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Assessment of seasonal variation in water quality of River Mini, at Sindhrot, Vadodara

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ABSTRACT

The indiscriminate dumping and release of wastes containing hazardous substances into Rivers might lead to environmental disturbance which could be considered as a potential source of stress to biotic community. Mahi River located west of Vadodara city passes through the Nandesari Industrial area (NIA), with industries on both sides, served as an excellent disposal agent. The objective of the study to investigate the seasonal variation in physico-chemical chemical characteristics of Mini River water at two different sampling stations of Sindhrot, Vadodara. The analyses of river water quality containing 12 parameters were analyzed during the months of summer, monsoon and winter in the year 2010-11. The results envisaged deteriorate water quality with significant seasonal changes. The data has been compared with the norms for River water of Central Pollution Control Board (CPCB) and Gujarat Pollution Control Board (GPCB). The findings of the data obtained revealed the enhanced level of Total Dissolved Solids (TDS), Ammonia -N, Chloride (Cl^-), Sulphate, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Electrical Conductivity (EC), Alkalinity, Total Hardness (TH) and decreased in pH, Dissolved Oxygen (DO) and Turbidity during winter season. Moreover, increase of pollution load in winter season indicated the increase in organic matter in River water during the season due to the increase in anthropogenic interferences of the surrounding areas.

Key words: Seasonal variation, water quality, TDS, COD, BOD, EC, TH, DO, Turbidity.

1. Introduction

Rivers and their catchments are highly important parts of the natural heritage. Rivers have been utilized by mankind for thousands of years to the extent that few of them are now in their natural condition (Ngoye and Machiwa, 2004). Aquatic systems worldwide are reported to be much polluted due to untreated sewage disposal and industrial effluents being disposed directly into the rivers. Wastes usually contain a wide variety of organic and inorganic pollutants including solvents, oils, grease, plastics, plasticizers, phenols, heavy metals, pesticides and suspended solids. Pollutants entering a river system normally result from many transport pathways including storm water runoff, discharge from ditches and creeks, vadose zone leaching, groundwater seepage and atmospheric deposition. These pathways are also seasonal-dependent. Therefore, seasonal changes in surface water quality must be considered when establishing a water quality management program (Ouyang *et al*., 2006). Because of the anthropogenic activities fresh water resources are becoming deteriorate day-by-day at the very faster rate. So what, the water quality is becoming a global problem (Mahananda *et al*., 2005).

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The healthy aquatic ecosystem is depended on the biological diversity and Physico-chemical characteristics (Venkatesharaju *et al.*, 2010). Aquatic ecosystems are affected by several health stressors that significantly deplete biodiversity. In the future, the loss of biodiversity and its effects are predicted to be greater for aquatic ecosystems than for terrestrial ecosystems (Sala *et al.*, 2000). Serious ecological and sanitary problems are associated with pollutants discharged in river inflows (Vega *et al.*, 1998; Singh *et al.*, 2004 and Wang et al. 2007).Water pollution has significant effect on human health, balance of aquatic ecosystems, socio-economic development and prosperity (Milovanovic, 2007). High toxicity problems and eutrophication are associated with point and non-point sources of pollution (Sharma, 1996 and Jain, 2002).

Water quality, which is influenced by various natural processes and anthropogenic activities, is worldwide current environmental issue in research (Ouyang, 2005; Mukherjee *et al.*, 2007 and Shrestha and Kazama, 2007). The suspended and precipitated (non-floating) substances and organic substances in waters are capable of adhering pollutant particles (adsorption). The sediments, both suspended and precipitated substances stored on the water bottom, form a reservoir for many pollutants and trace substances of low solubility and low degree of degradability (Biney *et al.*, 1994).

Human and ecological use of in-stream water requires to be considered for both the quantity and the quality of water (Chang, 2008). Without adequate quantity and quality of fresh water sustainable development will not be possible (Kumar,1997).
Water quality is important to assess the health of a watershed and to make necessary management decisions to control current and future pollution of receiving water bodies (Khadam and Kaluarachchi, 2006). The information on water quality and pollution sources is important for implementation of sustainable water –use management strategies (Sarkar *et al*., 2007; Zhou *et al*., 2007 and Bu *et al*., 2009).

Anand–Vadodara belt is presently undergoing rapid industrial development and there have been incidences of toxic pollution from industry into the river. Hence, characterization of seasonal changes in surface water quality is an important aspect for evaluating temporal variations of river pollution due to natural or anthropogenic inputs of point and non-point sources like urban, agricultural, industrial, and domestic wastewaters, industrial wastewaters and sewage of metropolitan centers, small electroplating workshops, repair shops, hospitals and medical and scientific laboratories. The water quality measurements are important for minimizing industrial, mining or navigational accidents that cause short-term pollutant releases into or along river. The monitoring will be beneficial to warn downstream users and to mitigate secondary damages (Srivastava *et al.*, 2011).

The objectives of the present work were to (1) To assess physico-chemical characteristics of water of Mini River tributary in three different seasons (2) To establish the correlation between the parameters and the seasons . This study was conducted during August 2010 to March 2011, at three different selected sampling sites along the Mini River stream, Sindhrot a tributary of Mahi River, Vadodara.

2. Study site

The study area is located on the south-east of Anand and north–west of Vadodara district in the state of Gujarat. This belt is heavily industrialized and comes under golden corridor of

Gujarat, India. Nandesari Industrial Estate (NIE) of Gujarat is located on the banks of the Mini River and its tributary the Mahi River 20 km north of the city of Vadodara situated at 22° E and 73° N on the globe. The river passes from industrial areas of Ranoli, GSFC and other major industries. The Mini and Mahi Rivers and their easy accessibility served as excellent disposal agents, and attracted other industries to the area. Currently, the NIE has 250 small scale industries that produce organic and inorganic chemical compounds, pharmaceuticals, and drugs. (Misra, 2002). Rainfall in this area ranges from 4 to 346.1 mm. The region is characterized by the moderate subtropical monsoonal type of climate (Srivastava *et al.*, 2011).

3. Methedology

3.1 Materials

For analysis of various river water parameters AR Grade chemicals (Merck, India) were used. All glassware and other sample containers were rinsed with double-distilled water and sterilized prior to use.

3.2 Sample collection and Analysis

The seasons chosen for sampling were post-monsoon (Aug. 2010), pre-winter (Oct. 2010) and post-winter (Mar. 2011). The samples were taken between 10.00 am to 12.00 noon. All samplings represent instantaneous water quality at the particular time. Water samples were collected in polyethylene bottles, transported to the laboratory, and analyzed. Water samples were analyzed for most water quality influencing 12 physicochemical parameters, which included pH, conductivity, alkalinity, ammonia-nitrogen, chloride, sulphate, and total dissolved solid, total hardness, COD, BOD and DO. The parameters were determined using the standard methods mentioned in Table 1 for the examination of water and wastewater (Trivedi and Goel, 1984 and APHA 1998).

Table 1: List of physicochemical parameters and their test methods

S. No.	Parameters	Unit	Method used
1.	pH		pH meter
2.	Dissolved Oxygen (DO)	Mg/L	Winkler method
3.	Biochemical Oxygen Demand (BOD)	Mg/L	5 days incubation at 20° C and titration of initial and final DO
4.	Chemical Oxygen Demand	Mg/L	Open Reflux Method
5.	Alkalinity	Mg/L	Titration
6.	Total dissolved Solids	Mg/L	Digital conductivity meter
7.	Chloride	Mg/L	Argentometric titration
8.	Sulphate	Mg/L	Gravimetric method
9.	Turbidity	NTU	Nephelometric method
10.	Ammonia-Nitrogen (NH_3 -N)	Mg/L	Spectrophotometric(Phenate method)
11.	Total Hardness as $CaCO_3$	Mg/L	EDTA titration

12.	Conductivity	µS Cm^{-1}	Conductivity meter

4. Results and discussion

The Seasonal averages of physico-chemical characteristics are given in Table 2, different standards given by GPCB and CPCB with their permissible and desirable limits are given in Table 3 and Correlation Coefficient between various physico-chemical parameters are showed in Table 4.

Table 2: Summary (Mean and Standard deviation) of Physico-chemical parameters in different seasons- Seasonal Variations of water quality parameters in the Mini River during three subsequent seasons in 2010-11

Parameters	Post monsoon	Pre winter	Post winter
pH	8.16 ± 0.10	8.40 ± 0.14	7.70 ± 0.09
Conductivity	1400.00 ± 10.00	1516.67 ± 5.77	5423.33 ± 30.55
Total dissolved solids	890.00 ± 20.00	906.67 ± 55.29	3339.33 ± 11.37
Turbidity	15.67 ± 4.16	4.17 ± 0.29	3.00 ± 0.50
COD	50.33 ± 7.64	31.00 ± 20.30	163.00 ± 10.00
BOD	10.67 ± 1.16	8.0 ± 4.58	40.33 ± 2.52
DO	7.87 ± 0.30	12.73 ± 0.25	3.27 ± 0.12
Alkalinity	42.00 ± 0.00	166.67 ± 5.77	273.33 ± 56.86
Ammonia –N	1.84 ± 0.35	3.70 ± 3.59	22.21 ± 8.90
Chloride	198.57 ± 32.00	283.33 ± 5.77	1200.00 ± 100.00
Sulphate	218.33 ± 11.68	167.27 ± 3.18	290.67 ± 22.12
Total hardness	202.67 ± 16.17	323.33 ± 20.82	1010.00 ± 222.71

4.1 pH

Aquatic organisms are affected by pH because most of their metabolic activities are pH dependent. Optimal pH range for sustainable aquatic life is pH 6.5-8.2. pH of an aquatic system is an important indicator of the water quality and the extent pollution in the watershed areas (Kumar et al., 2011). The pH values were within the permissible level set by GPCB and CPCB i.e. 6.5 to 8.5, varying between 8.40 in the pre winter of 2010 to 7.70 in post winter of 2011. The lowering of pH in post winter seems to be due to greater input of waste from different type of industries. Whereas, higher pH during pre winter season revealed the existence of aerobic conditions and lesser anthropogenic sources as compared to the other seasons. Correlation analysis revealed significant positive correlation with all physico-chemical parameters (Table 4 and Figure 1). The pH of water affects the solubility of many toxic and nutritive chemicals; therefore, the availability of these substances to aquatic organisms is affected. As acidity increases, most metals become more water soluble and more toxic. Toxicity of cyanides and sulfides also increases with a decrease in pH (increase in acidity). Ammonia, however, becomes more toxic with only a slight increase in pH.

4.2 Conductivity

Conductivity itself is not a human or aquatic health concern, but because it is easily measured, it can serve as an indicator of other water quality problems. If the conductivity of a stream suddenly increases, it indicates that there is a source of dissolved ions in the vicinity.

Therefore, conductivity measurements can be used as a quick way to locate potential water quality problems. Higher the value of dissolved solids, greater the amount of ions in water (Bhatt *et al.*, 1999). Increasing levels of conductivity and cations are the products of decomposition and mineralization of organic materials (Abida, 2008).

Table 3: The different standards given by GPCB and CPCB with their permissible and desirable limits

Parameters	GPCB for surface water of river	CPCB Limit in mg/l	CPCB Proposed standards 2006
pH	6.5-8.5	6.0-8.5	6.0-8.5
Total dissolve solids mg/l		20 (SS)	20
Ammonia-N mg/l	50	NS	15
Chloride mg/l		NS	
COD mg/l	250	NS	125
BOD mg/l	30	15	15

Seasonal variations showed higher value of EC in pre-monsoon and lower value in monsoon due to dilution with rain water. Seasonal variations showed higher value in pre-monsoon and lower value in monsoon due to dilution with rain water. Conductivity showed significant positive correlation with all the parameters except Dissolved Oxygen, Total Dissolved Solids and Total Solids (Table 4 and Figure 1). Similar results were reported by Srivastava and Srivastava, 2011. The values obtained were very much higher than the permissible limits. The conductivity was recorded in different seasons from minimum of 1400 µS Cm^{-1}in post monsoon to a maximum of 5423.33 µS Cm^{-1} in post winter season.

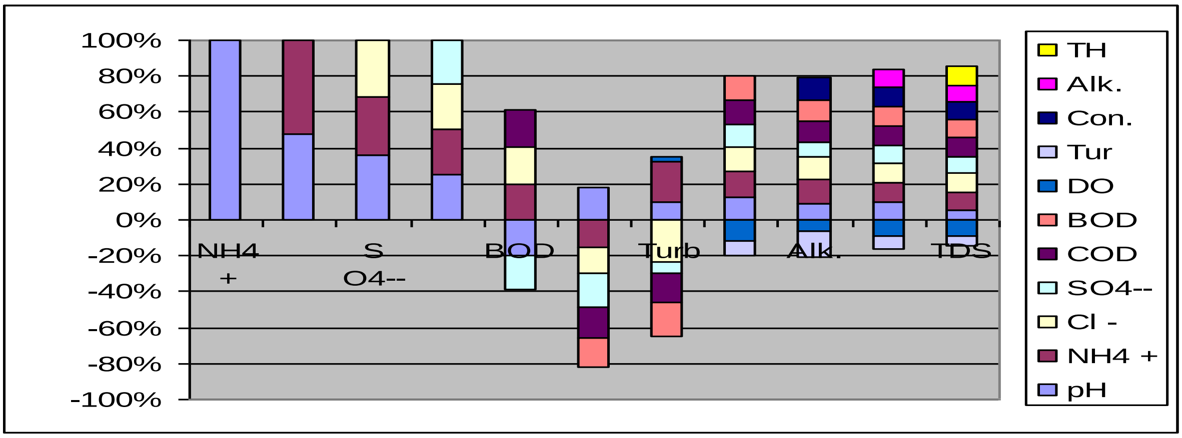

Figure 1: Correlation coefficient matrix of physico-chemical parameters of water

4.3 Total dissolved solids

In water, total dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium, sodium, potassium and manganese, organic matter, salt and other particles (Mahananda, 2010). At high flows, the TDS values tend to be diluted by surface runoff and for most rivers there are an inverse correlation between discharge rate and TDS (Charkhabi and Sakizadeh, 2006). As expected, the maximum total dissolved solids were observed during the post-winter season (3339.33 mg/l) than the pre-monsoon (890 mg/l), as a large amount of sediment load was transported from the watershed during the rainy season. Higher level of TDS during post winter season is more likely due to the influence of industrial activities such as effluent addition to the river. Correlation analysis showed significant positive correlation of pH with all the parameters except Dissolved Oxygen (Srivastava and Srivastava, 2011) supports the findings of the current research (Table 4). Some but not the entire dissolved solids act as conductors and contribute to conductance. Waters with high total dissolved solids (TDS) are unpalatable and potentially unhealthy.

4.4 Turbidity

Turbidity is another indicator of the amount of material suspended in water; it measures the amount of light that is scattered or absorbed. Suspended silt and clay, organic matter, and plankton can contribute to turbidity. In post – monsoon the concentration of chemical parameters show decrease trend due to dilution effect by the surface run-off received during rainfall (Srivastava *et al.*, 2011). The average concentration of Turbidity found was higher in post monsoon i.e. 18.67 NTU due to surface runoff of rainfall decreased after the settling of suspended matter after monsoon, which showed the decrease up to 3.00 NTU in post winter supported the statement of Srivastava *et al.*, 2011 (Table 2). Correlation analysis showed negative correlation with Conductivity, COD, BOD, Total hardness, TDS, Chloride, Sulfates and alkalinity except pH, DO and Ammonia (Table 4).

Table 4: Pearson correlation coefficients of water quality parameters of the Mini River across 9 sampling points in 2010-2011

	NH_4^+	Cl^-	SO_4^{--}	COD	BOD	DO	Turb	Con.	Alk.	TH	TDS
pH	0.910	0.913	0.997	0.978	-0.964	0.981	0.260	0.932	0.612	0.886	0.500
NH_4^+		1.000	0.874	0.976	0.988	-0.813	0.636	0.998	0.884	0.998	1.000
Cl^-			0.877	0.978	0.989	-0.816	-0.632	0.999	0.881	0.998	0.998
SO_4^{--}				0.959	-0.939	-0.993	-0.182	0.901	0.546	0.845	0.909
COD					0.998	-0.920	-0.454	0.987	0.762	0.962	0.990
BOD						-0.894	-0.508	0.995	0.800	0.977	0.997
DO							0.068	-0.845	-0.446	-0.779	-0.855
Tur								-0.591	-0.923	-0.679	-0.575
Con.									0.856	0.994	1.000
Alk.										0.909	0.846
TH											0.991

4.5 Chemical oxygen demand (COD)

Chemical Oxygen Demand is a measure of the oxidation of reduced chemicals in water. It is commonly used to indirectly measure the amount of organic compounds in water (Kumar et al. 2011). The measure of COD determines the quantity of organic matter found in water. This makes COD useful as an indicator of organic pollution in surface water (Faith, 2006). COD pointing to a deterioration of the water quality caused by the discharge of industrial effluent (Mamais *et al.*, 1993). It is a measure of the total quantity of oxygen required to oxidize all organic material into carbon dioxide and water. COD values are always greater than BOD values. Seasonal averages of COD values disclose variations in all the three seasons (Table 2). In post winter, COD levels of 163 mg/l found to be higher as compared to other seasons which reflected the high organic matter in the stream. Correlation showed strong negative correlation with DO (figure 2.) and Turbidity and positive correlation with BOD, Conductivity, Total Dissolved Solids, pH, Alkalinity and other parameters (Table 4).

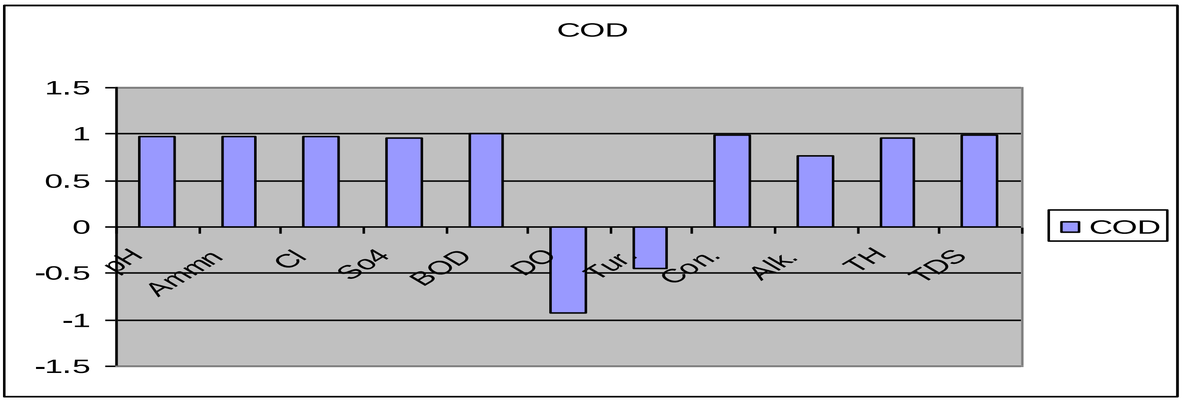

Figure 2: Correlation of COD with other physico-chemical parameters affecting water quality

4.6 Biochemical oxygen demand (BOD)

Biochemical Oxygen Demand is a measure of the oxygen in the water that is required by the aerobic organisms. The biodegradation of organic materials exerts oxygen tension in the water and increases the biochemical oxygen demand (Abida, 2008). BOD tests measures only biodegradable fraction of the total potential DO consumption of a water sample. High BOD levels indicates decline in DO, because the oxygen that is available in the water is being consumed by the bacteria leading to the inability of fish and other aquatic organisms to survive in the river (Pathak and Limaye, 2011). The average concentration of BOD in the study ranged from 8.0 mg/l in pre –winter. During post winter season, BOD level increased up to 40.33 mg/l crossing the permissible limit of GPCB and CPCB (Table 2 and 3). The data obtained from the study supported the statement, that high BOD during post winter and low BOD during pre-winter indicated decline and increase in DO content. The increase and decrease of BOD showed negative correlation with DO, pH, Suphates and Turbidity and positive with COD, and other parameters supports the study of Srivastava and Srivastava, 2011 (Figure 3).

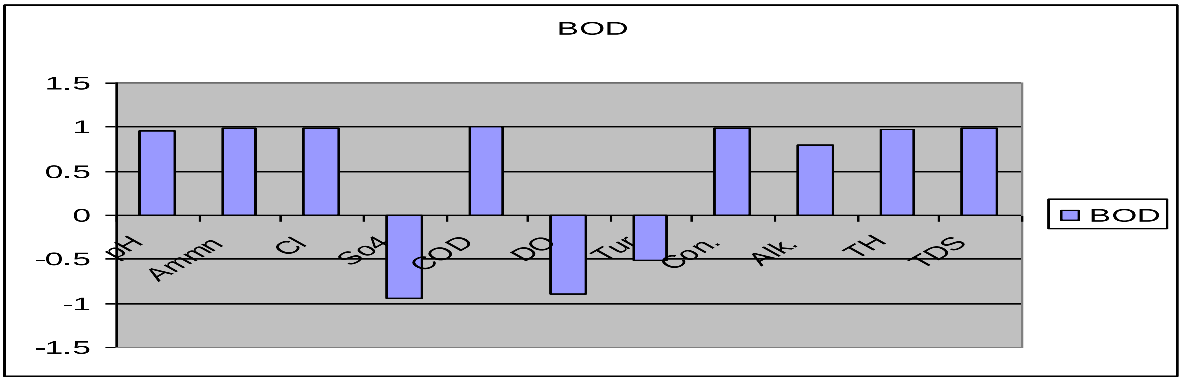

Figure 3: Correlation of BOD with other physico-chemical parameters affecting water quality

4.7 Dissolved oxygen (DO)

Dissolved oxygen is one of the most important parameters in water quality assessment and reflects the physical and biological processes prevailing in the water (Trivedi and Goel, 1984). The value of dissolved Oxygen is remarkable in determining the water quality criteria of an aquatic system. In the system where the rates of respiration and organic decomposition are high, the DO values usually remain lower than those of the system, where the rate of photosynthesis is high (Mishra *et al.*, 2009). When the water is polluted with large amount of organic matter, a lot of dissolved oxygen would be rapidly consumed in the biological aerobic decay which would affect the water quality; the decreased dissolved oxygen in water would affect the aquatic lives (Chhatwal, 2011). It was observed that during pre winter river water found lesser polluted as the DO content founds 12.73 mg/l, inhibited the better aquatic life for animals and plants. The enhanced DO level decreased the level of BOD and DO because of lesser organic matter for biological aerobic decay. The DO of the water showed negative correlation with BOD and COD and other related parameters (Figure 4), except for pH and turbidity which showed positive correlation (Table 4). As the discharge into the stream increased there was depletion of DO i.e. 3.27 mg/l observed during post winter. It may be possible that the industries increased the rate of discharge of untreated effluent into the stream. A stream must have a minimum of about 2 mg/l of dissolved oxygen to maintain higher life forms. In addition to this life-sustaining aspect, oxygen is important because the end products of chemical and biochemical reactions in anaerobic systems often produce aesthetically displeasing colours, tastes and odours in water (Hach *et al*.,1997).

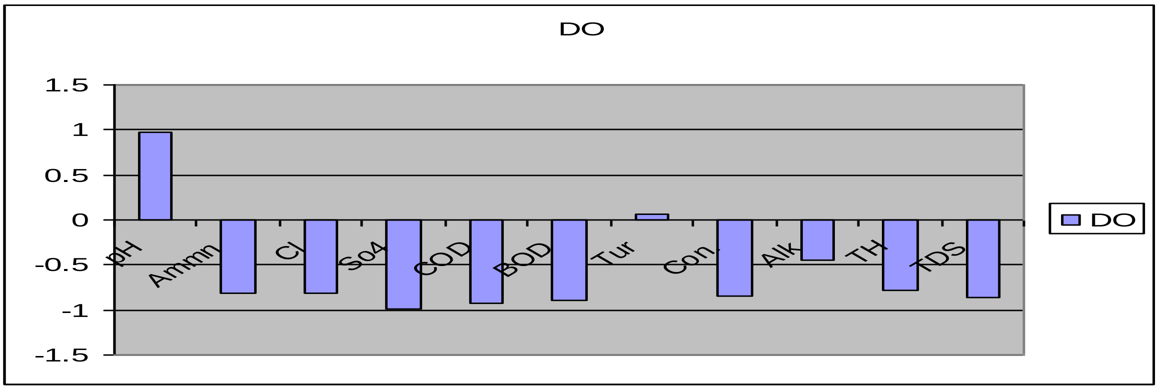

Figure 4: Correlation of DO with other physico-chemical parameters affecting water quality

4.8 Alkalinity and Total hardness

Alkalinity is the capacity to neutralize acids, and the alkalinity of natural water is derived principally from the salts of weak acids. Hydroxide, carbonates, and bicarbonates are the dominant source of natural alkalinity. Reactions of carbon dioxide with calcium or magnesium carbonate in the soil creates considerable amounts of bicarbonates in the soil. Organic acids such as humic acid also form salts that increase alkalinity. Alkalinity itself has little public health significance, although highly alkaline waters are unpalatable and can cause gastrointestinal discomfort. High average alkalinity (42–273.33 mg/l) and total hardness (202.67–1010 mg/l) in post-winter season may be ascribed due to the discharge of industrial and domestic sewage, which puts large amounts of alkaline ions into the river system. Total hardness is the parameter of water quality used to describe the effect of dissolved minerals (mostly Ca and Mg), determining suitability of water for domestic, industrial and drinking purpose attributed to presence of bicarbonates, sulphates, chloride and nitrates of calcium and magnesium (Taylor, 1949).

4.9 Ammonia –N

The most important source of ammonia is the ammonification of organic matter. Sewage has large quantities of nitrogenous matter, thus its disposal tends to increase the ammonia content of the waters. Occurrence of ammonia in the waters can be accepted as the chemical evidence of organic pollution (Trivedi and Goel, 1984). Naturally in unpolluted rivers, the concentration of NH_4^+ is generally higher during winter because the nitrification process in the river is more affected at higher summer temperature (Haag and Westrich, 2002). The average concentration of Ammonia in the study ranged from 1.84 mg/l in the post monsoon to 22.21 mg/l in post winter seasons (Table 2). In post winter it crossed the proposed standards of CPCB, 2006 of not more than 15 mg/l showed the increase in pollution load during the season (Table 3). Increase in ammonia content depicted the disposal of sewage disposal or effluent discharge of industries used ammonia liquor or ammonia gas for process of its production. Ammonia-N showed the strong positive correlation with Cl^-, COD, BOD, Conductivity, TDS and TH except with DO (Table 4 and Figure 1).

4.10 Chlorides

Chlorides occur naturally in all types of waters. In natural freshwaters, however, its concentration remains quite low and is generally less than that of sulphates and bicarbonates. Therefore, the chloride concentration serves as an indicator of pollution. The sewage water and industrial effluent are rich in Cl^- and hence the discharge of these wastes result in high chloride level in fresh water (Hasalam, 1991). The average concentration of chloride in the study ranged from 198.57 mg/l in post monsoon to 1200.00 mg/l in post winter (Table 2). Correlation matrix showed positive correlation with all the observed parameters except for DO and Turbidity showed negative correlation (Table 4).

4.11 Sulphates (SO_4^{2-})

Dissolved SO_4^{2-}can be derived from the dissolution of SO_4 minerals; oxidation of pyrite and other forms of reduced S; oxidation of organic sulfides in natural soil processes; and anthropogenic inputs, i.e. fertilizers (Grasby *et al*., 1997). Biological oxidation of reduced sulphur species to sulphate increase in concentration. Discharge of industrial wastes and domestic sewage in waters tends to increase its concentration (Trivedi and Goel, 1984). Higher values of EC, Cl^- and SO_4^{2-} are observed in summer and fall and lower values in spring and winter (Zare Garizi *et al.*, 2011). The average concentration of SO_4^{2-}in the study ranged from 167.27 mg/l in pre winter to 290.67 mg/l in post winter (Table 2) supports the statement. Correlation matrix showed positive correlation with all the observed parameters except for BOD, DO and Turbidity which showed negative correlation (Table 4 and Figure 1).

5. Conclusion

The water quality of Mini River is deteriorating due to anthropogenic activities like, industrial use of water and discharge into the river without any pretreatment. In post winter the pollution load is more prominent as compared to other seasons. The validity of the results obtained from Mini River indicated the correlation found between the variables. The obtained BOD value (also crossed the permissible limit of GPCB) showed the contamination of water indicates decline in DO of the water; which affects the sustainable life of plant and animals into the river stream. The deterioration in water quality is found due to higher amount of organic pollutants into the water. We suggest that the strict measures should be taken against by GPCB, industries polluting the Mini River stream.

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