**	**81**

e-ISSN: 2582-5208
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February	79	85	57	63	58	78	82	64	62	55
January	69	77	75	Dry	72	64	77	71	Dry	75
December	75	79	84	Dry	77	75	83	79	Dry	72
November	82	81	72	62	67	82	75	65	65	69
October	84	85	34	64	81	62	85	Dry	64	78
September	86	84	84	67	75	84	85	85	61	77
August	80	84	84	65	81	76	85	72	64	79
July	64	83	77	65	77	64	72	67	64	77
June	80	81	88	66	80	77	87	71	64	82
May	Dry	79	83	64	72	87	73	82	66	74
April	80	77	83	44	81	84	74	77	41	80
Final Year	11-12	12-13	13-14	14-15	15-16	11-12	12-13	13-14	14-15	15-16
Sampling Station	**Panchganga River at U/s of Kolhapur town near Balinga Pumping Station**					**Panchganga river at D/s of Kolhapur town at Gandhi nagar near NH-4 bridge and MIDC intake well**				
Station Code	**1904**					**1905**				
Sub-Basin	**Krishna Upper**									
Basin	**Krishna**									

Source – Kolhapur Municipal Corporation- Environmental Status Report 2015-16

The Table 4 represents overall water quality of the Panchganga River has been recorded as 'Good' to 'Excellent' for both water monitoring stations for the last 5 years. Throughout the year until 2012–13, the Monitoring Station near Balinga Pumping Station, upstream of Kolhapur city, registered WQI in the 'Good to Excellent' category. Following that, there was a decline in WQI until the year 2015–16, when there were five observations in the 'Medium to Very Bad' category. Throughout the year of 2012–13, the downstream station at Gandhi Nagar recorded WQI in the 'Good to Excellent' category. In 2014-15, two observations at the same site were classified as 'Medium to Good,' but only one was classified as 'Bad.' Almost all observations in 2015-16 fell into the 'Good to Excellent' category.

Table 5: Water quality Index of Surface water at Kolhapur during 2017-18, 2018-19 and 2019-20

Station Code	2017-18			2018-19			2019-20		
	April	Dec/Oct	Average	April	Dec/Oct	Average	April	Dec/Oct	Average
1311	51	56	69	87	90	84	88	82	85
1904	54	56	68	88	89	85	91	83	85
1905	50	56	72	86	87	83	87	83	85
2163	52	58	68	85	88	84	82	83	85

Source – Water Quality of Maharashtra Report by MPCB for the year 2017-18, 2018-19 and 2019-20

The study carried out by MPCB for the Panchganga river during 2017-18, 2018-19 and 2019-20 showed the quality of the water as "Good to Excellent" during 2020 which is represented in Table 5.

Table 6: Classification of Water quality indices for surface water

Colour Code	Good to Excellent	Medium to Good	Bad	Bad to Very Bad	Dry
WQI	63-100	50-63	38-50	38 and less	-
Remarks	Non Polluted	Non Polluted	Polluted	Heavily Polluted	-

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
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Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

Source- Water Quality of Maharashtra Report by MPCB for the year 2017-18, 2018-19 and 2019-20

The Table 6 represents the WQI which is determines the quality of the water shown by colour code:

Kamble. S [25] 2017-18 sampled and analysed Panchganga River samples and found temperatures ranging from 24.6 to 34.20°C. pH, Total Dissolved Solids, Acidity, Total Alkalinity, and Chlorides ranged from 6.64 to 7.94 mg/L, 218 to 586 mg/L, 206 to 312 mg/L, 146 to 358 mg/L, and 36.12 to 57.34 mg/L, respectively. Nitrates and phosphorus concentrations ranged from 0.121 to 0.32 mg/l and 72 to 142 mg/L, respectively. Free CO^2 was found in the range of 8.8 to 22.56 mg/L, while dissolved oxygen (DO) was found in the range of 1.24 to 5.82 mg/L. BOD and COD concentrations ranged from 6.68 to 48 mg/L and 35.86 to 124 mg/L, respectively. Anthropogenic activities like discharge of organic load, sewage, and industrial effluents, according to the author, cause the pollution in the Panchganga River. The Water Quality of Maharashtra 2017-18 Report [48] of MPCB by TERI shows that the average WQI for various sampling stations is "Good to Excellent." According to the Action Plan for Clean-up of Polluted Stretch of Panchganga River Report [35], the pH of water samples taken in Kolhapur in 2017 ranged from 6.8 to 8.2. DO, BOD, and COD have a range of 5.2 to 7.1 mg/L, 2 to 3.2 mg/L, and 16 to 40 mg/L, respectively. FC has a range of 13 to 65 MPN/100 ml, and TC has a range of 70 to 280 MPN/100 ml. While the pH of the Panchganga River sample taken near Shirol ranges from 6.8 to 8.3. DO, BOD, and COD were measured at 4.5 to 6.9 mg/L, 2 to 3.6 mg/L, and 20 to 48 mg/L, respectively, whereas FC and TC were measured at 7 to 94 MPN/100 ml and 46 to 350 MPN/100 ml, respectively. When compared to the BIS, the values for DO, BOD, COD, and TC ranged from low to high, while FC was high (10500:1991) [7].

According to the MPCB's Water Quality of Maharashtra 2018-19 Report [49], the average WQI for the Panchganga River is "Good to Excellent." The pH was 6.9 to 7.8, with FC and TC of 5 to 17 MPN/100 ml and 70 to 210 MPN/100 ml, respectively. According to the Action Plan for Clean-up of Polluted Stretch of Panchganga River Report [35] DO, BOD, and COD levels were determined to be 6 to 7.1 mg/L, 1.8 to 2.8 mg/L, and 16 to 32 mg/L, respectively. The pH ranged from 6.6 to 8 in a study conducted in Shirol for Panchganga sampling. DO, BOD, and COD concentrations were 5.5 to 7 mg/L, 1.8 to 3.6 mg/L, and 12 to 40 mg/L, respectively. The FC ranged from 5 to 17 MPN/100 ml, while the TC was 79 to 210 MPN/100 ml. During the 2018-19 research, the values were found to be low to high when compared to BIS norms. (10500:1991) [7].

Patil. C [39] in 2019 assessed the surface water of the Panchganga River, looking at a variety of physical, chemical, gravimetric, and titration parameters. pH levels ranged from 7.09 to 8.29. The turbidity and EC were measured as 1 to 16.1 NTU and 72.5 to 958.2S/cm, respectively. For a few samples, the turbidity was found to be higher than the norms. TDS levels ranged from 40 to 500 mg/L, which is well below BIS guidelines (10500:2012) [6]. Acidity and alkalinity were measured at 5 to 18 mg/L and 68 to 252 mg/L, respectively. The alkalinity level, vary from low to high, when compared to the BIS norms for Alkalinity (250 mg/L) and chlorides were within the range for (15.88 to 193.61 mg/L). Calcium, Sodium, and Potassium are measured as 28 to 136 mg/L, 3.19 to 89.77 mg/L, and 0.1 to 1.65 mg/L, respectively. The study show that the main causes of Panchganga River pollution are industrial discharges, agricultural chemicals, and home sewage. Because of water pollution, the WQI for a few sampling locations is not in the acceptable range, as a few parameters are beyond the limitations. According to the MPCB's Water Quality of Maharashtra 2019-20 Report [50], the average WQI index for Panchganga water is "Good to Excellent."

The Krishna River in Maharashtra was also analysed by the Central Pollution Control Board (CPCB) in September 23, 2020 for the Assessment of Impact of Lockdown on Water Quality of Major Rivers [13], as Panchganga River is one of the right tributaries of Krishna River. pH was 7 to 8.3, DO was 6 to 6.7 mg/L, BOD was 1.8 to 6.3 mg/L, and FC was 7 to 300 MPN/100 ml during the pre-lockdown period, but during the lockdown period, the values were changed to 7 to 17 MPN/100 ml and BOD as 1.5 to 1.6 mg/L. While other parameters remained the same, such as pH was 7.8 to 8.2, DO 6.6 to 6.7 mg/L, and. During pre-lockdown and lockdown, the FC was over the limits, while the BOD was low to high when compared with the standards.

The measurements of various parameters of four separate sample sites, 1311, 1904, 1905, and 2163, were reported in the MPCB Action Taken Report No.988/2018 (PB) of the Maharashtra Pollution Control Board [34]. The sample temperature for sampling location 1311 ranges from 23 to 33 °C. Several other physicochemical, gravimetric, and nutritional parameters were also analysed. DO was found to be 5.4 to 7.3 mg/L, whereas COD was 12 to 28 mg/L, both of which were above the limit. COD was in excess of the allowed amount. The pH and

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

EC were found to be within limits, ranging from 7.1 to 8.1 and 126 to 587 us/cm. Turbidity was measured in the BDL-1.1 NTU range. BDL to 1.12 mg/L and BDL to 0.28 mg/L, respectively, for nutrient parameters such TKN and Phosphate. TDS, TFS, and TSS values ranged from 86 to 398 mg/L, 72 to 352 mg/L, and 10 to 14 mg/L, respectively, above the MPCB limit. Cations such as sodium, potassium, calcium, and magnesium were found in concentrations of 3.3 to 32 mg/L, BDL to 6 mg/L, 28 to 106 mg/L, and 12 to 114 mg/L, respectively, whereas anions such as fluoride and chloride were found in concentrations of BDL to 0.15 mg/L and 9 to 70 mg/L, respectively. P-Alkalinity and Total Alkalinity were found to be NIL and 32 to 144 mg/L, respectively. Boron was not found in any of the samples. N-Nitrate and N-Ammonia concentrations ranged from 0.31 to 2.41 mg/L, with BDL at 0.38 mg/L. Sulphates and Hardness ranged from 40 to 220 mg/L and 14 to 112 mg/L, respectively. microbiological analyses like TC and FC had of 21 to 79 MPN/100 ml and 4.5 to 17 MPN/100 ml while Faecal Streptococci was below the range of 1.8 MPN/100 ml. TC ranged from low to high, but FC was high.

Temperature and DO were measured at 1904 and were found to be 23 to 31 °C and 6.2 to 7.2 mg/L, respectively. pH, EC, BOD, N-Nitrate, N-Ammonia, and Turbidity were found to be in the range of 6.5 to 8.2, 85 to 376 us/cm, 1.6 to 2 mg/L, 0.20 to 2.25 mg/L, BDL to 0.90 mg/L, and 0.5 to 2.6 NTU. The concentrations of TDS, TFS, and TSS were changed from 60 to 253 mg/L, 54 to 220 mg/L, and 10 to 14 mg/L, respectively. Anions such as Chloride and Fluoride were found in concentrations of 4 to 36 mg/L and 0.032 to 0.2 mg/L, respectively, while Cations such as Potassium, Sodium, Calcium, and Magnesium were found in concentrations of BDL to 3.2 mg/L, 1.5 to 13 mg/L, 20 to 90 mg/L, and 14 to 66 mg/L, respectively. The concentrations of Phosphate, Sulphates, Total Alkalinity and Hardness were measured as BDL to 0.24 mg/L, 2 to 32 mg/L, 30 to 94 mg/L, and 40 to 156 mg/L, respectively. Boron was not available in the samples and P-alkalinity was NIL. COD and TKN were discovered to be 8 to 28 mg/L and BDL to 1.12 mg/L. TC were 17 to 84 MPN/100 ml and FC were below 1.8 to 11 MPN/100 ml. Faecal streptococci were below 1.8 MPN/100 ml. The COD, TC, and FC ranged from low to high, all of which were found to be above the limit.

The DO and sample temperature were found to be 6 to 6.7 mg/L and 24 to 30°Cin the investigation at sampling location 1905. TDS, TFS, and TSS are measured in 86 to 243 mg/L, 74 to 204 mg/L, and 10 to 40mg/L, respectively. Calcium, Magnesium, Sodium, and Potassium were discovered to have concentrations of 11 to 78 mg/L, 18 to 50 mg/L, 4 to 12.4 mg/L, and BDL to 2.02 mg/L, respectively, whereas Chloride and Fluoride had concentrations of 9 to 25 mg/L and BDL to 0.1 mg/L, respectively. pH, EC, BOD, N-Nitrate, and N-Ammonia were determined to be 6.8 to 7.8, 123 to 354 us/cm, 1.8 to 2 mg/L, 0.47 to 1.94 mg/L, and BDL to 0.40 mg/L, among other parameters. Turbidity, Hardness, Sulphates, Total Alkalinity and Phosphate were determined to be BDL to 20.2 NTU, 52 to 122 mg/L, 6 to 23 mg/L, 40 to 102 mg/L and BDL to 0.26 mg/L, respectively. COD concentrations ranged from 8 to 24 mg/L, while and TKN concentrations ranged from BDL to 1.12 mg/L. Water samples were devoid of boron and P-alkalinity. In samples, TC and FC were discovered to have concentrations of 24 to 130 MPN/100 ml and 6 to 21 MPN/100 ml, respectively, whereas faecal streptococci were reported to have a concentration of less than 1.8 MPN/100 ml. Turbidity, COD, and FC levels were all over the limits, whereas TC values ranged from low to high.

The values of DO and temperature at sampling station 2163 in 2020 were 5.8 to 7.4 mg/L and 22 to 32 ^{o}C, respectively. Magnesium, Calcium, Potassium, and Sodium were found in concentrations of 24 to 100 mg/L, 36 to 100 mg/L, BDL to 9 mg/L, and 3.6 to 34 mg/L, respectively, while Anions such as Sulphate, Phosphate, Fluoride, and Chlorides were found in concentrations of 5 to 76 mg/L, 0.01 to 0.20 mg/L, BDL to 0.1 mg/L, and 9 to 86. Faecal Streptococci were less than 1.8 MPN/100 ml, while TC and FC were 23 to 94 MPN/100 ml and 4.5 to 13 MPN/100 ml, respectively. pH, EC, BOD, N-Nitrate, and N-Ammonia were found to be 7 to 8.2, 140 to 719 us/cm, 1.6 to 2 mg/L, 0.20 to 2.31 mg/L, and BDL to 0.42 mg/L, respectively. TDS, TFS, and TSS values range from 99 to 495 mg/L, 72 to 416 mg/L, and 10 to 34 mg/L, respectively, according to the gravimetric parameters investigation. The water samples were devoid of boron and P-alkalinity. Physical factors such as turbidity; chemical parameters such as Hardness, COD, and Total Alkalinity; and nutrient parameters such as TKN were investigated as BDL to 16.6 NTU; 60 to 202 mg/L, 8 to 24 mg/L, 46 to 186 mg/L, and BDL to 1.12 mg/L, respectively. Turbidity, COD, and FC readings were all greater than the limits, whereas TC was found to be low to high.

e-ISSN: 2582-5208
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Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

The average readings of various parameters throughout the course of the year 2020 for DO and temperature onsite varied from 6.52 to 6.73 mg/L and 26.73°C to 27.73°C, respectively. Physical parameters such as pH ranged from 7.52 to 7.68, EC from 154 to 377 us/cm, nutrient parameters such as N-Nitrate and N-Ammonia ranged from 0.67 to 0.80 mg/L and 0.24 to 0.31 mg/L, demand parameters such as BOD ranged from 1.75 to 1.87 mg/L, and microbiological parameters such as TC and FC ranged from 44.36 to 71.91 MPN/100 ml and Physical parameters like as turbidity; gravimetric parameters such as TDS, TFS, and TSS; and inorganic parameters such as hardness, fluoride, boron, chlorides, total alkalinity, and P-alkalinity: Demand data such as COD and nutritional parameters such as T.K.N, Phosphate, Sulphates, Sodium, Potassium, Calcium, Magnesium, and a Faecal Streptococci Microbiology Study TDS, TFS, and TSS gravimetric analyses ranged from 106 to 258 mg/L, 90.73 to 220 mg/L, and 10.73 to 13.09 mg/L, respectively. The turbidity of the water ranged from 0.85 to 2.58 NTU. Hardness, Fluoride, Chlorides, and Total Alkalinity were measured at 64.73 to 113 mg/L, 0.06 to 0.09 mg/L, 12.86 to 39.91 mg/L, and 49.45 to 88.73 mg/L, respectively. The water samples were devoid of boron and P-alkalinity. COD was studied, since it is an important demand parameter that ranges from 14.55 to 18.18 mg/L. T.K.N, a nutrient parameter, ranged from 0.56 to 0.71 mg/L. Phosphate, Sulphates, Sodium, Potassium, Calcium, and Magnesium were measured in the ranges of 0.06 to 0.08, 9.16 to 41.66 mg/L, 4.85 to 16.22 mg/L, 1.17 to 3.04 mg/L, 37.27 to 65.82 mg/L, and 27.45 to 48 mg/L, respectively, while Faecal Streptococci were found below the 1.8 MPN/100 ml of range. For COD and FC, the readings were greater than the limitations, whereas TC was determined to be low to high.

Piper Plot -The piper plot [5] is used to investigate the cation and anion concentrations. The ions prominent in surface water samples taken by MPCB from four sampling sites in 2020 are depicted in the diagram. Calcium was in the 40-50 percent meq/L range, whereas Magnesium was in the 50-60 percent meq/L range, and Na+K was in the 0-15 percent meq/L range. Anions such as chloride were found to be 25-60 percent meq/L, sulphates were 40-52 percent meq/L, and carbonates and bicarbonates were 10-60 percent meq/L. Three samples had no dominant type among the Cations, while one sample had Magnesium, while one sample had Chloride, one sample had Bicarbonate, and two samples had no dominant type among the Anions. The diamond structure represents anion and cation interactions, with two calcium chloride samples, one magnesium bicarbonate sample, and one mixed type sample. One sample is in the weak acid exceeding the strong acid range, while three others are in the strong acid exceeding weak acid range.

Wilcox -The Fig [6] depicts the Wilcox graph, which is used to determine if surface water is suitable for agricultural use. The bulk of surface water samples were rated good which indicates that the Panchganga water can be used for irrigation.

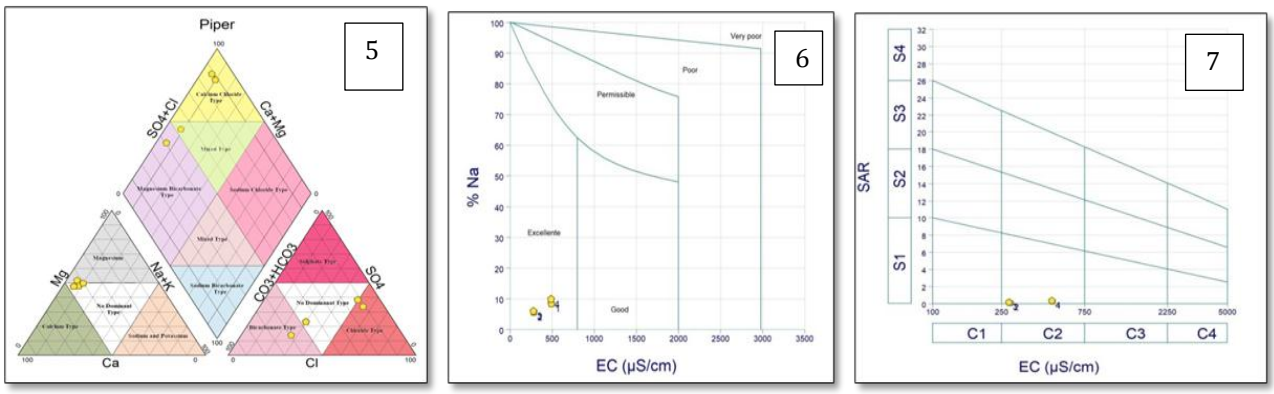


Fig: 5, 6 and 7 represents the Piper Plot, Wilcox and SAR Graph

Sodium Absorption Ratio (SAR) - The SAR is also used to characterise sodium risks, which can limit soil permeability and so it prevents crops from absorbing water. Water suitability can be determined by plotting a graph of SAR against EC using a graph from the US Salinity Laboratory. Approximately 100 percent of the samples are classed as C2S1, suggesting medium salinity/low sodium, as shown in the graph [7]. As a result, it is appropriate for agricultural application

Principle Component Analysis-

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

The PCA 8 th Graph shows the PC 1 of total variability as 99.99 % while PC 2 has 0.01 %. D site is in the IIIrd quadrant which is in the positive correlation with PC1 and PC 2 while Site A, B and C are in positive correlation with PC 1 and negative correlation in PC 2. The Electrical Conductivity (EC) is dominant in Site D which is at acute angle to the site D while Total Floatable Solids (TFS) and Total Dissolved Solids (TDS) are found to be lying in between Site A and D which is more nearer to the site A. The PC 1 variability is 75.86 % and PC 2 is 23.74 % in 9 th Graph. The Site is at negative correlation at PC 1and PC 2 while Site A and D are at positive correlation at PC 1 and negative at PC 2. The site B is at positive correlation with PC 1 and PC 2. The N-Nitrate (N-NO3), N-Ammonia (N-NH 4) and Total Kjeldhal's Nitrogen (TKN) are found to be in between Site A. B and D. The N-Nitrate is found to be positive correlation at Site A while N-Ammonia and TKN are found in between Site B and D. The N-NO3, N-NH4 and TKN are adjacent angle to the Site D. While the 10 th Graph shows the Variability of PC 2 at 14.73 % and PC 1 at 84.51 % where site B is positive correlation with PC 1 and negative correlation with PC 2 while site C is at negative correlation with PC 1 and PC 2. The Site A is at positive correlation with PC 1 and PC 2 whereas site D is at positive correlation with PC 2 and negative at PC 1. The COD is dominant at site A while Calcium and Chloride is found to be near site D.

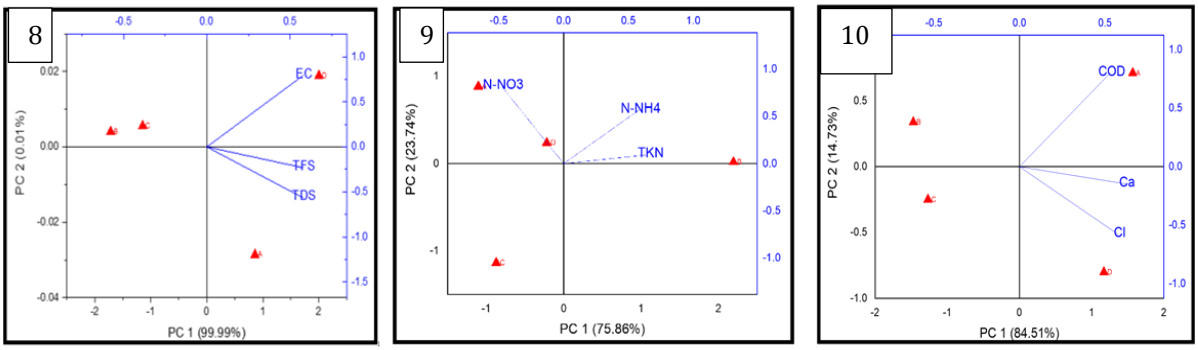
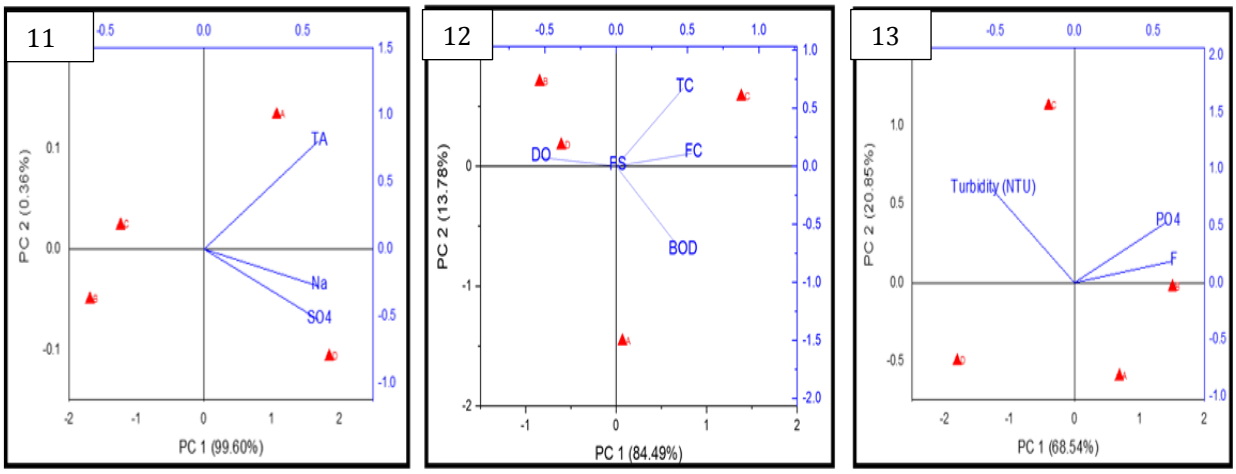


Fig 8: represents the PCA for Electrical Conductivity (EC), Total Dissolved Solids (TDS) and Total Floatable Solids (TFS); **Fig 9:** represents PCA for N-Nitrate (N-NO3), N-Ammonia (N-NH-4) & Total Kjeldahl's Nitrogen (TKN) and Fig. 10 PCA for Chemical Oxygen Demand (COD), Calcium and Chlorides

Fig 11: represents the PCA for Total Alkalinity (TA), Sodium (Na) and Sulphates (SO_4); **Fig 12:** represents PCA for Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Total Coliforms (TC), Faecal Coliforms (FC) and Faecal Streptococci (FS) and Fig. 10 PCA for Turbidity, Phosphate (PO_4) and Fluoride(F)



The 11 th graph of PCA is having variability of 99.60 % at PC 1 and 0.36 % at PC 2 where site B is at negative correlation with PC 1 and PC 2 while site C is at positive correlation at PC 1 and negative correlation at PC 2. The site A is at positive correlation with PC 1 and PC 2 while site D is at negative correlation at PC 1 and positive correlation with PC 2. The Total Alkalinity (TA) is dominant at site A whereas Sodium and Sulphates are near the site D whereas the 12 th graph shows the PC 1 at 84.49 % and PC 2 at 13.7 %. The site B and D ate at positive correlation at PC 1 and negative correlation at PC 2. The site C for PC 1 and PC 2 are at positive

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
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Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

correlation while A is at negative correlation with PC 1 and positive correlation with PC 2. Dissolved Oxygen (DO) is dominant at site D and is near to site B while Total Coliforms (TC) and Faecal Coliforms (FC) are near the site C. BOD is near the site A. The DO, TC and FC forms an Adjacent angle. The PC 1 and PC 2 are at 68.54 % and 20.85 % in 13 th graph. The sampling sites D is at negative correlation with PC 1 and 2 while site C is at positive correlation with PC 1 and negative correlation with PC 2. The site A and B are positive at PC 1 and negative at PC 2. The Turbidity is near the site C while Fluoride and Phosphate are near the site B.

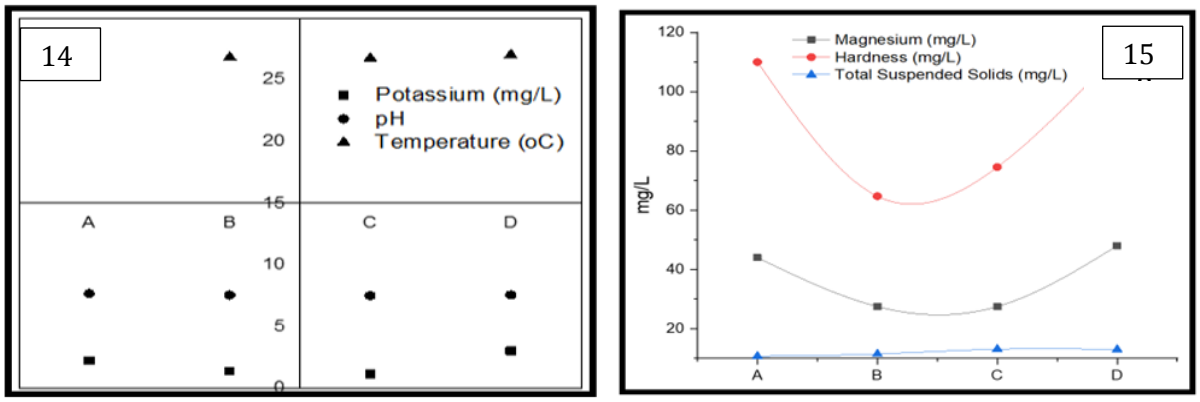

Fig 14: represents the variation for pH, Temperature and Potassium and Fig. 15 represents ranges of Total Suspended Solids (TSS), Hardness and Magnesium

The 14th graph represents the values for the four sampling site in 2020 for Potassium, pH and temperature of the water samples, where potassium was found to be below 5 mg/l, pH was above 5 and below 10 representing neutral to alkaline nature of the sample. The temperature of the water samples are found to be above 25^0 C. The 15 th graph represents the Magnesium, Hardness and Total Suspended Solids (TSS) in mg/L for four sampling sites for the year 2020. The TSS, Magnesium and Hardness are found to be is higher at site D when compared with other sites.

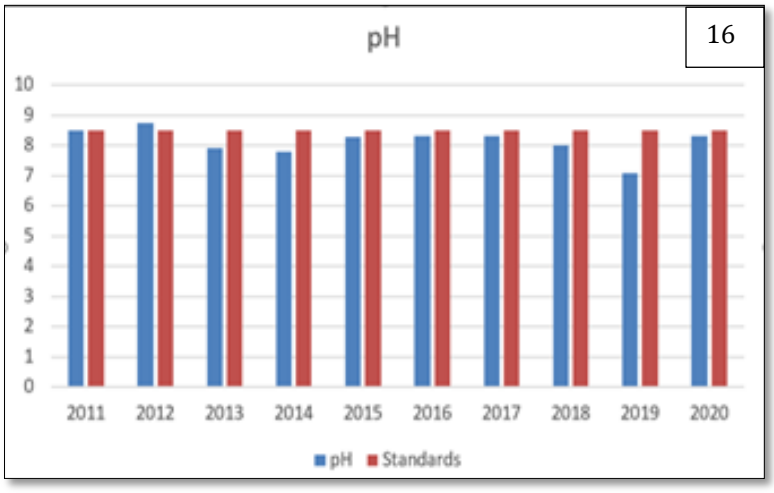

Fig 16: represents variation studies in pH from 2011 to 2020

The plotted 16 th graph represents the pH for the water samples studied from 2011 to 2020 where pH was vary from low to high. The pH was found to be high during 2012 and 2020.

e-ISSN: 2582-5208
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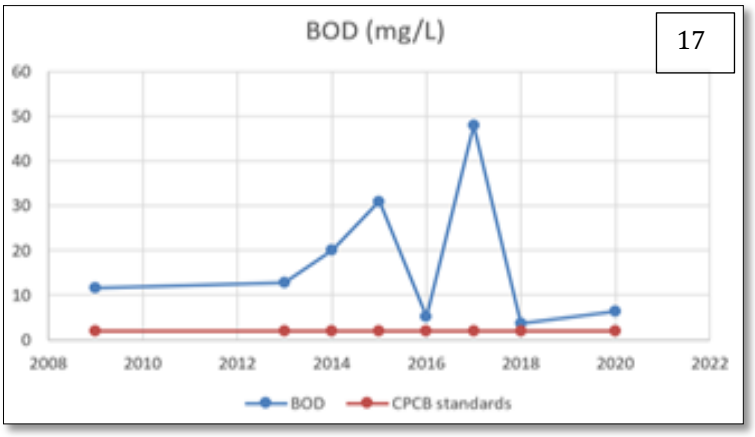

Fig 17: represents the variation of Biological Oxygen Demand (BOD) from 2009 to 2020

The 17 th graph represents the study carried out for BOD from 2009 to 2020 where the samples were found to be higher than the CPCB standards due to the discharge of waste from various point and non-point sources in the river.

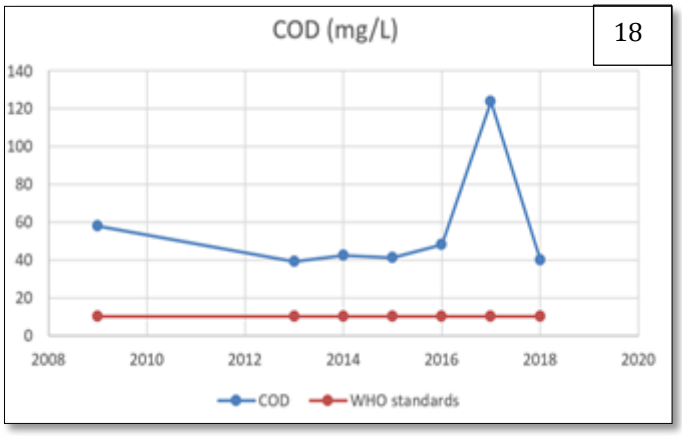

Fig 18: represents the variation of Chemical Oxygen Demand (COD) from 2009 to 2020

The 18 th graph shows the COD study from 2009 to 2020 where the sites were found to be higher than the WHO standards of drinking water. The reason for the higher COD is may be due to the untreated industrial effluent discharge in the river.

VI. CONCLUSION

The Panchganga River is the primary source of drinking water and irrigation for villages along the river's banks. River water has grown significantly contaminated in numerous areas over time. The water at Panchganga has exceptionally high BOD, COD, Turbidity, TDS, and Coliform levels, as well as changing DO levels. The pollution induced by manmade activity is the primary source of these indicators' high values. Textile effluents, insufficient sewage treatment and discharge, agricultural runoff, and other factors have resulted in point sources in Kolhapur, Ichalkranji, and Shirol. A few enterprises, primarily textile and chemical companies, are located along the river's banks and contribute to river pollution, which has negative health consequences for humans.

For many people, the Panchganga provides a source of drinking water, and there are still places where people drink untreated water directly from the river. The DO was 0.6 to 8 mg/L, the BOD was 0.1 to 48 mg/L, the COD was 6 to 124 mg/L, and the Coliform content was 70 to 350 mg/L, all of which were greater than the standards. BOD levels in drinking water should be less than one; coliform bacteria contain E. coli bacteria, which are extremely dangerous if swallowed. The temporal investigation revealed that B.O.D, Faecal Coliform, Total Coliform, and COD levels in river water have risen dramatically in recent years when compared to other

metrics. The main cause for this is that as the population grows, so does the amount of sewage produced, which ends up in the river polluted.

ACKNOWLEDGEMENT

The authors want to dedicate this paper to Mrs. Morami Kalita (Pr. Scientist) from CSIR-NEERI (HZC).

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