ANALYSIS OF PHYSICOCHEMICAL AND BIOLOGICAL QUALITY PARAMETERS OF PHULELI CANAL WATER AND WASTEWATER ADJACENT TO HYDERABAD CITY

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ABSTRACT

The purpose of this study was to examine the level of physicochemical and biological parameters of Phuleli canal water and effluents entering the canal along the entire length of Hyderabad city. In this regard, five different locations, each for investigations of canal water and wastewater were selected. The parameters studied were temperature, pH, turbidity, electrical conductivity, total dissolved solids and suspended solids, chlorides, sulfates and nitrate-nitrogen, biochemical oxygen demand (BOD), chemical oxygen demand (COD) and faecal coliforms count. The study confirmed the extraordinary increase of electrical conductivity and total dissolved solids especially during lower flow periods of canal water. Higher level of COD with 1056 mg/l and faecal coliforms with 207 to 867 MPN/100 ml was also recorded, which exceeds permissible surface water limits. It was observed that the level of BOD and COD were increasing with entering of effluents in the canal and decreasing with the passage of time due to self-purification by canal water. The results revealed that the continuous inflowing of untreated or partially treated sewage and industrial effluents into the canal has changed its physicochemical and biological characteristics, which make it unfit for human consumption and can have long-term irrevocable ecological threats if left unmanaged.

Key words: *physicochemical characteristics, biological properties, faecal coliforms, wastewater effluents, canal water*

1. INTRODUCTION

Water is one of the principal commodities, which human has exploited more than any other resource for sustenance of life. It is commonly referred to as the universal solvent as it dissolves many substances and easily gets polluted. Thus, it is rarely found pure in nature. The major cause of water contamination is receiving of untreated municipal, industrial effluents and hazardous substances from the nearby areas [1, 2]. The characteristic parameters of water bodies indicate its pollution level and quality to be used for household or any other applications [3]. The main physiochemical parameters of water and wastewater are temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), turbidity, chlorides, sulfates and nitrates. The biological and microbial parameters include biochemical oxygen demand (BOD), chemical oxygen demand (COD) and presence of coliforms or disease causing bacteria in the water bodies.

1.1 Physicochemical and Biological Quality Parameters of Water

Temperature is one of the most important parameters for aquatic environment as it alters the characteristics of the water. The rate of chemical reaction and other biological activities are reliant on the water temperature. The increase of temperature increases the oxygen demand and decreases the oxygen solubility in water, leading to oxygen depletion problem in the water bodies. The second most important physicochemical parameter is the level of pH, which is a negative logarithm of the hydrogen ion concentration [4, 5]. The value of pH for pure water is 7.0. Its value is less than 7.0 indicate acidic and greater than 7.0 basic nature of waters. The examination of electrical conductivity shows the capacity of ions in a solution to carry electric current. The current is carried out by inorganic dissolved solids such as anions of chloride, nitrate, sulfate and phosphate, and cations of sodium, calcium, magnesium, iron and aluminum. Total dissolved solids consist mainly of inorganic substances, such as calcium, magnesium and sodium, bicarbonates, chlorides and sulfates [6, 7]. The World Health Organization (WHO) guide line value for TDS in drinking water is 500 mg/l and for wastewater is 3500 mg/l. Most surface waters contains suspended solids load due to the presence of dispersed clay, slit, and finely divided organic and inorganic substances and other microorganisms [8]. Quantification of total suspended solids helps to improve the operational efficiency of treatment units and sewerage lines. The turbidity test

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measures of optical property of water samples which results from the scattering and absorbing of light by the particulate matter present in it. High levels of turbidity protect the microorganisms from the effect of disinfection and can stimulate the growth of bacteria. The guideline value for turbidity is 5.0 Nephelometric Turbidity Unit (NTU) [9].

Chloride, sulfates and different forms of nitrogen are present in natural water and wastewater bodies with variable concentration levels. The higher level of chlorides in water bodies is either due to the contact with chloride containing geological formations or mixing of sewage and industrial effluents. The chlorides have a corrosive effect on metal pipes and structures. It is also harmful to most trees and plants, if its level exceeds the permissible value. Higher levels of sulfates are mostly attributed to the leaching of magnesium sulfate and sodium sulfate deposits [10]. However, industrial and domestic wastes can also increase its concentration. Various forms of nitrogen with respect to decreasing oxygen level in the water bodies are nitrate, ammonia and organic nitrogen. Nitrate generally occurs in trace quantities in surface waters but may get higher levels in some ground waters. The fertilizer use, decayed vegetable and animal matter, domestic effluents, sewage sludge disposal to land, industrial discharges, leachate from refuse dumps and atmospheric wash outs all contribute to these ions in water sources. Such sources can contaminate the streams, rivers, lakes, and also groundwater bodies.

In addition, organic matter is one of the major pollutants in wastewaters. Generally it is measured as biochemical oxygen demand (BOD) and chemical oxygen demand (COD) [11]. BOD test is one of the major tests to quantity the level of oxygen utilized by microorganisms in the aerobic oxidation of organic matter. This test is also used to determine the relative oxygen requirements of treated effluents and polluted waters. The level of organic pollutants or organic strength of wastewater and pollution of natural waters is determined by COD test. As this test indicates the quality of natural waters and helps to control oxygen consuming (both organic and inorganic) pollutants. Moreover, in the 19th century, microorganisms were identified as the cause of diseases. The microorganisms in wastewater originated mainly from human's excreta, as well as from the food industries. The high concentration of microorganisms may create a severe health risk when raw wastewater is discharged into the receiving water bodies [12]. Human and animal wastes carried to the streams are sources of pathogenic or disease-causing bacteria and viruses. Fecal coliform, Enterococci, and E. coli bacteria are used as indicator organisms. These species indicate the probability of finding the pathogenic organisms in any stream or water body. Unfortunately, most of the industrial effluents and municipal wastewaters are being disposed-off directly into the surface water bodies in Pakistan, without any treatment. Moreover, no concerns are shown to the proper assessment, monitoring and prevention of water bodies from contaminants. The presence of huge number of organic contaminants in the environment poses potentially precarious consequences [13]. Therefore, it is prime need to establish the information databases, which reveals the level, amount and types of pollutants present in the water bodies.

1.3 Background of Phulei Canal

Hyderabad is located at 25.36ºN latitude and 68.36ºE longitude with an elevation of 13 m above sea level. It is located on the east bank of the River Indus [14]. Phuleli canal is a main water supply source for both irrigation as well as human consumption for Hyderabad city dwellers as well as in its adjoining areas, which takes-off water from Kotri Barrage. Although, there are facultative ponds for the treatment of municipal wastewaters of the city, yet the network of sewerage lines is not so good to divert all the effluents towards these ponds. Therefore, some part and areas of municipal wastewater as well as toxic industrial effluents are directly disposed-off either by gravity flow or by means of pumping into the Phuleli canal without any treatment [15]. The municipal wastewater which inflows into the Phuleli canal comprised of the areas of cantonment, Hirabad, Khuwaja colony, Silawat para and Northern part of Liaqat colony and old Power House [16]. It also receives the toxic substances emitted from vehicles and bangle industries, liquid wastes generated from slaughter houses and poultries and heavily contaminated industrial affluent from Hala Naka to Husri and also from Zeal Pak cement factory [17, 18]. The increasing level of pollutants in Phuleli canal water put the lives of millions of people residing in Hyderabad, Badin, Tando Muhammad Khan and Matli towns at the risk, as they use this canal water for drinking purpose [19,20]. Such practice is creating serious multi-dimensional problems to the people of Hyderabad city and those living in the downstream areas. Therefore, it is necessary to assess the quality of canal water and wastewater effluents so as to make potential recommendations for the treatment of wastewater inflowing towards canal water. This study is carried out to check the physicochemical and biological characteristics of Phuleli canal water and wastewater effluents at different locations along the entire course of canal passing through the Hyderabad city.

2. MATERIALS AND METHODS

A total of ten sampling locations were selected, five each for canal water and wastewater analysis, after conducting preliminary survey of canal along the entire 15 km length of Hyderabad city. The first location was selected at reduce distance (RD) 04 of Phuleli Canal near Akhund Village before entrance of any wastewater effluents. Three locations were chosen between two main point sources of wastewater entrance and the last location was taken at RD 45, where canal leaves the city limits as shown in Figure 1.

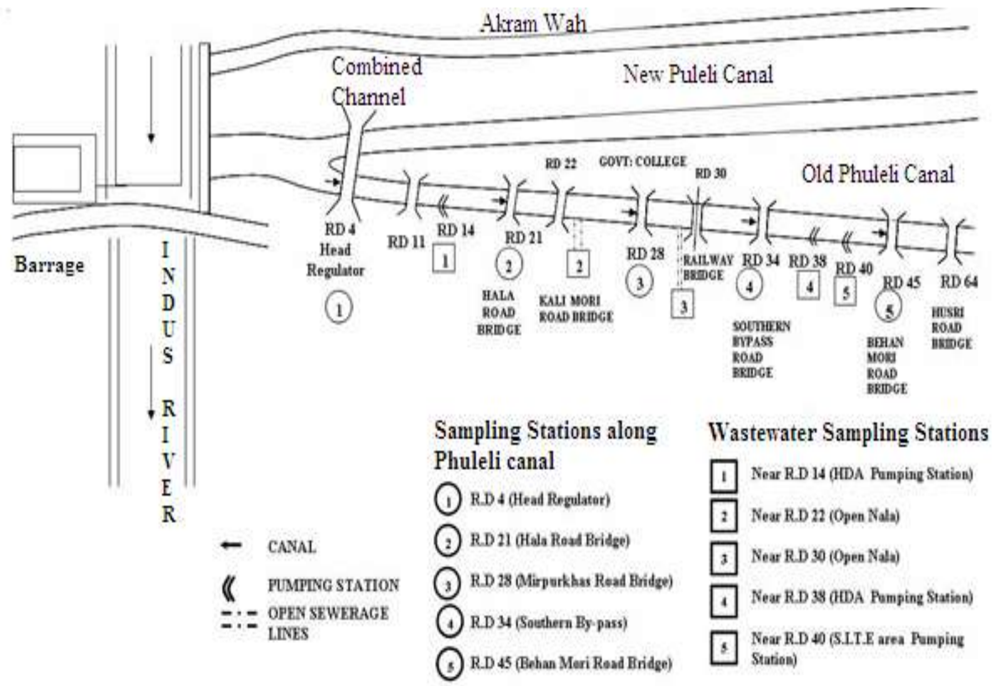

Figure 1. Selected sampling locations on Phuleli canal water and wastewater effluents

An integrated method and composite sampling technique was adopted for the collection of water samples to represent the true picture of canal water quality and water entering the canal. First, the individual grab samples were collected in sterilized plastic and glass bottles from morning to evening at different sewerage lines and then mixed. The bottles were rinsed with canal water and wastewater twice before collection of samples. Then, bottles were properly sealed/labeled and brought to laboratory for analysis. The physicochemical quality parameters namely temperature, pH, electrical conductivity (µS/cm), total dissolved solids (TDS), total suspended solids (TSS), turbidity (NTU), chlorides (mg/l), sulfates (mg/l), nitrate-nitrogen (mg/l) were examined. The microbiological parameter tests were biochemical oxygen demand (mg/l), chemical oxygen demand (mg/l) and faecal coliforms count (MPN/100 ml).

The air and water temperatures were measured with the help of Thomas Double-Safe Precision General Purpose Liquid-In-Glass Thermometer, 200mm Length, -10ºC to 110ºC, 50mm immersion mercury-glass thermometer. The air temperature was taken 1m above water surface at each sampling location by shading the thermometer from direct sun light. The temperature of canal water and wastewater was recorded by dipping the thermometer directly into the water stream and waiting until the reading was constant. The pH was recorded using a pre-calibrated PH-2601 PH/Temp Meter by dipping the pre-cleaned electrode in the water samples. The turbidity of the samples was recorded by 2020e/2020i Turbidity Meter Jackson turbidity tube following the standard procedure. The level of total dissolved solids and electrical conductivity was determined through a pre-calibrated ELE-515, Bench-top TDS, Conductivity meter, by immersing pre-cleaned electrodes in the samples and total suspended solids through spectrophotometer. Chlorides were determined by Mohr Method, in which 10ml sample was titrated with Silver Nitrate (0.025N) after adding 1ml of Potassium Chromate as an indicator. The level of sulfate in the water samples was determined by titration method and dissolved oxygen test by Winkler method.

The biochemical oxygen demand (BOD_5) test was carried out by means of difference of dissolved oxygen (DO) level in water samples before and after incubation. First the dissolved oxygen (DO) level of samples was examined and then the samples were kept in an incubator at 20ºC for five days. After incubation period, the dissolved oxygen level of the samples was again determined. The BOD_5 was calculated from the difference of dissolved oxygen before and after incubation. The chemical oxygen demand (COD) test was conducted using COD meter, model HI 83214 accordance with EPA 410.4 and ISO 15705:2002 standards. The most probable number (MPN) technique was adopted for the determination of bacteriological analysis of samples.

3. RESULTS AND DISCUSSIONS

The results of physicochemical and biological characteristics of Phuleli canal water and wastewater samples are illustrated in Figures 2-8. It was established from the study that the temperature of wastewater was slightly higher than that of canal water. However, the results were within the range of 23.0 to 38.0°C during the study period. The slightly higher temperature of the samples may be due to the presence of pollutants with various thermal properties. The level of pH in canal water at location 1 was ranging between 7.7 and 8.6, whereas the pH level in rest of the samples was between 7.2 and 8 as shown in Figure 2. It was observed that the level of pH in the samples was less basic except the sample taken from location 1. This could be due to development of free CO_2 resulting the lower level of dissolved oxygen and ultimately pH of canal water. However, all pH values of canal water samples were within the WHO standards.

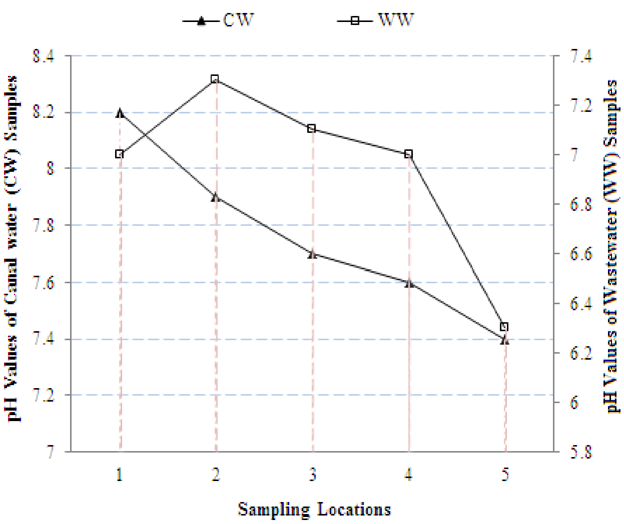

Figure-2. Average pH level in canal water and wastewater samples

The level of pH in wastewater samples during study period were between 5.1 and 8.0 indicating the acidic to alkaline nature of sewage. Acidic pH with mean value of 6.3 was observed at location 5, while the rest of wastewater samples were neutral to slightly alkaline. The results revealed that the sewage effluent contained the composite mixtures of varied nature of complex acidic to alkaline substances. But slightly acidic pH at location 5 could be due to the higher concentration of acidic material mixed with sewage that lowered the pH levels. However, all the pH values of wastewater samples were within the NEQS range of 6.0 -10.0.

3.1 Electrical Conductivity and Total Dissolved Solids

The average level of electrical conductivity (EC) and total dissolved solids (TDS) in canal water and wastewater are shown in Figure 3. It is observed from the analysis of canal water samples that the level of EC was 434µS/cm at location 1. There was positive shift in the base line of electrical conductivity from location 2 to 5 along the entire length of Phuleli canal. The average maximum rise in the electrical conductivity was 1051µS/cm found from location 4 near Bhatti village. That rise of values could be attributed to the influx of large fraction of wastewater from the adjoining open sewerage lines near old power house. The results reflected that the wastewater is liable for elevating the electrical conductivity level in canal water samples from location 2 to 5 as compared to the reference location 1. It was observed that the samples taken from locations 3 to 5 showed higher values than the WHO guideline value of 800µS/cm.

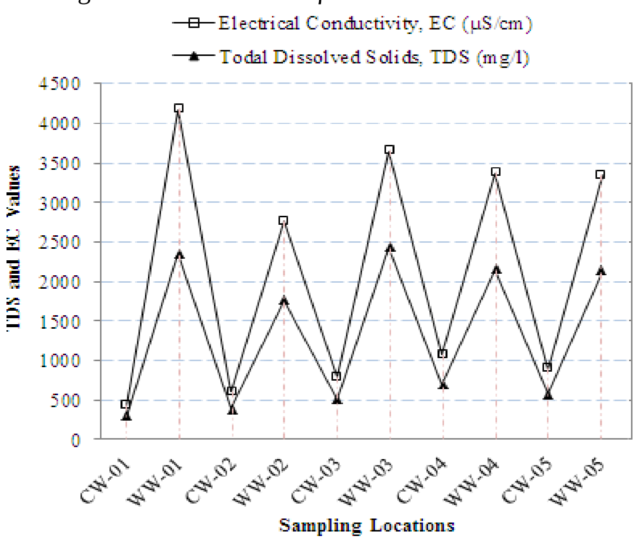

Figure-3. Average TDS and EC level in canal water and wastewater samples

During investigation period, the electrical conductivity of wastewater samples reached its upper limit of 5628µS/cm at location 1, while lower limit was recorded at location 2 with 1327µS/cm. The maximum average value of sewage EC was found 4182µS/cm at location 1, whereas, the average observed value of EC was less than 3600 µS/cm in other locations. It was revealed that the presence of large amount of electrolytic substances elevated the conductance of wastewater samples taken from location 1 as compared to other points. Since, all wastewater samples showed higher values than NEQS guideline value of 900µS/cm.

The concentration of total dissolved solids in wastewater samples were found to be from 849 mg/l to 3606 mg/l, with maximum average value of 2676 mg/l recorded from the sample taken from location 1, and minimum average value of 1769 mg/l from location 2. The higher level of TDS at location 1 indicates the presence of large amount of in-organic components in wastewater samples. Since, the average values of all the wastewater samples were within the NEQS limits.

3.2 Total Suspended Solids and Turbidity

The average values of total suspended solids (TSS) and turbidity level of canal water and wastewater are given in Figure 4. The average level of TSS at location 1 was 652 mg/l, with the variation of 487 - 964 mg/l. The overall values of TSS were fluctuated between 466 and 727 mg/l from location 2 to 5. The lowest average TSS value of 575 mg/l was recorded from the samples taken from last location. The increase in the concentration of TSS could be attributed to the mixing of un-treated municipal wastewater coming from various open drains which were highly loaded with finely divided organic and inorganic matter, microorganisms, silt and suspended clays. The decrease in TSS at sampling location 5 could be ascribed to the dilution factor as well as the self-settling and purification process of the canal.

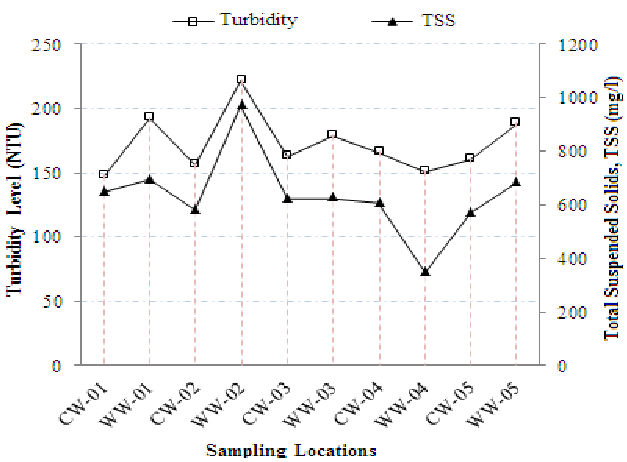

Figure-4. Average turbidity and TSS level in canal water and wastewater samples

The concentration of suspended solids in wastewater samples was observed in the range of 284 mg/l to 1135 mg/l, with average maximum of 972 mg/l from location 2 and average minimum of 354 mg/l from location 4. The average maximum value was 2.75 higher than the average minimum recorded from location 4. This may be due to an open sewerage line passing through thickly populated area of the city containing large amount of suspended solids at location 2. Since, it was observed that the TSS values in all wastewater samples were higher than the NEQS value of 200 mg/l.

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 of turbidity in canal water samples were 121 to 214 NTU. The mean maximum value of 166 NTU was noted at location 4, while mean minimum value was 148 NTU recorded from the samples of location 1. The increasing values of turbidity from location 2 to 5 could be ascribed to the addition of highly turbid wastewater through different sewage outlets of the city.

Turbidity is a reciprocal of clearness as it is directly related to the level of suspended solids. The turbidity values of wastewater samples were varied from 129 NTU to 241 NTU. The maximum average value of 223 NTU noted at location 2, and minimum average 151 NTU at location 4. Highest values of turbidity at location 2 may be due to the presence of greater amounts of non-filterable residues, whereas, the lowest values of were observed at location 4.

3.3 Chlorides and Sulfates

The average values of chlorides and sulfates in canal water and wastewater samples are given in Figure 5. It was observed during investigations that the values of chlorides in canal water samples were between 46 mg/l and 101 mg/l with their mean value of 69 mg/l. The considerable changes in the concentration of chloride content were detected from location 2 to 5 as the result of mixing of wastewater from numerous sewerage lines with the fresh canal water. The overall fluctuation in the chlorides from location 2 to 5 was between 61 mg/l and 122 mg/l. The maximum average rise in concentration with 89 mg/l was found at location 2. This could be due 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 the last sampling location, which indicate the absence of major external sources, dilution factor and high flow rate of the canal water. Since, all the observed values of chlorides in canal water samples were below the WHO standard of 250 mg/l.

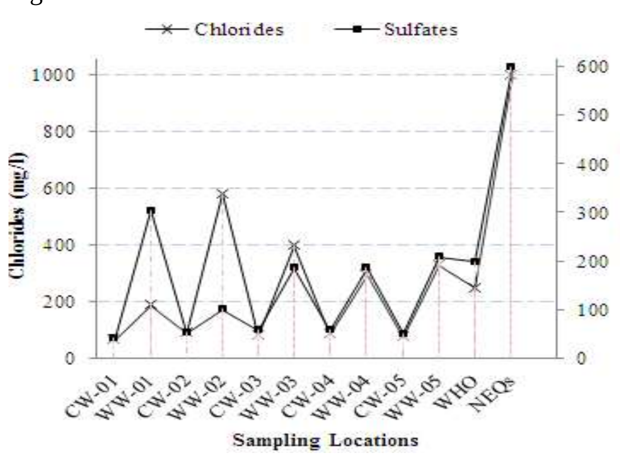

Figure-5. Average level of chlorides and sulfates in canal water and wastewater samples

The concentration of chlorides in wastewater samples were found to be between 141 mg/l and 823 mg/l. The mean maximum value of 580 mg/l was found from the samples taken at location 2 and mean minimum value 190 mg/l at location 1. The higher values at locations 2 and 3 could be due to the sewage coming from thickly populated areas of the city, as well as washouts from small scale manufacturing units of caustic soda, bleaching powder and dyes etc. Since, all the measured values from wastewater samples were below the NEQS limit of 1000 mg/l.

Moreover, the mean value of sulfate concentration was recorded 42 mg/l in the canal waters, which ranges from 36 to 54 mg/l at location 1, before the introduction of sewage from the city. The values of sulfate content were fluctuated between 44 mg/l and 73 mg/l from location 2 to 5 with maximum average of 59 mg/l at location 4 and the minimum average of 52 mg/l at location 5. The results revealed that the considerable influence of sewage elevated the sulfate content in canal water samples. However, the overall values of sulfates were within the WHO guideline value of 200 mg/l.

In wastewater samples, the sulfate concentration was found to be between 90 mg/l and 472 mg/l. The mean maximum value was 304 mg/l recorded at location 1 and mean minimum value 101 mg/l at location 2. The higher concentration of sulfate at location 1 could be attributed to the entrance of excreta, animal dung coming from cattle farms and washouts of small scale detergents, paints and pigments processing units in the nearby areas. However, the results of all wastewater samples were within NEQS value of 600 mg/l.

3.4 Nitrate-N

In canal water samples, the level of Nitrate-N was between 4.4 mg/l and 7.7 mg/l as shown in Figure 6.

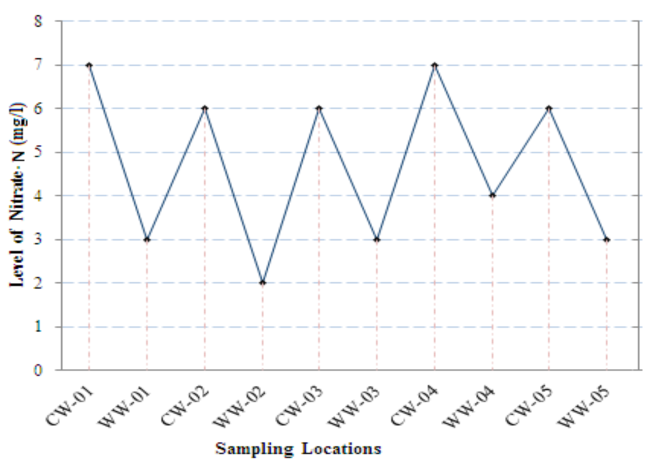

Figure-6. Average level of Nitrate-N in canal water (CW) and wastewater (WW) samples

The lowest average concentration was 5.6 mg/l found at location 4 and highest average was 6.47 mg/l at location 1. These results reflected that aerobic bacteria become more active in bringing about the oxidation at location 1, in the presence of higher concentration of oxygen and low oxygen demand as compared to location 4, where de-nitrification process could be dominant due to lower level of dissolved oxygen and higher oxygen demand. Since, nearly all the canal water samples showed lower values than WHO standard of 10 mg/l.

The concentration of Nitrate-N in wastewater samples was in the range of 1.39 mg/l to 5.4 mg/l with the highest average of 3.58 mg/l at location 4 and the lowest average of 2.28 mg/l at location 2. It was observed that the samples taken from locations 2 and 3 showed lowest concentration of Nitrate-N, as there was an open drain. This may be due to the de-nitrification of nitrate into free N_2 and NH_3 due to higher oxygen demand.

3.4.5 Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)

The level of biochemical oxygen demand (BOD) and chemical oxygen demand (COD) in canal water samples are shown in Figure 7. The average level of BOD in canal water was 14.5 mg/l at noted from the canal water samples at location 1. The maximum average level of BOD was found at location 4 with 30.6 mg/l and minimum average was 19.0 mg/l at location 2. Since, the overall BOD level was ranged from 13.0 to 43 mg/l. The significant changes in the level of BOD were observed from location 2 to 5. These were attributed to the consequence of wastewater introduction from five sewerage lines. The elevated level of BOD in the canal waters was corresponding to the maximum depletion of dissolved oxygen.

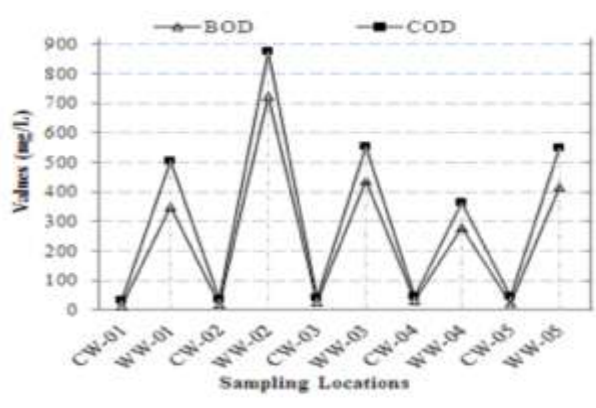

Figure-7. Average level of BOD and COD in canal water and wastewater samples

In wastewater samples, the higher values of BOD were found at location 2. The BOD values of wastewater samples were in the range of 221 mg/l to 864 mg/l with average maximum of 724 mg/l at location 2 and average minimum of 281 mg/l at location 4. Since, it was established that all examined wastewater samples showed three times higher values than NEQS value of 80 mg/l.

Furthermore, the mean concentration of COD in canal water was 30 mg/l at sampling location 1, where the fluctuation of COD was within 20 to 42 mg/l. The average maximum level in COD in the canal waters was 45.6 mg/l at sampling station 5 and minimum average was 37 mg/l at sampling location 2. It was found that the COD level was fluctuated between 32 and 66 mg/l during study period. The significant changes in the concentration of COD from sampling location 2 to 5 were observed as a consequence of wastewater introduction to the canal water.

The maximum average value of COD in wastewater was 873 mg/l at sampling location 2 while the minimum average value was 362 mg/l was estimated at sampling location 4. The overall fluctuation of COD in wastewater was between 298 and 1056 mg/l, whereas the NEQS value is 180 mg/l. The higher value of COD at sampling location 2 and 3 reflect the strength of organic matter.

3.5 Faecal Coliforms Count

The identification of faecal coliform bacterial count is very important as they provide a measure the degree of water contamination in the surface water bodies. The results of faecal coliforms colonies in canal water and wastewater samples are shown in Figure 8.

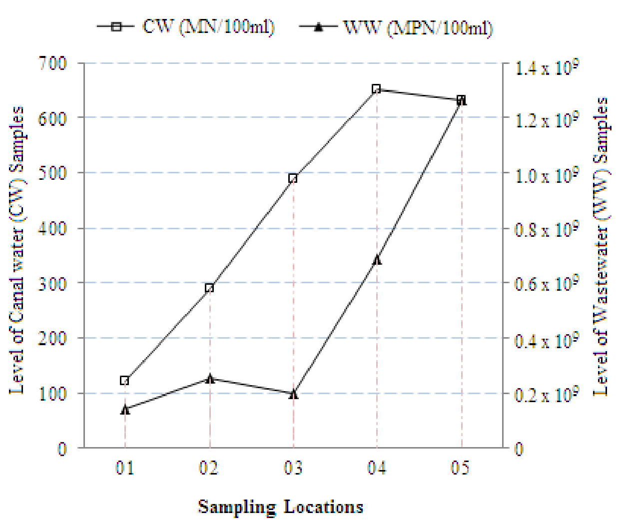

Figure 8. Average level of fecal coliforms in canal water and wastewater samples

The faecal coliform bacterial load in the examined samples of canal water was between 78 and 216 MPN/100 ml. The average bacterial count of 120 MPN/100 ml was noted in the samples taken from location 1, and 207 to 867 MPN/100 ml from location 2 to 5 respectively. The minimum average level of the faecal coliform bacterial concentration was 290 MPN/100 ml recorded at location 2, whereas, the maximum mean value was 650 MPN/100 ml at location 4, which was about 5.4 times higher than the mean of the bacterial number estimated at location 1. The above findings provide a clear indication that there is marked impact of sewage on the canal water from locations 2 to 5. 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.

The faecal coliform bacterial load in the wastewater samples was recoded between $1x\ 10^7$ - $9.2x\ 10^8$ MPN/100 ml. The minimum and maximum average level of the faecal coliform bacterial load was $1.1x10^8$ MPN/100 ml and $2.5x\ 10^8$ MPN/100 ml at the location 4 and 2 respectively. The high bacterial load at location 2 was due to the presence of considerable amounts of organic matter which was verified by high biochemical oxygen demand. All the wastewater samples showed higher concentration than NEQS value of 1000 MPN / 100 ml for irrigation.

4. CONCLUSIONS

The purpose of this study was to examine the level of physicochemical and biological quality parameters of Phuleli canal water and effluents entering the canal along the entire extent of Hyderabad city area. The first sampling location of canal water was taken as reference point to compare the level of pollutants in the canal.

- The results revealed that the continual inflowing of untreated or partially treated sewage and industrial effluent into the canal has changed the physicochemical and biological characteristics of canal water.
- The electrical conductivity of wastewater was found to be around 5628 μS/cm at few locations, which indicated the presence of electrolytic substances in the sewage. The level of EC increased up to double during lower flow conditions as compared to higher periods.
- The prominent aspect of sewage was seen at location 2 and 3, as there was low level of dissolved oxygen and high level of COD with 1056 mg/l.
- The microbial study of canal water indicated the presence of faecal coliforms in the canal water samples with 207 to 867 MPN/100 ml, exceeding permissible surface water limits.
- The rise in the nutrient was noted in the samples that may be responsible for the speedy growth of biological organisms and ultimately create oxygen deficit situation in the canal water.

It is established that the canal water was being contaminated because of inflowing of un-treated wastewater and industrial effluents. Such situation may be the major cause of irreparable ecological harm in the long-term basis if left unmanaged.

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