

ZIBELINE INTERNATIONAL
PUBLISHING

ISSN: 2637-0778 (Online)

CODEN: ECRNAE

Environmental Contaminants Reviews (ECR)

DOI: <http://doi.org/10.26480/ecr.02.2020.77.86>

RESEARCH ARTICLE

COMPREHENSIVE ANALYSIS ON THE PHYSICAL, CHEMICAL, NUTRIENT, HEAVY METAL AND MICROBIOLOGICAL PARAMETERS AT SELECTED STATIONS OF BUCKINGHAM CANAL, CHENNAI, TAMIL NADU, INDIASamuel Vinod Kumar^a, Little Flower Pascal^b, Mohamed Meeran^c, Mohammed Byrose^c, Vaithiyathan Selvi^d, Grace Marin^e, Subramanian Arivoli^f, Samuel Tennyson^g*^a Department of Animal Science, Manonmaniam Sundaranar University, Tirunelveli 627 012, Tamil Nadu, India^b Department of Zoology, Periyar University, Salem 636 011, Tamil Nadu, India^c Department of Zoology, Hajee Karutha Rowther Howdia College, Uthamapalayam 625 533, Tamil Nadu, India^d Department of Microbiology, Sourashtra College, Madurai 625 004, Tamil Nadu, India^e Department of Zoology, Scott Christian College, Nagercoil 629 001, Tamil Nadu, India^f Department of Zoology, Thiruvalluvar University, Vellore 632 115, Tamil Nadu, India^g Department of Zoology, Madras Christian College, Chennai 600 059, Tamil Nadu, India*Author for correspondence: samtennyson@gmail.com

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ARTICLE DETAILS

Article History:

Received 03 April 2020

Accepted 05 May 2020

Available online 27 May 2020

ABSTRACT

The physical, chemical, nutrient, heavy metal and microbiological parameters of water samples of Buckingham canal were ascertained from December 2018 to May 2019. The water colour was found to be brownish to black and possessed a sewage smell and taste was objectionable. Atmospheric temperature, water temperature, electrical conductivity, turbidity, total suspended solids and total dissolved solids ranged from 28 to 38°C; 28 to 38°C; 1745 to 2215mmho/cm; 150 to 458NTU; 280 to 360mg/L; and 1365 to 4250mg/L respectively. The respective values of pH, salinity, total hardness, total alkalinity, dissolved oxygen, biological oxygen demand and chemical oxygen demand ranged from 7.33 to 7.53; 2.03 to 7.02ppt; 270 to 1265mg/L; 456 to 1396mg/L; 2.05 to 4.2mg/L; 146 to 508mg/L; and 640 to 1572mg/L. The nutrient parameters, calcium, sodium, potassium, magnesium, nitrate, nitrite, chloride, sulphate, phosphate and silica values ranged from 67 to 282mg/L; 320 to 453mg/L; 40 to 88mg/L; 24 to 150mg/L; 8.0 to 13.2mg/L; 0.1 to 3.7mg/L; 441 to 1112mg/L; 48 to 62.7mg/L; 15.2 to 18.7mg/L; and 37.6 to 63.7mg/L respectively. Free ammonia was nil throughout the period of study and fluoride of water samples was nil except for station 1 (0.6mg/L) during post monsoon. Heavy metal parameters, arsenic and manganese content of water samples was nil throughout the study period. Chromium, copper, iron, lead and zinc content ranged from 0.007 to 0.011mg/L; 1.06 to 1.34mg/L; 0.34 to 1.55mg/L; 1.2 to 2.5mg/L; and 0.23 to 0.32mg/L respectively. In addition, microbiological parameters revealed that it was not safe for domestic applications.

KEYWORDS

Physico-chemical, nutrient, heavy metal, microbiological, Buckingham canal water.

1. INTRODUCTION

Environmental protection is necessary for the existence of living beings as water is the elixir of life (Kaza and Jafer, 1997). Aquatic systems are mainly polluted through domestic sewage and nutrients, agricultural, aquacultural and industrial wastes, endangering the existence of aquatic resources. The quantity of utilizable water decreases due to over exploitation and also by pollution. Wise and restrained use of the earth's resources, especially water being the most vital one is emphasized (Bhosle and Patil, 2001). Water quality deserves special attention because of its implication for affecting the public health and the quality of life. Physical and chemical characters of water are changed due to the addition of organisms to water. These changes are harmful for the health and thus reduced the usefulness of water. Water supplies once considered pure are found to have contaminants. One cannot expect pure water, but everyone requires safe water. Microorganisms enter the water supply in several

different ways. In congested centre, water supplies get polluted by domestic and industrial wastes (Rajan and Lalmingchhuansangi, 2012). Thus, for the quantification of the effects of aquatic habitats contamination, analysis of the composition of aquatic constituents, physicochemical and biological parameters are needed.

Rapid industrialization has led to contamination of natural water with metals due to dumping of untreated wastes in the aquatic habitats (Javed, 2004). Since the industrial revolution, industries have been booming and, consequently, millions of anthropogenic compounds have entered our environment. Increasing pollution and its necessities healed to the deprivation of surface and sub-surface water. The causative factors for the pollution of water are industries, agriculture and domestic activities. Further, the industrial growth and consequent pollution let into the freshwater system are a challenge for the fragile freshwater ecosystems (Ghosh, 1992). Besides these, heavy metals are being passed on into

Quick Response Code



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Website:

www.contaminantsreviews.com

DOI:

10.26480/ecr.02.2020.77.86

aquatic environment through industrial processes, sewage disposal, soil leaching and rainfall. It is well documented that the effect of heavy metals are dependent upon the physical and chemical conditions of the environment especially water salinity, hardness, pH and dissolved oxygen and can act synergistically. The accumulation of metals in an aquatic environment has direct consequences to man and to the ecosystem also. Although, trace metals are essential for normal physiological process, abnormally high concentrations can be toxic (Javed, 2003).

Buckingham canal water contains different kinds of dissolved and particulate matters including gases and solids. The chemical nature of water affects phytoplankton, zooplankton and other aquatic animals, fishes being the major among them. About 60% of the untreated sewage gets into the Buckingham canal as several tons of municipal solid waste being dumped every day makes its way through the Buckingham canal into the sea. Presently, the Buckingham canal has been severely polluted by sewage, sullage, industrial wastes, storm water drainage and garbage, as urbanization has occurred. Earlier, researchers have reported on the physicochemical, nutrients and a few heavy metals of water quality parameters of Buckingham canal (Samuel et al., 2018a,b,c). Therefore, in continuation to the earlier studies, the physical, chemical, nutrient, heavy metal and microbiological parameters of water samples collected at selected stations of Buckingham canal were ascertained in detail in the present study.

2. MATERIALS AND METHODS

2.1 Study area

Chennai the capital of Tamil Nadu situated on the eastern coast of India (13.0827° N, 80.2707° E) stretches nearly 25.60km along the coast of Thiruvanniyur in the south to Thiruvattiyur in the north. Three water ways, viz., Cooum, Adyar river and the Buckingham canal flows through this city. The Buckingham canal is a man-made canal linking the two rivers, Cooum and Adyar river. The stretch of the Buckingham canal inside the city is only a small part of a much longer water way (420km in length) extending from Nellore in Andhra Pradesh to Marakkanam near Puducherry. The length of this canal in Andhra Pradesh is 257km, and 163km is in Tamil Nadu. Approximately, 31km is within the city limits of Chennai. The canal was known as Lord Clive's canal and later as Buckingham canal. However, the section in Chennai was known as Cochrane's canal for much of the 19th century. Buckingham canal is polluted with nearly 60% of the estimated untreated sewage being let into it on a daily basis making the water quality highly toxic and non-potable. Water samples were collected from two different stations, Station 1 marked from the first entrance near Basin Bridge and Station 2 from the area near to the small-scale industries near to Puratchi Thalaivar Dr. M.G. Ramachandran central railway station, Chennai (Figure 1).

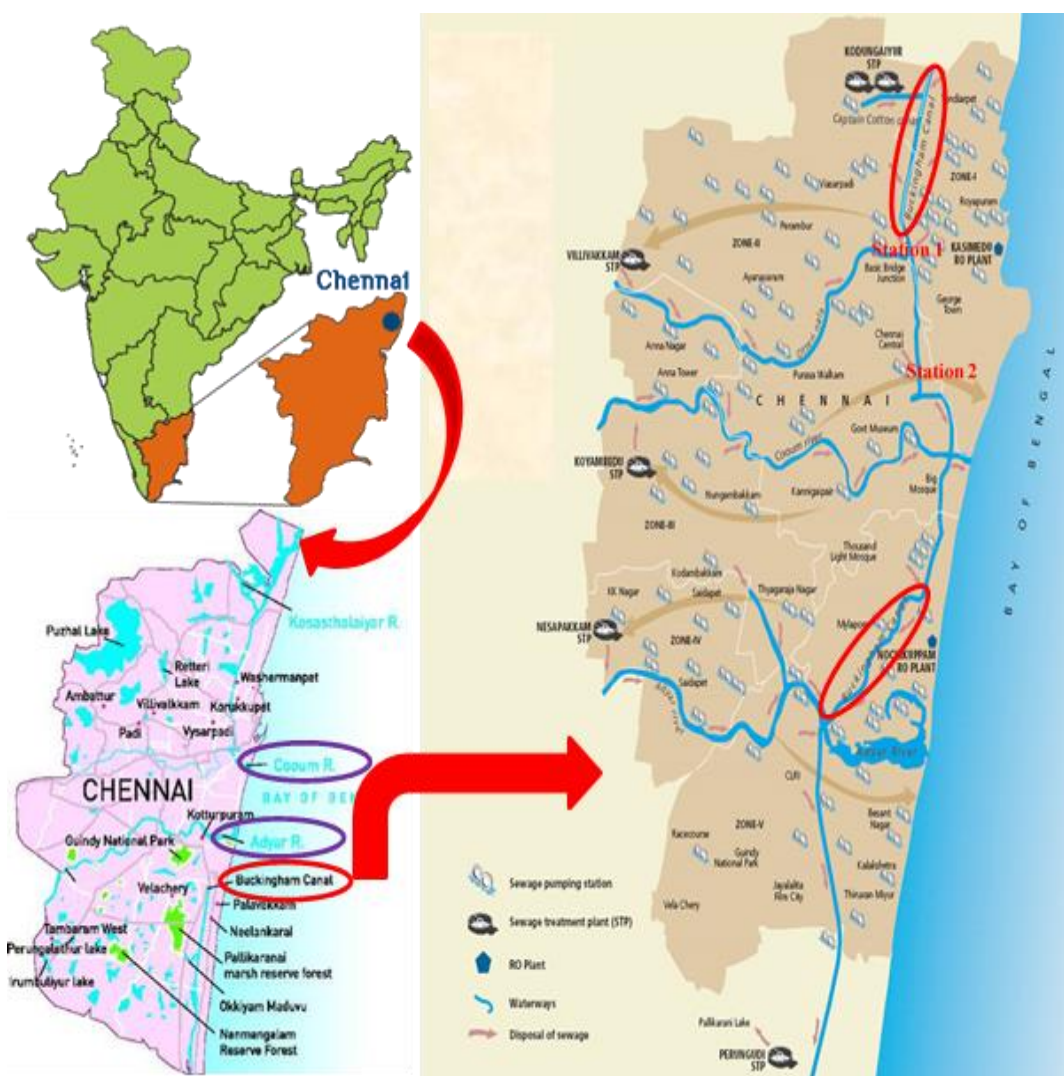


Figure 1: Sampling stations of the study area

2.2 Sample collection

Sampling procedures for water samples collected at Station 1 and 2 were followed according to the standard methods (APHA, 2005). Water samples were collected for a period of six months during post monsoon and summer from December 2018 to May 2019 in high-density polyethylene 'Tarson' brand bottles after 2-3 times rinsing with the sample; while for microbiological analysis, samples were taken in sterilized Tarson bottles covered with aluminium foils. All the chemicals and reagents were of

analytical grade, purchased from Merck, India. Analytical grade water from Millipore water purification system (Make: Millipore, USA; Model: Elix and Synergy) was used for the preparation of all standards and solutions. The description of procedures of water quality parameters to be analysed with the standard permissible limits of water quality (ICMR, 1975; EPA, 1976; WHO, 1989; ISI, 1991) are tabulated and presented in Table 1. Correlation matrix analysis was performed to determine significantly the parameter responsible for influencing the water quality of the study area.

Table 1: Procedure for water quality parameters and permissible limits for each parameter set by standards

Parameter for analysis	Unit	Method	WHO	ISI	USEPA	ICMR	CPCB	
Physical								
Colour/Appearance	Hazen	Visual comparison	-	5	-	-	-	
Odour	-	Physiological sense	Acceptable	Acceptable	-	Acceptable	Acceptable	
Atmospheric temperature	°C	Mercury-in-glass thermometer	-	-	-	-	-	
Water temperature			-	-	-	-	-	
Electrical conductivity	µS/cm	Conductivity meter	-	-	-	-	2000	
Turbidity	NTU	Nephelometric turbidity meter	<5	10	-	25	10	
Total suspended solids	mg/L	Gravimetric EPA	30	40	50	50	60	
Total dissolved solids		Ion selective	500	500-1500	-	500	-	
Chemical								
pH	-	Systronic digital pH meter	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	
Salinity	ppt	Silver nitrate titration	<0.5	0.5-17	-	-	-	
Total hardness	mg/L	EDTA titration	500	300	-	600	600	
Total alkalinity		Acid titration	120	200	200	-	600	
Dissolved oxygen		Winkler's titration with azide modification	6	-	-	-	-	
Biological oxygen demand		BOD chamber and Winkler's titration	6	30	5	-	-	
Chemical oxygen demand		COD digester	10	150	40	-	-	
Nutrient								
Calcium	mg/L	Flame photometer	75	75	-	200	200	
Sodium			200	180	200	-	-	
Potassium			12	-	-	-	-	
Magnesium		Complexometric EDTA titration	150	30	-	-	-	
Free ammonia		UV visible spectrophotometer	0.5	1.5	-	-	-	
Nitrate			45	45	50	100	100	
Nitrite			3	45	0.5	-	-	
Chloride		Argentometric titration	200	250	250	1000	1000	
Fluoride		SPADNS spectrophotometer	1.5	0.6-1.2	4.0	1.5	1.5	
Sulphate		Nephelometer and Turbidimeter	250	200	250	400	400	
Phosphate		Stannous chloride	0.1	-	-	-	-	
Silica		Molybdosilicate	5-25	-	-	-	-	
Heavy metal								
Arsenic		mg/L	Atomic absorption spectrophotometer	0.05	0.05	0.05	0.05	-
Chromium	0.05			0.05	0.05	0.05	-	
Copper	1			0.05	1.3	1.5	1.5	
Iron	0.1			0.3	-	1	1	
Lead	0.05			0.1	-	0.05	-	
Manganese	50			30	-	-	100	
Zinc	5			5	-	0.1	15	
Microbiological								
Bacteria	cfu/mL	Multiple tube fermentation technique	-	-	-	-	-	
Fungi			-	-	-	-	-	

Table 2: Correlation matrix of physical, chemical, nutrient and heavy metal parameters of water in the study area

	AT	WT	EC	TU	TSS	TDS	PH	SA	TH	TA	DO	BOD	COD	CA	SO	PO	MA	FA	NA	NI	CL	FL	SL	PH	SI	AR	CH	CU	IR	LE	MN	ZI
AT	1																															
WT	0.997	1																														
EC	0.832	0.854	1																													
TU	0.986	0.987	0.906	1																												
TSS	0.990	0.996	0.845	0.975	1																											
TDS	0.991	0.988	0.871	0.996	0.972	1																										
PH	0.126	0.181	0.157	0.081	0.258	0.037	1																									
SA	0.900	0.909	0.635	0.834	0.934	0.839	0.470	1																								
TH	0.997	0.999	0.837	0.981	0.998	0.982	0.200	0.923	1																							
TA	0.995	0.992	0.869	0.996	0.979	0.999	0.068	0.855	0.988	1																						
DO	-0.967	-0.968	-0.929	-0.995	-0.950	-0.989	-0.024	-0.778	-0.958	-0.986	1																					
BOD	0.940	0.950	0.970	0.981	0.938	0.964	0.113	0.761	0.938	0.963	-0.989	1																				
COD	0.977	0.977	0.916	0.998	0.960	0.994	0.037	0.801	0.968	0.992	-0.999	0.985	1																			
CA	0.988	0.995	0.897	0.991	0.993	0.984	0.205	0.888	0.992	0.989	-0.977	0.972	0.983	1																		
SO	0.952	0.963	0.961	0.985	0.956	0.969	0.158	0.798	0.954	0.969	-0.988	0.998	0.986	0.983	1																	
PO	0.991	0.995	0.897	0.997	0.988	0.993	0.147	0.869	0.990	0.995	-0.986	0.975	0.991	0.998	0.984	1																
MA	0.996	0.999	0.841	0.981	0.998	0.981	0.212	0.925	0.999	0.987	-0.958	0.940	0.968	0.993	0.956	0.991	1															
FA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1														
NA	0.944	0.963	0.864	0.936	0.980	0.920	0.425	0.934	0.965	0.931	-0.909	0.924	0.917	0.973	0.945	0.957	0.969	NA	1													
NI	0.846	0.861	0.588	0.774	0.895	0.775	0.568	0.992	0.878	0.795	-0.713	0.705	0.737	0.842	0.746	0.816	0.880	NA	0.915	1												
CL	0.984	0.980	0.887	0.997	0.963	0.998	0.011	0.813	0.973	0.996	-0.994	0.971	0.997	0.980	0.973	0.990	0.972	NA	0.909	0.746	1											
FL	-0.653	-0.634	-0.147	-0.520	-0.652	-0.564	-0.258	-0.831	-0.660	-0.581	0.442	-0.362	-0.48	-0.566	-0.406	-0.556	-0.655	NA	-0.590	-0.824	-0.524	1										
SL	0.777	0.815	0.929	0.823	0.837	0.777	0.509	0.733	0.808	0.786	-0.821	0.889	0.815	0.862	0.899	0.840	0.816	NA	0.914	0.729	0.780	-0.232	1									
PH	0.826	0.856	0.739	0.796	0.895	0.773	0.661	0.936	0.866	0.792	-0.753	0.786	0.766	0.867	0.820	0.836	0.872	NA	0.958	0.951	0.754	-0.610	0.893	1								
SI	0.887	0.908	0.732	0.846	0.939	0.834	0.565	0.977	0.919	0.852	-0.800	0.812	0.816	0.907	0.845	0.882	0.923	NA	0.973	0.979	0.814	-0.702	0.852	0.987	1							
AR	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1					
CH	0.960	0.939	0.702	0.933	0.916	0.958	-0.108	0.819	0.939	0.956	-0.915	0.851	0.928	0.910	0.859	0.927	0.934	NA	0.818	0.745	0.951	-0.700	0.577	0.657	0.755	NA	1					
CU	0.653	0.701	0.743	0.660	0.748	0.613	0.774	0.767	0.705	0.632	-0.631	0.710	0.634	0.739	0.737	0.700	0.715	NA	0.864	0.802	0.602	-0.333	0.936	0.943	0.881	NA	0.420	1				
IR	0.983	0.989	0.919	0.997	0.981	0.989	0.148	0.850	0.983	0.991	-0.990	0.985	0.993	0.996	0.992	0.998	0.983	NA	0.956	0.797	0.989	-0.513	0.860	0.833	0.873	NA	0.910	0.712	1			
LE	0.984	0.992	0.839	0.966	0.999	0.962	0.298	0.945	0.994	0.970	-0.939	0.930	0.950	0.989	0.949	0.982	0.996	NA	0.986	0.910	0.951	-0.660	0.846	0.912	0.952	NA	0.901	0.770	0.975	1		
MN	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	
ZI	0.908	0.924	0.713	0.860	0.951	0.854	0.512	0.991	0.935	0.871	-0.811	0.811	0.830	0.915	0.845	0.894	0.938	NA	0.969	0.986	0.832	-0.750	0.817	0.971	0.996	NA	0.797	0.838	0.881	0.962	NA	1

NA: Not Applicable; Bold values indicate significant correlation ($r \geq 0.60$)

3. RESULTS

The results of the physical, chemical, nutrient, heavy metal and microbiological parameters of water quality of Buckingham canal are as follows in Station 1 and Station 2 during post monsoon and summer respectively. Table 2 displays the correlation coefficients between each water parameter influencing the quality of water in the study area. Based on the Spearman's correlation, values in bold indicates significant positive correlation ($r \geq 0.60$). With reference to the physical characteristics, the water colour was found to be brownish to black both in the post monsoon and summer seasons. The canal water possessed a sewage smell and taste was objectionable throughout the study period. Atmospheric temperature ranged from 28 to 29°C and 36 to 38°C and was minimum in the month of January and February and maximum in March and April. The water temperature also varied from 28 to 29°C and 36 to 38°C, and minimum temperature was recorded in the month of December and was found to be maximum in April. Electrical conductivity and turbidity ranged from 1745 to 1950 and 2066 to 2215mmho/cm; and from 150 to 175 and 416 to 458NTU respectively. Total suspended solids and total dissolved solids ranged from 280 to 295mg/L and 340 to 360mg/L; and from 1365 to 1422mg/L and 4075 to 4250mg/L respectively (Figure 2).

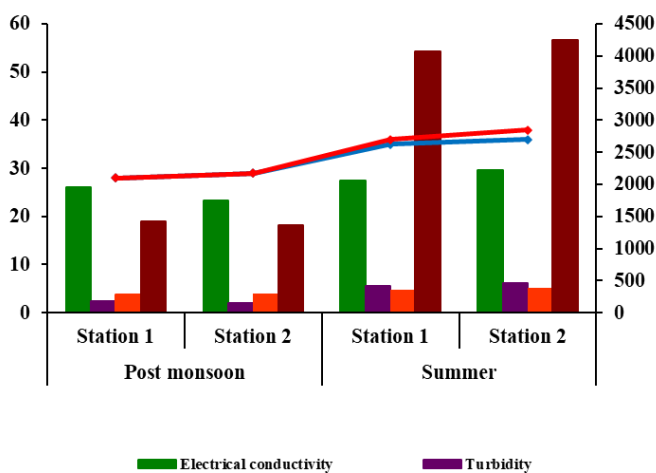


Figure 2: Physical analysis of water samples at study area

In context to the chemical characteristics, the pH ranged from 7.33 to 7.42 and 7.24 to 7.53. The observed values of salinity ranged from 2.03 to 4.16ppt and 5.22 to 7.02ppt. The total hardness and total alkalinity ranged from 270 to 410mg/L and 1060 to 1265mg/L; and from 456 to 464mg/L and 1308 to 1396mg/L respectively. Dissolved oxygen values ranged from 3.8 to 4.2mg/L and 2.05 and 2.25mg/L. Biological oxygen demand and chemical oxygen demand ranged from 146 to 240mg/L and 428 to 508mg/L; and from 640 to 772mg/L and 1482 to 1572mg/L respectively with high values recorded during summer for both the parameters (Figure 3).

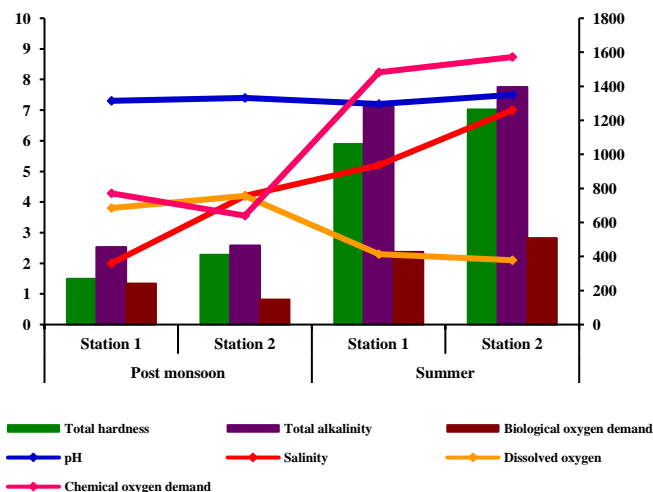


Figure 3: Chemical analysis of water samples at study area

In the case of nutrient parameters, calcium was found to be high during summer than post monsoon and values ranged from 67 to 68mg/L and 224 to 282mg/L. Sodium and potassium ranged from 320 to 286mg/L and 410 to 453mg/L; and from 40 to 39mg/L and 78 to 88mg/L respectively. Magnesium was found to be high during summer than post monsoon and values ranged from 24 to 41mg/L and 122 to 150mg/L. Free ammonia was nil throughout the period of study. Nitrate and nitrite ranged from 8 to 8.5mg/L and 10.8 to 13.2mg/L; and from 0.1 to 1.8mg/L and 2.1 to 3.7mg/L respectively. Chloride ranged from 441 to 380mg/L and 1080 to 1112mg/L; and fluoride of water samples was nil throughout the study period except for station 1 during post monsoon and the value was 0.6mg/L. Sulphate and phosphate ranged from 48 to 43mg/L and 50 to 62.7mg/L; and from 15.2 to 16mg/L and 16.4 to 18.7mg/L respectively. Silicates of water samples ranged from 37.6 to 45.2mg/L and 50.2 to 63.7mg/L (Figure 4).

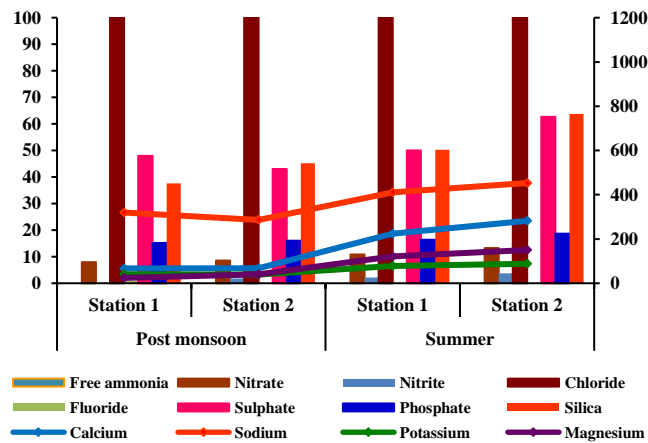


Figure 4: Nutrient analysis of water samples at study area

In reference to metal parameters, arsenic and manganese content of water samples was nil throughout the study period. Chromium and copper content ranged from 0.007 to 0.008mg/L and 0.012 to 0.011mg/L; and from 1.06 to 1.12mg/L and 1.09 to 1.34mg/L. Iron of water samples ranged from 0.34 to 0.23mg/L and 1.25 to 1.55mg/L. Lead and zinc content ranged from 1.2 to 1.4mg/L and 2.08 to 2.5mg/L; and from 0.23 to 0.26mg/L and 0.28 to 0.32mg/L respectively (Figure 5).

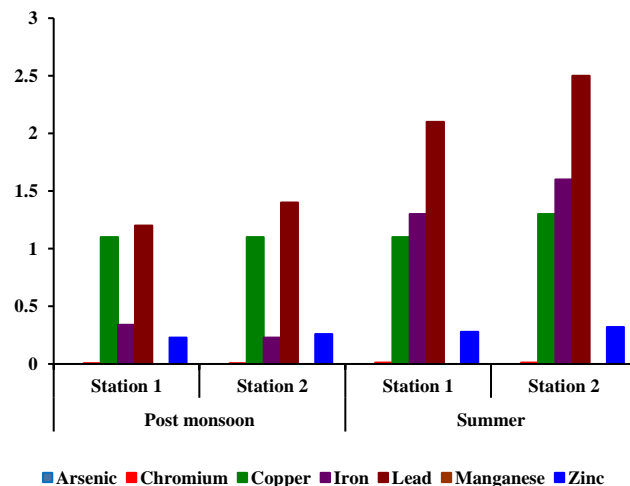


Figure 5: Heavy metal analysis of water samples at study area

Bacteria ranged between 5.46×10^2 and 123.56×10^2 CFU/mL in the water samples from the study area. Highest bacterial content was recorded during the months of summer. The fungal numbers encountered were found to be 346.58 CFU/mL. The water samples from the study area was also found to be contaminated with strains of *Escherichia coli* and *Salmonella* species, in addition, to the occurrence of *Vibrio*, *Shigella* and *Staphylococcus* species. *Aspergillus* species were dominant especially *Aspergillus niger*, *Aspergillus flavus*, *Aspergillus terreus* and *Aspergillus fumigatus*. Apart from these, species of *Penicillium*, *Curvularia*, *Trichoderma*, *Mucor*, *Phoma* and *Rhizopus* were also present.

4. DISCUSSION

One of the most important physicochemical feature of any water is temperature as they are affected by rainfall and availability of light. Temperature influences the chemical, biochemical and biological characteristics of the aquatic system and indirectly regulates the colouration in aquatic organism especially fishes. High temperatures have a profound effect on the physicochemical properties and the biotic spectrum present within the water. Low temperature brings about the darkening effect while its rise results in the concentration of pigments with consequent lightning of the colour (Kumar and Garg, 2019). In the present study, temperature of water varied between 28 and 38°C. Naturally, water remains at low temperature and evaporates to high temperatures. Seasonal and diurnal variations in temperature of natural water rarely cause any problems. High temperatures in natural waters are recorded when heated waters or effluents are discharged from industries or power plants which was observed in the present study.

Natural water have different tastes and odour which differs from place to place and rarely creates problems. The Buckingham canal water indicated bad taste and undesirable odour which may be due to the waste discharged from different small-scale industries and sewage discharge from household. The colour of the canal water was found to be brown to black during the study which was due to the dissolution of various impurities. This indicated that colour ranged from 1.8 to 56Hazen (Kumar and Garg, 2019). The effluents and sewage from industries and household also impart black colour to the water. At some places of the canal, the water appeared greenish due to the presence of plants. Colour may specify dissolved organic material, inadequate treatment and high disinfectant demand, and may indicate the potential for the production of excessive amounts of disinfectant by products. Other contaminants that may be related to change in water colour include aluminium, copper, foaming agents, iron, manganese and total dissolved solids, making the water undesirable for many uses.

Electrical conductivity is a measure of water capacity to convey electric current and is based on the existence of dissolved ions in water (Rao and Venkateswaralu, 2000). This parameter is a useful tool to evaluate the purity of water and is controlled by geology of the area where the water body is situated, wastewater from sewage treatment plants and septic systems, urban runoff from roads and agricultural (Thangamalathi and Anuradha, 2018). Conductivity shows significant correlation with other parameters, viz., temperature, pH, alkalinity, total hardness, calcium, total suspended solids, total dissolved solids, chemical oxygen demand and, chloride and iron concentration of water. Greater the concentration of dissolved solid, greater the conductivity of water (Sooraj, 2018). The electrical conductivity in the present study varied between 1745 and 2215mho/cm. The values were high during summer which indicated less species diversity and population of fish fauna. High values indicate the presence of high amount of dissolved organic substances in ionized form (Krishnaswamy and Jayaraj, 2017). Ellis stated that specific conductivity supporting a good fish fauna lies between 150 to 500micro/mho/cm (Ellis, 1937). Thus, the values noted in the present study represent an alarming situation in context to degradation of fish fauna. Similar reports were given in support to the present study (Sharma and Pande, 1998).

Pure water has a slightly blue colour that becomes a deeper blue as the thickness of the observed sample increases due to turbidity (Kumar and Garg, 2019). The estimation of turbidity is a key trial of water quality caused by suspended matter such as clay, finely divided organic and inorganic matter, soluble coloured organic compounds, plankton, and other microscopic organisms (Pokhriyal et al., 2019). The suspended solids and dissolved matter impart turbidity to natural waters, hence the penetration of light to lower layers of water gets restricted. This will damage the aquatic life and also deteriorate the quality of surface water. During monsoon, heavy soil erosion and suspended solids from sewage increased the turbidity which has an effect on the river and aquatic life (Verma et al., 1984). Therefore, in turbid waters, plant life in subsurface layers of water is reduced in addition to oxygen production in water. Turbidity reduces the general usefulness of water and its high values of turbidity minimize the filter runs which cause pathogenic organisms to be more hazardous to the human life and the values of the present study was several times more than the permissible limits set by standards. Similar reports were given wherein the load of dissolved solids carried by the water makes it unfit for washing and cleaning purposes (Sharma and Pande, 1998).

Total dissolved solids is an important parameter for measuring the amount of solid materials dissolved in the water which imparts a peculiar taste to water and reduce its potability. It is also an important category to

find the salinity indicator for classification of water in total dissolved solids measurement. It imparts hardness to the water concerned which interferes with foam forming capacity of the water when used with soap for cleaning purposes. Total suspended particles absorb heat which causes water temperature to increase and it holds less oxygen than cold water (Holum, 1977). High values of total dissolved solids may be due to water pollution when waste waters from both residential and industrial areas are discharged into it (Aravindkumar et al., 2014). High values causes harmful effect to the public health such as the central nervous system, provoking paralysis of the tongue, lips and, face, irritability, and dizziness (Gupta et al., 2017). In the present study both total suspended and dissolved solids crossed the values of standard permissible limits.

pH is considered as an important ecological factor and provides an important piece factor and piece of information on many types of geochemical equilibrium, besides being the major determinant to the corrosivity of water (Shyamala et al., 2008; Kumar and Garg, 2019). The pH of natural water is 7 and the dissolved materials and gases shifts the pH of natural waters to acidic or alkaline side. A decrease in pH value leads to acid nature which gives sour taste and an increase results in alkalinity nature gives bitter taste to water. The pH of Buckingham canal remained constant between 7.3 and 7.5 in the present study and fell within the standard permissible limits. Waters with pH above 7 carry a greater quantity of dissolved substances and are capable of supporting a good plant life which was true in the present study. Researchers reported that water with a pH range between 6.7 and 8.7 is good for growth of phytoplanktons and zooplanktons (Osborne, 1987; Nirmala et al., 2012). Exposure to extreme low and high pH values results in irritation to the eyes, skin, mucous membranes, and gastrointestinal regions (Kumar and Garg, 2019).

Salinity relates to salt content of water samples. High concentration of salts may be due to acidic and basic salts in water from the soaps and detergents being used in the canal which corroborated to the present study as the values of salinity fell above WHO limits (Kataria and Jain, 1995). Hardness of water mainly depends upon the amount of calcium or magnesium salts or both (Krishnaswamy and Jayaraj, 2017). Total hardness is the measurement of mineral content in water and represents the total content of chlorides, sulphates, bicarbonates and carbonates (Sooraj, 2018). Hard water have an undesirable taste and little utility and the values of the present study is indicative of hard water (Pradeep and Chourasia, 2000). Alkalinity refers to the water capacity to neutralise the acid and is important as knowledge of this parameter provides useful information about bicarbonate, carbonate and hydroxide content of natural waters (Sooraj, 2018). Alkalinity in water comes from calcium carbonate, being leached from soil and alkaline waters are usually more productive as they are able to carry a greater load of dissolved solids (Pokhriyal et al., 2019). The alkalinity varied between 456 and 464mg/L during post monsoon and from 1308 to 1396mg/L during summer in the present study which was above the permissible limits set by standards. Alkalinity in itself is not harmful to human being, but in large quantity, imparts bitter taste to water and may cause eye irritation in human (Buridi and Gedala, 2014).

Dissolved oxygen data are useful in assessing the water quality criteria of an aquatic system since it is one of the most vital parameter indicating the health of water bodies, and its capacity to support a balanced aquatic ecosystem of plants and animals. Its correlation with water body gives direct and indirect information (bacterial activity, photosynthesis, availability of nutrients, and stratification) (Vikal, 2009). Dissolved oxygen may play a large role in the survival of aquatic life during summer as temperatures play an important role in determining dissolved oxygen in an aquatic body (Sagar et al., 2015). During summer, dissolved oxygen decreases due to increase in temperature and also due to increased microbial activity (Moss, 1972; Morrisette, 1978; Kataria et al., 1996). High dissolved oxygen in summer is due to increase in temperature and duration of bright sunlight which has influence on the percentage of soluble gases (oxygen and carbon dioxide). During summer, the long days and intense sunlight seem to accelerate photosynthesis by phytoplankton, utilizing carbon dioxide and giving off oxygen. This possibly accounts for the greater qualities of dissolved oxygen recorded during summer (Krishnamurthy, 1990). Secondly, dissolved oxygen reveals the changes that occur in the biological parameters due to aerobic or anaerobic phenomenon and signifies the condition of the river/streams water for the purpose of the aquatic as well as human life (Chang, 2005). In an aquatic system, where organic decomposition are high, dissolved oxygen values remain low due to high pollution load (Kumar and Garg, 2019). Dissolved oxygen was found to range from 2.05 to 4.2mg/L in the present study which limits the growth of fish population. Low values of dissolved oxygen in summer in the present study may be due to the fact that at higher

temperature the water has lesser oxygen holding capacity and surplus oxygen is lost to the atmosphere (Munawar, 1970; Saha and Pandit, 1986). Warm water released from industrial outlets, flowages or storm sewers can also reduce dissolved oxygen levels. The values of dissolved oxygen in the present study is highly alarming and could be due to increased microbial activity and the same was one of the reasons for bad odour around the Buckingham canal as reported (Purna and Shashikanth, 2002).

The concentration of water quality parameters depends upon the freshwater inflow, discharge of domestic sewage and industrial effluent. The partial of dissolved oxygen in water depends upon the partial pressure of gas in the air close to water, rate of photosynthesis and oxygen holding capacity of water (Moore, 1989). Biochemical oxygen demand, a measure of organic material contamination is an important parameter to measure the pollution load in aquatic system which supports the growth of microorganisms. It is the amount of dissolved oxygen required for the biochemical decomposition of organic compounds and the oxidation of certain inorganic materials, used for determination of requirement of oxygen for stabilizing household and industrial wastes (De, 2003; Aravindkumar et al., 2014). The effluents disposed by domestic and industries into the water contaminate the quality of the water (Sawyer et al., 1994). It is reported that an overall high nutrient status, low oxygen content and high biological oxygen demand are positive factors that favour the growth of phytoplankton (Palmer, 1969). The present study indicated high biological oxygen demand values which may be due to maximum biological activity of elevated temperature. High values might be due to the decomposition of organic matter and decay of vegetation in river which mixed with sea water during rainy season and high chemical oxygen demand due to runoff from the surrounding areas of the lakes.

Distribution of nutrients is due to seasonal, tidal conditions and freshwater flow from land sources. The maximum values of calcium, magnesium, iron, chloride, and sulphate concentration were recorded at summer season and minimum was recorded at monsoon season. The presence of high amount of these nutrients in summer may be due to heavy influx of fresh water derived from land drainage, electroplating, tanning, dyeing and textile manufacturing industries (Michaud, 1991). Calcium has been a basic parameter for detecting pollution of water by sewage plant before development of bacteriological procedure. Calcium content in water can come from the hydrolysis of silicate minerals and contribute to the hardness, thus influencing the organoleptic quality of water (Matini et al., 2009; Kahoul et al., 2014). The present investigation observed that the level of calcium was above the permissible standard limits.

Sodium naturally occurs in water owing to the minerals present in the region (Todd, 1980). The assessment of sodium concentration is necessary while considering the suitability of water. High sodium chloride indicates pollution from human and animal waste, which enters the canal through open defecation practices in the vicinity of a water body observed in the present study indicative of high values. Potassium, an important macronutrient, generally appears in water and impart softness and makes water salty. Though, found in small amounts, it plays a vital role in metabolism of fish in aquatic environments (Chapman, 1996). Increased high concentration of potassium in water was observed in the present study as the values crossed standard limits and this can certainly cause scale formation and corrosion of boilers (Todd, 1980). Magnesium level in the present study fell almost close to equal and below the permissible standard limits. Untreated domestic sewage and industrial wastes are considered to be the important source of magnesium which is responsible for hardness of water (Mishra and Saxena, 1989).

The levels of free ammonia in the present study were nil throughout the period of study. This may be due to increased anaerobic decomposition of benthic organic matter and dissolved organic matter by microbial population. A study stated ammonia as a product of decomposition of organic matters which tends to be high in water polluted by sewage as in the case of Buckingham canal (Kofold, 1903). Free ammonia is the most reduced form of nitrogen and constitutes the end product of the degradation of organic and inorganic matter in soil and aquatic environments and its presence in percolation indicates anthropogenic contamination, besides from bacterial activity of the soil, agriculture and industrial wastes (Kabour et al., 2012). Nitrate is an oxidized form of nitrogen which is a very present element in the soil essential for the growth of plants. Nitrogen exists in the soil in reduced, oxidized or organic forms and agricultural activities increase nitrate concentration in ground and surface water (Nas and Berkta, 2006; Derwich et al., 2010; Benrabah et al., 2016). Increased nitrate amounts in water causes different problems such as decreased oxygen level resulting in effects on aquatic life, plants and algae, and further can change normal haemoglobin to methaemoglobin (Davie, 2003; Sagar et al., 2015). Nitrites are less present

than nitrates as they originate from the degradation of organic matter, reduction of nitrates and the oxidation of ammonia. Their excessive presence in drinking water presents a health hazard because of their toxic oxidizing power (Belghiti et al., 2013). However, the values of nitrates and nitrites were well within the standard limits throughout the study period.

The chloride concentration depends on the characteristics of pollution load and serves as an indicator of pollution by sewage and also due to fertilizers return from agricultural fields. Thresh et al. (1944) pointed out that high chloride concentration are indicators of large amount of organic matter in the water which has been further supported by researchers who reported lower chloride content in unpolluted waters which ranged between 2 and 10mg/L (Munawar, 1970; Adoni, 1985; Saha and Pandit, 1986). Though chloride is less harmful, it still gives unpleasant taste to the water, and damages the floral vegetation (Sooraj, 2018). The present study indicated that the canal water was highly polluted as the chloride content ranged between 441 and 1112mg/L making the water not fit for any use. Further, the presence of chlorides at sampling points may be due to natural processes such as the passage of water through natural salt formations in the earth or it may be an indication of pollution from industrial or domestic use (Aravindkumar et al., 2014). Fluoride values were nil throughout the study period except for Station 1 during post monsoon which was within the permissible limits. Fluoride ions have high significance in water quality monitoring. Fluoride content in water increases the resistivity of tooth enamel against acids which cause the initiation of tooth decay when its concentration becomes high and when low it causes discolouration and moulting of teeth (Reddy et al., 2009). Elevated fluoride levels also may cause skeletal damage and bone disease as fluoride are common in groundwater.

Sulphate is derived from the dissolution of salts of sulphuric acid and are abundantly found in almost all water bodies. High concentration of sulphate may be due to oxidation of pyrite and mine drainage (Meride and Ayenew, 2016). Sulphate when present in higher quantity produces a cathartic effect in human beings, but in the present study it was within the permissible limits set by standards. The presence of high phosphate concentrations is an index of pollution that affects the quality of waters which was proved in the present study as the values shot ten times more than the permissible limits. They could have originated from industrial and domestic discharges or agricultural products through the use of fertilizers and pesticides (Rodier et al., 2009). Pollution due to industrial and sewage waste contains presence of phosphates which cause growth of microorganisms. The maximum use of fertilizer is the main source of phosphate which comes from agricultural or residential cultivated land into surface waters with storm runoff. High phosphate level causes muscle damage, breathing problem, and kidney failure, and increased concentrations leads to eutrophication and depletion of dissolved oxygen (Davie, 2003; Nyamangara et al., 2013). The major input of phosphates into an aquatic ecosystem comes from the domestic sewage, detergents, residual fertilizers and industrial wastes. Most of the phosphates come from metabolic breakdown of proteins and phosphates in urine. All phosphorus containing compounds yield inorganic phosphate after decomposition. The surface water can have significant phosphorous concentrations contributed by the above factors. Phosphorous was the most important limiting factor responsible for eutrophication of water all over the world (Shivnikar et al., 2000). The silica content of the Buckingham canal was found to be between 37.6 and 63.7mg/L and these values were high when compared to the standard limits which may be due to the result of sediment content from the shallow bottom of the canal to the surface water due to influx of rain water (Sultana, 2002).

Heavy metals in water threatens the life of human and animals as well as its effects on environment. Heavy metal toxicity is potentially dangerous owed to bioaccumulation through the food chain which causes hazardous effects on livestock and human health (Aschner, 2002). However, heavy metals are essential as a micronutrient for plants, microbes and human beings, but when exposed in high amount they produce different side effects of the flora and fauna (Singh et al., 2005; Zaki, 2014). Most of the high values of heavy metals concentrations in the water samples during the monsoon season can be due to the addition of heavy metals by soil erosion and run off during the rainy season (Brain, 2007). It is observed that the very presence of various heavy metal ions in their dissolved state are hindering the beneficial uses of canal waters. Arsenic has a great environmental importance and the main source of its pollution in surface water is by biological activity, weathering of rocks and anthropogenic activities that includes industrial effluents which are rapidly absorbed into fish (Kinniburgh and Smedley 2001; Kapaj et al., 2006). A study reported that arsenic is a highly toxic heavy metal which produce carcinogenicity, genotoxicity, skin pigmentation loss or skin cancer, lung cancer and several other disease after acute and chronic exposure (Zaki, 2014).

Nevertheless, arsenic values were nil throughout the period of study. Chromium is essential to animals and human but in excess amounts can be toxic and in the present study, their values were below the standard limits. Chromium is used in metal alloys and pigments for paints, cement, paper, rubber, and other materials. Electroplating process can release chromic acid and air-borne chromium trioxide, both can result in direct damage to skin and lungs, and chromium dust is considered as a potential cause of lung cancer (Grounse et al., 1983). Copper is an essential substance to human life, but chronic exposure to copper in water can result in the development of liver and kidney damage (Bent and Bohm, 1995). In the present study, copper values were within the permissible limits. Copper in large doses are dangerous to infants and people with certain metabolic disorders. On the other hand, lack of copper intake causes anaemia, growth inhibition, and blood circulation problems (Jennings et al., 1996).

Iron concentration was high indicating the unsuitability of canal water in the present study in addition to the other heavy metals as the values of iron were very high when compared with standard limits. Their entry into the water body may be through the tinkering and electroplating shops, paint factory, electrical engineering works contributing to the increase in the heavy metal content of the Buckingham canal in the present study. Iron is an essential element in the human diet and its toxicity to the human body is governed by the absorption rate (Kumar and Garg, 2019). Iron is one of the most important constituent of blood in human and other living organism and an essential element for human nutrition and metabolism, but in excess quantities results in toxic effect like hemochromatosis in tissues (Sagar et al., 2015). Lead is being potentially hazardous and toxic to most forms of life (USEPA, 1986). It produces neurotoxic effects on developing fetuses and lead stored in the maternal bone are mobilized at high rate especially during pregnancy and lactation period (Gonzalez-Cossio et al., 1997; Gulson et al., 1997). Several health problems are reported due to high exposure of lead in water causing convulsion, renal failure and at higher concentration death may occur. In the present study, the values of lead were four times higher than the limits set by standards. Other source of lead into the environment is from used dry-cell batteries, from sewage effluent, runoff of wastes and atmospheric deposition. Manganese is present as manganous ion in water and its high concentration may cause some adverse health effects (Williams et al., 2012). However in the present study their values were nil throughout the period of study. Zinc could be toxic to aquatic organisms such as fish in high concentration and has been found to have low toxicity to man and prolonged consumption of large doses can result in fatigue, dizziness, and neutropenia (Alabaster and Lloyd, 1980; Hess and Schmid, 2002). Conversely, their recorded values throughout the period of study fell below the permissible limits.

The microbiological parameters were encountered by the most potable number (MPN) technique. High MPN values and species diversity of bacteria and fungi recorded in the present study may be due to waste discharge from industries and households abounding the canal as reported (Abel, 1989). The faecal contamination was seen throughout the period of study, which suggested that the water was surcharged with human and animal waste. The results of the present investigation indicated that the importance of regular examination of bacteriological quality of Buckingham canal water by simple, rapid and inexpensive tests is required. The pollution of water ways affects the natural and human environment in a variety of ways and their impacts can be categorized into three broad areas, viz., ecological, health and socio-economic from the outcome of the present study.

With reference to ecological impact, the extent of pollution in this study is so high that it is incapable of supporting fish life which gets corroborated to their research work in Chennai Cooum (Azariah et al., 1982). They have also showed substantial decrease in the species diversity of these ecosystems due to urbanization (Azariah et al., 1986). However, in the present study, the existence of certain fish species like *Anabas*, *Oreochromis* and *Arius* were observed only in the month of January, which might be due to the flow of storm water from other unpolluted or partially polluted water ways into this canal. With reference to the health impact, in tropical countries, the combination of rainwater, air and sunlight is sufficient to degrade to pollution from human settlements. However, when the population density increases, these natural regenerative processes are too slow, to meet the need at hand. This results in the outbreak of diseases as reported (Dasgupta, 1982). Studies have shown inadequate waste disposal contribute significantly to water-borne diseases (Saunders and Warford, 1976). Therefore, more detailed research is needed to ascertain if the pollution of this canal water ways poses a serious health problem to those living in close proximity to the water ways. In reference to socio-economic impact, this canal is a natural resource which has been utilized in a very inefficient manner. Buckingham canal is occupied on its bank by

many small-scale industries which outlet their waste and sewage directly into the canal. In addition, there are other small-scale industries which send their sewage and waste materials indirectly into this canal. Therefore, the Buckingham canal, if clean, could be used for recreation and transportation and could add to the aesthetic enjoyment of this study. Moreover, this canal still have to function as flood carriers during the monsoon seasons, as there are no alternate water ways of disposing off the flood waters. Therefore, the discharge of wastes (sewage, sullage, industrial wastes) into this canal has to be decreased substantially.

5. CONCLUSION

On the basis of overall findings, it was concluded that water quality of the Buckingham canal was that all physical, chemical, nutrient, and heavy metal parameters in the sampling stations, were high and above the standard limits except for some parameters. In addition, microbiological determination of water from the canal was also not safe for other domestic applications. The effects of water pollution are not only devastating to people, but to animals, fish, and birds also, besides destroying aquatic life. Polluted water is unsuitable for drinking, recreation, agriculture, and industry and diminishes the aesthetic quality and eventually becomes a hazard to human health. Above all, open refuse dumping is adversely affecting the Buckingham canal water in this area, which is a serious concern and immediate action should be initiated to prevent further deterioration of the canal. The present paper embarked to bring an acute awareness among the people about the quality of water. The individual and the community can help minimize water pollution by simple housekeeping and management practices and thereby the amount of waste generated can be minimized.

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