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Temporal Variation of Surface Water Quality in Urbanized Watershed of Shimla, Himachal Pradesh, India

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Abstract
The Water quality of Ashwani Khad, a drinking water resource for Shimla city was studied to find out it's suitability for drinking purposes since this stream is receiving treated sewage effluent from a nearby Sewage Treatment Plant. The sewage contaminated water had caused Hepatitis A outbreak in the city few years ago. This for the first time created a hue and cry among the people leading to a constant monitoring of the water quality of Ashwani Khad since this water is directly being used for drinking purposes in the study area. Fifteen water quality parameters were tested for 26 water samples along the stream both in pre and post monsoon seasons in April 2013 and October 2013 respectively. These included pH, EC, TDS, BOD, COD, hardness, alkalinity, nitrates, phosphates, fluoride, sulphates and chlorides. The pH, EC and TDS were evaluated in the field while the other parameters were evaluated in the laboratory. The higher values of few parameters especially the BOD and COD in the water samples indicated that the water is not suitable for drinking purposes and needs certain levels of purification techniques to make it suitable for drinking purposes. The results also revealed that the Sewage Treatment Plant is not working effectively as the effluents were highly contaminated.
Keywords: Water, Sewage, Pollution, Shimla, Sewage Treatment Plant, Ashwani Khad

1. Introduction

Water is one of the most precious resources on the planet. Surface water is used for domestic, industrial, water supply and irrigation all over the world. Assessment of water quality is very important for different uses (Choubey et al, 2008). According to World Health Organization (WHO), about 80% of all the diseases in human beings are caused by water. Diseases contacted through drinking water kill about 5 million children annually and make 1/6th of the world population sick (WHO, 2004). A large number of people have to die because of water borne diseases every year in our country. The quality of surface water is a sensitive issue, especially if this surface water is used for drinking purposes. This quality of the surface water within a region is governed by both natural processes (such as precipitation rate, weathering processes and soil erosion) and anthropogenic effects (such as urban, industrial and agricultural activities and the human exploitation of water resources) (Jarvie et al. 1998). Ideally, drinking water should not contain any microorganisms known to be pathogenic or any bacteria indicative of faecal pollution (Rasheed M. Abdul et al. 2010). Therefore it is utmost important to find out the potability of water for drinking purposes. Potable water is the water that is free from disease producing microorganisms and chemical substances that are dangerous to health (Lamikaran, 1999). Periodic monitoring and assessment of water quality helps to develop management strategies to control surface water pollution (Shuchun et al. 2010) in spite of increasing urbanization and anthropogenic pressure on them. Almost 70% of the water in India has become polluted due to the discharge of domestic sewage and industrial effluents into natural water source, such as rivers, streams as well as lakes (Sangu et al. 1987). Municipal sewage discharge is a major component of water pollution which is compounded in areas where waste water treatments are inefficient. The treated sewage water cannot be used for drinking purposes unless it has been given a tertiary treatment before being discharged into the surface water body which is being used for drinking purposes. The discharge of such untreated or partially treated sewage water to the open fields or water bodies causes contamination of water. The scarcity of clean water and pollution of fresh water has therefore led to a situation in which one- fifth of the urban dwellers in developing countries and three-quarter of their rural dwelling population do not have access to reasonably safe water supplies. (Lloyd et al. 1992). Assessment 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 (Y. Ouyang, et al. 2006). The present study was carried out to study the water quality of Ashwani Khad which is supplying drinking water to the Shimla city on one hand and is receiving treated sewage water from a sewage treatment plant around 6 kms upstream on the other hand. The study will also help to suggest suitable ameliorative measures for the proper treatment of sewage and proper treatment of drinking water. The present study was carried out to study the water quality of Ashwani Khad which is supplying drinking water to the Shimla city on one hand and is receiving treated sewage water from a sewage treatment plant around 6 kms upstream on the other hand. The study will also help to suggest suitable ameliorative measures for the proper treatment of sewage and proper treatment of drinking water.

2. Description of the study area

Shimla, the capital of Himachal Pradesh, is a hilly town situated in the Himalayas. It is at an average altitude of 2397.59 meters (7866.10 ft) above mean sea level. It lies between North latitude $30^0$45'48'' to $30^0$43'0'' and East longitude $76^0$59'22'' to $78^0$18'40''. Location map of study area is shown in (Figure 1). The municipal area of the city is 31.6 sq.km. The total population of Shimla is 1,69,758 (Census 2011) with the sex ratio of 916 females per 1000 males. The average total annual rainfall is around 1650 mm and the humidity varies from 89% (Maximum) to 51% (Minimum). The drinking water supply to Shimla city is mainly fed by 7 major water sources. 80% of the population is served by these water supplies. The total installed capacity of various water sources is 71.24 MLD and out of this installed capacity, on an average only 42.00 MLD water is being lifted to Shimla. Shimla Municipal Corporation (SMC) and Department of Irrigation and Public Health (I&PH) are responsible for water supply to Shimla city. Ashwani Khad is the third largest water source for the city with an installed capacity of 10.80 MLD. The sewage from various parts of the city is collected by a network of underground sewers and then treated at 6 different Sewage Treatment Plants (STP's) located at six different parts of the city. Presently only 65% of the city is covered under the sewage network and the remaining is either running into drains/nallahs or is dumped into septic tanks. The total installed capacity of the six STP's is 35.63 MLD. The Malyana Sewage Treatment Plant is the third largest treatment plant in the city, having a capacity of 4.44 MLD. Sewage here is treated upto the secondary level and the treated effluent is thereafter discharged into the adjoining *nallahs.* The treated effluent from the Sewage Treatment Plant Malyana moves downstream and after a few kilometers drains into the Ashwani Khad. Thereafter, this water of the Ashwani Khad is collected and stored for further treatment, about 3 kms downstream of the confluence and is supplied to the city as drinking water. The physico- chemical parameters of this surface water body were evaluated to find out its suitability for drinking purposes. The samples were taken along the Ashwani Khad during pre Monsoon (2013) and post Monsoon (2013) seasons and the analysis of various physico-chemical parameters was done

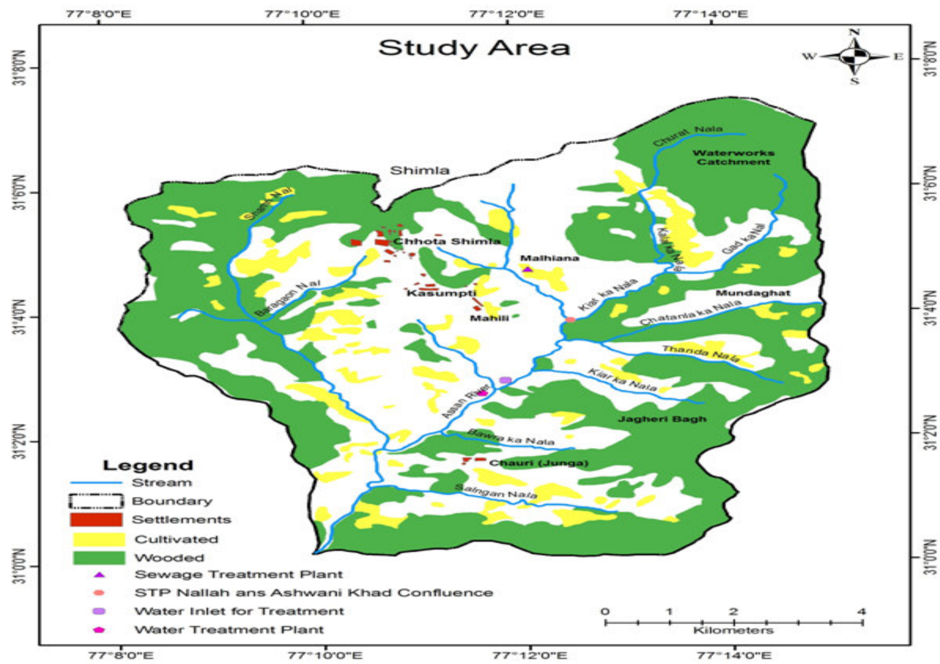

Figure 1. Location map of the study area

3. Materials and Methods

A total of 58 surface water samples (one from left and right bank each) were collected, each at a distance of about 100 meters intervals along the Ashwani Khad, making it a total of 24 sampling sites. One sample each was taken from the water treatment plant and from a household water connection in Kasumpti (since water from Ashwani Khad is supplied to Kasumpti). Two samples marked as A1 and A2 were taken from two respective streams which were joining and meeting into the Ashwani Khad stream. Samples of raw sewage and treated sewage were also taken from the inlet and outlet of Sewage Treatment Plant. Good quality, air tight plastic bottles with screw caps were used for sample collection and safe transfer to the laboratory for analysis. Before the samples were collected, all the plastic bottles were thoroughly cleaned and washed and thereafter sun-dried. Just before the samples were collected the plastic bottles were rinsed twice with the collected water samples. After this, the bottles were labeled and the co-ordinates of the sampling sites were noted. The parameters like pH, EC and TDS were analyzed on the spot using potable water and soil analysis kit. Further analysis of the other parameters, like chlorides, nitrates, sulphates, phosphates etc, were carried out in the laboratory. The bottles were transported and stored at 4°C. For the assessment of BOD and COD samples were collected in borosil glass bottles and were taken to the laboratory within 24 hours. The sampling was done in pre monsoon season in the month of April 2013 and during the post monsoon season in the month of October 2013. The samples were analyzed as per the standard methods for the examination of Water and Wastewater (APHA, 2005) within a short period of time for accurate results. (Figure 2) below shows the sampling sites.

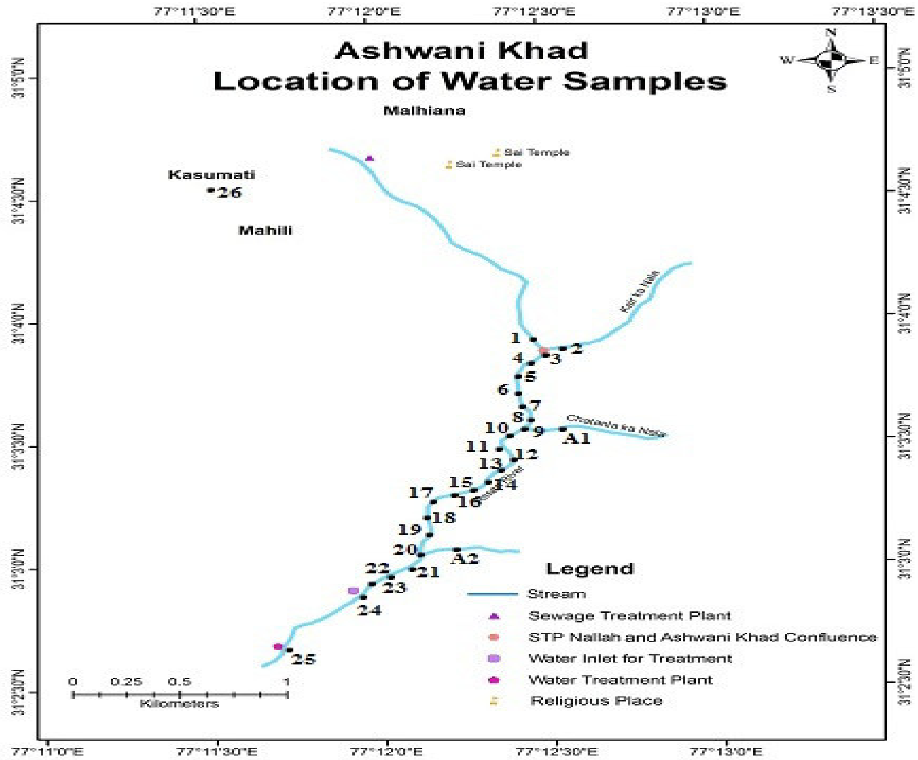

Figure 2. Location Map Showing the Sampling Sites in the Study Area

4. Results and Discussions

In the present study 58 water samples taken from various sites along the Ashwani Khad, shown above in (Figure 2) were tested for parameters like pH, electrical conductivity, total dissolved solids, hardness, alkalinity, nitrates, phosphates, sulphates, chlorides, BOD, COD, DO. These parameters were evaluated in the laboratory and based on the results the water quality was assessed. The results showing the values of various parameters are given in Table 1. The pH of most water samples was within the permissible limits. The EC, TDS and TH were high in some of the samples. Ca^{2+}, Mg^{2+}, SO_4^{2-}, PO_4^{3-}, NO_3^-, F^-, Cl^- all were within the permissible limits as given by BIS and WHO. However the Biological parameters like DO, BOD and COD were high in almost all the samples taken along the stream, thereby indicating a high level of sewage pollution in the water body. The ISO (2012) Indian Standards, Drinking water specifications were used to calculate and evaluate the results of the various parameters in the water samples. Table 1: Parameters showing Permissible limit, Maximum & Minimum range, Mean & Standard deviation for the water samples

Parameter			PRE MONSOON				POST MONSOON			
	Desirable Limit	Permissible Limit	Range	Mean	Standard Deviation	No of samples above Permissible limits	Range	Mean	Standard Deviation	No of samples above Permissible limits
pH	6.5 – 8.5	No relaxation	8.9 -7.72	7.90	0.21	1	8.2 – 7.29	7.85	0.19	None
EC (µS/cm)	-	-	1466 -530	982.64	141.70	-	1140 -312	622.14	188.19	-
TDS (µS/cm)	500	2000	733 - 265	491.28	70.84	None	570 -152	310.25	94.88	None
TH (mg/l)	200	600	287 -178	232.89	24.10	None	178 -78	114.36	24.35	None
TA (mg/l)	200	600	188 -128	158.93	15.29	None	120 -42	68.03	17.77	None
Ca^{2+} (mg/l)	75	200	48.42 -32.4	36.95	3.85	None	41.21 -19.34	29.60	5.01	None
Mg^{2+} (mg/l)	30	100	24.32 -14.3	18.19	2.40	None	19.5-27.22	10.65	3.42	None
Cl^- (mg/l)	250	1000	64.68 -20.26	34.22	7.94	None	52.68 -13.92	27.04	7.33	None
NO_3^- (mg/l)	45	No relaxation	28.5 -1.2	6.26	6.38	None	13.3 -0	2.64	2.98	None
SO_4^{2+} (mg/l)	200	400	36.5 -30.22	32.29	1.14	None	25.4 -19.5	22.91	1.59	None
PO_4^{3-} (mg/l)	-	-	0.66 -0.25	0.52	0.06	None	0.54 -0.11	0.31	0.09	None
F^- (mg/l)	1.0	1.5	1.1 -0.85	0.92	0.06	None	0.98 -0.88	0.91	0.20	None
DO (mg/l)	-	5	9.1 -2.1	5.7	1.31	5	11.9 -3.2	6.88	1.44	1
BOD (mg/l)	0	5 (WHO)	43.5 -8.4	27.11	10.43	28	38.7 -4.8	21.20	8.17	27
COD (mg/l)	0	10 (WHO)	332 -61	159.86	54.22	28	227 -54	130.60	38.60	28

4.1 pH

pH is the hydrogen ion activity and a measure of acidity and alkalinity in aquatic bodies. In general waters having pH between 6.5 and 8.5 are categorized as suitable, whereas waters with pH 7.0 to 8.0 are highly suitable (ideal) for all purposes. The pH values of the water samples ranged between 7.72 to 8.9 in the pre monsoon season and between 7.29 and 8.2 in the post monsoon season indicating a slightly alkaline nature.

4.2 Electrical conductivity (EC)

The Electrical Conductivity of water is a direct function of its total dissolved salts (Harilal et al. 2004) and is used as an index to represent the total concentration of soluble salts in water (Purandara et al. 2003). It is a measurement of water's capacity to carry electrical current and is directly related to the concentration of ionized substance in the water. The values of EC varied between 530 µS/cm to 1466 µS/cm in pre monsoon and 312 µS/cm to 1140 µS/cm in post monsoon season respectively.

4.3.Total Dissolved Solids (TDS)

Total dissolved salt concentration is the primary indicator of the total mineral content in the water and is related to problems such as excessive hardness. TDS concentrations in the study area ranged between 265 mg/l to 733 mg/l with a mean value of 491.28 mg/lt in pre monsoons, and between 152 mg/l to 570 mg/l in post monsoons. The TDS levels were high in few of the samples as shown in (Figure 3).

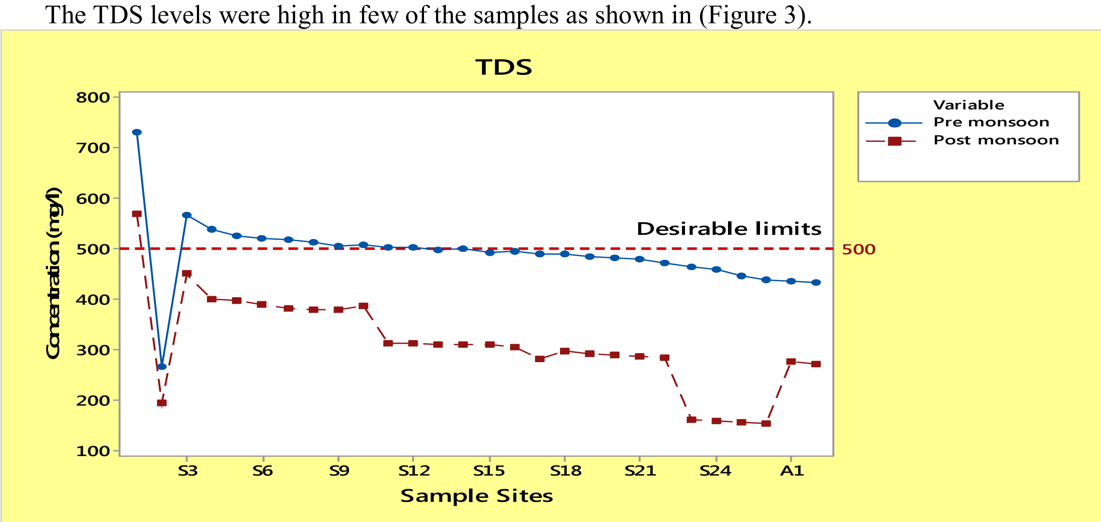

Figure 3. Distribution of TDS in the surface water

4.4 BIOLOGICAL PARAMETERS

The biological analysis of surface water samples showed that the levels of BOD and COD were above the permissible limits for almost all the samples. The DO levels were also above the permissible levels in some of the samples. The reason for these high values could directly be linked to the discharge of treated sewage water from the STP Malyana. Since sewage here is only being treated upto the secondary level, the effluent is not fit to be discharged into a drinking water stream. Moreover there is no power back up in the STP, due to which the sewage is discharged without proper treatment or no treatment at all, sometimes.

4.4.1 Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand (BOD) is the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions (Sawyer and McCarty, 1978). The Biochemical Oxygen Demand for Drinking water should be nil as per BIS. The permissible limit of BOD as given by WHO for drinking water is 5 mg/l. However in the water samples taken along the Ashwani Khad the BOD levels were found to be between 8.4 mg/l to 43.5 mg/l in pre monsoons and between 4.8 mg/l to 38.7 mg/l in post monsoons. The discharge of treated sewage effluent from STP Malyana into the Ashwani Khad is the reason for high value of BOD in the water samples. The (Figure 4) below shows the high levels of BOD in most of the water samples, thereby indicating that the water is unfit for drinking purposes.

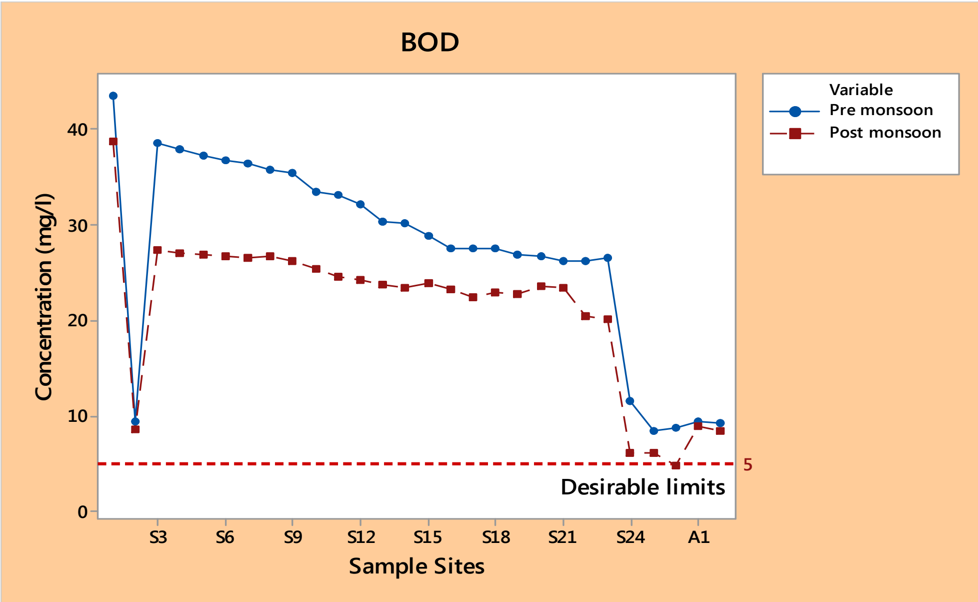

Figure 4. Distribution of BOD in the surface water

4.4.2 Chemical Oxygen Demand (COD)

Chemical Oxygen Demand is the test is commonly used to indirectly measure the amount of organic and inorganic compounds in water. In conjunction with the BOD, the COD test is helpful in indicating toxic conditions and the presence of biologically resistant organic substances (Sawyer and McCarty, 1978). The COD for drinking water should ideally be Zero(Nil) according to BIS. The permissible limit of COD as given by WHO is 10 mg/l. On analysis of COD for the water samples in Ashwani Khad, it was found out that the levels of COD were higher than normal. The pre monsoon COD levels ranged from 61 mg/l to 332 mg/l and the post monsoon COD levels ranged from 54 mg/l to 227 mg/l. The treated sewage water discharge from STP Malyana into Ashwani Khad is the main cause of high levels of COD in all the water samples taken along the Khad. These high levels of COD in the water samples again proves that this water cannot be used for drinking purposes. The (Figure 5) below shows the levels of COD in the samples, both in pre and post monsoon seasons. It is clearly seen that the COD levels are above the desirable limits both in the pre monsoon and post monsoon seasons.

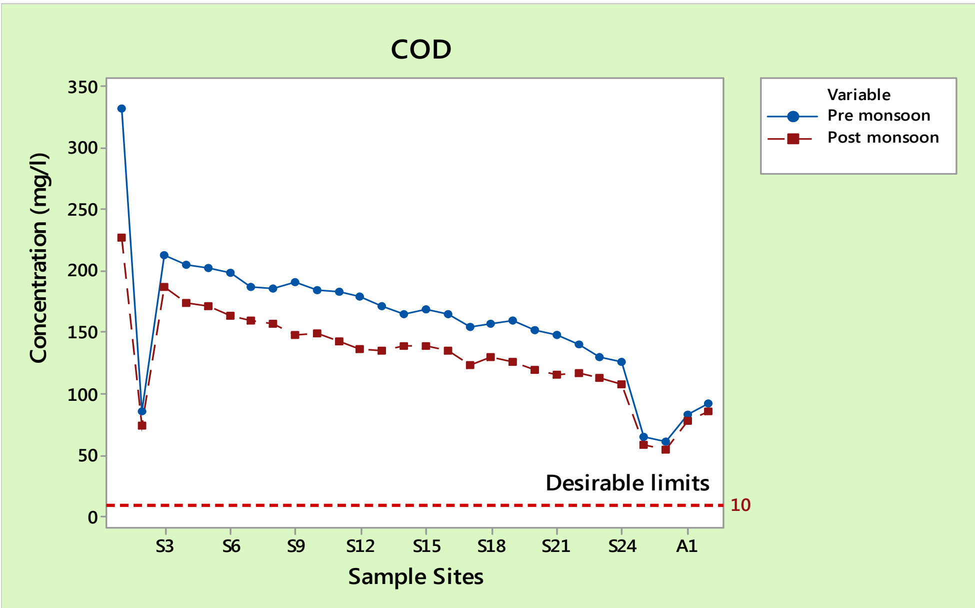

Figure 5. Distribution of COD in the surface water

4.4.3 Dissolved Oxygen (DO)

Oxygen is measured in its dissolved form as dissolved oxygen (DO). Decreased DO levels may also be indicative of elevated amount of bacteria and an excess conentration of BOD. DO is an important parameter to assess the waste assimilative capacity of the waters (Rao and Rao 2010). The DO levels in pre and post monsoon seasons were in the range of 2.1 mg/l to 9.1 mg/l and 3.2 mg/l to 11.9 mg/l, respectively. The minimum tolerance limit of DO as given by ISI for river waters is taken to be 5 mg/l. The DO levels for the samples has been shown in the (Figure 6) below.

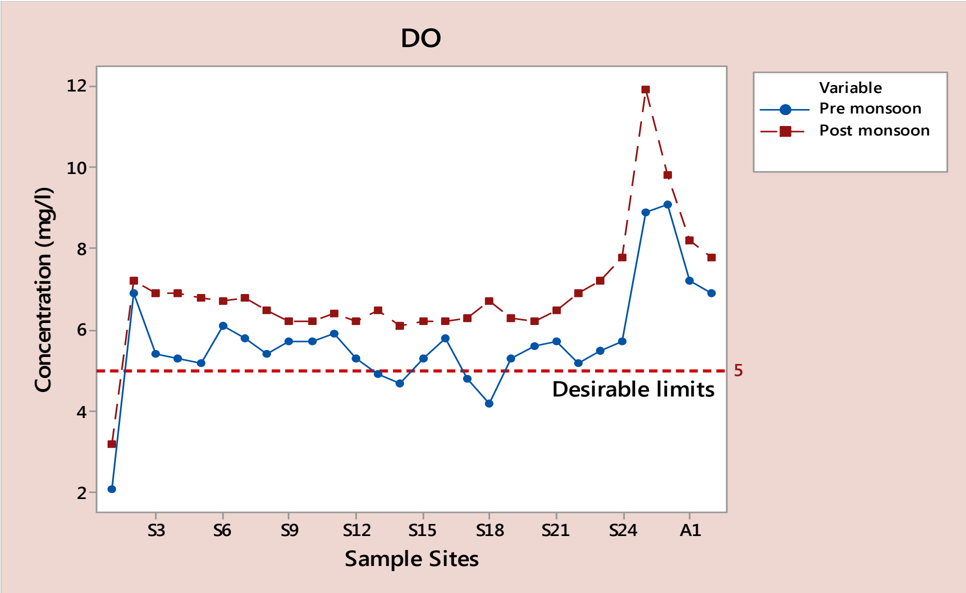

Figure 6. Distribution of DO in the surface water

4.5 PHYSICO-CHEMICAL PARAMETERS

On evaluation, it was found that most of the physico-chemical parameters were found within the desirable levels, except for a few parameters like Total Dissolved Solids (TDS) and Total Hardness (TH). Most of the other parameters were within the desirable limits.

4.5.1 Total Hardness (TH)

Total Hardness results from the presence of divalent metallic cations of which calcium and magnesium are the most abundant. The values of Total Hardness ranged from 178 mg/l to 287mg/l in pre monsoon season and 78 mg/l to 178 mg/l in post monsoon season. The mean values of Total Hardness in pre and post monsoon seasons were 232.89 mg/l and 114.36 mg/l respectively. The desirable limits of Total Hardness however is 200 mg/l. The (Figure 7) below shows the levels of TH in the samples in pre and post monsoon seasons.

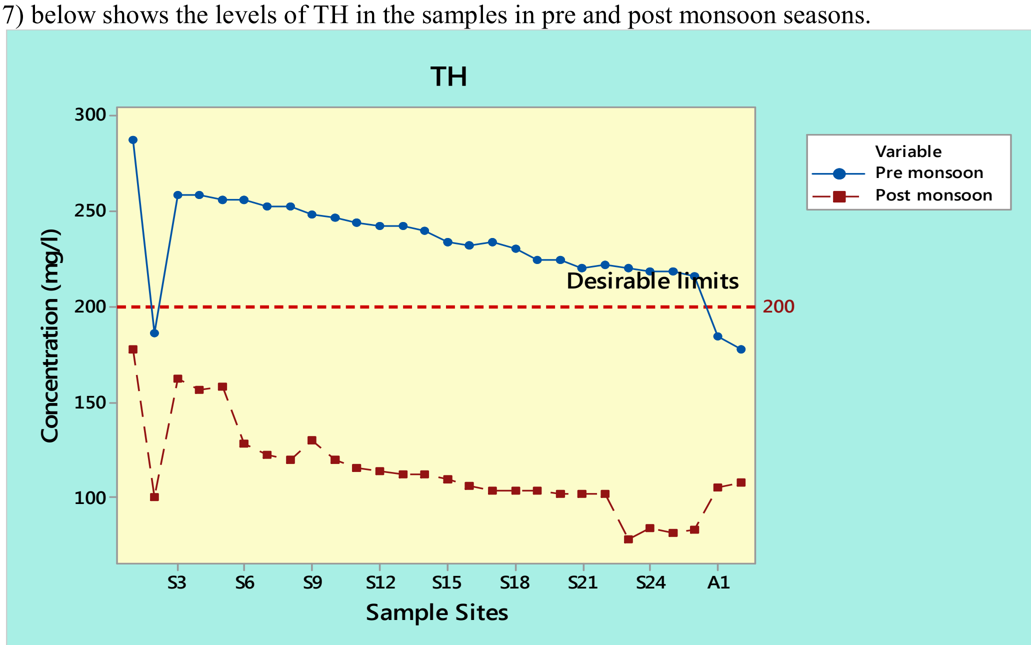

Figure 7. Distribution of TH in the surface water

4.5.2 Total Alkalinity (TA)

Alkalinity mostly is due to the presence of carbonates, bicarbonates and hydroxide ions. Alkalinity, in itself is not detrimental to human body, but is generally associated with high pH values. The values of alkalinity in the various samples of the study area varied from 128 mg/l to 188 mg/l and from 42 mg/l to 120 mg/l in pre and post monsoon seasons respectively. The mean values were 158.93 mg/l in pre monsoons and 68.03 mg/l in post monsoons.

4.5.3 Calcium (Ca^{2+})

The Calcium content in all the water samples was within the permissible limits. According to the BIS standards the desirable limit for calcium is 75 mg/l. The calcium content in the water samples was between 32.4 mg/l and 48.42 mg/l with an average value of 36.95 mg/l in pre monsoon season and 19.34 mg/l to 41.21 mg/l in post monsoon season with the average value of 30.24 mg/l.

4.5.4 Magnesium (Mg^{2+})

The magnesium content ranged between 14.3 mg/l and 24.32 mg/l. In pre monsoons and between 7.81 mg/l to 19.52 mg/l in post monsoons. The average values of magnesium in pre and post monsoons were 18.19 mg/l and 10.65 mg/l, respectively. The BIS desirable limit however is 30 mg/l showing that the magnesium levels in the water samples were within the permissible limits.

4.5.5 Chloride (Cl^-)

Chloride in drinking water is not generally harmful to humans until it is present in high concentrations. The Chloride concentrations ranged between 20.26 mg/l and 64.68 mg/l in pre monsoons and 13.92 mg/l to 52.68 mg/l in post monsoons, indicating that the values were well within the desirable limit of 250 mg/l. The mean values of Chlorides in the water samples was found to be 34.22 mg/l in pre monsoons and 27.04 mg/l in post monsoons.

4.5.6 Nitrates (NO_3^-)

Consumption of excess of nitrates by the humans particularly infants is likely to cause health hazards and may lead to methaemoglobinemia (blue baby syndrome). The values of nitrates in the various water samples ranged between 1.2 mg/l to 28.5 mg/l in pre monsoons and 0.12 mg/l to 13.3 mg/l in post monsoons, with mean values of 6.26 mg/l and 2.64 mg/l, respectively. The values were within the permissible limits of 45 mg/l as given by the BIS. The levels of nitrates were within the desirable limits in all the samples as shown in the (Figure 8) below.

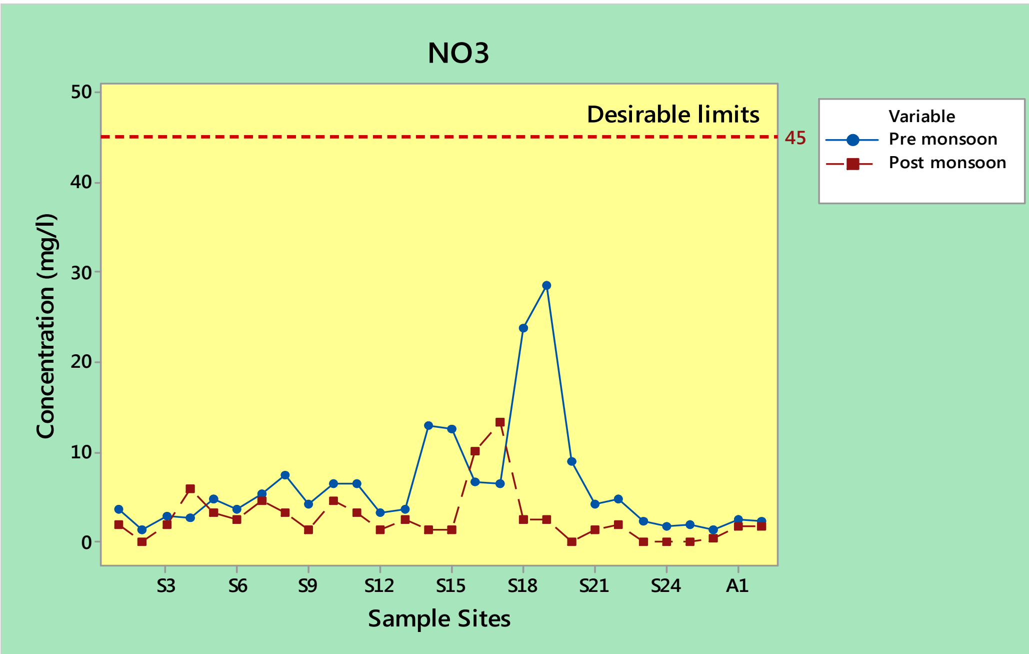

Figure 8. Distribution of NO_3^- in the surface water

4.5.7 Sulphates (SO_4^{2+})

Sulphates occur commonly in natural waters, but the levels can increase due to industrial contaminations with sulphuric acid, bisulphate and aluminum sulphate, etc, used in water purification plants. The values of sulphates ranged between 30.22 mg/l to 36.5 mg/l in pre monsoons and between 19.5 mg/l to 25.3mg/l in post monsoons. The average values of sulphates in pre and post seasons were, 32.29 mg/l and 22.91 mg/l, respectively. These values were also within the desirable limits of 200 mg/l as given by the BIS.

4.5.8 Phosphates (PO_4^{3-})

Phosphates generally come from fertilizers, pesticides, industry and cleaning compounds. Among the natural sources, are phosphate containing rocks and solid or liquid wastes. The values of phosphates in the water samples collected along the Ashwani Khad were found to be between the range 0.25 mg/l and 0.66 mg/l in pre monsoons and between the range 0.19 mg/l to 0.68 mg/l in post monsoons, with mean values of 0.52 mg/l and 0.31 mg/l, respectively. Though there are no limits prescribed by the BIS for the phosphate levels in drinking water, the (Figure 9) below shows the variation in the concentration in pre and post monsoon seasons.

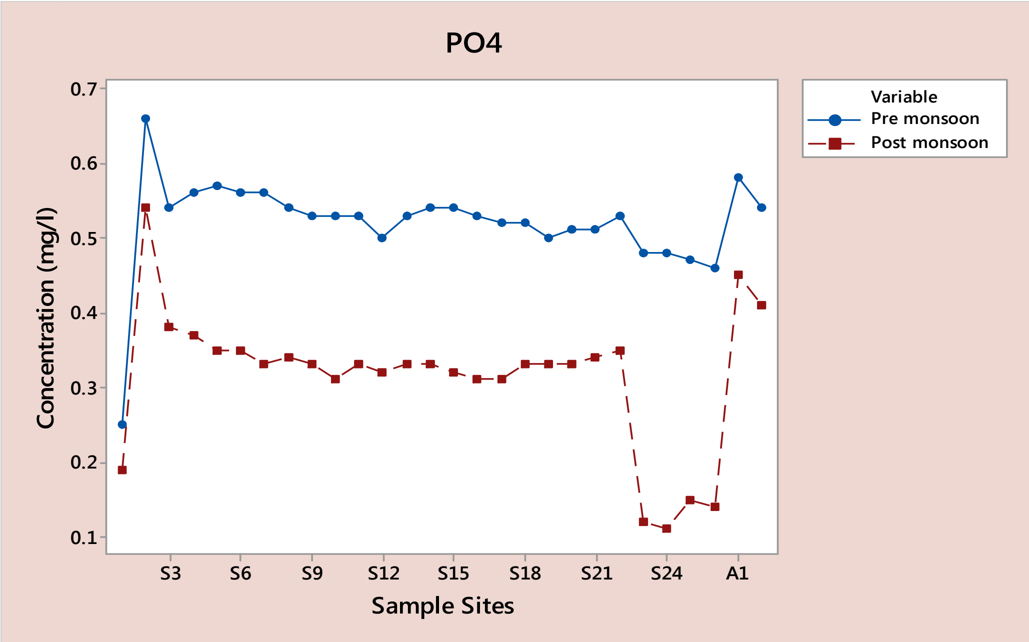

Figure 9. Distribution of PO_4^{3-} in the surface water

4.5.9 Fluorides (F^-)

Fluorides are present naturally in low concentration in drinking water. High levels of fluorides lead to health problems including mottling of teeth and fluorosis. The Flouride concentration in the water samples was found to be between 0.85 mg/l to 1.1 mg/l in pre monsoons and between 0.88 mg/l to 0.98 mg/l in post monsoons.

5. Conclusion

The present study of the physical and chemical characteristics of various surface water samples taken along the Ashwani Khad have given the detailed insight into the quality of water. Since this water is being used for drinking purposes, it's quality is directly related to health. The values of EC, TDS and TH were above the permissible levels in some of the water samples. Although most of the physico-chemical parameters like Ca^{2+}, Mg^{2+}, SO_4^{2-}, PO_4^{3-}, NO_3, F^-, Cl^- etc, were well within the permissible limits of drinking water quality standards, the high values of BOD and COD, however, clearly indicate that the water is unfit for drinking purposes. The sewage treatment plant at Malyana is not working efficiently and is discharging its effluent into the Ashwani Khad after a secondary level of treatment. This treatment of sewage at the STP needs to be upgraded to the tertiary level before it discharges the effluent into the Khad. The sewage treatment plant does not have a Power back up and during the power cuts is unable to perform it's functions and therefore the sewage is sometimes discharged without proper/no treatment into the open drain which carries it to the Ashwani Khad. Also the Water Treatment Plant located near Ashwani Khad which is pumping the water from Ashwani Khad to the main city for drinking purposes is not being able to achieve the desired levels of purification. The purification technique is simple and the basic rapid and slow sand filtration method is being practiced here. The water which is supplied to the residents for drinking purposes contains BOD and COD above the permissible limits. Also the mean value of BOD and COD are more pronounced in the pre monsoon than post monsoon season, this may be due to the dilution effect during monsoon season (Sidhu et al, 2015). The high levels of BOD and COD is a threat to the health of the people in the areas which receive drinking water from Ashwani Khad. Most people are however unaware about the quality of water. Hence it is highly advisable that the purification techniques be upgraded before this water is pumped to the city for drinking purposes.

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