Eco. Env. & Cons. 27 (May Suppl. Issue) : 2021; pp. (S398-S406)

ISSN 0971–765X

Germane code of practice destined for site-specific regulatory and restoration advisory strengthening integrity and survival of the lake ecosystem

***Shekhar Salunke[1] and Balbhim Chavan[2]**

[1]Department of Environmental Science, Punyashlok Ahilyadevi Solapur University, Solapur, MS, India
[2]Department of Environmental Science, Dr. B.A.M. University, Aurangabad, MS, India

(Received 10 September, 2020; Accepted 24 November, 2020)

ABSTRACT

A diagnostic study was conducted at the lake under investigation. After identifying the problem of deterioration of the ecological health evident by the impaired quality of water, a site-specific prototype for the coherent treatability likelihood and restoration, was designed and assessed for its effectiveness towards polluted lake water treatment. The aim was to meet the IS 10500 water quality standards after a combined treatment and preordain a methodology for primary and secondary and if needed tertiary treatment for potable purpose. For the diagnostic study a detailed representative data collection was carried out with the help of 20 L representative sample, for characterization and treatability study of the polluted lake water under investigation. The treatability study was carried out for a specified short period. The samples of water were subjected for different treatability studies. The higher values were considered for feasibility report infrequent streams of water with a higher load value. The treatability study was merely to identify and approve a germane code of practice for the treatment methodology. The composite sample was prepared and analyzed following methods depicted in the Standard methods of water analysis, APHA nineteenth Edition. The studies conclude with a recommendation of primary treatment consisting of settling tank required for storage of 1-hour retention, Alum/PAC dosing recommended for fast removal of settable solids, aerobic treatment by biofilter/cascading recommended for COD and BOD removal, the rapid or slow sand filterat this stage is recommended for the removal of residual suspended matter and turbidity. Nevertheless, color and odor removal can be achieved by the use of carbon filter treatment and disinfection by chlorination with 0.2 mg/L dose required for the lake water treatment.

Key words : *Lake Ecosystem, Feasible treatability studies, Restoration action.*

Introduction

Generally, along with water, dissolved materials, particulates as soil, enter the lake from its watershed areas. Lakes are constantly receiving such materials from watersheds, atmospheric dust, and energy from the sun and wind along with anthropogenic activities. Therefore, water quality and productivity are as much influenced by what goes into the lake as by what is already there. Important factors include watershed topography, local geology, soil fertility, attrition, vegetation in the watershed and other surface water sources such as runoff and tributary streams. The amount of water entering the lake from its watershed controls volume and several other factors that influence the lake's overall health.

Unlike rivers, lakes essentially slow the flow of water thus; any water entering the lake will remain in it for a period called the hydraulic residence time. The quality of water of a lake portrays the history and the inflow quality of the lake water. Evidently the management programmes for the improvement of the quality of the lake waters must be initiated on priority. The longer the hydraulic residence time, the greater the lag since water affects and is affected by the biota, sediments, and' existing' water chemistry, additional delays between changes in the quality of incoming water and that if in-lake, water too occurs. Siltation at lakes is a common observation across the globe that sustains pervasiveness of vegetation with a tendency showing adaptation at the drenched soil areas. The undesired organism usually the microbes, algal blooms, flies and mosquitoes cause foul odours of the lake waters. The destruction of our lakes again is commonly due to anthropogenic activities, grazing, drainage, or due to dumping of paraphernalia. The lakes support an immense biodiversity specific to the region. The lakes act as a resting station for the migratory birds. Further, the wetlands or lakes are facing a tremendous devastation threat with a greater disturbed ecological health due to the site-specific reasons as chemistry of the waters, topographical differences, hydrological patterns vegetation cover, altercation of the soil, erosion and sedimentation. For the reason, the lakes fail to support shelter and food supplies for the aquatic flora and fauna (reptiles, pieces, mollusks, birds, fishes, aquatic flora both epi-hydrophytes and hypo-hydrophytes vegetation) and as such the biota falls victim for not having the survival, feeding sites and spawning habitat. The vegetation cover of the lakes and the soils aid as flood and erosion control factors for they assist as natural filters of suspended matter. The vegetation cover acts as an absorber of water during the rainy season and as in turn during the dry seasons release through outlets as springs or seeps into the lake waters.

Presence of *E.coli* makes the water unfit for consumption. *E. coli* inhabits the intestines of animals and humans. When cultured aerobically, *E. coli* is the dominant species found in feces. In 1995, more than 60 E. coli serotypes had been identified that produced Shiga-like toxins; the serotype O157:H7 was the most predominant and most frequently associated with human infections worldwide [856]. *E. coli* O157:H7 has a low infectious dose; studies have estimated exposure between 20 and 700 organisms can cause illness. The majority of outbreaks have been linked with the consumption of contaminated food. However, water-related exposures have been reported from recreational uses of surface waters. Drinking water sources may become contaminated with E coli when human or animal feces containing the bacteria are introduced into drinking water supplies via sewage overflows or agricultural runoff (EPA, *E. coli* O157)**.** Higher concentrations of nitrates and phosphates primarily contribute to the eutrophication of urban water bodies. Higher values of NO_3N were observed during the post-monsoon season (Srivastava *et al*., 2007; Bharali *et al*., 2008; Dhanalakshmi *et al.,* 2008; Edokpayi and Aneke, 2008). When a lake is polluted, it is a great loss for the biosphere as each lake serves as a harbor for the migratory birds, besides supporting the native biodiversity. When the ecological health is found to be under stress or unhealthy, it is of profound importance for us to understand the specific problems and design the combating strategy against the same. Doing so, the attempts help us prioritizing the restoration actions and devise robust alternatives addressing the issue. At Solapur district of Maharashtra State, India, in the recent years, it is witnessed that the lake Sambhaji is experiencing a considerable scale of aggravation and seems to be vulnerable. As such, it was cogitated to comprehend the predicament, investigate the eminence of the lake water and formulate alternatives towards meeting the water quality standards as per IS 10500. In accordance to the same, a prototype was designed and evaluated as a treatability alternative. Several plant designs for biochemical oxygen demand (BOD) removal include facultative pond, complete- mix pond systems, and anaerobic-based lagoons to stabilize large quantum of organic solids in waste-waters (Abis and Mara, 2003; Mara *et al.,* 1992; Mara, 2004). The treatment and disposal of domestic sewage has become a serious issue in many parts of the globe including India. Among the various technologies used, waste stabilization ponds or lagoons are adopted due to its low operation and maintenance (OM) costs and adequate land availability. These treatment systems work with an initial anaerobic stabilization followed by the facultative and aerobic oxidation ponds (Mahapatra *et al.,* 2011a, b,c) or high-rate oxidation ponds (Park *et al.,* 2011). In India >40 billion L day – 1 of wastewaters are generated mostly from the urban areas

(CPCB 2011), and these untreated or partially treated wastewaters find their way into receiving water bodies enriching the aquatic systems with nutrients (Mahapatra *et al.,* 2011a,b,c). A site-specific germane code of practice is needful to restore the normal ecological health of the lakes. Among the possible alternatives, investigation in the context of cost effective and site-specific applicable method of treatability of polluted water of lake Sambhaji was undertaken.

About the Study Area

The selected site or study area was Lake Sambhaji at 3.6 km at the city Solapur City of Maharashtra State. It is a natural lake located geographically, between Latitude: N 17° 38' 55.61 The aerial & Longitude: E 75° 54' 13.9. In the year 2015 the lake had clean waters (Fig.1) as against the current eutrophication status of the lake (Fig.1,3,4). Whereas, the current reconnaissance portrays that the lake suffers a great ecological disturbance and seems to be vulnerable. The lake can be divided into three segments. The site 1 considered the central larger area, the northwest region of the lake dissected due to the railway route (broad gauge), and the southeast region again dissected due to the erstwhile narrow-gauge rail route (currently abandoned). At lake Sambhaji the northwest section is being used for the laundry works and along with the same the lake experiences a drainage of domestic wastes from the adjoining areas. As such the northwest region, in major, adds tremendous wastes into the lake waters. The lake waters of the northwest region of the lake, has waste waters so to say, as such it eventually adds to the central main lake waters. Thus, the total ecological health is disturbed and a mosaic of aquatic weed vegetation is found to flourish throughout the year round. For the reason that, there is an immediate need of water treatment for the restoration of the ecological health of the lake to aid for its survival.

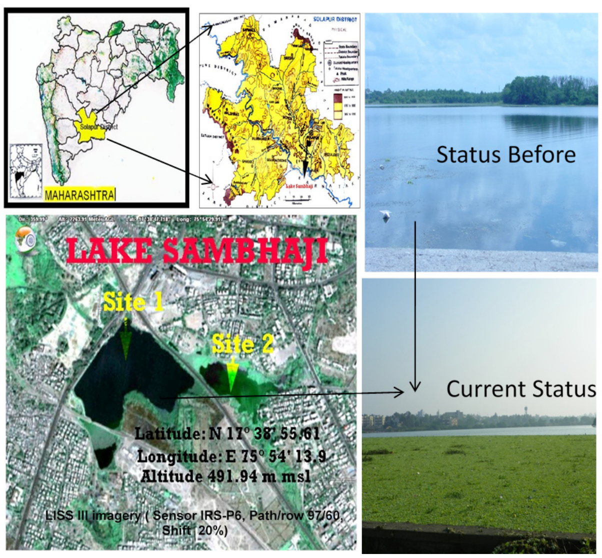

Fig. 1. Geographical location and status of lake Sambhaji

Materials and Methods

For the preparation of this report a detailed representative data collection was carried out for characterization and treatability study of the polluted lake water. This treatability study was carried out for the short time period. The polluted water from the lake is collected in large quantity and used for carrying out different treatability studies. The higher values are considered for feasibility report so as to accommodate the occasional water streams having higher load. These treatability studies are merely to establish the treatment methodology. Par-

Fig. 2. Aerial photograph of Lake Sambhaji (*Erstwhile status with clean waters*)

Fig. 3. Eutrophication evidenced at Lake Sambhaji *(Contemporary status)*

Fig. 4. Mosaic of aquatic vegetation at Lake Sambhaji (*Contemporary status*)

ticular precautions require to be taken during feasibility report preparation to obtain overall efficiency.

The aim of the treatability study is to achieve the treated water quality after a combined treatment and establish methodology for primary and secondary and if needed tertiary treatment for potable purpose. The target aimed at is to achieve treated

Table 1. Water quality standards (IS 10500)

S.No	Parameter	Unit	Values
1.	pH	-	6.5-8.5
2.	Total Dissolved Solids	µmhos/cm	<2000
3.	Alkalinity	mg/l	<500
4.	Total Hardness	mg/l	<600
5.	Calcium	mg/l	<200
6.	Magnesium	mg/l	<100
7.	Chlorides	mg/l	<1000
8.	Sulphates	mg/l	<400
9.	Turbidity	NTU	<1.0
10.	Colour	-	Colourless
11.	Odour	-	Odourless
12.	Most Probable Number	/100ml	Nil
13.	*Escherichia coli*	/100ml	Nil

waterquality as per IS 10500 as follows-

Sample Collection

20 Liters representative sample was procured and subjected for laboratory analysis immediately.

Composite sample collection: The composite sample prepared was analyzed by the methods described in Standard Methods of Water and Waste Water analysis APHA 19th Edition. The studies involved treatment criteria as Primary treatment including; settling, neutralization, turbidity removal, analysis after physical settling. Then it was followed by secondary treatment subjecting the sample to Anaerobic treatment, Facultative treatment and Aerobic treatment. Further tertiary treatment for colour and odour removal, disinfection treatment was followed. The results are discussed further.

Results and Discussion

The analyzed sample showed the average characteristics as depicted in the Table 2. The pH recorded was 6.89 however the standard as per MPCB, is between, 5.5 to 9.0, where acceptable limits are 6.5 to 8.5. As the majority reactions as biochemical and chemical get influenced by pH the parameter has importance. The unfavorable effects in the lake waters can be observed with the pH below 5 and above 9.5. The lake water is tending to be acidic. The alkalinity factor measured was 200 mg/L whereas the acceptable limits fall below 500 mg/L. Alkalinity parameter is helpful in determining the water quality. The sample recorded the dissolved oxygen value as 1.9 mg/L where for the fisheries and propagation of wildlife the the primary water quality criteria is 4 mg/L and for potable purpose the limits acceptable are 6.5 to 8.5 for the drinking water source without conventional treatment but with chlorination. (MPCB guidelines, 2007-08).

The dissolved oxygen plays an important role in determining dissolved oxygen in the lake waters. It further seems to be important to determine the quality of lake water. When at a lake experiences a high rate of respiration coupled with the decomposition of organic consequently the dissolved oxygen values are lower as compared with the areas with higher photosynthetic rates. It is also evident that when the lake waters experience a high pollution loading resultantly the dissolved oxygen values fall down proportionately. Evidently the lowered dissolved oxygen values are because of high growth

Table 2. Average characteristics of the composite sample analyzed

S.No	Parameter	Unit	Values
1.	Colour (Visual)	-	Yellowish
2.	Odour	-	Algal
3.	Temperature	^{0}C	Ambient
4.	pH	-	6.89
5.	Total Solids	mg/l	1620
6.	Total Dissolved Solids	mg/l	1440
7.	Suspended Solids	mg/l	180
8.	Chemical Oxygen demand	mg/l	52
9.	Biochemical Oxygen Demand 5 @ 20^{0}C	mg/l	28
10.	Chlorides	mg/l	380
11.	Oil and Grease	mg/l	Nil
12.	Sulphates	mg/l	316
13.	Hardness	mg/l	370
14.	Calcium	mg/l	84
15.	Magnesium	mg/l	39
16.	Most Probable Number of Coliform	/100ml	200

Table 3. Treatment Criteria and trials

Settling;	The settling time of settable matter was observed for 30 minutes. It is observed that satisfactory settling was completed in 15 minutes.
Neutralization:	The pH of the sample is 6.89. The required pH is between 6.5 and 8.5. It is not necessary to neutralize the said sample.
Turbidity Removal:	The turbidity of sample after settling is found to be 5 NTU which must be <1 NTU. Alum & Polyelectrolyte doses were determined to turbidity removal also to reduce the time consumption for settling.

and activities of microorganism. The lake water shows a value 28 for biological oxygen demand (BOD) (3 days at 25^{0}C). The COD value is 52 as against BOD 1.9. as the COD limits exceeded beyond the defined value of 20 mg/L. Primarily this indicates the disturbed ecological health of the lake. It has been used as a measure of the amount of organic matter supporting the growth of microorganism. The Chemical Oxygen demand (COD) was measured and was as 52 mg/L it is indicated that the BOD > COD whereas it is expected that COD > BOD. It indicates the disturbed ecological health of the lake making it unfit. The component chloride is the inorganic anion present in major in the waters and waste waters. Chlorides are present due to the mineral dissolution. Chlorides at lake waters are usually added from the sewage, salts from roads runoff, drainage, and due in major due to siltation. The chloride was measured as 380 mg/L. Electrical conductance is reciprocal to electrical resistance and G values shows total ion per cm. It is numerical expression of the ability of water sample to carry an electric current. The value recorded was 2380 µmhos/s. Nitrate is the end product of oxidation of nitrogenous matter where its concentration usually depends on the microbial process as nitrification and de-nitrification. The MPN and E. coli recorded were 200/100 mL and 80/100 mL respectively which are significantly higher indicating microbial activity and the water being unhealthy. From the detailed analysis, it is observed that the required treatment should be focused on the parameters namely, Color, Odor, Suspended Solids, COD, BOD, MPN.

Treatment Criteria and Trials

Primary Treatment

The optimized clones are-

Table 4. Optimized clones

Coagulant	Dose (in ppm)
Alum	6
PAC	0.3

The sample contains no presence of oil and grease. The turbidity also can be removed by the use of rapid filter or slow sand filter, the sample after physical settling showed following characteristics; -

Secondary Treatment

COD/BOD removal

The different biological treatment techniques were used on trial basis for this purpose.

A. Anaerobic Treatment

The water contains BOD in the tune of 8-9 mg/l. The anaerobic treatment is used if BOD is more than 2000 mg/L. It also liberates obnoxious odour, H_2S and mercaptans. Therefore, it is not feasible for the treatment of given lake water. Hence, is not recommended.

B. Facultative Treatment

The water contains BOD in the tune of 8-9 mg/L. The facultative treatment is used if BOD is more than 1000 mg/L. It also liberates obnoxious odor, H2S and mercaptans and also reduces the oxygen level. Therefore, it is not feasible for the treatment of given lake water. Hence, is not recommended.

C. Aerobic Treatment

Aerobic treatment is used for treatment of water containing BOD. Simple aeration isfound to be suf-

Table 5. Characteristics of the sample post physical treatment

S.No	Parameter	Unit	Value
1.	Colour (Visual)	-	Yellowish
2.	Odour	-	Algal
3.	Temperature	^{0}C	Ambient
4.	pH	-	6.85
5.	Total Solids	mg/l	1440
6.	Total Dissloved Solids	mg/l	1440
7.	Suspended Solids	mg/l	Nil
8.	Chemical Oxygen demand	mg/l	30
9.	Biochemical Oxygen Demand 5 @ 20^{0}C	mg/l	8
10.	Chlorides	mg/l	385
11.	Oil and Grease	mg/l	Nil
12.	Sulphates	mg/l	312
13.	Hardness	mg/l	375
14.	Calcium	mg/l	84
15.	Magnesium	mg/l	40
16.	Most Probable Number of Coliform	/100ml	120

Table 6. Water characteristics after secondary treatment

S.No	Parameter	Unit	Value
1.	Colour (Visual)	-	Pale yellow
2.	Odour	-	Algal
3.	Temperature	^{0}C	Ambient
4.	pH	-	7.10
5.	Total Solids	mg/l	1440
6.	Total Dissloved Solids	mg/l	1440
7.	Suspended Solids	mg/l	Nil
8.	Chemical Oxygen demand	mg/l	2
9.	Biochemical Oxygen Demand 5 @ 20^{0}C	mg/l	Nil
10.	Chlorides	mg/l	383
11.	Oil and Grease	mg/l	Nil
12.	Sulphates	mg/l	313
13.	Hardness	mg/l	375
14.	Calcium	mg/l	82
15.	Magnesium	mg/l	41
16.	Most Probable Number of Coliform	/100ml	45

ficient inwhich DOlevel is more than 4 mg/L. This reduces BOD to 0 mg/l. This method is feasible and recommended. The aeration by cascading will be sufficient for the BOD removal and therefore is recommended. Plastic media biofilter and stone media biofilter were also tried and found to be suitable with retention period of 8 hours.

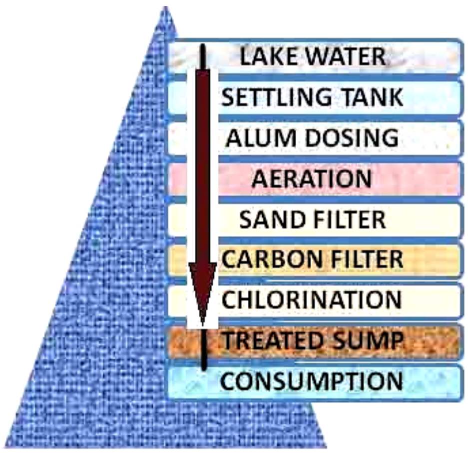

Fig. 5. Reminiscent Flow Chart for site-specific lake water treatment

The water characteristics after secondary treatment are depicted in Table 6.

Tertiary Treatment

Colour and Odour Removal

The water after primary treatment has pale yellow colour. This is mainly found to be due to algal growth. For removal of colour, activated carbon filter is tried and found to be effective. The characteristics of water after carbon treatment are;

Disinfection treatment

For removal of coliform bacteria from the water after secondary aerobic treatment chlorine dosing is carried out. The chlorine demand of the water is found to be 0.1 mg/l. The chlorine dose required is 0.2 mg/L to kill the coliform organisms including fecal *Escherichia coli*. This can be carried out by using bleaching powder (1 gm/l), Sodium Hypochloride (0.5 ml/1 li.t) is suggested and recommended. The characteristics of water after chlorination are as follows;

The sample of the water was analyzed and the results indicate that the lake water is chemically and bacteriologically not potable.

The results indicate that the lake water is chemically and bacteriologically not potable. The studies conclude with the site-specific suggestions for the primary treatment consisting of settling tank being required for storage of 1-hour retention. Alum- Aluminum sulfate is a nontoxic material commonly used in water treatment plants to clarify drinking water. In lakes alum is used to reduce the amount of the nutrient phosphorus in the water. Reducing phosphorus concentrations in lake water can have a similar clarifying effect by limiting the availability of this nutrient for algae production. Phosphorus enters the water either externally, from run-off or ground water, or internally from the nutrient rich sediments on the bottom of the lake. Increased nutrient loading, particularly phosphorus accelerates

Table 6. Characteristics of water after carbon treatment

S.No	Parameter	Unit	Value
1.	Colour (Visual)	-	Colourless
2.	Odour	-	Odourless
3.	Temperature	^0C	Ambient
4.	pH	-	7.10
5.	Total Solids	mg/l	1440
6.	Total Dissloved Solids	mg/l	1440
7.	Suspended Solids	mg/l	Nil
8.	Chemical Oxygen demand	mg/l	Nil
9.	Biochemical Oxygen Demand 5 @ 20^0C	mg/l	Nil
10.	Chlorides	mg/l	380
11.	Oil and Grease	mg/l	Nil
12.	Sulphates	mg/l	316
13.	Hardness	mg/l	370
14.	Calcium	mg/l	86
15.	Magnesium	mg/l	40
16.	Most Probable Number of Coliform	/100ml	45

eutrophication of lakes and consequently reduce their ecological health and recreational value. Frequent and pervasive algal blooms, low water transparency, noxious odors, depletion of dissolved oxygen, and fish kills frequently accompany cultural eutrophication. External sources of phosphorus de-

Table 7. Evaluation after disinfection treatment

S.No	Parameter	Unit	Value
17.	Colour (Visual)	-	Colourless
18.	Odour	-	Odourless
19.	Temperature	^0C	Ambient
20.	pH	-	7.10
21.	Total Solids	mg/l	1440
22.	Total Dissloved Solids	mg/l	1440
23.	Suspended Solids	mg/l	Nil
24.	Chemical Oxygen demand	mg/l	2
25.	Biochemical Oxygen Demand 5 @ 20^0C	mg/l	Nil
26.	Chlorides	mg/l	380
27.	Oil and Grease	mg/l	Nil
28.	Sulphates	mg/l	316
29.	Hardness	mg/l	370
30.	Calcium	mg/l	86
31.	Magnesium	mg/l	38
32.	Most Probable Number of Coliform	/100ml	Nil

Table 8. The MPCB standards for water quality

S.No	Parameter	Unit	SampleValues	Standard as per MPCB
1.	pH	-	6.89	5.5 – 9.0
2.	COD	mg/l	52	<250
3.	BOD 3 at 25^0C	mg/l	28	<100
4.	Total Dissolved Solids	mg/l	1440	<2100
5.	Suspended Solids	mg/l	180	<100
6.	Chlorides	mg/l	380	<600
7.	Sulphates	mg/l	318	<1000
8.	Oil and Grease	mg/l	Nil	<10

Table 9. The acceptable limits for water quality

S.No	Parameter	Unit	SampleValue	AcceptableLimits
1.	pH	-	6.89	6.5 – 8.5
2.	E. Conductivity	µmhos/cm	2380	<3100
3.	Alkalinity	mg/l	200	<500
4.	Total Hardness	mg/l	370	<600
5.	Permanent Hardness	mg/l	310	
6.	Temporary Hardness	mg/l	60	
7.	Calcium	mg/l	84	<200
8.	Magnesium	mg/l	39	<75
9.	Carbonates	mg/l	Nil	Nil
10.	Bicarbonates	mg/l	244	<610
11.	Chlorides	mg/l	380	<1000
12.	Turbidity	NTU	490	<1.0
13.	Colour	-	Yellowish	Colourless
14.	Odour	-	Algal	Odourless
15.	Most Probable Number	/100ml	200	Nil
16.	*Escherichia coli*	/100ml	80	Nil

livered in run-off from the watershed are often the main contributor of excessive phosphorus to lakes, (Wisconsin Dept. of Natural resources, March 2003). The alum/PAC (Powdered activated Carbon) dosing is recommended for fast removal of settable solids. Aerobic treatment by biofilter/cascading is recommended for COD and BOD removal. The rapid or slow sand filter at this stage is recommended for removal of residual suspended matter and turbidity. Color and odor removal can be achieved by use of carbon filter treatment. Disinfection by chlorination with 0.2 mg/L dose is required. The suggestive Flow-Chart for site-specific lake water treatment is depicted in figure 5. The lake water analysis indicates a greater intensity of polluted nature and hence it attracts immediate attention towards formulation of an advisory to reinforce the integrity of the lake ecosystem for its survival, addressing restoration strategy through a specific germane code of practice.

Acknowledgement

We express our gratitude to Director School of Earth Sciences and the staff of Department of Environmental Science, Solapur University, Solapur, M.S. India, and the for providing requisite resources and laboratory work station and conveniences for the successful completion of the assignment. With sincere expectations that the studies shall bea continued effort our project to extend advanced scientific and technological studies to enrich improve and focus on priority sites, for detailed inventories in the proposed subsequent phase. We also extend our sincere thanks to Nikhil analytical laboratory, district Sangli, Maharashtra State, India for the crucial insight towards the assays and statistical analysis.

Funding and conflict of interests

We further undertake that the article is original outcome through the Ph.D. research.The funding for the research is self-funded and we declare that we have not received any financial grants from any individual or agency neither Government nor private. There rests no conflict of interest.

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