Evaluation of the Subsurface Soil at Bhandup Pumping Station, Mumbai

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Abstract: ***Bhandup Pumping Station (BPS), Mumbai Suburban, is an ideal habitat for the birds and other organisms. To understand the soil ecology, subsurface soil samples were collected from 10 different sampling stations (S1-S10) and physicochemical parameters; pH, organic carbon (OC), organic matter (OM), Nitrate-nitrogen (N), Phosphate-phosphorus (P), calcium carbonate (Ca) and heavy metals Zn, Cd, Cr, Cu, and Pb were determined. The soil pH ranged from 6.5 (acidic) to 7.9 (basic). Maximum levels of OC and OM were 3.6 g% and 6.2 g%, respectively. Nutrient concentrations peaked at 8.50 µg/g for N, 7.81µg/g for P, and 4.9 g% for Ca. Highest heavy metal levels were 7.00 ppm (Zn), 3.07 ppm (Cd), 7.576 ppm (Cr), 8.93 ppm (Cu), and 16.12 ppm (Pb). This study evaluates soil conditions to reduce anthropogenic impact and preserve the BPS ecosystem.***

Keywords: Soil, Bhandup Pumping Station, Physicochemical, Heavy metal

1. Introduction

Bhandup Pumping Station (BPS) is a sewage treatment plant where the sewage and wastewater from Mumbai suburbs are received, treated, and recycled. It is located along the Eastern Express Highway, near the Thane creek. This place is an amalgamation of three biomes -the mangrove biome, the grassland biome, and the marshy land biome. Along with the Bhandup mangroves and the pumping station, there are salt pans that attract several migratory birds to the area. It has become a bird watcher's paradise, and flamingos are seen from October to March. Several studies on the bird diversity have been done and about 69 avifaunal species have been reported[1,2,3]. Sighting of grey-headed lapwing (*Vanellus cinereus*) has also been reported from the mudflats of Thane creek near Bhandup pumping station[4]. Biodiversity studies have also been conducted in the area[5].

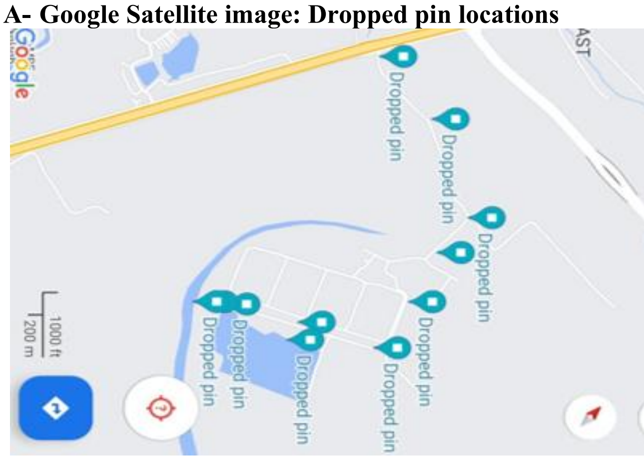
In recent times, many anthropogenic activities such as habitat destruction, wastewater pollution, tourism, and overexploitation have been noted. These may adversely deteriorate the soil ecology and reduce the soil fertility, hampering the biodiversity in this ecosystem drastically. Water pollution research has been carried out here[6]. The heavy metal pollution is of great threat to the flora and fauna as it undergoes bioaccumulation in the food chains. Accumulation of mercury in fish from Thane creek and Ulhas River estuary, Mumbai has also been reported[7]. Heavy metal concentrations in water, sediments, and body tissues of redworm collected from natural habitats in Mumbai indicate bioaccumulation[8]. The occurrence of Keratinophilic fungi in the soils of BPS has also been recorded[9].

However, the literature survey reveals that no study has been undertaken to evaluate the soil conditions at BPS. This study, conducted in the year 2024, is an attempt to understand the influence of the sewage treatment plant and other anthropogenic activities on soil health at BPS.

2. Materials and Methods

1) **Sampling area/stations:** Ten sampling stations S1-S10 were selected along the BPS area (Figure 1).

A- Google Satellite image: Dropped pin locations



B- Google Earth image: Sampling stations marked in yellow

(Image Courtesy Google Maps)

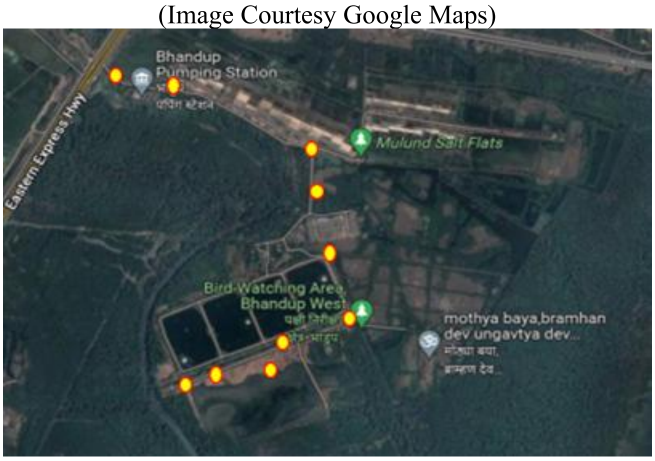


Figure 1: Sampling stations at the Bhandup Pumping Station.

2) Sampling methods and analysis:

Soil samples from sub-surfaces were collected by the scoop and trowel method. Later in the lab, soil samples were oven-dried and used for analyses. Soil solutions were prepared by mixing 2g of soil in 20 ml of distilled water to achieve a 1:10 ratio (Figure 2). The mixture was stirred, allowed to settle, and filtered using Whatman filter paper. The supernatant was used for analysis of physicochemical parameters. For the heavy metal analysis, the soil samples were subjected to acid digestion for the extraction of heavy metals[10] (Figure 3).

Figure 2: Soil Solutions for Analysis

Figure 3: Acid extracts of soil for heavy metal Analysis

a) Physicochemical Analysis:

pH was determined using an Elico Benchtop pH meter. Organic Carbon was estimated by the Walkley and Black method (1934)[11]. Organic matter was determined by Alison's modification (1935)[12]. Nitrate-Nitrogen was estimated by the AOAC Diazotization method (1995)[13]. Phosphate-Phosphorus was detected by the Ammon and Hinsberg method (1936)[14]. $CaCO_3$ was determined by the Jeffery and Hutchison Method (1981)[15].

b) Heavy Metal Analysis:

The heavy metals Zn, Cd, Cr, Cu, and Pb in the soil samples were analysed by different methods. Zinc (Zn) was detected using the method described by Shaw & Dean (1952) [16]; At a suitable pH of 4.8, Zinc reacts with dithizone to produce coloured compounds, which are measured on a colorimeter. Cadmium was estimated by the Cd-EDTA complexometric titration method described by Rao and Shetty [17]. This method involves initially complexing cadmium and other metal ions in the sample solution with an excess of EDTA. The surplus EDTA is then titrated with lead nitrate solution at pH 5.0–6.0 using xylenol orange as an indicator. Subsequently, 2-mercaptoethanol is added to selectively mask cadmium(II), releasing EDTA from the Cd-EDTA complex. The released EDTA is again titrated with standard lead nitrate solution.

Chromium (Cr) was detected using methods described by Kalembkiewicz and Sočo. (2009)[18]. The soil samples are leached with sodium pyrophosphate ($Na_4P_2O_7$), followed by the extraction of Cr (VI) using sodium diethyldithiocarbamate in n-amyl alcohol. The Cr (VI) is then quantified via a Jasco V-730 spectrophotometer using diphenylcarbazide. Copper (Cu) was estimated using methods by Russella Henderson (1929)[19]; In an alkaline medium, copper displaces sodium in the sodium diethyldithiocarbamate to produce a colloidal yellow brown copper diethyldithiocarbamate, which is measured colorimetrically. Lead (Pb) was analyzed by methods described by Manley (1940)[20]; In an alkaline medium, lead reacts with sulphide to form a brown precipitate of lead sulphide. Fine suspension of lead sulphide can be measured colorimetrically.

3) Statistical Analysis

Each soil sample was analysed in triplicate. Mean values and standard deviation values were obtained for physicochemical parameters and recorded in Table 1. The mean concentrations of heavy metals are presented in Figure 10, and one-way ANOVA was applied to statistically assess the differences in heavy metal levels.

3. Results

Table 1: Physicochemical parameters measured from BPS soil, Mean values with SD levels < to 0.1

Sampling stations	pH	Organic Carbon g%	Organic Matter g%	NO_3-N (µg/g)	PO_4-P (µg/g)	$CaCO_3$ (g%)
S1	6.8	3.36	5.79	3.33	5.54	2.2
S2	6.91	1.38	2.37	3.66	3.36	1.2
S3	6.6	1.92	3.31	4.16	1.45	2.5
S4	7.3	3.6	6.2	3.66	2.36	1.5
S5	7.2	1.2	2.06	3.66	2.54	1.7
S6	6.8	1.5	2.58	3	7.81	4.9
S7	7	1.74	2.99	2.66	7.72	3
S8	6.5	3.12	5.37	4.66	2.09	1.9
S9	7.9	1.26	2.17	3.83	3.54	2.3
S10	7.1	2.64	4.55	8.5	6.63	1.9

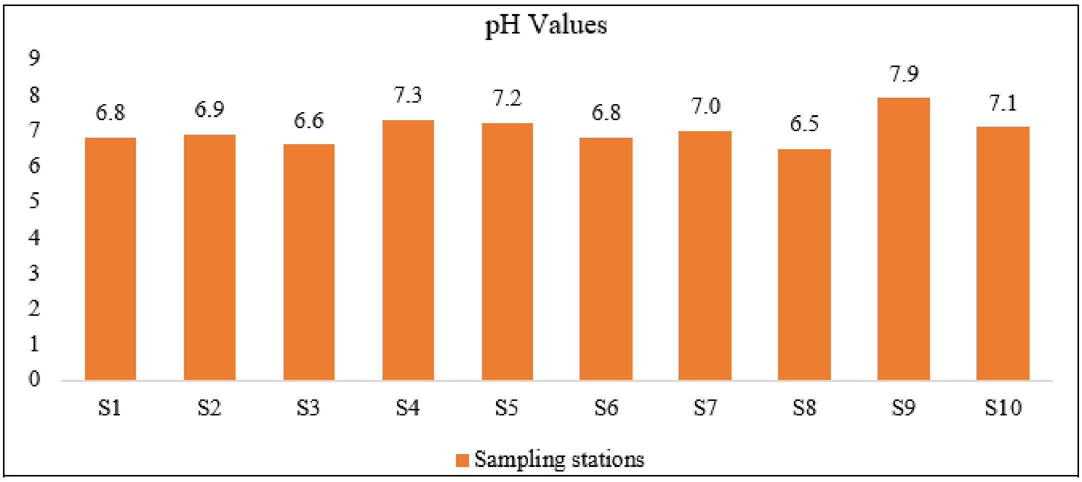


Figure 4: pH values at different sampling stations (S1-S10).

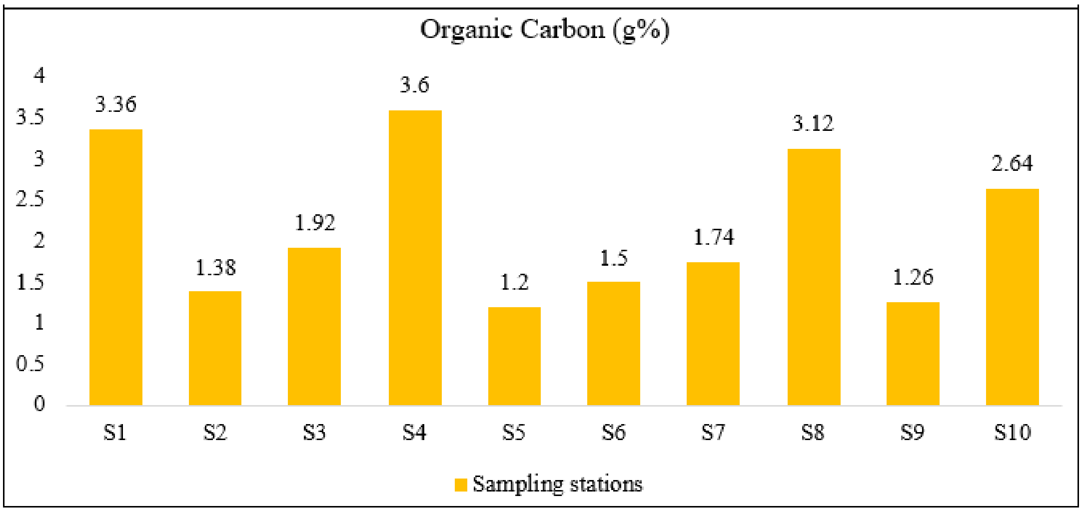


Figure 5: Levels of organic carbon in g% at different sampling stations (S1-S10).

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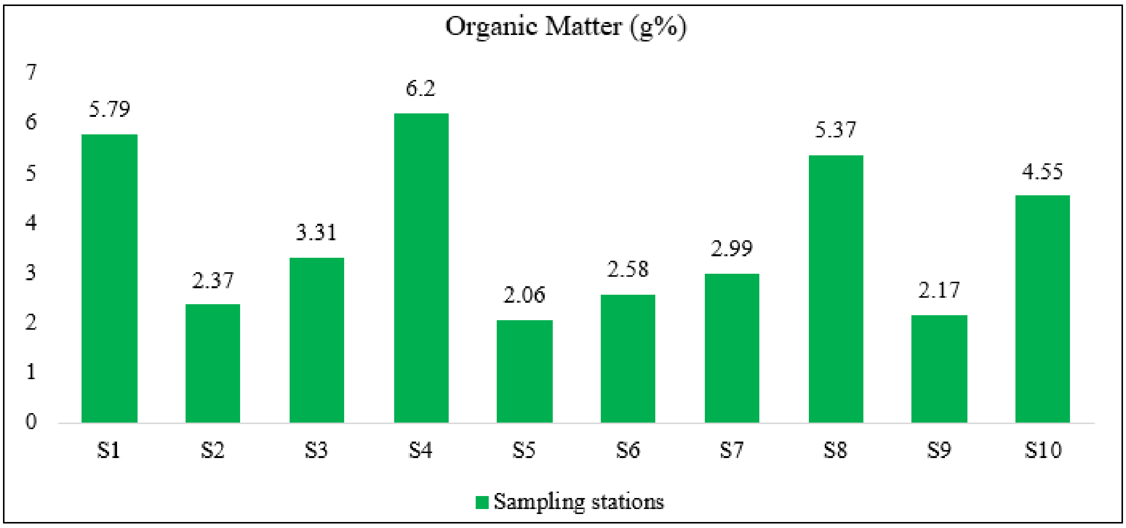

Figure 6: Levels of organic matter in g% at different sampling stations (S1-S10).

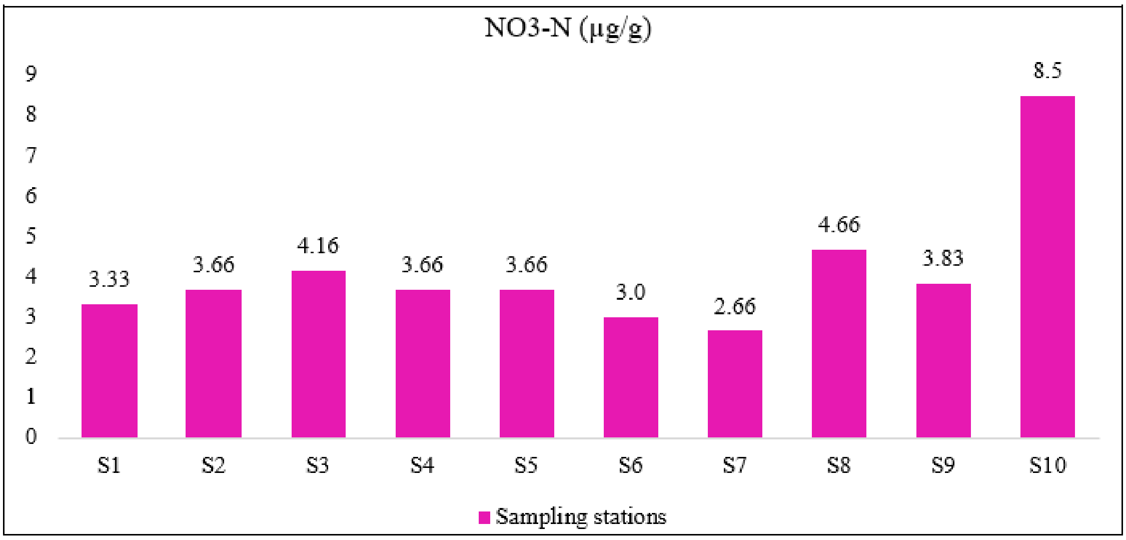

Figure 7: Levels of NO_3-N (µg/ g) at different sampling stations (S1-S10).

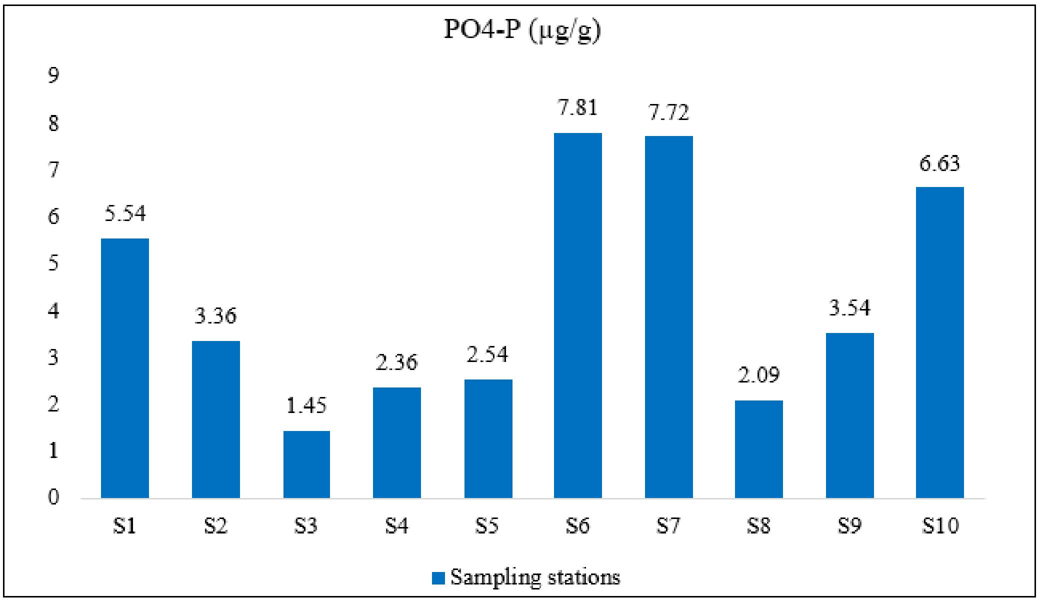

Figure 8: Levels of PO_4-P (µg/g) at different sampling stations (S1-S10).

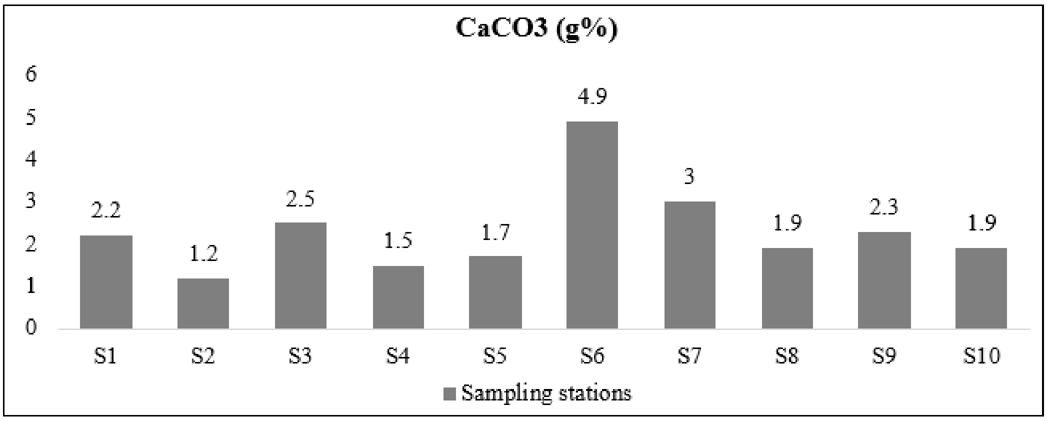

Figure 9: Levels of $CaCO_3$ in g% at different sampling stations (S1-S10).

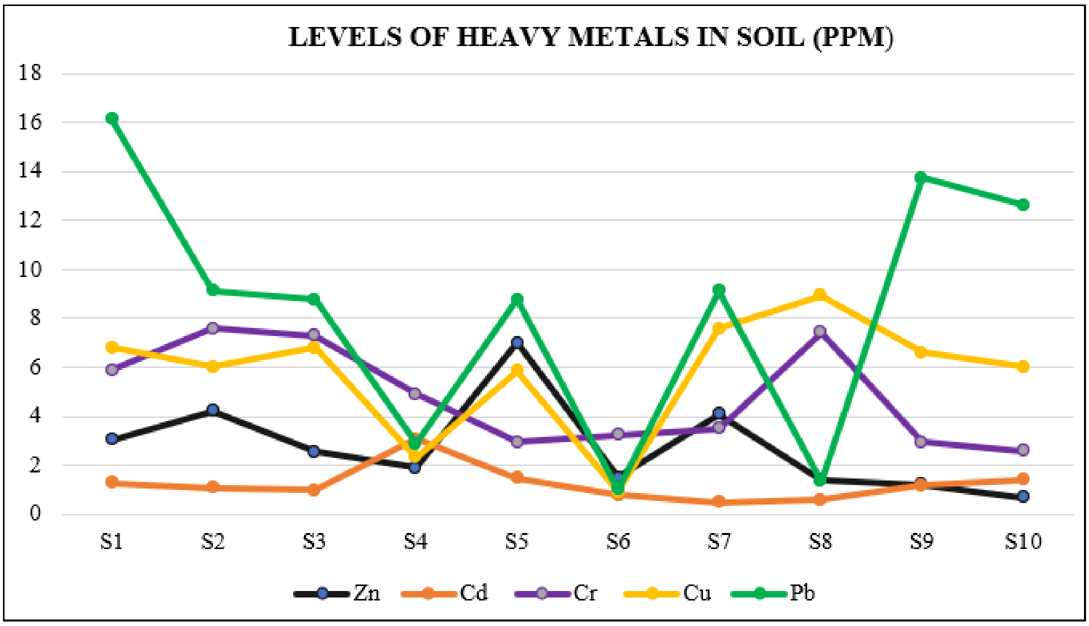

Figure 10: Levels of different heavy metals in ppm at different sampling stations (S1-S10).

4. Discussion and Conclusions

The sampling stations S5, S6, S7, and S9 were located close to the Sewage Treatment Plant (STP). The soil pH ranged from 6.5 (acidic) at sampling station S8 to 7.9 (basic) at sampling station S9, indicating a variation in pH near the STP area. Soil pH plays an important role in the availability of nutrients essential for plant growth. The pH process control is of great importance in the chemical industry, especially wastewater treatment plants[21].

At S4, the highest values of OC and OM were recorded at 3.6 g% and 6.2 g%, respectively, while the peak value for NO_3-N was 8.50 µg/g at S10. Sampling stations S4 and S10 being away from STP show elevated levels in OC, OM, and NO_3-N, thus enhancing the soil fertility. Studies indicate that total organic carbon in the soil plays a major role in both chemical and biological processes[22]. Many studies suggest that increased levels of NO_3-N have been found to enhance the soil fertility[23,24]. The maximum levels of PO_4-P were 781.81 µg/g at S6, and $CaCO_3$ was 4.9 g% at S6, suggesting a rich source of phosphorus and calcium in the area adjacent to STP. Elevated levels of PO_4-P have been found to increase soil fertility [25,26]. However, the high levels of CaCO3 in this area impair the soil productivity[27].

Inversely, lower levels of OC and OM were found at S5 with 1.2g% and 2.06 g% respectively due to the STP in this station area. NO_3-N was found to be lowest at S7 with 2.66µg/g, and PO_4-P was reported as lowest at S3, 1.45 µg/g. Low levels of $CaCO_3$ were detected at S2 with 1.2 g%. From the above results, it is understood that the soil fertility parameters show a decline in sampling stations S5 and S7 close to STP.

The concentration of heavy metal Zn was highest at 7.00 ppm at S5, located close to STP. However, this value remains within permissible limits and does not pose a risk to soil health. Therefore, it does not indicate zinc pollution. [28] The highest concentrations of Cd (3.07ppm), Cr (7.57ppm) and Cu (8.93ppm) were recorded at sampling stations S4, S2 and S8 respectively, located away from the STP. The Cd value exceeds the Indian and some international thresholds, suggesting a potential concern for soil pollution in a localised area. The recorded levels of Cr and Cu are within the established safety standards and currently do not pose a heavy metal risk[29]. The elevated Pb concentration of 16.12 ppm at the S1 sampling station is likely attributed to its proximity to the Eastern-Express highway, where vehicular emissions contribute to lead pollution[30]. A one-way ANOVA test comparing the concentrations of heavy metals Zn, Cd, Cr, Cu, and Pb across the sampling stations yielded a p-value of 0.000016. Since this p-value is much less than 0.05, there is a statistically significant difference in the mean concentrations of the various heavy metals under study across the sampling stations.

The current study reveals a decline in the soil fertility parameters at the sampling stations close to STP. This is indicative of the impact of STP at the BPS. However, no heavy metal pollution is reported in the current study. Further studies focusing on the sewage treatment processes and other indices of soil fertility have to be evaluated to reduce the soil pollution and preserve the biodiversity at the Bhandup Pumping Station.

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