Mysore J. Agric. Sci., 56 (2) : 389-397 (2022)

Status of Physico-Chemical Parameters of Surface Water Bodies along Rural and Transition Zone of Bengaluru

S. N. Uday Kumar, A. S. Devakumar and R. Krishnamurthy
Department of Forestry and Environmental Science, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : udaysugatur@gmail.com

Abstract

Surface water bodies are the major source for irrigation, drinking, domestic and livestock use in rural, transition and urban population in India. The present study was aimed at assessing the water quality status of surface water bodies in the agro-ecosystems of rural and transition zone of Bengaluru. One of the major sources of water contamination is leaching of inorganic fertilizers and pesticides from agriculture fields since excess of these chemicals and their residues are bound to reach the water bodies over a period of time. The water samples were collected from sixteen different locations and samples were analyzed for physical and chemical properties namely, pH, electrical conductivity, total dissolved solids, potassium, calcium, magnesium, boron along with heavy metals such as, arsenic, iron, zinc, cadmium, nickel, chromium, copper, manganese and lead. Heavy metals like arsenic, nickel, iron and aluminum exceed BSI limits and with permissible limits in rural and transition zone of Bengaluru. The cadmium (0.003 mg/L) concentration was found only in the transition zone of south Bengaluru. The water quality index of surface water in the south transact ranged from 21.31 to 98.89 which falls under C_1 (excellent drinking, irrigation and industrial) to C_4 (poor irrigation) category and 30.69 to 104.07 in north transact, falls under C_2 (good domestic, irrigation and industrial) and C_5 (very poor restricted use for irrigation). The highest water quality index falls under C_3 and C_2 categories along the south and north transact of Bengaluru.

Keywords : Surface water bodies, Rural zone, Transition, Transact, Heavy metals, Inorganic fertilizers, Pesticides, Water quality index

Modern agriculture and other sector depend on the technological advancements made in various facets of science to maximize the productivity. The use of fertilizers and plant protection chemicals were the major drivers that increased the crop production to achieve the self sufficiency in food production in India over the past fifty years (Sah and Devakumar, 2018). The human ignorant sentiment of 'if little is good, a lot more is better' has prevailed among farmers and led to indiscriminate use of these inputs over years and resulted in accumulation of these chemicals in soil, water and air resulting in degradation of these natural resources with serious implications on crop productivity and human health. The residues of inorganic chemicals used such as fertilizers, pesticides, insecticides and herbicides used in crop cultivation processes have accumulated over years, resulting in changes in physical and chemical properties of soil, water and air. The nature and intensity of the ill effects of residues depend on the extent and nature of crops grown. In order to assess the changes in the water bodies, agriculture lands in the urban, transition and rural areas are ideal because the crops grown, quantity and nature of agrochemicals used in these regions are different.

Increasing urbanization has made noticeable changes in the nature of crops cultivated across the rural-urban transitions of Bengaluru. More commercial crops with intensive cultivation practices are grown in the urban areas compared to less intensive, resource driven staple food crops in the rural areas (Dhanush & Devakumar, 2019 and Lekhashree *et al.,* 2016). Studies have also revealed that these changes in cropping systems have intensified the use of fertilizers and plant protection chemicals more in crop cultivation has resulted in increased concentrations of chemical residues and heavy metals in the soil and water bodies and causing pollution. Inorganic fertilizers are a potential source of heavy metals in the soil and the water bodies, especially phosphatic fertilizers produced from rock phosphate that contain various metals (Ukpabi *et al.,* 2012). As a result, water bodies in and around Bengaluru are being contaminated considerably and is a major hindrance in fulfilling the water requirements of rapidly growing city (Ravikumar *et al.,* 2013).

The environmental risk of heavy metal pollution is of great concern. The non-degradable, toxic and persistent nature of heavy metals will have widespread serious ecological ramifications (Mateo *et al.,* 2017). Heavy metal pollution caused by the agriculture sector was serious concern over the past few decades (FAO 2013). The heavy metals would accumulate in the crops absorbed from the soil and water and biomagnified in the biological systems. Heavy metal contaminated water will not only lead to various adverse health effects on humans and animals (Shubhra *et al.,* 2015) but eventually lead to a shortage of surface water. According to the UN estimates, waste water production is six times more than the water present in all rivers of the world (WWAP, 2003) suggesting, the global water scarcity, in general, is largely due to the deterioration of water quality than the physical scarcity.

Agriculture is considered to be one of the major deterrents causing soil and water pollution (UNEP, 1996). However, there is no specific information on the nature and quantity of contaminants contributed from the agriculture sector in India in general and across the rapidly urbanizing Bengaluru cosmopolitan city in particular. This information is essential to take appropriate management measures to sustain the water quality in this region. Hence, the present investigation is an effort to assess the water quality across the rural and transition regions in the agro-ecosystems of Bengaluru.

MATERIAL AND METHODS

Study Area

Bengaluru district is situated in the heart of the South-Deccan plateau in peninsular India to the South-Eastern corner of Karnataka State between the latitudinal parallels of 12°39'N and 13°18'N and longitudinal meridians of 77°22'E and 77°52'E at an average elevation of about 920 m (3,020 ft) covering an area extent of land of about 2,174 km2 (Bengaluru rural and urban districts). Bengaluru has two unique topography terrains namely, North Bengaluru taluk and South Bengaluru taluk. The North Bengaluru taluk is a relatively more level plateau and lies between an average of 839 to 962 meters above sea level (Ravikumar *et al*., 2013).

The South Bengaluru taluk has an uneven landscape with intermingling hills and valleys. The southern and western portions of the city consist of a topology of granite and gneissic masses. An eastern portion is a plane, with rare minor undulations. The hottest summer day on average has a maximum temperature of about 37°C and the coldest winter day has a temperature of about 13°C. Bengaluru records high temperatures during April with daily mean temperatures of 33.4°C and mean daily minimum in the month of December at 25.7°C, as the coolest month. The mean annual rainfall is 859.6 mm, with three different rainy periods covering 8 months of the year. June to September being the rainy season receives 54 per cent of the total annual rainfall in the South-West monsoon period and 241 mm during the North-East monsoon period (October-November).

Assessment of the water quality in the rural and transition zone of the water bodies located in the close proximity of agriculture fields is assessed. Stratification of rural, urban and transition regions in the north and south directions of Bengaluru is done based on the stratification index (Hoffmann *et al.,* 2017). The present study has to be confined to the rural and transition zone of Bengaluru because of the non-availability of suitable water bodies in the urban zone.

A total of 16 surface water bodies were assessed that represented water bodies from the rural and transition zone of Bengaluru in north and south directions. In each direction, eight samples were collected during the post-monsoon season in the Agro-ecosystem in rural and transition zone (Table 1). Surface water bodies were selected within one-kilometer radius of agricultural fields. Further, it was also ensured that these water bodies are not contaminated by other sources of contamination such as domestic waste and industrial discharge.

TABLE 1

Location details of the surface water sample points in rural and transition zone

Sampling Sites	Locations	Latitudes	Longitudes
South Bengaluru			
South rural	Swarnamuki	12º70'59.6"N	77º45'89.9"E
South rural	Gabbadi	12º70'62.2"N	77º48'45.1"E
South rural	Gollarapalya	12º73'68.7"N	77º45'82.1"E
South rural	Gollapura	12º73'51.1"N	77º44'72.8"E
South transition	Gulakamale	12º48’23.9"N	77º31’ 0.9"E
South transition	Kaggalahalli	12°47’50.4"N	77°30’21.8"E
South transition	Somanahalli	12º76'95.3"N	77º50'00.8"E
South transition	Nelaguli	12°46’41.5"N	77°29’33.9"E
North Bengaluru			
North rural	Shivapura	13°18’58.2"N	77°34’06.8"E
North rural	Gunjur	13º43'99.5"N	77º51'42.4"E
North rural	Hosakunte	13º32'59.6"N	77º56'32.9"E
North rural	Kollur	13°20’45.6"N	77°30’52.0"E
North transition	Mallathana halli	13º32'45.3"N	77º53'63.5"E
North transition	Gantiganahalli	13°08’17.5"N	77°34’38.6"E
North transition	Marasandra	13 º22'78.3"N	77º54'40.0"E
North transition	Ganganahalli	13 º14'09.4"N	77º59'087.4"E

Physical and Chemical Property Analysis of Water Samples

The water samples were analyzed for pH, EC, Salinity, TDS, and Turbidity, using a combined water analyzer (Systronics, Model-371, India). The chemical quality assessment is based on the quantification of potassium, calcium, magnesium, boron and heavy metals like arsenic, cadmium, cobalt, chromium, copper, manganese, nickel, lead, zinc, iron and aluminium using the inductively coupled plasma optical emission spectrometry (ICP-OES- Spectra Genesis, Germany).

Derivation of Water Quality Index (WQI)

WQI is derived using Horton’s method as follows :

$$WQI = \sum qnWn / \sum Wn$$

Where,

qn = Quality rating of n^{th} water quality parameter

Wn = Unit weight assigned to n^{th} water quality parameter.

Water Quality Rating (qn)

The quality rating (qn) is calculated using the expression given in Equation.

$$qn = [(Vn - Vid) / (Sn - Vid)] \times 100$$

Where,

Vn = Estimated value of n^{th} water quality parameter at a given sample location

V_{id} = Ideal value for nth parameter in pure water (V_{id} for pH = 7 and 0 for all other parameters)

Sn = Standard permissible value of n^{th} water quality parameter

Unit Weight (Wn) (Table 2)

The unit weight (Wn) is calculated using the expression given in Equation.

$$Wn = k / Sn$$

Where,

Sn = Standard permissible value of n^{th} water quality parameter.

k = Constant of proportionality, calculated by using the Equation.

$$K = [1/ (\Sigma/S_{n=1,2\ldots n})]$$

Statistical Analysis

The data analyzed from experiment were subjected to statistical analysis as described by Gomez and Gomez (1984). One-way ANOVA technique used to assess the sample means, standard errors of mean and range of detection for a laboratory experiment using Microsoft Excel 2016.

TABLE 2

The k-value and unit weight of each of the physicochemical parameters used for WQI determination

Parameters	Sn	K Value	Wn
pH	8.5	0.00235	0.00028
Electrical conductivity (μS/L)	2000	0.00235	1.2E-06
TDS (mg/L)	500	0.00235	4.7E-06
Potassium (mg/L)	10	0.00235	0.00023
Calcium (mg/L)	75	0.00235	3.1E-05
Magnesium (mg/L)	30	0.00235	7.8E-05
Sodium (mg/L)	100	0.00235	2.3E-05
Boron (mg/L)	0.5	0.00235	0.00469
Arsenic (mg/L)	0.01	0.00235	0.23474
Cadmium (mg/L)	0.01	0.00235	0.23474
Cobalt (mg/L)	0.05	0.00235	0.04695
Chromium (mg/L)	0.05	0.00235	0.04695
Copper (mg/L)	0.05	0.00235	0.04695
Manganese (mg/L)	0.1	0.00235	0.02347
Nickel (mg/L)	0.02	0.00235	0.11737
Lead (mg/L)	0.01	0.00235	0.23474
Zinc (mg/L)	5	0.00235	0.00047
Iron (mg/L)	0.3	0.00235	0.00782
Aluminium (mg/L)	5	0.00235	0.00047

RESULTS AND DISCUSSION

The results are discussed in the light of various quality standards prescribed for specific water uses such as; for drinking (DW), irrigation (IR) and livestock consumption (LC) purposes. Quality standards are determined considering various physical and chemical properties of water.

The pH is the numerical expression of hydrogen ion concentration that determines the acidic, alkaline or corrosive nature of water which is in turn critical for utilization of almost all essential plant nutrients (Suchithra *et al.,* 2011). Lower pH values tend to make water corrosive and higher pH leads to bad taste and has negative impact on skin and eyes (Rao and Rao, 2010). The pH value in the surface water along the rural and transition vary from 6.70 to 7.15 and 6.82 to 7.41in south transact and 7.87 to 8.40 and 8.20 to 8.76 in north transact (Table 3 and 4). The pH of surface water bodies in the rural and transition zone was slightly alkaline and exceeded the permissible limit in the north transact of transition zone (BSI, 2012).

The electrical conductivity is a function of total dissolved salts and is used as an indicator to represent the concentration of soluble salts in water (Purandara *et al.,* 2003 and Gupta *et al.,* 2008). The highest electrical conductivity was recorded in the south rural zone (331.16 μS/L) and north transition zone (378.75 μS/L) (Table 3 and 4). The EC values were within the permissible limits for irrigation, drinking and livestock use. A similar study also says that the conductivity in water is mainly due to the presence of inorganic dissolved compounds like sulphate, nitrate, phosphate, chloride, calcium, magnesium, sodium, iron and aluminium ions (Anima and Chandrakala, 2015).

The total dissolved solids (TDS) mainly consist of inorganic salts such as carbonates, bicarbonates, chlorides, sulfates, phosphates and nitrates of calcium, magnesium, sodium, potassium etc. and a small amount of organic matter. Fertilizers from agriculture runoff can add some of these compounds as residues to water bodies and results in the deposition of salts in the water bodies (Rachna and Disha, 2016). The mean concentration of TDS for surface water in the agro-ecosystem along the rural and peri-urban was in the range 46.90-418.50 to 29.65-214.50 mg/L in southern transects while it ranged from 44.20 - 142.67 mg/L to 71.50 - 461.00 mg/L in the northern transects. The maximum mean concentration of TDS was found in north transition and south rural zones (Table 3 and 4). The maximum concentration of TDS was within the permissible limits as per BSI standards (2000 mg/L). The results suggest that the TDS will reach near to maximum permissible limits in the near future.

The mean concentrations of K, Ca, Mg and Na were more in a rural zone of south transact and transition zone of north transact. The concentrations of K, Ca, Mg and Na were within the acceptable limit for drinking purpose and not exceeded the maximum permissible limits (Table 3 and 4). The hardness of water is caused due to the presence of multivalent cations mainly calcium and magnesium. The

TABLE 3

Minimum, maximum, and mean values of Physico-chemical parameters of surface water bodies of South Transect

Parameters	Rural			Transition			BSI (2012) Acceptable Limit	Minimum permissible limits FAO, BSI Fipps (2003)	
	Mean and SEm Values	Range of detection		Mean and SEm Values	Range of detection				
		Min.	Max.		Min.	Max.	DW	IW	lW
pH	6.95 ± 0.084	6.70	7.15	7.10 ± 0.14	6.82	7.41	6.5-8.5	6.5-8.6	6.5-8.7
EC (µS/L)	331.16 ± 105.90	96.15	730.50	236.22 ± 77.17	52.15	365.50	2000	750-2000	1500
TDS (mg/L)	189.83 ± 60.45	46.90	418.50	137.55 ± 45.36	29.65	214.50	500-1000	450-2000	1500
K (mg/L)	4.66 ± 0.65	3.42	7.46	6.82 ± 1.68	3.25	10.38	10	-	-
Ca (mg/L)	15.08 ± 3.82	8.99	32.03	16.10 ± 2.14	10.89	19.28	75	-	500
Mg (mg/L)	6.66 ± 2.64	2.30	18.21	6.21 ± 1.76	2.05	9.27	30	-	250
Na (mg/L)	30.07 ± 10.48	3.48	61.16	16.52 ± 1.74	13.03	20.37	100	69	-
B (mg/L)	0.027 ± 0.005	0.009	0.043	0.044 ± 0.01	0.068	0.020	5	0.7	5
As (mg/L)	0.012 ± 0.005	0.002	0.032	0.008 ± 0.002	0.003	0.012	0.01	0.1	0.2
Cd (mg/L)	0	0	0	0.003 ± 0.002	0.00	0.008	-	-	0.01
Co (mg/L)	0.028 ± 0.001	0.025	0.029	0.028 ± 0.002	0.026	0.033	-	0.05	1.5
Cr (mg/L)	0.016 ± 0.002	0.013	0.023	0.017 ± 0.002	0.013	0.022	0.05	0.1	1
Cu (mg/L)	0	0	0	0	0	0	0.05	0.2	0.5
Mn (mg/L)	0.033 ± 0.020	0	0.11	0.019 ± 0.002	0.014	0.024	0.1	NA	0.05
Ni (mg/L)	0.034 ± 0.002	0.03	0.039	0.031 ± 0.006	0.017	0.041	0.02	0.2	NA
Pb (mg/L)	0.002 ± 0.001	0.001	0.004	0.002 ± 0.001	0.002	0.003	0.01	5	0.1
Zn (mg/L)	0.053 ± 0.034	0.007	0.21	0.045 ± 0.03	0.003	0.12	5	2	15
Fe (mg/L)	1.64 ± 0.84	0.02	4.43	0.51 ± 0.40	0.016	1.52	0.3	5	50
Al (mg/L)	2.56 ± 1.23	0.09	6.83	1.25 ± 0.96	0.06	3.62	0.03	5	5

NA: Not Assigned, DW: Drinking Water, IW: Irrigation Water, LW: Livestock Water

TABLE 4

Minimum, maximum, and mean values of Physico-chemical parameters of surface water bodies of North Transect

Parameters	Rural			Transition			BSI (2012) Acceptable Limit	Minimum permissible limits FAO, BSI Fipps (2003)	
	Mean and SEm Values	Range of detection		Mean and SEm Values	Range of detection		DW	IW	LW
		Min.	Max.		Min.	Max.			
pH	8.14 ± 0.09	7.87	8.40	8.51 ± 0.01	8.20	8.76	6.5-8.5	6.5-8.6	6.5-8.7
EC (µS/L)	216.04 ± 63.23	77.17	393.00	378.75 ± 139.23	124.50	814.50	2000	750-2000	1500
TDS (mg/L)	83.58 ± 18.29	44.20	142.67	214.95 ± 78.97	71.50	461.00	500-1000	450-2000	2000
K (mg/L)	7.69 ± 1.52	3.72	12.25	6.60 ± 0.89	5.07	9.65	10	-	-
Ca (mg/L)	13.21 ± 2.83	7.14	21.28	19.31 ± 5.89	8.77	38.03	75	-	500
Mg (mg/L)	4.59 ± 0.91	2.25	7.60	6.80 ± 3.18	1.72	17.55	30	-	250
Na (mg/L)	9.93 ± 3.51	2.27	18.95	18.88 ± 7.53	3.49	38.22	100	69	-
B (mg/L)	0.012 ± 0.002	0.007	0.017	0.012 ± 0.002	0.008	0.02	5	0.7	5
As (mg/L)	0.004 ± 0.002	0.003	0.009	0.008 ± 0.004	0.002	0.02	0.01	0.1	0.2
Cd (mg/L)	0	0	0	0	0	0	-	-	0.01
Co (mg/L)	0.027 ± 0.001	0.025	0.03	0.026 ± 0.001	0.024	0.028	-	0.05	1
Cr (mg/L)	0.016 ± 0.001	0.014	0.02	0.014 ± 0.001	0.013	0.016	0.05	0.1	1
Cu (mg/L)	0	0	0	0	0	0	0.05	0.2	0.5
Mn (mg/L)	0.021 ± 0.011	0.006	0.06	0.002 ± 0.001	0.001	0.011	0.1	NA	0.05
Ni (mg/L)	0.035 ± 0.001	0.032	0.04	0.032 ± 0.001	0.029	0.03	0.02	0.2	NA
Pb (mg/L)	0.004 ± 0.001	0.001	0.006	0.006 ± 0.002	0.003	0.012	0.01	5	0.1
Zn (mg/L)	0.008 ± 0.003	0.001	0.016	0.014 ± 0.005	0.003	0.03	5	2	24
Fe (mg/L)	0.43 ± 0.16	0.016	0.94	0.75 ± 0.37	0.13	2.04	0.3	5	50
Al (mg/L)	0.97 ± 0.34	0.06	1.11	0.45 ± 0.17	0.15	1.01	0.03	5	5

NA: Not Assigned, DW: Drinking Water, IW: Irrigation Water, LW: Livestock Water bicarbonates, chlorides and sulphates of calcium and magnesium impart hardness of water and also increases the electrical conductivity (Anima and Chandrakala, 2015).

Results obtained on heavy metals concentrations in the surface water bodies of agroecosystems along the rural and transition zone of south and north transact are presented in Tables 3 and 4. The mean concentrations of heavy metals like arsenic (0.012 mg/L), iron (1.64 mg/L), zinc (0.053 mg/L), nickel (0.034 mg/L), manganese (0.033 mg/L) and aluminum (2.57 mg/L) were more in south rural region compared to transition and cadmium concentration was not found in surface water bodies of north and south transact except for transition region of south transact (0.003 mg/L). The concentration of arsenic (0.008 mg/L), lead (0.006 mg/L), zinc (0.014 mg/L) and iron (0.759 mg/L) was found highest in transition of north transact (Table 3 and 4). The other heavy metals like aluminum, nickel, manganese, chromium and cobalt were found highest in north rural region. The mean concentrations of aluminum, iron and nickel were more than acceptable limits in both the transacts but within the permissible limits of BSI standards while heavy metal concentration of other residues did not exceed the minimum permissible limits of BSI for drinking, irrigation and for livestock use. Studies have also revealed that these changes in cropping systems have intensified the use of fertilizers and plant protection chemicals more in crop cultivation which results in increased concentrations of heavy metals and their residues in soil and reaching the water bodies and polluting them. Inorganic fertilizers are a potential source of heavy metals in soil and water bodies especially phosphatic fertilizers produced from rock phosphate that contain various metals as minor constituents in the ores (Ukpabi *et al.,* 2012). Though heavy metal concentrations are within the prescribed standards for all said end uses at present, results suggest that along with the rural and transition they are increasing at alarming rates for all selected end uses of surface water. It is important to note that very small concentrations of heavy metals are capable of producing adverse health effects on humans, plants and other organisms.

The water quality index of surface water in the south rural zone ranged from 33.34 to 98.89 and 21.31 to 83.30 in transition and the mean water quality index of rural surface water was highest (62.49) which falls in C_2 (Fair Irrigation and Industrial) category, but it ranges from C_2 (Good Domestic, Irrigation and Industrial) and C_4 (Poor Irrigation) category in south rural transact but in transition it ranges from C_1 (Excellent Drinking, Irrigation and Industrial) to C_4 (Poor Irrigation) category (Table 5 and 6).

In north transact of transition zone water quality ranged from 31.62 - 104.07 and 30.69 - 60.13 in rural and water quality falls in between C_2 (Good domestic, irrigation and industrial) and C_5 (Very poor restricted use for irrigation) but mean water quality of surface water of transition zone was 55.61 which falls in C_3 (Fair irrigation and industrial) category and 44.64 for rural which falls in C_2 (Good domestic, irrigation and industrial) category.

The highest water quality index falls under C_3 (8) and C_2 (5) categories along the south and north transact of Bangalore. The parameters selected for quantification of water quality index and their classification is given in Table 2.

The above results indicate that the water quality is better except for transition zone of south and north Bangalore. Similar studies were conducted earlier

TABLE 5

Water quality index in rural and peri-urban zones of Bengaluru

Zones	South Transact			Zones	North Transact		
	Average	Min.	Max.		Average	Min.	Max.
Rural	62.49	33.34	98.89	Rural	44.64	30.69	60.13
Peri urban	54.52	21.31	83.30	Peri urban	55.61	31.62	104.07

(Ravikumar *et al.,* 2013) in two water bodies in Bengaluru found (Sankey tank and Mallathahalli lake) that, Sankey tank waterfalls under good water class (50-100) while Mallathahalli lake water falls under poor water (100-200) category.

It is concluded that the pH, EC and TDS did not exceed the minimum permissible limits as recommended by FAO and BSI standards, but heavy metals like arsenic, nickel, iron and aluminum exceeds BSI limits and with permissible limits in rural and transition zone of Bangalore. The cadmium concentration was found only in the transition zone of south Bangalore. After comparing with water quality index, the water in surface water bodies in south and north Bangalore can be used for irrigation, industrial, domestic and livestock use. If the water is filtered it can be used for drinking purpose also. Hence, by observing and analyzing the physicochemical parameters, surface water bodies in south and north transact of Bengaluru can be used as an alternate source of irrigation to nearby agricultural areas if water bodies are properly maintained, restored and protected. Since surface water bodies are more easily accessible than groundwater, it is relied on for much human and livestock uses. Surface water is an important source of drinking water and for the irrigation of farmland and this helps to reduce the dependency on groundwater resources.

Acknowledgements : The authors wish to acknowledge the Department of Biotechnology, Government of India for (BT/IN/German/DFG/14/ BVCR/2019-Phase-II) the financial support.

REFERENCES

ANIMA, U. AND CHANDRAKALA, M., 2015, Study on the water quality parameters of Kukkarahalli lake water Mysore, Karnataka, India. *Inter. J. Tech. Engg. Manage. Appl. Sci.,* **4** (12) : 2278 - 2540.

BSI, 2012, Specifications for drinking water. New Delhi: *Bureau of Indian Standards*.

DHANUSH, C. AND DEVAKUMAR, A. S., 2019, Impact of urbanization on water bodies in agro-ecosystems of Bengaluru-metropolitan city of India. *Tropentag Conference, Germany*.

FAO, 2013, Guidelines to control water pollution from agriculture in China. *Water Report*. Food and Agriculture organization of the United Nations, Rome. http://www.fao.org/3/i3536e i3536edfaccessed on 10 May 2019.

FIPPS, G., 2003, Irrigation water quality standards and salinity management strategies. Available electronically from *http://hdl.handle.net /1969.1 /87829*.

GUPTA, S., MAHETO, A., ROY, P., DATTA, J. K. AND SAHA, R. N., 2008, Geochemistry of groundwater Burdwan district, West Bengal India. *Environ. Geol.,* **53** : 1271 - 1282.

GOMEZ, K. A. AND GOMEZ, K. A., 1984, Statistical procedure for agricultural research. 2nd edition, Johan Willy and Sons, Inc. New York, USA.

HOFFMANN, E. M., JOSE, M., NOLKE, N. AND IMOCKEL, T., 2017, Construction and use of a simple index of urbanization the rural-urban interface of Bangalore, India. *Sustain.,* **9** : 2146.

LEKHASHREE, S. M., KRISHNAMURTHY, K. N. AND SRINIVASAMURTHY, C. A., 2016, Factors contributing to the pollution of selected lakes in and around Bengaluru district. *Mysore J. Agric. Sci.,* **50** (1) : 33 - 38.

MATEO, S. J., ZADEH, S. M. AND TURRAL, H., 2017, Water pollution from agriculture : A global review (Executive summary). Food and agriculture organization, United Nations, Rome and the international water management institute on behalf of the water land and ecosystems research program, Colombo, pp. : 1 - 29.

PURANDARA, B. K., VARADARAJAN, N. AND JAYASHREE, K., 2003, Impact of sewage on ground water : A case study. *Poll. Res.*, **22** (2) : 189 - 197.

RACHNA, B. AND DISHA, J., 2016, Water quality assessment of lake water : A review. *Sustain. Water Resour. Manag.*, **2** : 161 - 173.

RAO, G. S. AND RAO, G. N., 2010, Study of groundwater quality in greater Visakhapatnam city, Andhra Pradesh (India). *J. Environ. Sci. Eng.,* **52** (2) : 137 - 146.

RAVIKUMAR, P., MEHMOOD, M. A. AND SOMASHEKAR, R. K., 2013, Water quality index to determine the surface water quality of Sankey tank and Mallathahalli lake, Bangalore urban district, Karnataka, India, *App. water sci.,* **3** : 247 - 261.

SAH, D. AND DEVAKUMAR, A. S., 2018, Carbon footprint of agricultural crop cultivation process in India, *Carbon Management,* **9** (3) : 213 - 225, DOI10.1080/17583004.2018.145790.

SHUBHRA, S., JANARDHANA, R. N. AND NAZNEEN, S., 2015, Environmental risk of heavy metal pollution and contamination sources using multivariate analysis in the soils of Varanasi environs, India. *Environ. Monit. Assess.,* **187** : 345.

SUCHITHRA, K. P., CHANDRA PRAKASH, J., RAMAKRISHNA PARAMA, V. R., CHANDRASHEKARA REDDY, K. H. AND NAGARAJAIAH, C., 2011, Evaluation of potable water quality of different hotels in Bengaluru. *Mysore J. Agric. Sci.,* **45** (1) : 67 - 73.

UKPABI, C. F., AKUBUGWO, E., AGBAFOR, K. N., LEBE, N. A. AND NWAULARI, N. J., NNEKA, E. D., 2012, Appraisal of heavy metal contents in commercial inorganic fertilizers blended and marketed in *J. Chem.*, **2** (4) : 228 - 233.

UNEP, 1996, Groundwater : A threatened resource. *UNEP Environment Library No. 15*, UNEP, Nairobi, Kenya.

WWAP (United Nations World Water Assessment Programme)/UN-Water, 2003. The world water development report 1: Water for people, water for life. Paris, UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000129 556 accessed on 15 May 2019.

(*Received :* November 2021 *Accepted :* April 2022)