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ASSESSMENT OF ULHAS RIVER WATER TO CHECK ITS QUALITY AND EFFECT ON ENVIRONMENT

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Abstract: **The present study evaluates the quality of water of the *Ulhas* River in Maharashtra, India on a monthly basis for a period of 3 years. The site of study experiences daily influx of industrial & household sewage discharge while clay & POP idol immersions and *nirmalaya* disposal during *Ganesh* festival. The presence of landfill adds to the overall deterioration of the river water. The study aims to document the quality of the river water over the duration of study and state the possible reasons for the results obtained. Physico-chemical parameters like pH, temperature, EC, TSS, TDS, DO, BOD, COD, acidity, alkalinity and total hardness of the river water were analyzed and the results obtained were compared with the standard values provided by BIS and EPA. Only pH was found to be in acceptable range, BOD is slightly higher whereas COD, TDS, Alkalinity and Total Hardness values very high than acceptable values. This comparison indicated the grave state of the river and the need to take care of it. To understand the effect of one parameter on another, Karl Pearson's coefficient of correlation was studied statistically.**

Index Terms - Ulhas River, Durgadi Fort, COD, BOD, TDS, TSS.

I. INTRODUCTION

Water is elixir of life and needs to be sustained for future generations. It is a well-known fact that water bodies are deteriorating day by day. UNESCO's report highlights how India is staring at seeping water crisis with few steps being taken to ameliorate this bleak situation. According to UNESCO, India will suffer from an intensified water crisis by 2050 (M. Vyawhare 2018). According to CPCB, 49 rivers of Maharashtra are polluted including Ulhas River (B. Chatterjee 2017). The Ulhas River receives effluent wastewater from industries that eventually enters into the sea causing water pollution. This puts aquatic life under the risk of causing irreversible changes in them. Water pollution also promotes water-borne diseases. Therefore, monitoring the pollution levels of water bodies for a prolonged period of time is necessary Water analysis measures the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose. Water analysis includes determination of chemical (Chemical Oxygen Demand, Acidity, Alkalinity, Total Hardness), physical (Temperature, pH, Conductance, Total Dissolved Solids, Total Suspended Solids, Biological Oxygen Demand) and radiological characteristics of water. The most common standards used to assess water quality related to the health of ecosystems, safety of human contact, and potable water. Sewage disposal into the Ulhas River near the Durgadi Fort, Kalyan area has led to elevated levels of pollution of the river. Disposal of floral offerings, immersion of idols made of clay and POP, recreational activities like boating that acts as a tourist attraction for people are among some of the common practices that are detrimental to the marine biome. The food stalls installed at the site of sample collection, discards the organic waste into the river, adding to pollution. The acres land of Adharwadi dumping ground that handles about 700 metric tonnes of solid waste a day is situated next to the river bank. This dumping ground has been used since 1984 by Kalyan Dombivli Municipal Corporation to dispose the waste prior to application of any scientific procedure to prevent its consequences like environmental pollution and health hazards. Only 10% of the 216 million liters a day (MLD) sewage generated daily by the Kalyan-Dombivli Municipal Corporation (KDMC) is treated before it is released into the river (https://numerical.co.in/numerons/collection/59b41b66250a41f81b6ef477%20(accessed%20Apr.%2016,%202020)). In 2016, abrupt burning of the dumping ground was reported frequently. Incessant burning of the waste leads to smoke which causes problems to the local residents and also to the hydrological environment. The problem is further aggravated by the unrestrained dumping of solid waste, construction debris and other waste into the creek. Any deviation from natural temperatures of a habitat ranging from high temperatures associated with industrial cooling activities to discharge of cold water into streams below large impoundments contributes to thermal pollution of a water body. Such abrupt temperature changes affect the fish with thermal shock and is fatal to it. The municipal discharges alter the stream temperatures for considerable distances downstream of the discharge point (R.M. Baxter 1977). Deforestation eliminates the riparian vegetation, this increases solar penetration and temperature to an extent causing thermal pollution (W.K. Dodds 2010). Increase in temperature of water body, increases the respiration rates of organisms and depletes the dissolved oxygen at a faster rate. Populations of certain species of organisms that have acclimatized to such environmental changes flourish while incompetent species decline, changing the dynamics of the ecosystem.

pH is a simple parameter but is extremely important, since most of the chemical reactions in aquatic environment are controlled by any change in its value. Aquatic organisms are sensitive to pH changes and biological treatment requires pH control or monitoring. Surface waters having a pH values below six can be hazardous to aquatic life. Thus, pH is having primary importance in deciding the quality of waste water effluent. Waters with pH value of about 10 are exceptional and may reflect contamination by strong base such as NaOH and $Ca(OH)_2$ (P.U. Singare 2012). High pH values alter the toxicity of pollutants in the river like ammonia. It is highly toxic in alkaline water than acid. A decrease in pH decreases the solubility of the essential elements such as Se and upon consumption of such water, people may face Se deficiency. Low pH also increases the solubility of elements like Al, B, Cu, Cd, Hg, Mn and Fe. Low pH values in a river affect aquatic life and impair recreational uses of water (G. Morrison 2001).

Electrical conductivity (EC) of water is an indicator of its salinity. Wastewater effluents often contain high amounts of dissolved salts from domestic sewage and other sources of salts like windblown sea salt, municipal storm water drainage and industrial effluent discharges. Build-up of salts from domestic wastes and waste brines can interfere with water reuse by municipalities, and various industries. Sodium chloride and potassium sulphate salts pass through conventional water and wastewater-treatment plants unaffected (J. Mark 2012). EC is an indirect indicator of Total Dissolved solids in the form of salts. High amounts of TDS decrease the oxygen solubility in water bodies thereby being fatal to the marine life.

The "dirt" is the most common pollutant in the world in the form of Total Suspended Solids (TSS). When the TSS concentration is high, they may settle out onto the bottom of the water body and cover the aquatic organisms and their eggs thereby preventing the sufficient amount of oxygen transfer, therefore resulting in the death of buried organisms. The high amounts of TSS also hinder efficiency of the disinfecting agents as these TSS serve as "hiding spots" for microbes (https://www.michigan.gov/documents/deq/wb-npdes-TotalSuspendedSolids_247238_7.pdf).

Alkalinity can exist in the basic forms like carbonate, bicarbonate, or hydroxide based on the pH of the water. Total alkalinity refers to the sum of these three forms present in water (https://www.taylortechnologies.com/en/page/162/testing-alkalinity-in-boiler-water). Carbonate alkalinity usually makes up most of the total alkalinity in the natural environment because of the common occurrence and dissolution of carbonate rocks and presence of carbon dioxide in the atmosphere. The borate, hydroxide, phosphate, silicate, nitrate, dissolved ammonia, the conjugate bases of some organic acids and sulfide are some of the natural components which contribute to the alkalinity (https://www.freedrinkingwater.com/water_quality/quality1/28-08-alkalinity-page2.htm). The environmental factors affect the total Alkalinity of a water body. Alkalinity influences the anaerobic digestion process during the treatment of wastewater and drinking water (https://www.freedrinkingwater.com/water_quality/quality1/28-08-alkalinity.htm).

Currently, rate at which CO2 is entering world oceans is too rapid for it to be buffered against (S.C. Doney 2012). Thus, reducing the availability of carbonate ions and decreasing the pH, which is largely controlled by the ratio of carbonic acid to carbonate ions in seawater. The biotic processes in aquatic ecosystem and tides affect quality of water (G.G. Waldbusser 2014). An additional factor that likely enhances acid production (lower pH) during times when DO levels are increasing, is the oxidation of anaerobic metabolites. The reduced constituents (e.g. NH^{4+}, HS^{-}, Fe^{2+}, Mn^{2+}) that build up in surface sediments during hypoxia oxidize seasonally when systems re-oxygenate (M.A. Green 1998). These oxidation reactions produce strong acids that titrate alkalinity and lower pH (M.A. Green 1998). The dissolved oxygen (DO) concentration reflects equilibrium between oxygen-producing processes and oxygen-consuming processes that depend on water quality parameters (A.M. Ahmed 2017). Biological oxygen demand refers to the amount of oxygen required for the aerobic microbes present in the sample for oxidation of the organic matter a stable organic form. Excessive BOD loads are detrimental to the river water quality as it reduces the DO concentration thus affecting flora and fauna in the river (C.J. Gobler 2009). Chemical Oxygen Demand is the measure of the oxygen required for the oxidation of the organic matter content by strong chemical oxidants. $K_2Cr_2O_7$ is mainly used for assessing the water quality of moderately or heavily contaminated water bodies. COD is superior representative of the Oxygen Demand of water than BOD as it also oxidizes inorganic matter and is considered as one of the best indicators for determining the degrees of pollution. High COD waters usually has high organics substance (G.B. Ruben 2018). Water hardness is the amount of dissolved calcium and magnesium in the water. Hard water is high in dissolved minerals, largely calcium and magnesium (https://www.usgs.gov/special-topic/water-science-school/science/hardness-water?qt-science_center_objects=0#qt-science_center_objects).

Total Alkalinity and Total Hardness can be directly compared with each other. When Ca and Mg are also present in forms other than carbonate hardness, the total alkalinity is less than the total hardness (S. Gholami 2009). Also, the presence of excessive bicarbonate, chloride and dissolved sulphate in water make the water hard (N. Gupta 2013).

The statistical correlation within these parameters were studied by applying Karl Pearson's Coefficient of Correlation. Karl Pearson's Coefficient of Correlation is a mathematical method used to calculate the degree and direction of the relationship between linear related variables. The 'Coefficient of Correlation' is denoted by "r". If the relation between two variables X and Y is to be ascertained, then the following formula is used:

$$r = \frac{\Sigma(X-\overline{X})(Y-\overline{Y})}{\sqrt{\Sigma(X-\overline{X})^2}\sqrt{(Y-\overline{Y})^2}}$$

Where, $\overline{X}$ = mean of X variable
$\overline{Y}$ = mean of Y variable

i. The value of the Coefficient of Correlation (r) lies between ±1. Viz.:
   r = +1, perfect positive correlation
   r = -1, perfect negative correlation
   r = 0, no correlation
ii. The coefficient of correlation does not depend on the origin and scale. By origin, it means subtracting any non-zero constant from the given value of A and B the value of "r" remains unchanged. By scale it means, there is no effect on the value of "r" if the value of A and B is divided or multiplied by any constant.
iii. The Coefficient of Correlation is a geometric mean of two regression coefficient. It is represented as: $r = \sqrt{Cxy + Cyx}$

The coefficient of correlation is 'zero' when the variables A and B are independent but the converse is not true.The study aims at analyzing the physicochemical properties (pH, Temperature, Conductance, TSS, TDS, DO, BOD, COD, Total Hardness, Acidity and Alkalinity).

II. Study Methodology

Study Area

Ulhas river from the point of origin (Rajmachi hills) flows north turning left where it is joined by River Salpe. The river passes through various villages on its path and finally flows into Vasai Creek. The Ulhas basin lies between North latitudes of 18° 44' to 19° 42' and East longitudes of 72° 45' to 73° 48'. The study was carried out using Ulhas river water sample collected from Ganesh ghat near Durgadi Fort, Kalyan. (Latitude - 19.246974 and longitude - 73.118332).

The spot was selected due to its perennial accessibility. The sample collection spot has a landfill and sewage disposal site next to it. This may cause aberration in the readings during the rainy season and otherwise. The tropical climatic condition in the study area experiences an average temperature of 27.108 °C and average precipitation of 550.2 mm. (Note: There is a difference of 1115 mm of precipitation between the driest and wettest months. The variation in annual temperature is around 7.1 °C.)

In general, manuscripts may contain Title, Authors' names, Affiliation, E-mail address, Abstract, Keywords, Introduction, Literature Survey, Proposed Approach, Results and Discussion, Conclusion, Experimental Section, Acknowledgments, References and Endnotes. However, authors can organize the contents of the manuscript according to their requirements.

III. Materials and Methods

The river water sample was collected from the selected location as per standard sampling methods (IS: 2498, 1966 – Part-I). Observations were regularly recorded for the analysis of parameters like temperature, pH, DO to assess the nature of degree of pollution. Other parameters such as Conductance, Total Dissolved Solid (TDS), Total suspended solids (TSS), Chemical Oxygen Demand and Biological Oxygen Demand, Acidity, Alkalinity and Hardness were analyzed as per the standard guidelines and procedures (IS 3025, 1986).

Table no. 1: List of various methods used to study the different parameters

Sr. No.	Parameters Studied	Method used
01	Sampling method	Grab method
02	Acidity	Acid Base Titration
03	Alkalinity	Acid Base Titration
04	Biological Oxygen Demand	Wrinkler's method
05	Chemical Oxygen Demand	Open reflux method
06	Conductance	Conductometer
07	pH	On site - pH meter
08	Temperature	On site – Thermometer
09	Total Dissolved Solids	Gravimetric method
10	Total Suspended Solids	Gravimetric method
11	Total Hardness	Complexometric titration

Sampling from the Ulhas River near Durgadi area was done using grab sampling technique. This was done on a monthly basis through all the three seasons- summer, rainy and winter for a period of thirty-six months. The samples were collected in the cleaned polyethylene cans. The cans were completely filled up with water sample and were sealed air tight.

All instruments used for analysis were properly calibrated. Analytical grade chemicals (Merck, Loba) and reagents were used. The glass and plastic wares were cleaned with Sodium Bicarbonate followed by washing with distilled water. The samples were analyzed using the standard procedures from BIS and the values were compared with the standards given by BIS. All the parameters were analyzed monthly for the year 2016–18.

IV. 4. Results and Discussion:

Table no. 2: Physico-chemical properties of water sample collected from *Ulhas* River at *Durgadi* sampling point.

Year	Month	Temperature (°C)	pH	Conductance (µS/cm)	B.O.D (ppm of O_2)	C.O.D (ppm of O_2)	Acidity (ppm of $CaCO_3$)	Alkalinity (ppm of $CaCO_3$)	TSS (mg/L)	TDS (mg/L)
2016	Jan	29	7.4	129476	3.0	0.4	21.8	164	31	6185
	Feb	28	7.4	133637	3.5	5.0	25	127	58	7185
	March	28	7.4	165300	3.0	8.2	30.0	90	20	20306
	April	33	7.5	154675	4.4	85.2	112.3	291.3	240	20200
	May	32	7.5	144050	2.4	0.3	75.2	169.1	1000	20700
	June	32	7.4	260000	4.8	0.2	38.0	308	80	20000
	July	27	7.5	7300	0.5	36.8	31.8	206	10	213.3
	Aug	29	7.6	7600	0.1	0.3	25.5	104	10	240
	Sept	27	7.3	1690	0.3	29.6	14.1	87.2	510	693.3
	Oct	29	7.4	46645	2.1	48.4	21.1	81.8	275	4546.6
	Nov	29	6.9	91600	1.1	67.2	28.0	76.5	40	8400
	Dec	29	7.0	156200	0.2	0.1	33.0	171	50	5000
2017	Jan	29	7.0	155900	3.2	0.2	40.0	200	30	6085
	Feb	29	7.5	142575	2.6	4.0	1,078	147.5	60	7000
	Mar	30	8.0	129250	2.1	7.8	2,115	95	18	12893
	Apr	34	7.8	135000	2.1	0.1	17.9	465	100	12450
	May	34	7.5	111000	2.1	7.1	0.2	728	60	12080
	Jun	28	8.4	270500	3.3	3.9	1900	134.3	280	12600
	Jul	27	7.5	430000	0.9	7.4	1.8	50	210	280
	Aug	28	8.0	430000	3.3	4.8	4.8	45	620	253.3
	Sep	29	7.4	400000	3.4	0.1	3.9	36.7	270	120
	Oct	29	7.4	260000	1.2	10.8	2.0	32.6	150	213.3
	Nov	29	7.7	5220	3.2	13.6	9.1	79.2	400	3920
	Dec	29	7.4	6610	0.2	0.2	2.0	99	550	4200
2018	Jan	29	7.8	103052	3.4	0.2	3.4	128.4	35	5985
	Feb	29	8.4	124700	4.4	6.2	4.9	121.8	60	7370
	Mar	30	8.7	93200	1.2	8	4,200	100.1	100	5480
	Apr	34	8.1	135150	3.2	6.9	65.1	117.6	170	8513.3
	May	34	7.5	177100	3.7	5.8	8.8	135	500	11546.7
	Jun	28	6.3	563000	5.2	45.7	2.2	177.7	610	226.7
	Jul	27	6.8	7550	2.1	17.8	3.2	22.8	600	1650
	Aug	28	7.2	8300	2.0	50.9	1.4	36.7	250	240
	Sep	29	7.2	5600	4.8	24.6	8.7	102	330	3520
	Oct	30	8.8	700	3.0	0.3	3.4	81.9	300	6800
	Nov	28	7.3	121200	2.4	0.2	1.9	83.7	300	8800
	Dec	29	7.2	81405	0.2	0.2	2.0	135	200	4600

Table no. 3: Hardness of water sample collected from *Ulhas* River at *Durgadi* sampling point.

Month	Total Hardness (ppm of $CaCO_3$)	Month	Total Hardness (ppm of $CaCO_3$)	Month	Total Hardness (ppm of $CaCO_3$)	Month	Total Hardness (ppm of $CaCO_3$)
Jan	811.8	Apr	455.1	Jul	704	Oct	1344
Feb	1232	May	72.4	Aug	16	Nov	1312
March	837.8	Jun	705.6	Sept	328	Dec	1061.9

Temperature - Temperature observed was as per expectations with seasonal changes. The maximum temperature recorded was 34°C during April-May 2017&18. The minimum temperature recorded was 27°C in July for all three years and September 2016.

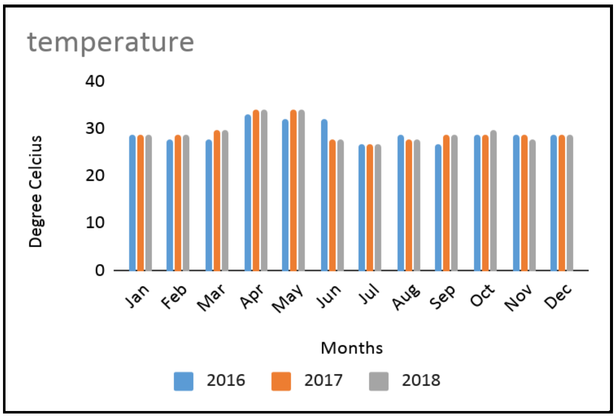

Figure 1

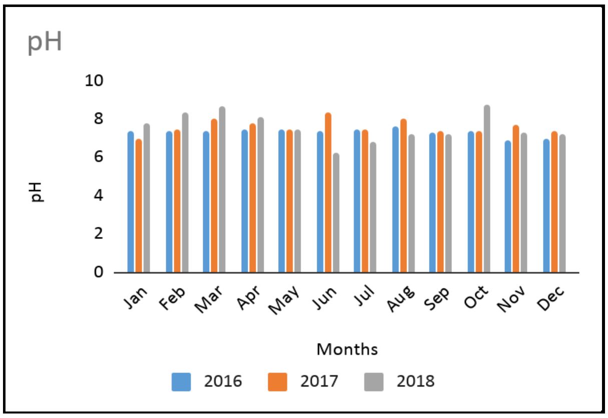

Figure 2

Figs.1&2: Figure 1 describes the variations in temperature while figure 2 describes the variations in the pH of the water body for the year 2016-18.

pH – The river water pH ranges from a minimum of 6.3 (June 2018) to a maximum pH of 8.8 (October 2018). pH does not change drastically with the season in 2016, the probable reason being meagre rainfall received throughout 2016. High temperatures during March-April 2017 was expected to produce a decrease in pH as with increase in temperature, BOD rates increase thus increasing carbon dioxide levels. The observations are not as expected due to the concentration of hydroxides in water, hence worsening the pollution caused by dumping ground lying next to the site of sample collection. During the rainy months, June and August of 2017, shows an increase in pH due to the runoff by rainwater as the sampling was carried out after heavy rains. February 2018 show high pH because of high temperatures causing evaporation of water and concentration of the organic waste discharged at site. Sampling was done at low tide, but due to high level of contamination at the site, the pH levels tend to be higher (February 2018). The spontaneous fire at the landfill releasing Carbon dioxide in the air and when enters water, and makes carbonic acid, bicarbonates and carbonates (March 2018). Thus, increasing alkalinity of water. Highest pH due to the fact that sample collection was done at high tide that causes the backflow of Ulhas River at Reti Bunder, which is highly polluted. Hence showing an increased effect in pH (October 2018).

Conductance – The maximum value was 563000 μS/cm (June 2018) while minimum was 700μS/cm (October 2018). An overall trend of high conductance during the year 2017 for the rainy season is observed as the average amount of rainfall received in 2017 was highest as compared to 2016 and 2018.The conductance of water sample decreases during monsoon and post monsoon months while it increases during the winter months and pre-monsoon months. In the year 2017, the sample collection was done immediately after a heavy downpour, hence the conductance values are elevated during July, August and September. The high rainfall effect is observed in October 2017 on conductivity of the river water. For the year 2018, the maximum rainfall received was in the month of June (230mm) while decreasing by mid-July. The peak in the graph for June is evident of this phenomenon. The values of 'r' show a weakly positive correlation of Conductance with TSS (r=+0.59), TDS (r=+0.083), Alkalinity(r=+0.013) and Total Hardness(r=+0.050). [Refer Figure No. 3 and Table No. 4]

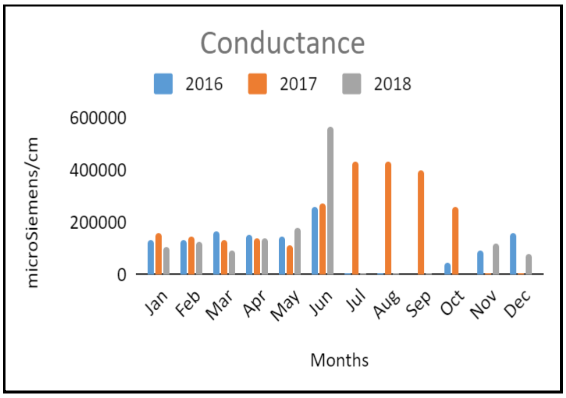

Figure 3

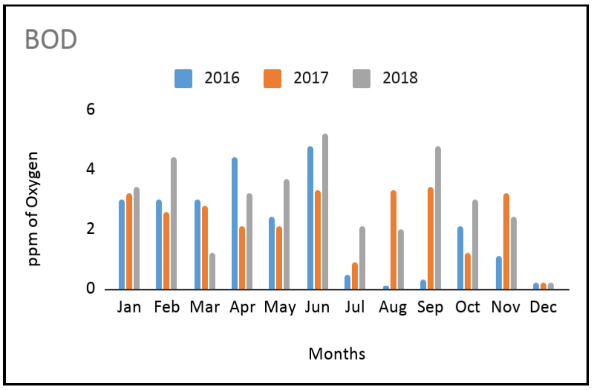

Figure 4

Figs. 3&4: Figure 1 describes the variations in Conductance while figure 4 describes the variations in the BOD levels of the water body for the year 2016-18.

BOD- The maximum BOD is 5.2 ppm of Oxygen (June 2018) while minimum is 0.1 ppm of Oxygen (August 2016). With the commencement of summer season, a peak is observed in BOD levels (April 2016). The BOD was expected to be high due to high temperatures and heavy on-site contamination (May 2016). But the results do not meet expectations, reason being the sampling was done at neap tide. High temperatures and scanty rainfall lead to an expected peak in BOD values (June 2016). The rainfall months of 2016, i.e., June, July and August show lower BOD values as expected. With October heat in 2016, BOD rises again, followed by decrease in levels in colder months Nov-Dec. The April-May 2017, less amounts of organic pollutants on-site contribute to lower BOD values as compared to June 2017 that shows high BOD due to spring tide at the time of sample collection. The observed minimum temperature has decreased BOD levels drastically in the water sample (July 2017). The Aug-Sept 2017 showed high BOD values as the sample was collected during heavy showers. The sample being collected at low tide, the BOD values in Oct 2017 are less as compared to 2016 and 2018. The sample collection on spring time shows elevated BOD levels (November 2017). BOD is less for 2016, 2017 and 2018 reason being low tide at time of sample collection accompanied by low temperatures. High level of contamination on site hence high BOD levels (February 2018). The sampling site was heavily polluted with organic waste during April-May 2018, BOD is increased in April-May 2018. Heavy rainfall as compared to July and August in 2018 and spring tide has led to elevation in BOD levels during June 2018. The increase in temperature along with spring tide are responsible for high BOD levels (September 2018). The effect of October heat is observed on BOD values in 2018 when compared to November 2018. [Refer Figure No. 4]

COD- COD values are low throughout the year with exceptions in 2016 (April, July, October and November), 2018 (June, August and September) due to sewage discharge into the river accompanied by other local factors like immersion of *Ganpati* idols, dredging activities. [Refer Figure No. 5]

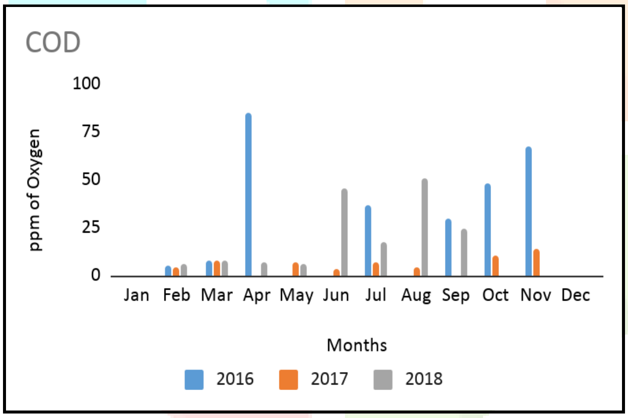

Figure 5

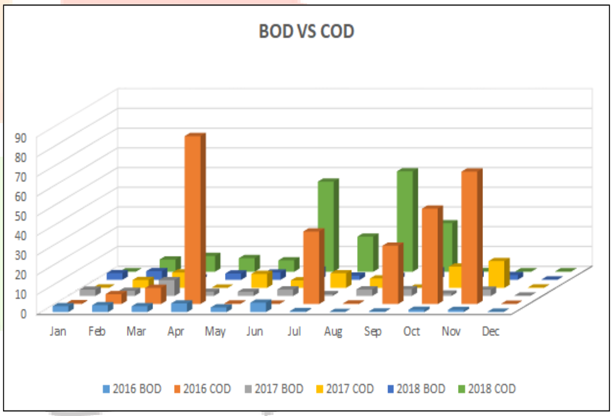

Figure 6

Figs.5&6: Figure 5 describes the variations in COD values while figure 6 describes the comparison between BOD and COD levels of the water body for the year 2016-18.

BOD vs COD

The BOD is generally low when compared to COD in a water body. But for Ulhas River at Durgadi Sampling point showed more BOD than COD in January (2016,17,18), April (2017) May- June (2016), and September (2017), Oct- Nov. 2018. Such conditions are observed when the site is heavily polluted by organic waste than chemical waste. [Refer Figure No. 6]

Acidity- The highest Acidity is observed as 4200ppm of Calcium Carbonate (March 2018) while minimum of 0.2 ppm of Calcium Carbonate (May 2017). High acidity is possibly be due to the fire that broke out in during that time, releasing landfill gases like hydrogen sulphide and hydrogen chloride (March 2018). When such gases mix with the river water, acidity is bound to increase. Higher acidity levels as compared to alkalinity levels indicates acid rain as the obvious cause of high levels in the acidity (June 2017). [Refer Figure No. 7]

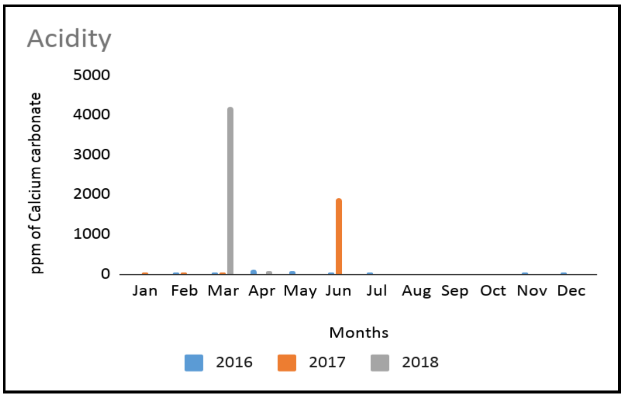

Figure 7

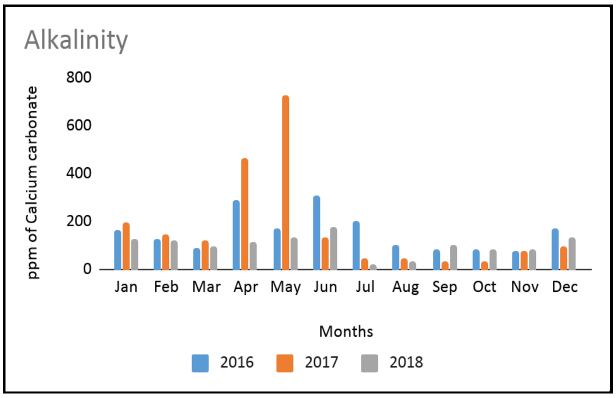

Figure 8

Figs.7&8: Figure 7 describes the variations in Acidity values while figure 8 describes the Alkalinity levels of the water body for the year 2016-18.

Total Alkalinity: The maximum alkalinity is 728 ppm of Calcium Carbonate (May 2017), while minimum as 22.8 ppm of Calcium Carbonate (July 2018). An alkalinity range of 100-250 ppm for a river is considered normal and will stabilize the pH of the river [23*]. The year 2016 observed less rainfall than average. April 2016, shows high levels of Alkalinity than the optimum range. In April 2016, the sample collection was done during high tide; when the creek water at *Reti bunder* which is highly polluted, mixes with the water at *Durgadi* creek, the augmentation in alkalinity levels is observed. In June 2016, the sample collection was done prior to rains and high temperature during summer season has caused concentration of the pollutants, therefore higher alkalinity than expected. The dumping ground present near the sampling site is the major contributor of the pollutants. June 2016 shows high alkalinity levels than the normal ones. The fire broke out in this month resulted in the increased amounts of carbon dioxide in the atmosphere. This carbon dioxide when dissolved in water, produces carbonates, increasing the alkalinity of water. For September 2016 and 2017 the sample collection was done immediately after immersion of Lord *Ganesh* idol. The floating materials released through idol in the river, after decomposition result in eutrophication, increase in acidity and heavy metal concentration (Effects of idol immersion on the water quality parameters of Indian water bodies: Environmental health perspectives). Thus, decreasing its alkalinity. This effect is seen at the month of October 2016 and November 2016 as well as it takes time for the water body to get rid of such waste. Such condition of river water quality is observed in year 2017 and 2018 as well for September, October and November. By December, the alkalinity levels come back to normal. The year 2017 and 2018 show very low levels of Alkalinity during July, August possibly the reason being acid rains in the area. In 2018, the site was heavily polluted with organic waste in the month of May, hence showing an increase in it as compared to April. The effect of pollutants on Alkalinity levels is observed in June as well as the sample was collected during the rainy season, yet the alkalinity levels are higher than April. The reason being, the decomposition of the organic waste that released phosphates into the water body. The Alkalinity shows a weakly positive correlation with Total Hardness (r = +0.350). [Refer Figure No. 8 and Table No. 4]

TSS – The maximum TSS value observed is 1000 mg/L (April 2017) while the minimum observed is 10 mg/L (July and August of 2016). For the water to appear clear, the TSS limit is 20mg/L (MDEQ. (n.d.). Total Suspended Solids. In Michigan Department of Environmental Quality. Retrievedfrom http://www.michigan.gov/documents/deq/wb-npdes-TotalSuspendedSolids_247238_7.pdf). The NDWQS of Malaysia, have 25 mg/L as limit for TSS of drinking water. https://www.doe.gov.my/portalv1/wp-content/uploads/2019/05/Standard-Kualiti-Air-Kebangsaan.pdf. During the rainy season, the TSS is generally high due to the mixing up on the soil particles during heavy rains, exception for the year 2016, as less rainfall was observed in this year. As the sample collection in September was done after immersion of *Ganesh* idols, a major peak in TSS in 2016 is observed and its effect is seen in October 2016 as well. This effect is observed in 2017 and 2018. The September 2016, shows high TSS as compared to 2017 and 2018 because the rainfall was scanty in September 2016 as compared to 2017 and 2018. The sample collection was done 10 days after the idol immersion in 2017, and the heavy rainfall led to was off the solids, thus decreasing the values than expected. In September 2018, sample collection was done the next day of idol immersion, but due to heavy rainfall the debris were washed off that were expected to produce high TSS as observed in 2016. The TSS levels do not show major differences in November, December, January and February, but a gradual increase in these levels with year 2017 and 2018 is observed, possibly due to population expansion. The month of April (2016) shows high TSS as compared to March as the summer temperatures are at peak that cause excess evaporation thereby concentrating the TSS in river. In April 2017, a peak was observed as the sampling site was polluted with the waste produced by the food stalls as a part of recreational activity. The TSS levels in April 2018 are affected and are high due to the burning of landfill near the sampling site, as the ash residues were deposited in the river. The month of May shows lower TSS levels as compared to April due to lower temperatures as compared to April at the time of sample collection. The June 2016 received less rainfall as compared to 2017 and 2018 during sample collection, whereas June 2018 received highest rainfall as compared to 2016 and 2017. The TSS values in June month indicate the effect of rainfall on TSS values. The TSS shows weakly positive correlation with Alkalinity (r = +0.121) while moderately negatively correlated with Total Hardness (r = -0.443). The negative correlation between TSS and Total Hardness is the indicative of the fact that when the water body gets saturated with solids in dissolved form, the number of TSS decrease while the total Hardness of the water increases. [Refer Figure No. 9 and Table No.4]

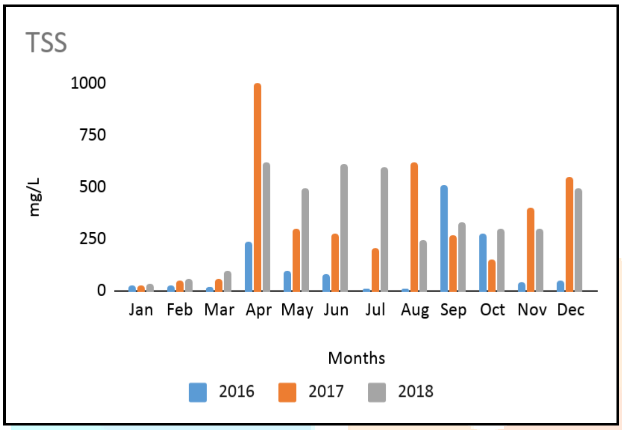

Figure 9

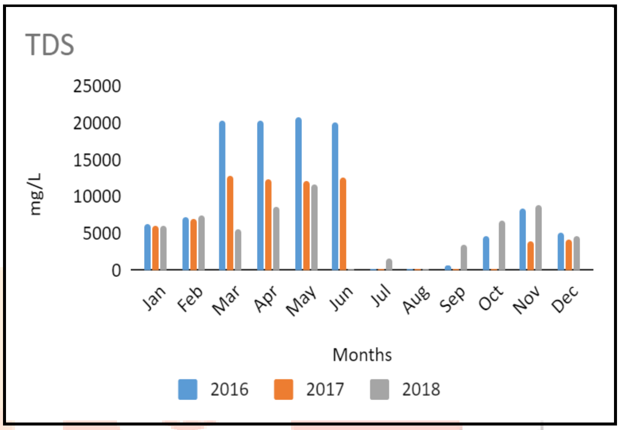

Figure 10

Figs.9&10: Figure 9 describes the variations in TSS values while figure 10 describes the TDS levels of the water body for the year 2016-18.

***TDS* –** As volume of the water in the river decreases accompanied by sewage discharges, the TDS observed is in the range of very high to extremely high more so in the summer months and much lower in the rainy season due to continuous replenishment caused due to rainfall.

The highest TDS value observed is 20700 mg/L (May 2016) while lowest observed is 120 mg/L (September 2017). More the rainfall received, less is the TDS value as the TDS in river water gets diluted. This is observed in June 2016, 2017 and 2018 where rainfall was least in 2016 at the time of sample collection, TDS was highest in the same. July and August months of monsoon season show low levels of TDS as per expectations. From September, TDS levels increase again, as the rainfall ceases. September 2018 shows higher levels of TDS as an effect of population explosion. The idol immersion in September affects TDS values in October. October 2016 and 2018 show high TDS as compared to October 2017 as the rainfall received was highest in year 2017 amongst these three years. The November and December months of 2017 start showing increased levels of TDS as per expectations. The effect of October heat of TDS values is observed in November. During December, January and February, lower temperatures also decrease the TDS values. The year 2015 observed less rainfall. Its effects on TDS values are reflected prominently in March, April and May months of 2016. The dumping ground caught fire affecting the TDS of April 2018. The May TDS values are higher than expected due to the pollution of the sampling site with organic waste. The TDS shows moderately positive and weakly positive coefficient of correlation with Alkalinity (r = +0.445) and Total Hardness (r = +0.281) respectively, while it is weakly negative correlated with TSS (r = -0.180). Such correlation is observed because when the TSS increases it precipitates and therefore no more remains as a suspended solid. Hence TSS values decrease with increase in TDS. [Refer Figure No. 10 and Table No.4]

***Hardness* -** Maximum Total hardness is 1344 ppm of calcium carbonate (October 2018) while minimum is 16 ppm of Calcium carbonate (August 2018). The rainy season has low Total Hardness as expected as the rainfall causing the dilution at sampling point, except for June as the sampling site was polluted with organic waste in May 2018 that has resulted in decomposition of organic waste which is evident from high values of BOD in this month, produces carbon dioxide which reacts with water to produce carbonates. This effect is observed in the Total Hardness values of June 2018. During rainy season the total hardness is low as per expectations. The activity of idol immersion polluting water is evident from September 2018 and it's after effects in October. November 2018 had a fire broke out in the landfill that gases like ammonia, hydrogen sulphide. These gases when mix with other metal ions present in river water, produces various compounds that lead to an increase in the total hardness of water. Its effect is continued till December, January and February. With the increase in temperature during March and April, the temporary hardness due to magnesium hydrogen carbonates and calcium hydrogen carbonates decomposes, thereby reducing the temporary hardness of water (May 2018). [Refer Figure No.11]

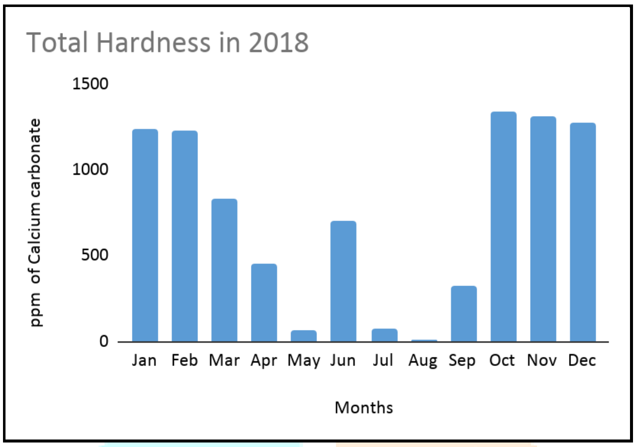

Figure 11

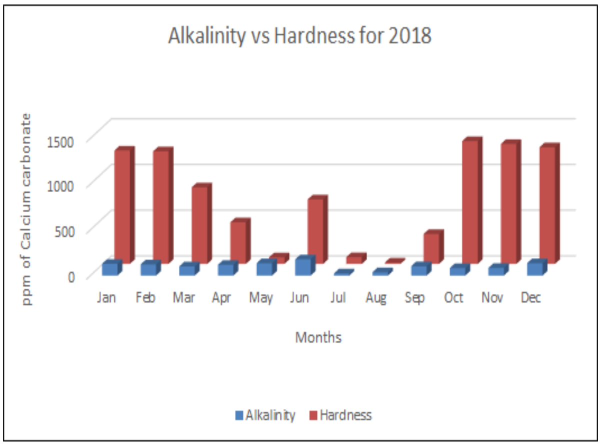

Figure 12

Figs.11&12: Figure 11 describes the variations in Total Hardness for year 2018 values while figure 12 describes the comparison of Alkalinity and Total Hardness values for year 2018.

Alkalinity vs Total Hardness Hardness Usually Total Hardness is always higher than Alkalinity. But in May 2018, Alkalinity is higher than Total Hardness as alkalinity is the measure of carbonates but Total hardness is inclusive of hardness contributed by non-carbonates hardness (chlorides, sulphates and nitrates of Calcium and Magnesium), carbonate hardness (bicarbonate, carbonate and hydroxide of Calcium and Magnesium) and Pseudo-Hardness (carbonates of Sodium, Potassium and Ammonium). The May month observed pollution of organic waste on the sampling site. The decomposition of organic waste produces Ammonia with other gases. The ammonia undergoes Nitrification by bacteria to produce nitrates. As these nitrates give rise to Non-carbonate hardness, the Total hardness is low in May as compared to the Alkalinity of water. [Refer Figure No. 12]

Table no. 4: Correlation coefficients among various water quality parameters

Karl Pearson's coefficient of Correlation					
Physico-chemical parameters	Conductance	TDS	TSS	Alkalinity	Total Hardness
Conductance	1				
TDS	0.059	1			
TSS	0.083	-0.180	1		
Alkalinity	0.013	0.445	0.121	1	
Total Hardness	0.050	0.281	-0.443	0.350	1

V. Conclusion

On many occasions the parameters have been much lower than expected due to regular dilution of water caused during high tides as the site is not far away from estuary. Still severe aberrations were observed in many of the parameters irrespective of the dilution during rainy season due to discharge of sewage water and STP. In addition to the residential discharge there is a high possibility of direct discharge from industrial units in the adjoining chemical industry belt. This observation is based on the pitch dark colored discharge falling into the river and muck found along the drainage system. To ascertain specific causes, further study needs to be done on these aspects. On comparing the values obtained with the Standard values provided by BIS, EPA and WHO, it can be concluded that only pH lies in the accepted range. BOD values are slightly higher the accepted values whereas COD, Alkalinity, TDS and Total Hardness values are higher than accepted values. Hence, to maintain the water quality such studies need to be conducted on regular basis and for a longer duration of time to effectively work for the solution to reduce water pollution.

Table no. 5: Comparison of river water quality with drinking water standards

Sr. No.	Parameter	Indian Standards	WHO standards	EPA guidelines	Values Observed
1.	Temperature (°C)	-	-	-	34
2.	pH	6.5 – 9.5	6.5 – 9.5	6.5 – 9.5	6.3 - 8.8
3.	EC (µS/cm)	-	-	2500	563000
4.	BOD (ppm of O_2)	6	4	5	5.2
5.	COD (ppm of O_2)	10	-	40	85.2
6.	Acidity (ppm of $CaCO_3$)	-	-	-	4200
7.	Alkalinity (ppm of $CaCO_3$)	-	200	-	728
8.	TSS (mg/L)	-	-	-	1000
9.	TDS (mg/L)	600	500	-	20700
10.	Total Hardness (ppm of $CaCO_3$)	200	200	< 200	1344

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