An analytic case study of lentic ecosystem and rejuvenation of Bellandur and Varthur lakes in Bengaluru, India

Abstract

Bengaluru, the town of Kempegowda was known as the city of lakes till the sixties decade of the twentieth century now transformed into pools of sewage over the years. The natural drainage system has been completely obliterated in the name of development and resulting in unprecedented floods in the south eastern part of the city during the 2022 monsoon and before. There were 612 lakes (live as well as disused) in the present area of Bengaluru city (except Anekal taluka). It is observed that the rejuvenation of lakes could not be succeeded because of the continuous inflow of sewage in them. Bellandur and Varthur lakes are no exception. Public and judiciary intervention has put pressure on the State to attempt rejuvenation of many lakes. Despite regular monitoring of rejuvenation works in the initial stages by a Committee appointed by National Green Tribunal, the works are not yet completed. Treatment of sewage generated in the catchment of Belandure and Varthuru lakes is around 453.50 MLD million litter per day (MLD) against the flow of 553 MLD. To regulate the outflow and foam formation, sluice gates are constructed and waste wear are renovated in both lakes. Desilting is a major task among the other works for rejuvenation. The silt removed from Varthuru lake is non-hazardous and used by farmers in their fields but the silt removed from Bellandur lake is dumped in the abandoned stone quaries since being contaminated. The results of soil analysis have been given in various tables.The groundwater is fond non -contaminated. Belandure lake play a role of buffer zone for Varthur lake.

Key words: National Green Tribuna , storm water drains, secondary treatment plant, lake series,

1.Introduction:

Bengaluru is an important Cosmo Metropolitan city in southern India comprised of more than one billion human population. The city is located at an average elevation of about 900 Meters from sea level and has undulating terrain with an upper profile of good red soil but the South-eastern part of the city was marshy lands in past and the built-up planes now. Due to this character, the areas under occupied township have a large number of manmade

tanks(lakes) primarily constructed in past for agriculture/horticulture irrigation and drinking water for humans and cattles. The tanks in Banglore are located in a series of clusters linked to each other through natural drains in past. Now man-made storm water drains have replaced the original drains resulted into narrowed and encroached drains at many places. All the tanks in the city are broadly part of four watersheds, viz. Hebbal, Koramangala, Challaghatta, and Vrishabhavathi and form valley ecozones of Hebbal valley or Rishbhavathi valley, or Kormangla-Chelghatta valley. The constructions of tanks in the city have a long history and goes back even to Ganga Dynasty (Bellandur, Agrium). The tanks in Bengaluru are the Heritage of the city and caused it to call the "City of lakes", UV Singh et al 2019,2020 ".

2.Material and Methods:

The then Chief Conservator of Forest of Lake Development Authority (LDA), the author, based on village maps had compiled the numbers of lakes/tanks in all the Four Taluks of Bengaluru Urban District. The numbers so arrived by him are/were 845. In addition to there were a large number of Kunte/katte (small natural water bodies considered as B-kharab land) in these four taluks. The CSIR-based National Environmental Engineering Research Institute (NEERI) as appointed by the Bruhath Bangalore Mahanagara Palike (BBMP) to study the lakes in Bengaluru, in response to the directions issued by the Karnataka High Court on a bunch of public interest litigations relating to lakes has submitted a report to the High Court. NEERI has identified and studied the water quality of 211 lakes. There are 19 disused lakes in addition to 211 live/used lakes in the BBMP area **Table -1.** There were about 81 lakes in the catchment of the Bellandur- Varthur lake series.

Table 1 Number of disused lakes as reported by BBMP in Bengaluru:

Sl. No	Zone	Name of lake	Village &survey nos.	Area. Acres	Gunta
1	East Zone	Konena Agrahara lake	Konena Agrahara -60	20.00	10.00
2	Mahadevpura Zone	Vijanapura Lake	Vijanapura-42	29.00	15.00
3	Bommanahalli Zone	Ittmadu	Chikkalasandra-83 Ittamadu-17,	10.00	23.00
4	Bommanahalli Zone	Chikkalsandra Lake	Chikkalasandra-76	12.00	26.00
5	Bangalore South	Thavarekare	Thavarekare-74	10.00	16.00
6	West Zone	Kamakshi palya	Sanegoruvanahalli-60	6.00	35.00
7	Bommanahalli Zone	Belakahalli	Belakahalli-172	7.00	0.00
8	Bommanahalli Zone	Doresani palya	Belakahalli-167	56.00	37.00
9	RajaRajeshwari Nagar Zone	Bovimaranahalli	Halage vaderahalli-124	19.00	15.00
11	Bangalore South	Nandi shettappa lake	-	0.00	0.00
12	RajaRajeshwari Nagar Zone	Gundopanth lake	Pantarapalya-59	2.00	17.00

13	Bangalore South	Karisandra lake	Karisandra - 7	13.00	0.00
14	West Zone	Anche Ramana kere (Gangondanahalli)	Gangondana halli-8	0.00	17.00
15	East Zone	Byatagunte Playa	Byatagunte palya-14	4.00	27.00
16	East Zone	Lingarajapura Lake	Lingarajapura-49	16.00	14.00
17	East Zone	Geddalahalli	Geddalahalli-03	21.00	18.00
18	West Zone	Sanigoruvahalli	Sanigoruvahalli-120	15.00	24.00
19	West Zone	Shivanahalli (Agrahara Dasarahalli)	Agraharadasarahalli-72	9.00	25.00

Koramangala Chellaghatta lake series (KC Valley) is located in the east of Bangalore urban district, encompasses nearly 35.7% of BBMP spatial extent, and constitutes the largest among the three major lakes series in Bengaluru. KC Valley catchment extends between 12.8365oN to 13.0153oN and 77.5651oE to 77.7873oE with a spatial extent of 292.38 sq. km.

Bellandur Lake is believed to be originally a tributary of the Dakshina Pinakini River (also known as the Ponnaiyar River). The lake itself was constructed during the reign of the Western Ganga Dynasty, who ruled between the 4-5th century to 10th centuries CE. Evidence of early human settlement has been excavated along the bed of the Bellandur lake by historian Dr. PV Krishnamurthy.

Bellandur and Varthur lakes are located in the suburb/en of Bengaluru in the southeast of the city and are the largest in area. Bellandur lake covers an area of 916.34 Acres and part of K.C.Velley series. It was used for landing amphibious aircraft during British rule. They are part of the Bellandur drainage system that drains the southern and the south-eastern parts of the city. The Bellandur lake is a receptor from three chains of lakes upstream and has a catchment area of about 148 square kilometers (37,000 Acres). But the K&C Valley catchment area is about 292.32 square kilometers. Water from Bellandur lake flows further east to Varthur lake, from where it flows down the plateau and eventually into the south Pinakani river/basin. Bellandur lake was highly polluted with sewage was attempted by many Govt agencies but to date no complete success. In May 2015 the foam covering the water's surface was claimed to caught fire and burned for hours. The lake grasses caught fire again in January 2018. Now the water is drained off in the process of rejuvenation for de-silting and as such no sewage inside the lake for two years. The lake/s have again been filled during the 2022 Bengaluru floods.

To keep the Bellandur lake noncontaminated, non-entry of sewage, desilting, and de-weeding, protection from dumping of waste in the lake bed, and protection from encroachment, the efforts of the society, various Govt.agencies including the then Lake Development Authority have been persistently done since last more than 23 years UVSingh et al.

A Committee under the chairmanship of Justice Santosh Hegde was also constituted for monitoring of works of various organizations by the National Green Tribunal, New Delhi (NGT.) The author was the expert member of this Committee. The rejuvenation works are not completed on the day this paper is being written. The state Government has provided the funds for rejuvenation of these two lakes on the direction of NGT, NGTreports2019, 2020.

At the end of K&C Valley, another manmade lake is located at Varthur village an area of 434.17 Acres commonly known as Varthur lake. This is one of the largest lakes in Bengaluru south Taluk. These two lakes are interconnected to the surrounding wetlands which drain into Varthur lake and finally into the Dakshina Pinakini River. It has a large surface area and is the main irrigation source to the surrounding agriculture fields. Varthur lake has played an important role in maintaining water resources for irrigation since its construction over the centuries. It has developed into a complex ecosystem that provides a habitat for a wide variety of flora and fauna, including resident and migratory waterfowl. The lake also endowed the local community with a pleasant microclimate and considerable aesthetic appeal. The lake is surrounded by small farms wherein rice, ragi, coconut, flowers, and a variety of fruits and vegetables, are grown using the lake water. But slowly, now the fields are converted to built up area. But slowly the area is getting developed.

3.Results and discussion:

A. Study area: Koramangala Chellaghatta valley Catchment (K&C Valley), Bellandur and Verthur lakes

K&C valley catchment (also known as Bellandur-Varthur lake series) had about 132 lakes as per the Topographic Maps during the ’60s and is now reduced to 81 and the majority of them are encroached partly/fully, filled with sewage, solid waste, construction debris, plastic waste etc.

To rejuvenate these two lakes, an integrated administrative approach, as well as development on technical grounds/data, has been adopted under a single umbrella of a Monitoring Committee appointed by the NGT. The Committee comprised expert members and a Judicial Chairman. The wings of the State Government involved in rejuvenation are the qualified agencies with a defined task in the process of rejuvenation. They are: Bengaluru Development Authority (BDA), Bruhath Bengaluru Mahanagara Palike (BBMP), Bengaluru Water Supply and Sewerage Board (BWSSB), Karnataka State Pollution Control Board (KSPCB), and the Revenue Department, Reports 2019-2020. To develop these lakes, National Green Tribunal (NGT) has played a vital role regarding review, directions, and issuing valuable suggestions to complete the various tasks within the time limit, NGT order 12.3.21. The task of the Committee ended on 31.3.2021 with an NGT order. Since then, the work is slow and to date unfinished.

Though the diversion of sewage was a temporary measure, the real task is to stop the permanently entering sewage into lakes. And for this purpose, the treatment of sewage is the main task for development. The task of treatment of all the sewage entering these lakes has been assigned to the BWSSB. They have installed many sewage treatment plants (STP) in the vicinity of lakes,Rasmi Das 2023.

That the BWSSB has to take steps to treat the remaining 8 to 10 % of sewage to stop completely flowing of sewage into the lakes after rejuvenation. It is noted here that, as per the recommendations of the Committee, the water level in these lakes shall be maintained by supplying treated water from the STPs daily to compensate for evaporation and seepage/ground charge losses. Only the surplus treated water should be allowed to flow to tanks of Kolar, Chikkaballapur, Anekal, etc.

The State Government is developing Rajakaluve K-100 for the length of 11.4 km from Chikkalalbagh to Bellandur lake. No Objection Certification was given in compliance with IA No.392/2020 in OA No.125/2017 with certain conditions by the Committee. The works at K-100 have been commenced.

Silt sampling in both lakes has been carried out jointly (by CPCB and KSPCB) and analyzed for essential parameters including heavy metals from the qualified labs. The standard protocol for assessing the hazards (if any) has been examined through Toxicity characteristic leaching procedure (TCLP) and Soluble Threshold Limit Concentration

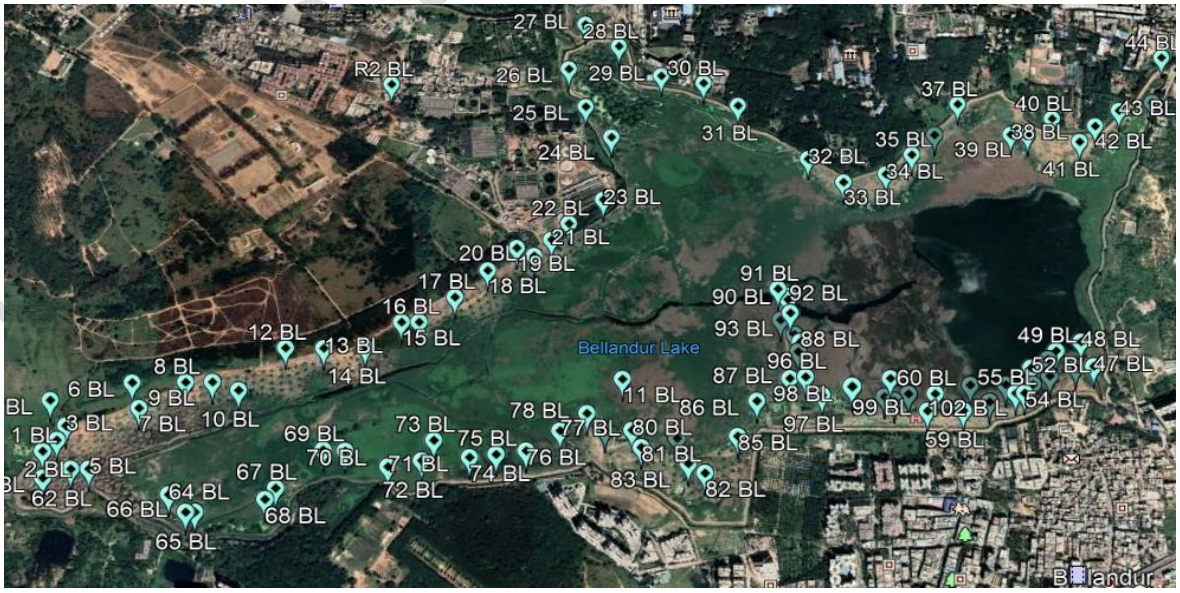
(STLC) methods of soil samples in both Bellandur and Varthur Lakes, Ramchandra et al. 2018.

B. Bellandur lake.

Karnataka State Pollution Control Board (KSPCB) carried out three sediment sampling exercises in Bellandur Lake on 18th September 2020, 12th November 2020, and 25th December 2020. Altogether, 123 sediment samples were collected from the Lake at 12, 8, and 103 locations during September, November, and December 2020 respectively. From each location, sediment samples were collected at three different depths (1, 3, and 6 feet deep).

The guidelines as stated in Guidance Document for Assessment and Remediation of Contaminated Site in India has been issued by MoEF & CC for such locations. The same has been followed for sampling in these two lakes. As per the said guidelines it suggests that *for large areas (e.g., 500m x 500m or more) where the spacing between sampling locations exceed 150 m, intermediate locations should also be identified (preferable in a square grid of 150 m x 150 m).* Accordingly, hypothetical Grid Sampling locations (on dated 25.12.2020) are marked at the Lake of 3.61 Km^2. The sampling should have been done as suggested in the guidance document, but due to the ground realities and hinderance; proper sampling in the entire lake area has not been done. Only 123 locations were done as against the 236 sampling grids Figure 1,

Figure 1: Sampling locations (25.12.2020) on google Maps in Bellandur Lake



The parameters like Boron, Chromium, Iron, Nickle, Copper, Zinc, Selenium, Molybdenum, Silver, Antimony Cadmium, Lead, Beryllium,Vanadium, Cobalt, Arsenic, Barium, Mercury, Thallium and Manganese for the assessment of the lake sediment quality as per the Guidance

Document for Assessment and Remediation of Contaminated Site in India, issued by MoEF & CC were considered.

Underground water samples at the depth of 6 to 10 feet deep pits have been collected from the areas where heavy metals are found in the silt. The water quality concerning some metals as indicated in the table was analysed (Table 3B). Except for iron and manganese, no other metals were found in all the samples collected at different places in both lakes. This indicates that there is no traces of heavy metals in groundwater around the lake and can be considered safe for domestic purpuses.

After analysis of the 20 parameters the exceedance count as indicated in Table 2 was taken into consideration and for such exceedance, the TCLP/STLC test for leachability was conducted as recorded in Table-3A. The sediment analysis results are based on the Screening Levels of soil quality parameters prescribed for Agriculture use in the guidance document issued by MoEF & CC.

Heavy metals like boron, cadmium, total chromium, copper, lead, molybdenum, nickel (at 1, location) and zinc were exceeding screening levels (agriculture use) in the sediment samples of Bellandur lake. Cadmium exceeded both response and screening levels and most of the exceedance concerning cadmium, copper, and zinc. It is suggested that zinc may not be taken as an exceeding factor, copper exceedance seems to be marginal and only a few samples are showing higher values. If the sediment samples are properly homogenized/mixed, issues of copper and zinc exceedance may be managed. Only cadmium is an issue and has to be addressed before disposing of the sediments.

The number of samples collected from Bellandur lake may not be representative of the extent of sediment/area of the lake as explained in preceding paras.

It is observed that in the preliminary sediment sampling carried out on 18.09.2020, heavy metals like boron, cadmium, total chromium, copper, lead, molybdenum, nickel, and zinc were exceeding screening levels in the sediment samples. However, due to the large extent of the lake area and inadequate sample numbers, it was apprehended that there might be chances of contaminated pockets in the lake elsewhere also. Taking that into consideration and also the analysis report of exceedance of copper and cadmium in many samples (Bellandur Lake), the re-sampling was done at locations that registered higher cadmium contamination. The samples were re- drawn within a distance of 150 m from the previous

sample points (where higher cadmium/copper contamination was found) and again analysis was done.

The second round of sampling was accordingly carried out on 12.11.2020, samples were drawn from eight locations adjacent to the previously sampled 5 locations which resulted in higher cadmium or copper content. On reviewing the analysis results, it was observed that many heavy metals which were not observed in the previous samples emerged in the analysis of the new set of samples, suggesting that there may be several localized pockets of contaminants in the inlet area and other scattered pockets.

In the third round of sampling carried out on 25.12.2020, exceedance was reported concerning 11 parameters. Cadmium (32 locations), Chromium (18), Cobalt (2), Copper (41), Lead (22), Molybdenum (22), Nickel (3), Selenium (63), Silver (45), Tin (39) and Zinc (38) exceeded the screening levels. Samples from 21 locations were within the prescribed screening values. But TCLP & STLC analysis of samples from 44 locations was carried out and samples from 38 locations that exhibited marginal exceedance concerning screening level for selenium, tin, and cobalt were not subjected to TCLP/ STLC tests which may be considered as non-hazardous. Samples from 28 locations turned out to be contaminated/ hazardous after TCLP/ STLC analysis. Samples from 16 locations were found to be non-hazardous concerning the prescribed limits as per the Schedule – II of Hazardous and Other Waste (Management and Transboundary Movement) Rules, 2016.

With the above-narrated facts, it was suggested to be safe to proceed further on the line of action here below:

The sediment/soil at the locations indicated by hypothetical grids, where there is no indication of toxicity/leachability and also qualify for the level/limit prescribed in the *Screening Levels of soil quality parameters prescribed for Agriculture use in the guidance document (Volume III – issued by MoEF & CC) / Schedule – II of Hazardous and Other Waste Management and Transboundary Movement) Rules, 2016;* may be disposed of/utilized for Agriculture use or likewise.

The grid samples exhibit potential leachability as per the TCLP/STLC tests carried out so far shall be treated as potentially hazardous and disposed of as per the Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016. The silt removed from Bellandur lake is dumped in the abandoned stone quaries atVittasandra and Mylasandra.

Table 2 . Exceedance count concerning Bellandur lake sediments (25-12-2020)

Parameters inmg/kg	*No. of samples taken**	Observed concentration in mg/kg		Response level in mg/kg		Screening level for Agricultural (mg/kg)	
		Min.	Max.	Standard	No of sample exceeded	Standard	No of sample exceeded
Antimony	103	1.288	2.497	22	0	20	0
Arsenic	103	0.449	5.835	50	0	12	0
Barium	103	7.771	626.026	-	0	750	0
Beryllium	103	BDL	BDL	-	0	4	0
Boron	103	BDL	BDL	-	0	2	0
Cadmium	103	1.094	106.241	13	29	1.4	32
Chromium	103	2.894	100.900	-	0	64	18
Cobalt	103	0.861	43.171	190	0	40	2
Copper	103	1.734	364.433	190	11	63	41
H. Chromium	103	0.000	0.000	50	0	0.4	0
Iron	103	1538.71	20940.04	-	0	-	0
Lead	103	2.479	199.858	530	0	70	22
Manganese	103	7.130	3621.280	-	0	_	0
Mercury	103	0.000	0.000	36	0	6.6	0
Molybdenum	103	0.272	26.138	190	0	5	22
Nickel	103	0.888	124.865	100	1	50	3
Selenium	103	1.026	3.020	-	0	1	63
Silver	103	1.035	359.743	-	0	20	45
Thallium	103	0.000	0.000	-	0	1	0
Tin	103	-1.183	37.407	-	0	5	39
Vanadium	103	6.111	60.132	-	0	130	0
Zinc	103	0.523	905.932	720	1	200	38

* In each location three sub-samples from three different depths collected

Table 3A. TCLP results of Belandur lake samples (25-12-2020)

Sl. No	Sample Location	Cr	Mn	Se	Ag	Cd	Ba	Pb	Exceedance
		5*	10*	1*	5*	1*	100*	5*	
1	23 Bellandur Lake-Top soil	0.86	1.72	#	0.88	#	3.11	0.78	**0**
2	23A Bellandur Lake-Middle soil	1.26	3.52	#	1.56	#	5.88	1.24	**0**
3	24 Bellandur Lake-Top soil	2.18	1.66	#	2.35	#	5.99	4.81	**0**
4	24A Bellandur Lake-Middle soil	1.90	3.90	#	1.24	#	6.21	0.81	**0**
5	24B Bellandur Lake-Bottom soil	3.21	4.00	#	2.77	#	10.28	3.21	**0**
6	25 Bellandur Lake-Top soil	0.89	3.40	#	0.77	#	4.48	0.32	**0**
7	27A Bellandur Lake-Middle soil	0.99	5.08	#	0.87	#	4.23	0.68	**0**
8	29 Bellandur Lake-Top soil	2.06	2.86	#	1.96	#	8.64	1.48	**0**
9	29A Bellandur Lake-Middle soil	1.89	3.47	#	5.88	#	9.39	2.79	**1**
10	30 Bellandur Lake-Top soil	3.12	4.02	#	4.01	#	10.12	3.81	**0**
11	31 Bellandur Lake-Top soil	2.32	1.07	#	1.89	#	5.16	2.32	**0**
12	37B Bellandur Lake-Bottom soil	6.88	4.14	#	4.88	1.22	21.96	5.43	**3**
13	38 Bellandur Lake-Top soil	4.77	3.94	#	2.17	0.56	7.93	1.56	**0**
14	52A Bellandur Lake-Middle soil	4.13	4.51	#	2.66	#	7.33	2.51	**0**
15	61 Bellandur Lake-Top soil	1.77	3.41	#	0.56	0.66	6.74	2.41	**0**
16	61A Bellandur Lake-Middle soil	1.87	4.22	#	1.88	0.57	12.67	3.95	**0**
17	64 Bellandur Lake-Top soil	1.86	4.79	#	1.44	1.09	11.63	3.77	**1**
18	64A Bellandur Lake-Middle soil	1.61	4.27	#	0.99	0.30	8.78	0.56	**0**

Sl. No	Sample Location	Cr	Mn	Se	Ag	Cd	Ba	Pb	Exceedance
		5*	10*	1*	5*	1*	100*	5*	
19	64B Bellandur Lake-Bottom soil	1.32	3.02	#	0.44	#	3.21	0.49	**0**
20	65 Bellandur Lake-Top soil	1.23	3.04	#	0.89	0.38	4.32	0.91	**0**
21	65A Bellandur Lake-Middle soil	2.86	2.28	#	2.99	#	7.02	1.16	**0**
22	65B Bellandur Lake-Bottom soil	2.99	3.28	#	3.56	1.66	8.21	2.53	**1**
23	66 Bellandur Lake-Top soil	1.05	2.80	#	0.33	#	6.27	0.45	**0**
24	69 Bellandur Lake-Top soil	1.88	3.25	#	0.56	#	5.76	0.91	**0**
25	69A Bellandur Lake-Middle soil	4.00	2.76	#	0.78	2.11	11.76	2.51	**1**
26	69B Bellandur Lake-Bottom soil	6.11	2.32	#	4.11	0.25	16.54	3.81	**1**
27	70 Bellandur Lake-Top soil	0.99	2.30	#	2.66	#	8.74	2.02	**0**
28	70A Bellandur Lake-Middle soil	2.12	2.14	#	2.33	2.33	11.17	4.02	**1**
29	70B Bellandur Lake-Bottom soil	2.32	2.27	#	2.66	#	7.62	1.88	**0**
30	71 Bellandur Lake-Top soil	1.99	1.70	#	3.11	#	4.68	1.90	**0**
31	71A Bellandur Lake-Middle soil	1.99	1.69	#	4.78	#	7.64	1.88	**0**
32	72A Bellandur Lake-Middle soil	4.89	1.59	#	3.55	0.14	6.37	2.76	**0**
33	73A Bellandur Lake-Middle soil	3.01	4.77	#	3.99	0.55	8.22	1.34	**0**
34	74 Bellandur Lake-Top soil	3.89	3.29	#	1.99	0.20	6.49	2.20	**0**
35	75 Bellandur Lake-Top soil	3.33	1.84	#	3.56	1.06	9.68	2.01	**1**
36	75A Bellandur Lake-Middle soil	2.99	9.49	#	4.11	3.66	11.41	1.98	**1**
37	76 Bellandur Lake-Top soil	3.56	1.38	#	1.77	#	4.21	1.54	**0**
38	77 Bellandur Lake-Top soil	1.76	2.98	#	0.99	0.44	6.33	2.10	**0**
39	77B Bellandur Lake-Bottom soil	5.99	1.40	#	4.11	0.99	11.67	5.89	**2**
40	78 Bellandur Lake-Top soil	3.66	3.06	#	3.44	2.89	12.76	3.76	**1**
41	78A Bellandur Lake-Middle soil	NA	NA	NA	3.99	NA	NA	NA	**0**
42	78B Bellandur Lake-Bottom soil	0.67	NA	NA	#	#	3.66	0.78	**0**
43	83 Bellandur Lake-Top soil	NA	NA	NA	5.99	2.11	8.54	2.56	**2**
44	83A Bellandur Lake-Middle soil	NA	NA	NA	1.01	0.21	3.55	NA	**0**
45	86 Bellandur Lake-Top soil	NA	NA	NA	4.67	2.67	9.77	2.43	**1**
46	86A Bellandur Lake-Middle soil	NA	5.88	NA	1.56	NA	7.11	NA	**0**
47	86B Bellandur Lake-Bottom soil	NA	NA	NA	4.11	0.99	8.99	NA	**0**
48	87 Bellandur Lake-Top soil	NA	NA	NA	4.67	2.55	10.67	NA	**1**
49	87A Bellandur Lake-Middle soil	NA	NA	NA	4.45	2.10	11.67	NA	**1**
50	88 Bellandur Lake-Top soil	NA	NA	NA	4.44	0.78	9.56	NA	**0**
51	88A Bellandur Lake-Middle soil	NA	22.57	NA	4.01	0.87	8.67	NA	**1**
52	89 Bellandur Lake-Top soil	NA	10.31	NA	1.34	NA	8.11	NA	**1**
53	89A Bellandur Lake-Middle soil	2.58	NA	NA	4.22	0.31	10.34	NA	**1**
54	90 Bellandur Lake-Top soil	NA	NA	NA	4.12	2.34	12.67	2.56	**1**
55	90A Bellandur Lake-Middle soil	NA	NA	NA	3.99	1.76	9.78	2.60	**1**
56	91 Bellandur Lake-Top soil	NA	NA	NA	4.12	0.78	10.78	NA	**0**
57	91A Bellandur Lake-Middle soil	3.01	9.45	#	6.04	2.23	12.67	3.87	**2**
58	92 Bellandur Lake-Top soil	NA	6.75	NA	6.34	2.45	18.67	2.43	**2**
59	92A Bellandur Lake-Middle soil	3.14	9.38	#	1.46	4.13	16.78	3.56	**1**
60	93 Bellandur Lake-Top soil	2.89	5.84	#	6.99	2.15	11.78	4.01	**2**
61	93A Bellandur Lake-Middle soil	3.56	NA	#	7.15	2.56	NA	NA	**2**
62	93B Bellandur Lake-Bottom soil	NA	45.89	NA	1.77	0.21	9.56	NA	**1**
63	94 Bellandur Lake-Top soil	3.01	5.88	#	6.84	2.44	12.89	4.16	**2**

Sl. No	Sample Location	Cr	Mn	Se	Ag	Cd	Ba	Pb	Exceedance
		5*	10*	1*	5*	1*	100*	5*	
64	94A Bellandur Lake-Middle soil	2.99	6.44	NA	6.89	2.10	14.78	4.45	**2**
65	95 Bellandur Lake-Top soil	3.67	5.78	NA	7.01	4.78	17.67	4.89	**2**
66	96 Bellandur Lake-Top soil	2.71	6.89	#	6.77	2.14	14.90	4.43	**2**
67	96A Bellandur Lake-Middle soil	NA	NA	NA	5.99	2.19	13.90	4.06	**2**
68	97A Bellandur Lake-Middle soil	NA	NA	NA	6.01	2.43	12.90	3.86	**2**
69	98 Bellandur Lake-Top soil	3.17	5.99	#	6.84	1.88	16.89	3.89	**2**
70	98A Bellandur Lake-Middle soil	NA	NA	NA	4.01	0.56	NA	NA	**0**
71	99 Bellandur Lake-Top soil	NA	NA	NA	6.56	1.89	10.11	3.18	**2**
72	100 Bellandur Lake-Top soil	NA	NA	NA	5.12	1.90	15.88	NA	**2**
73	101 Bellandur Lake-Top soil	NA	NA	NA	5.87	2.08	14.28	3.56	**2**
74	102 Bellandur Lake-Top soil	2.47	NA	#	5.22	0.85	15.89	3.23	**1**
75	103A Bellandur Lake-Middle soil	NA	NA	NA	5.44	2.16	NA	3.19	**2**

* mg/L

2.Varthur Lake: The lake is located in the eastern part of the city . It is the last lake in the K- C valley series and almost surrounded by builtup area, Figure-2.

Soil samples analysis and reccomondations for Varthur lake**:** Soil samples, at three different depths of two meters pits have been collected on 16.09.2020, 19.12.2020, and 05.01.2021 Figure 2. The soil samples were got analyzed from a CPCB-recognised laboratory in Chennai (India). About 20 parameters have been taken into consideration for sediment quality as per the guidelines document for the assessment and remediation of contaminated sites in India of MoEF&CC. The parameter considered for sediment quality are the same as in Belandure.The sediment analysis results are based on the screening levels of soil quality parameters prescribed for agricultural use in the guidance document (Vol-III issued by MoEF&CC). The exceedance concerning the screening level of parameters in the sediment samples of Varthur lake collected on 05.01.2021 is given in **Table 4**. From the table, it is noted that the sample collected on 05.01.2021 indicates the presence of boron, selenium, and cadmium at some points, above the screening level for agricultural use. The said parameters are indicated in the shades in the tables. The corresponding TCLP of the STLC analysis was done for agricultural use of sediment/silt and results are given in **Table 5.**

Figure 2: Soil sampling locations taken on 25.12.2020) shown on google map of Varthur Lake.

For the parameters which exceed the threshold value, TCLP and STLC tests were carried out to determine the leachability and hazardous waste matter of sediment for screening of agricultural use. As per the TCLP/STLC results of the samples, it is found complied with Se, Cr, and Cd limits prescribed in Schedule II of HOWM Rules in 2016. Based on these results, the silt of Varthur lake has been found suitable for agricultural use and the State allowed the farmers to use the silt as a farmyard manure substitute in agriculture fields.

For utilisation of non–hazardous sediment i.e., after qualifying TCLP/ STLC tests, the for agriculture use shall be carried out in consultation with the Department of Agriculture, Govt. of Karnataka for determining the number of sediments to be applied per hectare, type of land to be applied and the crops to which it should be supplemented as manure based on the soil fertility parameters. Record of such sediment disposal shall be maintained with details of farmers, survey number, crop pattern, etc. It is also suggested to carry out soil sampling of land before and after the application of sediments for record by the Agricultural Department.

Underground water samples at the depth of 6 to 10 feet deep pits have been collected from the areas where heavy metals are found in the silt. The water quality concerning some metals as indicated in the **Table-3(B).** was analyzed. Except for iron and manganese, no other metals were found in all the samples collected at different places in both lakes. This indicates that in the groundwater around the lake, there is no trace of heavy metals and water quality is normal.

Table 3B. Underground water quality analysis for heavy metals (Bellandur Lake)

Name of customer: S.Jeyapaul Scientist 'D' CPCB, RD Bengaluru.	Sampling location: Bellanduru lake, Bengaluru
Nature of sample: Freshwater	Sampling type: Grab
Date of sampling: 22.01.2021	Date of receipt: 25.01.2021.
Date of commencement and completion of	Date of report issue: 29.01.2021

analysis: 25.01.2021 -27.01.2021.	
Code no. of sample: FW/01/21/110	Req. slip no. / Date: 05.01.2021/FW/01/21/23,
No. of pages: 01	Report issue no.: FW/HM/01/23

S. No.	Metal	Detection limit	Bellandur lake Groundwater (8 feet depth) 12° 55' 55'' N 77° 40' 40'' E	Reference Method
1.	Cadmium, mg/L	0.1	BDL	APHA 3120-B 23rd Edition 2017.
2.	Copper, mg/L	0.1	BDL	
3.	Total chromium, mg/L	0.1	BDL	
4.	Iron, mg/L	0.1	0.155	
5.	Manganese, mg/L	0.1	4.673	
6.	Nickel, mg/L	0.1	BDL	
7.	Lead, mg/L	0.1	BDL	
8.	Zinc mg/L	0.1	BDL	
9.	Arsenic mg/L	0.1	BDL	
10.	Cobalt mg/L	0.1	BDL	
11.	Molybdenum mg/L	0.1	BDL	
12.	Silver mg/L	0.1	BDL	
13.	Selenium	0.1	BDL	

Table 4 Exceedance: Varthur lake sediment samples collected on 05.01.2021

Varathur Lake sediment samples (Total metal conc. Jan 2021)												
Sample	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Se	Cd	Ba
Top	46.20	21.21	135.03	11936.37	12.83	17.24	21.29	19.77	1.91	1.68	BLQ	117.63
Middle	27.30	13.69	162.37	7954.26	8.35	8.19	9.90	13.73	1.21	BLQ	BLQ	83.68
Bottom	52.87	21.14	198.92	14785.51	9.25	17.66	19.75	20.63	2.26	BLQ	BLQ	92.12
Top	23.40	13.73	137.00	6200.04	10.09	13.61	11.30	14.18	1.23	1.34	BLQ	137.83
Middle	30.39	13.94	1391.21	7419.38	25.18	19.57	12.37	14.58	2.91	2.13	BLQ	365.92
Bottom	43.99	13.12	247.11	9584.89	6.81	19.56	18.33	28.09	2.98	1.29	BLQ	101.04
Top	26.55	11.07	180.18	6192.30	7.12	9.10	11.97	13.02	1.16	1.72	BLQ	94.80
Middle	63.00	33.12	1103.17	16480.95	29.91	30.24	21.25	17.02	3.36	2.53	BLQ	299.36
Bottom	17.47	10.01	142.12	4624.26	6.11	10.57	9.43	11.90	1.03	1.14	BLQ	155.79
Top	26.13	13.96	154.48	7591.24	7.53	11.86	12.79	12.48	1.41	1.64	BLQ	147.72
Middle	32.48	17.84	195.90	9367.07	9.83	15.36	15.65	19.76	1.67	1.58	BLQ	224.17
Bottom	27.42	15.14	170.86	7769.21	7.66	13.50	13.49	17.99	1.39	1.85	BLQ	133.93
Top	29.74	68.26	68.68	8104.90	5.09	8.01	9.69	11.23	1.64	BLQ	BLQ	25.75
Middle	41.06	29.00	96.05	12588.21	8.10	12.00	17.24	33.47	2.31	1.18	BLQ	69.59
Bottom	51.28	28.73	153.33	15904.73	10.87	16.06	21.35	19.25	3.20	2.19	BLQ	59.42

Top	39.98	26.61	1838.99	21667.59	11.19	15.34	18.45	22.26	2.65	1.60	BLQ	117.51
Middle	29.11	18.75	189.18	8004.27	9.97	14.16	11.76	11.38	1.69	BLQ	BLQ	154.88
Bottom	34.35	13.58	888.95	8982.13	18.84	15.68	13.45	10.53	3.36	1.83	BLQ	238.14
Top	28.10	17.91	93.60	11399.09	4.75	13.16	48.00	147.81	1.18	1.73	7.04	98.88
Middle	21.88	17.95	149.24	7844.39	5.13	9.41	14.17	29.22	1.44	BLQ	BLQ	139.62
Bottom	19.11	12.45	96.73	6971.40	6.01	8.94	8.81	11.82	1.82	BLQ	BLQ	58.55
Top	16.73	16.30	383.51	5960.39	7.12	15.20	11.16	20.55	1.07	BLQ	BLQ	171.66
Middle	21.18	19.66	46.59	6028.56	4.84	7.60	8.90	8.16	1.12	BLQ	BLQ	23.04
Bottom	26.52	15.32	209.42	6845.60	9.83	15.48	12.25	9.58	1.87	1.57	BLQ	140.54
Limit (mg/Kg)	64.0	50.0	-	-	40.00	50.00	63.00	200.00	12.00	1.00	1.40	750.00

Note: Limit – Screening level of soil quality parameters prescribed for Agricultural use

Table 5. TCLP/ STLC test results of Sediment Samples (05-01-2021) of Varthur lake

TCLP/ STLC (mg/L)			
Sample	***Selenium***	***Cadmium***	***Chromium***
Top	BLQ	NA	NA
Middle	NA	NA	NA
Bottom	NA	NA	NA
Top	BLQ	NA	NA
Middle	BLQ	NA	NA
Bottom	BLQ	NA	NA
Top	BLQ	NA	NA
Middle	BLQ	NA	NA
Bottom	BLQ	NA	NA
Top	BLQ	NA	NA
Middle	BLQ	NA	NA
Bottom	BLQ	NA	NA
Top	NA	NA	4.98
Middle	BLQ	NA	NA
Bottom	BLQ	NA	NA
Top	BLQ	NA	NA
Middle	NA	NA	NA
Bottom	BLQ	NA	NA
Top	BLQ	0.54	NA
Middle	NA	NA	NA
Bottom	NA	NA	NA
Top	NA	NA	NA
Middle	NA	NA	NA
Bottom	BLQ	NA	NA
Class/List	**A8 / 1.0 mg/L**	**A3 / 1.0 mg/L**	**A4 / 5.0 mg/L**
NA: Not analyzed			

4. Conclusion:

Bengaluru was known as the city of lakes till recent past. The natural drainage system has been completely obliterated in the name of development. There were 612 lakes (live as well as disused) in the present area of Bengaluru city. Most of them are polluted because of continuous large inflow of sewage. Bellandur and Varthur lakes are no exception. Public and judiciary intervention has put pressure on the State to attempt rejuvenation of many lakes. Due to intervention of National Green Tribunal, rejuvenation works has been initiated in these two lakes. A Committee had been appointed by NGT to supervise the works. Treatment of sewage generated in the catchment of these lakes has been attempted and the combined capacity of all STPs are around 664.50 million litter per day against the presently measured flow of 553.0 MLD. Various works have been proposed and are being executed. Desilting is a major task in the process. The silt removed from Varthuru lake is used by farmers in their fields as manure. But having contaminated, the silt of Belandure lake is dumped in abandoned stone quarries.

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