Analysis of physicochemical and biological water characteristics of Phuleli canal

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ABSTRACT

Dumping of solid waste and application of municipal wastewater of Hyderabad city directly into the Phuleli canal deteriorates its water quality. This study was conducted to analyze the physicochemical and biological characteristics, namely temperature, pH, turbidity, conductivity, total dissolved solids, total suspended solids, chlorides, sulfates, hardness, alkalinity, acidity, nitrate nitrogen, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand and fecal coliform of canal water at five different locations along the city. World Health Organization (WHO) and the American Public Health Association (APHA) standards were followed for the characterization of canal water samples. The results revealed that the canal water was slightly alkaline with electrical conductivity of 1200 μS/cm. The concentrations of dissolved oxygen, chemical oxygen demand and biochemical oxygen demand near Kotri barrage were within WHO standards. The dissolved oxygen level in the samples was found decreasing, and biological oxygen demand and chemical oxygen demand level was found increasing from first sampling station to the last along the entire course of the canal. The microbial study of the samples indicated the presence of fecal coliforms in the ranges from 207 to 867 MPN/100ml, which were exceeding the allowable surface water limits. It is discovered from the study that the Phuleli canal water became contaminated due to application of municipal solid waste and untreated wastewater from the city.

1. Introduction

Water is one of the principal commodities, which human has exploited more than any other resource for sustenance of life (Jakhrani et al., 2012a). Approximately 97.5 % of all water on Earth is salt water and just 2.5 % is fresh water, and about 70 % of that fresh water is ice-covered and the remaining is present as soil moisture, or lies in deep underground aquifers as groundwater, which is not accessible to human use. Less than 1 % of the world's fresh water (around 0.007 % of all water on earth's surface) is available for direct human consumptions (Epstein and Jezeph, 2001). Water is commonly referred as the universal solvent as it dissolves many substances. Because of this property, it is rarely found pure in nature. The water quality is of the vital concern for human health and life (Karbassi et al., 2011). However, it is being mainly deteriorated due to intrusion of toxic metal ions from various industrial effluents, such as mining, refining ores, tanneries, and producers of fertilizer, batteries, paper, plastics, pigments etc. (Ileri et al., 2014). The main water quality issues in urban water bodies' result from contaminants such as sediment, nutrients and hazardous substances, carried through the municipal wastewater and industrial effluents (Jakhrani, 2002; Jakhrani et al., 2009). In urban areas, the water quality of small streams is predominantly impacted by structural degradation of stream morphology, agricultural land use in the catchment, and a high load of treated wastewater (Stalter et al., 2013).

Over the last decades a fast economic development has contributed to an intensive increase in the content of waste, accompanied by the

problem of their disposal (Bartkowiak et al., 2016). Various studies have been conducted to assess the level of pollutants and develop effective methods and techniques to treat the water supplies used of drinking purpose around the world. Ohowa et al. (2011) investigated the effects of sewage discharge on nutrient concentrations and BOD_5 levels in the coastal waters and sediments of the City of Mombasa. The superfluous influxes of sewage to the water bodies combined by occasional re-suspension of nutrient enriched sediments are found to be reducing water quality. Pamer et al. (2011) assessed the microbiological and physicochemical characteristics of four lake ecosystems in the Province of Vojvodina in northern Serbia namely, Provala, Ludas, Zobnatica and Palic. It was found that Provala Lake had the best water quality followed by Zobnatica, while significant level of organic water pollution was found in the lakes Ludas and Palic in the month of June and October. Mohseni-Bandpei and Yousefi (2013) investigated the effects of industrial wastes, municipal sewage, fish farming and agricultural runoff on river water quality. Pourang and Noori (2014) determined the level of six heavy metals, namely Cr, Mn, Ni, Pb, V and Zn in top soil, surface water of four streams and groundwater of eight wells and four qanats from an agricultural area located at southern side of Tehran oil refinery. The mean levels of all the elements in the surface and groundwater were found lower than that of standards. Shoaei et al. (2014) pointed out that Cd and Pb were the main pollutants in the Shahid Rajaei Dam Reservoir and it may pose health risks to residents and water receiving areas. Pakistan is not exception regarding water pollution problem in the developing countries. Pakistan ranks at number 80 among 122 nations regarding drinking water quality. Both surface and groundwater all over the country is being contaminated with coliforms, toxic metals and pesticides (Azizullah et al., 2011). The presence of trace heavy metals in the water can cause serious complications to all organisms, especially to human health (Waseem et al., 2014).

Kotri barrage is the last controlling structure constructed on the Indus River, built on the confluence of Hyderabad, Kotri and Jamshoro cities, in 1955. The barrage was constructed to pass a maximum flow of 24,780 cumecs (875,000 cusecs). It is a source of domestic, industrial and irrigation water supply for an area of about 1.126 million hectares (2.78 million acres) and more than 25 million people. There are four canals off-taking from Kotri Barrage, one from right bank and the rest from the left bank (Sohag and Syed, 2014). The Phuleli canal off-takes water from the left bank of Kotri Barrage. It runs through the periphery of Hyderabad city and provides water for agricultural, industrial and domestic purposes to Hyderabad, Tando Muhammad Khan and Badin districts. Besides agriculture use, a fraction of canal water is in direct consumption of people and livestock. It also acts as a receiving body for the municipal wastewaters and industrial effluents, as many inhabitants have constructed their homes on its embankments (Soomro et al., 2014). The consumption of water has been increased with the increase of urban population. Meanwhile, the volume of municipal wastewater is also increased, which is being introduced into the canal without any treatment (Jakhrani et al., 2012b). Such practice is creating serious engineering and environmental problems to the people of Hyderabad city and those living in the downstream areas (Soomro and Kumbhar, 2009). Therefore, it is necessary to assess the impact of wastewater on the canal water quality so as to make the canal water fit for drinking purpose. This study was carried out to check the physicochemical and biological characteristics of Phuleli canal water along Hyderabad city. The findings of this study enable us to recommend the possible precautionary measures to save the lives of people residing in the periphery of the canal and utilizing the canal water for drinking purpose.

2. Materials and method

The study was conducted to examine the contamination level of Phuleli canal water, which receives the municipal wastewater and industrial effluents from different locations of Hyderabad city. Hyderabad city has a population of about 2.2 millions. Two sewage ponds are located in the vicinity of Hyderabad city where the organic matter partially decomposed through aerobic and anaerobic stabilization by the action of microbiological organisms. Both ponds ends in Phuleli canal one near the old power house and the other at Darya Khan Panhwer pumping station. Cantonment Board and Industrial Area pumping stations are also throwing their effluents in the canal. Moreover, two large open sewerage lines directly discharge their effluents in the canal near Kali Mori.

After preliminary survey of the canal along the Hyderabad city, five sampling stations were selected. The sampling stations (SS) were stretched over a distance of about 15 km, from Reduce Distance (RD) 04 to RD 45, covering the entire range of study area. The first sampling station (SS-01) was selected at RD04, the Head Regulator near Akhund Village before entry of any sewage line. A total of three sampling points were chosen between the two main point sources of sewage lines. Second sampling station (SS-02) was at RD21, Hala Road Bridge, third (SS-03) at RD28 Mirpurkhas Road Bridge and the fourth (SS-04) at RD34, Southern Bypass Road Bridge. The fifth and last sampling station (SS-05) was selected at RD45, Behan Mori Road Bridge, where the canal leaves the city limits as shown in Fig. 1.

An integrated methodology was adopted for collection of water samples from the entire course of canal to represent the actual conditions of water quality, as the canal water content distinctive characteristics due to introduction, mixing and dilution of wastewater and industrial effluents from the city.
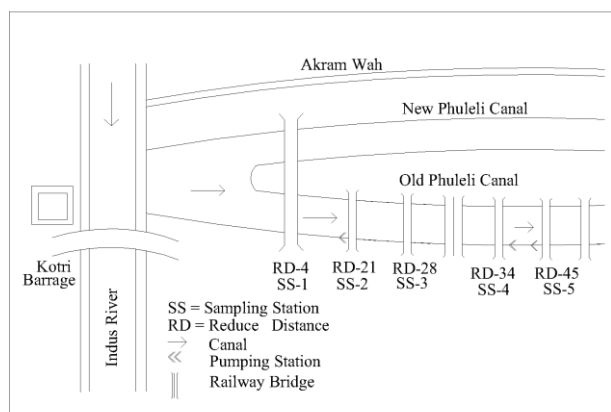
Fig. 1: Sampling stations of Phuleli canal water and wastewater entry points along Hyderabad

The samples were taken from morning to evening for determination of physicochemical and biological properties of canal water quality. The plastic and glass bottles were used for collection of water samples from canal from the selected locations. These bottles were sterilized in the laboratory under standard conditions. All pre-washed bottles were rinsed with canal water twice before collecting the samples. These samples were properly sealed and labeled (showing location, time and date of sampling) and then brought to the laboratory for analysis. The physical quality parameters namely temperature of water was noted at the time of sample collection (°C), whereas, the pH Value, conductivity (μS/cm) and turbidity (NTU) of samples were examined in the laboratory as per standards (APHA, 2005). The chemical quality parameters, like total dissolved solids (TDS), total suspended solids (TSS), chlorides (mg/l), sulfates (mg/l), hardness (mg/l), alkalinity (mg/l), acidity (mg/l), nitrate-nitrogen (mg/l) were also investigated. In addition, the biological parameters namely, dissolved oxygen (mg/l), biochemical oxygen demand (mg/l), chemical oxygen demand (mg/l) and faecal coliforms (MPN/100 ml) of canal water samples were also checked.

The air and water temperatures were measured with mercury-glass thermometer (ranging between 0°C to 50°C with 0.1°C least count). The air temperature measurement was made approximately 1m above the surface of water at sampling point. The thermometer was shaded from the sun light. The temperature of canal water was measured by dipping the thermometer directly in the water body and waiting until the reading was constant. The measurement of pH, conductivity and total dissolved solids (TDS) was made by pre-calibrated pH and conductivity/TDS meters respectively by dipping the pre-cleaned electrode in the water samples. The turbidity of samples was measured by the help of Jackson Turbidity Tube according to the set standards. The level of total suspended solids (TSS) values of canal water samples were measured directly through spectrophotometer in mg/l. In addition, the chlorides were determined by Mohr method, hardness by EDTA (disodium ethylenedi-aminetetraacetate dehydrate titrant 0.01 N) and sulfates, alkalinity and acidity by means of titration method.

Nitrate-Nitrogen level of the samples was determined by Cadmium Reduction Method using direct reading of Spectrophotometer. The Winkler's (Iodometic) method was applied for the determination of dissolved oxygen (DO). For biochemical oxygen demand (BOD_5) analysis, the samples were collected in brown Winkler glass bottles and placed in the incubator at 20°C for five days. After incubation the dissolved oxygen of the sample was determined as described in DO test. The BOD was calculated from the difference between dissolved oxygen before and after incubation. Chemical oxygen demand of samples was tested through titration. The most probable number (MPN) technique was used for bacteriological examination of water samples.

3. Results and discussion

The temperature of canal water was found to be fluctuated between 20°C and 36°C at the time of collection of samples and the air temperature one meter above the surface of water was varied from 29°C to 43°C. The observed temperature of canal water was lower than the temperature of the surrounding air. Fluctuation in temperature of canal water could be due to different time of sampling, climatic conditions and the location of collected sample. Moreover, the pH value at SS-01 of Phuleli canal was ranging between 7.7 and 8.6, and at the rest of sampling stations its value was between 2 and 5 as shown in Fig. 2.
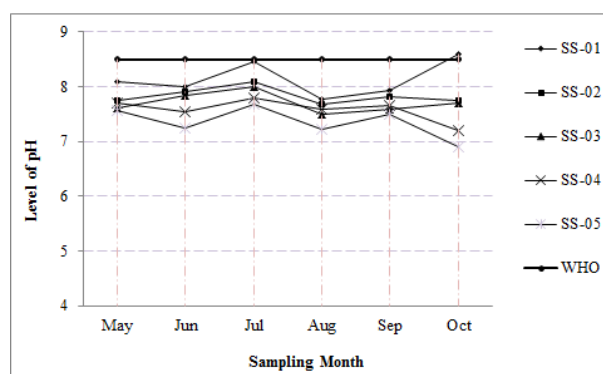
Fig. 2: pH level of Phuleli canal water at different sampling stations

The overall investigation of pH values from Kotri barrage to entire range of study showed that the Phuleli canal water from SS-02 to SS-05 was comparatively less alkaline than the SS-01. This could be attributed to the fact that there was low oxygen content from SS-02 to SS-05 as compared to SS-01. It generally develops free CO_2 which resulted in lowering the pH of canal water. However, the pH values of all canal water samples were within the WHO standards.

3.1. Physicochemical characteristics of canal water

The average value of electrical conductivity observed at SS-01 was 434 µS/cm as shown in Fig. 3. There was positive shift in the base line of conductivity from SS-02 to SS-5 along the entire length of Phuleli canal. The average maximum rise in conductivity was 1051 µS/cm found in water samples of SS-04 near Bhatti village which could be attributed to the influx of large fraction of wastewater from the adjoining open sewerage lines near old power house. That sewage was loaded with higher concentration of dissolved electrolytic salts containing Ca, Mg, K, Cl, bicarbonates, and sulfates as principal constituents.
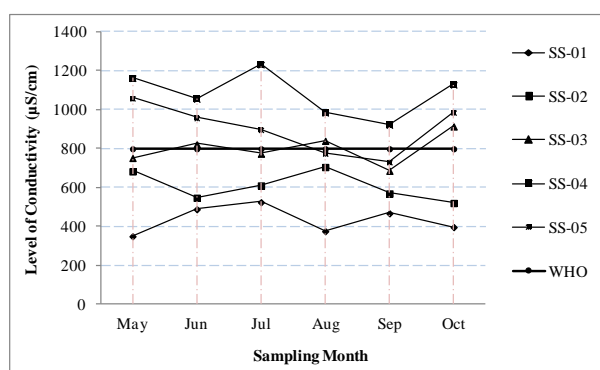

Fig. 3: Electrical conductivity level of Phuleli canal water at different sampling stations

The results reflected the pronounced influence of wastewater in elevating the conductivity of Phuleli canal water from SS-02 to SS-05 as compared to the reference SS-01 near Akhund village. The level of conductivity from SS-03 to SS-05 showed higher as compared to WHO guideline value of 800 µS/cm. In addition, the turbidity of canal water was mainly due to silt contents produced because of high water discharge during the period of study. The observed values range was from 121 to 214 NTU as shown in Fig. 4.
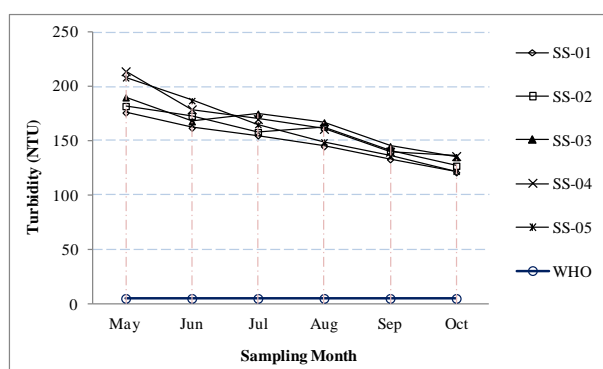

Fig. 4: Turbidity level of Phuleli canal water at different sampling stations

The mean maximum value of 166 NTU was observed at SS-04 while mean minimum value 148 NTU was obtained at SS-01 which corresponds to the lowest values of non-filterable residue and suspended solids bearing indirect relationship with transparency. The increasing values of turbidity from SS-02 to SS-05 could be attributed to the addition of highly turbid wastewater through different sewage outlets of the city. The average value of turbidity for all water samples was found to be higher than the WHO guideline value of 5.0 NTU.

The average values of TDS were 278 mg/l with the variation of 224 – 336 mg/l at SS-01 and the mean results of TDS along the canal were ranged between 388 mg/l at SS-02 and 692 mg/l at SS-04. The overall fluctuation in TDS along the Phuleli canal was 224 to 789 mg/l as shown in Fig. 5.
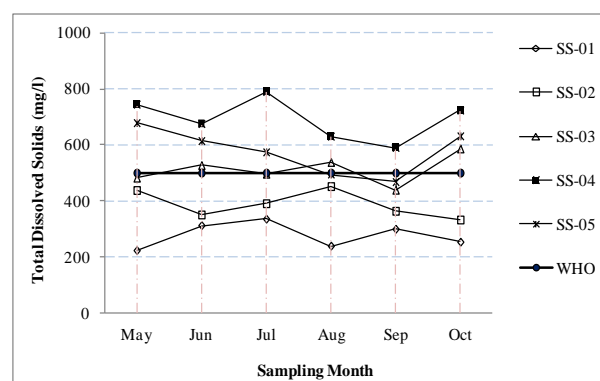

Fig. 5: Total dissolved solids level of Phuleli canal water at different sampling stations

The above results revealed that there was a regular increase in concentration of TDS along the canal. The large increase at SS-04 could be attributed to the introduction of higher concentration of electrolytic salts from the open sewerage line near railway crossing. However due to dilution factor and sedimentation process the decrease in TDS at SS-05 was observed. Since, the samples taken from SS-02 to SS-05 indicated higher values as compared to WHO standard of 500 mg/l.

Likewise, the average value of total suspended solids (TSS) at SS-01 was 652 mg/l, with the variation of 487 - 964 mg/l. The overall values of total suspended solids in the canal were found to be fluctuated between 466 and 727 mg/l from SS-02 to SS-05. At the last sampling station, the mean value of TSS was 575 mg/l as shown in Fig. 6.
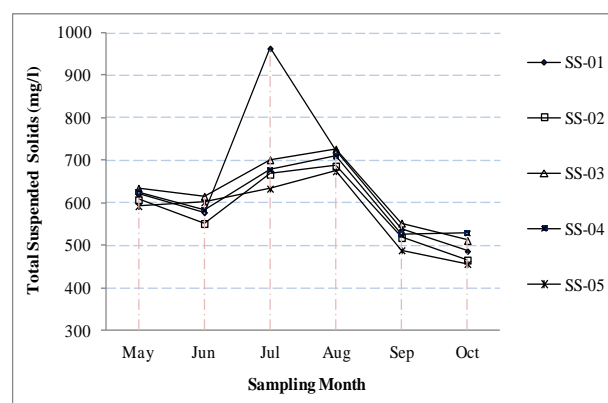

Fig. 6: Total suspended solids level of Phuleli canal water at different sampling stations

The increase in the concentration of TSS could be attributed to the mixing of un-treated municipal wastewater coming from various open drains which was highly loaded with finely divided organic and inorganic matters, microorganisms, silts and suspended clays. The decrease in TSS at SS-05 could be attributed to the dilution factor as well as the self-settling and purification process of the canal.

The values of chlorides were found ranges from 46 mg/l to 101 mg/l with the mean value of 69 mg/l at SS-01 as shown in Fig. 7. The considerable changes in the concentration of chloride content were detected from SS-02 to SS-05 as the result of mixing up of saline wastewater from numerous sewerage lines with the fresh canal water.
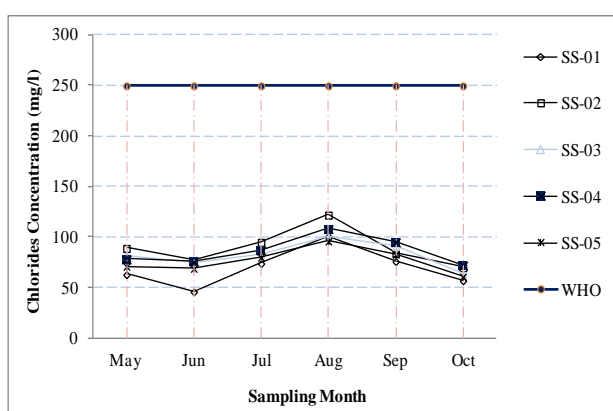

Fig. 7: Chlorides concentration of Phuleli canal water at different sampling stations

The overall fluctuation in the chlorides at these stations was between 61 mg/l and 122 mg/l. The maximum average rise with the value of 89 mg/l was found at SS-02. This could be attributed to the influx of large fraction of salinity rich wastewater from the Cantonment Board Sewage Pumping Station near Barkat colony or Jacob tanks. Comparatively lower values of chlorides were recorded at SS-05, which indicates the absence of major external sources, dilution factor and high flow rate of the canal water. Since, all the observed values of chlorides were below the WHO standard of 250 mg/l. Furthermore, the mean value of sulfate concentration was recorded 42 mg/l, which ranges from 36 to 54 mg/l at the SS-01, before the introduction of sewage from the city as shown in Fig. 8. The values of sulfate content fluctuated between 44 mg/l and 73 mg/l from SS-02 to SS-05 with maximum average of 59 mg/l at SS-04 and the minimum average of 52 mg/l at SS-05. The results reflect the considerable influence of sewage in elevating the sulfate content of Phuleli canal water. However, the overall values of sulfates were within the WHO guideline limit of 200 mg/l.

The mean level of hardness was 72 mg/l at the SS-01 with a minimum of 45 mg/l and maximum of 110 mg/l as shown in Fig. 9. The variations in the level of hardness were noted from 54 mg/l to 132 mg/l throughout the canal length from SS-02 to SS-05. The average higher level of hardness with 92 mg/l was found at SS-04, while a slight decline in the

mean value was observed at the last station which is the indicator for dilution factor and high flow rate of canal water during the summer season. Since, the level of hardness the water samples were less than WHO standard of 150 mg/l. In addition, the average level of alkalinity at SS-01 was found to be 125 mg/l, with a minimum value of 94 to a maximum value of 168 mg/l. The alkalinity level was varied between 96 and 175 mg/l from SS-02 to SS-05 as shown in Fig. 10. The results showed no significant change in the level of alkalinity throughout the entire period of study. It may be due to the interaction of bicarbonates, sulfates and chlorides with the equivalent amount of strong acids present in the wastewater before mixing with the canal water. Alkalinity level was in the acceptable range for canal water quality.
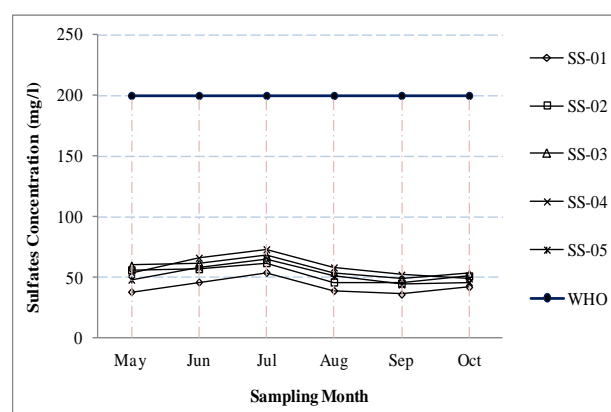

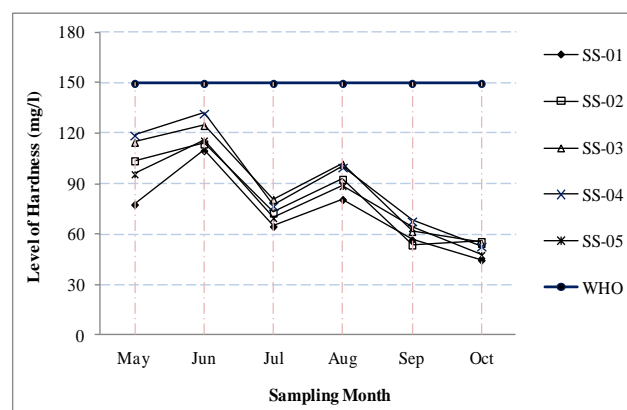**Fig. 8:** Sulfates concentration of Phuleli canal water at different sampling stations

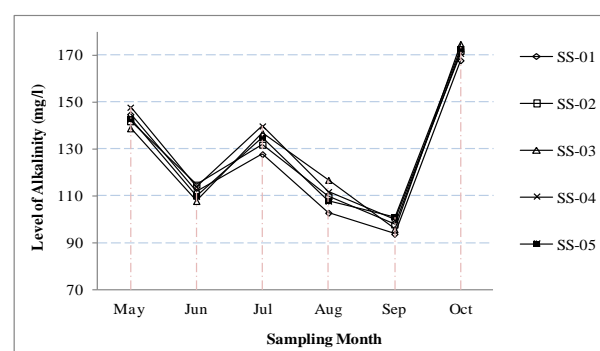**Fig. 9:** Level of hardness of Phuleli canal water at different sampling stations

Fig. 10: Alkalinity level of Phuleli canal water at different sampling stations

In the meantime, the level of acidity at SS-01 was in the range of 7.8 to 12 mg/l with a mean value 9.4 mg/l. The fluctuation in the values was observed from SS-02 to SS-05 with the values from 9 mg/l to 15 mg/l. Since, the maximum average of 12 mg/l was observed at the SS-04 as shown in Fig. 11. The results showed that there was a small but continuous increase in the concentration of acidity in the canal water due to addition of contaminated water coming from sewerage lines and industrial effluent outlets. However, there is no WHO guideline value for acidity concentration of surface waters.

The fluctuation in N-Nitrate in Phuleli canal was in the range of 4.4 mg/l to 7.7 mg/l. The lowest average concentration was 5.6 mg/l found at SS-04 and highest average was 6.47 mg/l recorded at SS-01 as shown in Fig. 12. It was deduced from the results that aerobic bacteria become more active in bringing about the oxidation at SS-01 in presence of higher concentration of oxygen and low oxygen demand as compared to SS-04. The denitrification process could be dominant due to lower value of dissolved oxygen and higher oxygen demand at SS-04. However, almost all values of examined samples were within WHO standard of 10 mg/l.
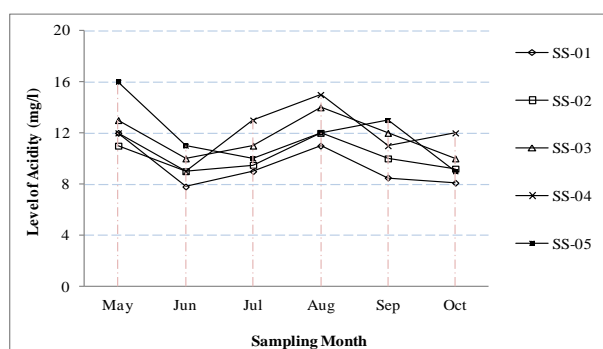

Fig. 11: Acidity level of Phuleli canal water at different sampling stations
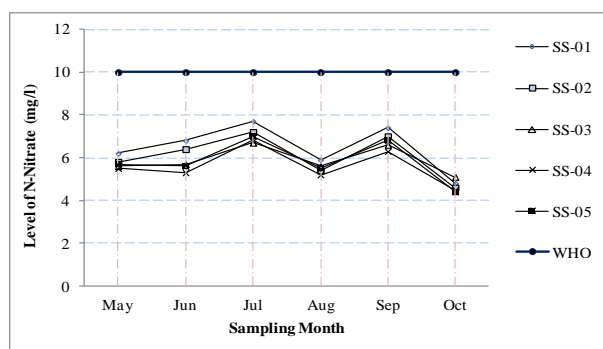

Fig. 12: Level of N–Nitrate of Phuleli canal water at different sampling stations

3.2. Biological characteristics of canal water

The level of dissolved oxygen in the samples was found between 6.8 and 9.0 mg/l with mean concentration of 8.0 mg/l as shown in Fig. 13. The continuous decline in the dissolved oxygen level was found at all the sampling stations, from SS-02 to SS-05 throughout the length of the canal. The values at these stations were found to be 6.4 to 8.2 mg/l. The

lowest mean value 4.7 mg/l was found at SS-05, while the highest mean of 7.1 mg/l was observed at SS-02. The primary cause of overall depletion in oxygen from the canal water may be the addition of oxygen demanding wastes from different sewerages of the city. These materials were easily broken by bacterial activity in presence of oxygen. Hence the dissolved oxygen of Phuleli canal water was utilized in oxidation of such materials causing the deficit of DO levels. Water samples of SS-04 and SS-05 averagely showed DO level less than WHO standard of 6.0 mg/l. In addition, the mean concentration of COD in Phuleli canal was 30 mg/l at SS-01, where the fluctuation of COD was within 20 to 42 mg/l as shown in Fig. 14. The average maximum level in COD along the study area of the canal was 45.6 mg/l estimated at SS-05, while the minimum average was 37 mg/l at SS-02. During the entire study period, the COD level was found to be fluctuated between 32 and 66 mg/l. The significant changes in the concentration of COD from SS-02 to SS-05 were observed as a consequence of wastewater introduction from five sewage sampling stations. The elevated level of COD in the Phuleli canal was corresponding to the maximum depletion of DO. Besides, COD, the mean BOD level in Phuleli canal waters was 14.5 mg/l at SS-01 with ranges from 9.0 to 28.0 mg/l as shown in Fig. 15. The average maximum increase in BOD along the examined area was 30.6 mg/l found at SS-04, while the mean minimum was 19.0 mg/l at SS-02. The overall BOD level was ranged from 13.0 to 43 mg/l. The significant changes in the level of BOD were observed from SS-02 to SS-05. That was attributed to the consequence of wastewater introduction from five sewage sampling stations. The elevated level of BOD in the Phuleli canal was resultant to the maximum depletion of DO.

The monitoring of surface water in terms of faecal coliform bacterial count and identification of special organisms is very important as they provide a measure of degree of contamination of the water. The presence of bacteria is hygienically suspected for intended uses of water. The Faecal coliform load was found between 78 and 216 MPN/100 ml, with a mean bacterial count of 120 MPN/100 ml of the samples at the uncontaminated SS-01 near Akhund village as shown in Fig. 16. The bacterial load in Phuleli canal from SS-02 to SS-05 was fluctuated within 207 to 867 MPN/100 ml. The minimum average level of the faecal coliform concentration was 290 MPN/100 ml at SS-02. Whereas, the maximum mean value reached up to 650 MPN/100 ml at SS-04 which is about 5.4 times higher than the mean of SS-01. The above findings provide a clear indication of the pronounced impact of sewage on the degree of bacterial contamination of Phuleli canal water from SS-02 to SS-05. As the canal flows further downstream, the bacterial pollution load decreases due to dilution factor and self-purification process of the canal. The WHO guideline value for Faecal coliform in drinking water is 0.00 MPN/100 ml.
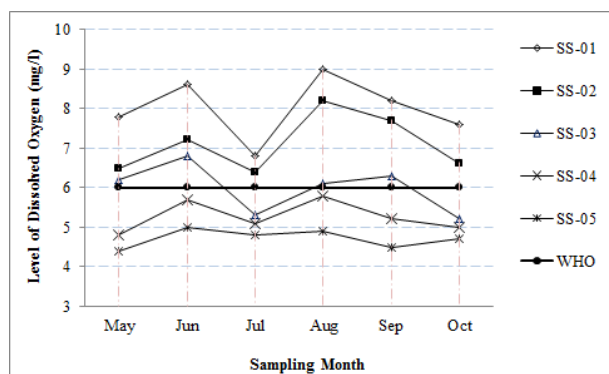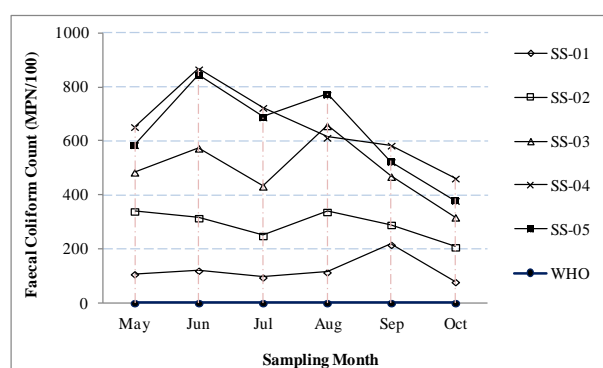
Fig. 13: Dissolved oxygen level of Phuleli canal water at different sampling stations
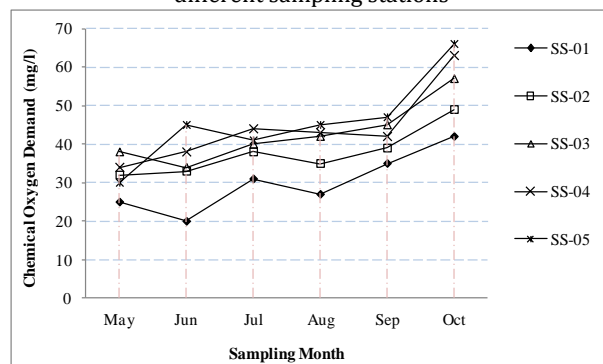
Fig. 14: Chemical oxygen demand level of Phuleli canal water at different sampling stations
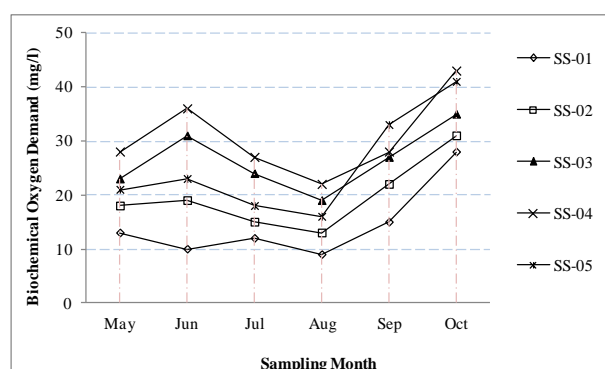
Fig. 15: Biochemical oxygen demand level of Phuleli canal water at different sampling stations

Fig. 16: Faecal coliform count in Phuleli canal water at different sampling stations

4. Conclusion

The electrical conductivity of canal water samples was found 1200 μS/cm at one sampling point, which indicates slightly alkaline as compared to WHO standards. The dissolved oxygen level in the samples was found decreasing and biological oxygen demand and chemical oxygen demand level was found increasing from first sampling station to the last along the entire course of the canal, however, these were within standards. The organic matter was found more from the samples SS-02 and SS-03 due to absence of dissolved oxygen contents. These results show alarming levels of BOD and COD in the canal water. The faecal coliforms were found from the range of 207 to 867 MPN/100 ml, which were exceeding the permissible surface water limits. It indicates the contamination of water with feces due to the application of municipal solid waste and untreated wastewater from the city. It is recommended that the wastewater and solid wastes generated from municipal and industrial areas should not be disposed-off into the canal waters without prior treatment, and no garbage should be dumped besides the canal embankments.

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