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Impact of Heavy Metal Contamination on Soil and Cultivated Vegetation with Mitigative Measures Using Nanotechnology: A Case Study

H. Chandrashekar, K.V. Lokesh, G. Ranganna

Abstract: ***Any country's freshwater ecosystems would be incomplete without its lakes. A freshwater lake might have numerous advantages in an urban setting, provided pollution is avoided. Due to thermal cooling, reaction centres, and other factors, urban lakes are utilised more frequently—& distressing sites in the highly pressured urban environment. In addition to providing food for the local inhabitants, lakes recharge groundwater, raise the water table, sustain a diversity of aquatic plants and animals, and avoid flooding. Through irrigation with sewage-led lake water, this investigation seeks to ascertain the level of heavy metal pollution in agricultural soil and plants in the land near Byramangala reservoir, its watershed, and adjacent command areas located in semi-urban areas—the location of the Vrishabhavathi River. Atomic absorption spectrophotometry has been performed to analyse water, soil, and crop plant samples for heavy metals, specifically Fe, Mn, Cu, Zn, Cd, and Pb. According to the study, irrigation utilising sewage-contaminated water that contains varying concentrations of heavy metals causes the concentration of metals in both the soil and vegetation to rise. The reservoir's surface water contained concentrations of heavy metals, including zinc, cadmium, lead, iron, and copper. Heavy metal traces were discovered in soil and various vegetation sections that received irrigation water from reservoirs. Iron, zinc, and cadmium have a higher transfer factor from soil to vegetation in fodder and radish. By using microbes to synthesise nanoparticles with varying chemical compositions, sizes, shapes, and controlled molecular dispersities both intracellularly and extracellularly, the heavy metals found within the soil are efficiently immobilised. This constitutes a financially feasible but environmentally responsible approach. Additionally, the concentration of Pb and Cd pollutants can be immobilised by applying nano-hydroxyapatite (nha) chemical, one of the nano fertilisers smaller than 20 nm. Additionally, immobilising agents, including nano-scale zero-valent iron, bentonite-Nzvi, nanoalumina, and nanocarbon dendrimers, can be employed. All nano-immobilising agents demonstrated considerable efficacy in lowering the amount of DTPA extractable-Cd and Pb.***

Keywords: ***Urbanisation, Reservoir, Irrigation Techniques, Lake Management***

Abbreviations:
BIS: Bureau of Indian Standards
CNTs: Carbon Carbon Nanotubes
GO: Raphene Oxide
SWNTs: Single-Walled Carbon Nanotubes

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I. INTRODUCTION

Water is considered an essential input in agriculture, and its quality is paramount for the successful growth of crops and aquatic life. Poor-quality water, apart from having a direct detrimental effect on crop growth, also indirectly affects the physicochemical properties of soils, further leading to groundwater pollution. Hence, there is a need to defend groundwater.

As the body of water, surface water is evaluated based on the physical, chemical, and biological characteristics of the Byramngala tank located 40 kilometres away from Bangalore, which receives both treated and untreated wastewater from the urban area of Bangalore. The lake water's physical, chemical, and biological characteristics are qualitatively analysed. Five samples were taken at a time: one kilometre before the lake, close to the lake's inlet, close to the lake weir, close to the lake's northern shore, and close to the irrigation channel.

pH, temperature, turbidity, conductivity, dissolved oxygen, BOD, COD, suspended particles, dissolved solids, sodium, potassium, calcium, magnesium, hardness, total alkalinity, fluoride, chloride, nitrate, phosphate, and sulphates are among the 28 factors taken into consideration—iron, copper, lead, zinc, nickel, hexa-chromium, total coliform, and fecal coliform. The Bureau of Indian Standards (BIS) and AWWA-recommended standard methodologies were followed in the analysis. The soil samples were collected at two different spots fed by this polluted tank and analysed for micronutrients and macronutrients. A diverse blend of organic, mineral, and living matter makes up soil. The appropriateness of soil is mainly determined by its physical properties for the growth of a particular crop. Soil nutrients can be classified into macro- and micro-nutrients. Nitrogen, phosphorus, and potassium are generally found in manure and fertilisers and are called fertiliser elements. Iron, Zinc, Copper, Manganese, Boron, and Molybdenum are micronutrients. Each nutrient has a particular impact on the development and growth of crops, particularly when present in insufficient quantities; the growth and crop yield may be reduced considerably as the deficiency of any of them makes it impossible for the plant to complete its life cycle.

II. STUDY AREA

Before meeting the Suvarnamukhi river close to Bhadragundamadoddi (North latitude 120 39 40" & East longitude 770 25 00"), in the Kanakapura taluk, the fourth-order upstream Vrishabhavati drains an aerial area of 545 sq. km. Located in the Cauvery Basin, the Suvarnamukhi River is among the Arkavathi River's principal tributaries within Karnataka. However, its study space is closed at all times. Way to the Byramangala tank, wherein the Vrishabhavathi stream system ends. This covers 340 square kilometres in the air. It is surrounded by latitudes 120 45 00"-13002 40" in the north and longitudes 770 23'45"-770 34'16" in the east. India's topographic maps No. 57 H/5, H/9, and G/12 were surveyed, scaled at 1:50000, showing the area's topographic coverage.

[Fig.1: Satellite Image of Byramangala Reservoir]

Bidadi Hobli in the Ramanagaram district is where the Byramanagala tank is located. The urban areas of Bangalore, governed by the Bruhat Bangalore Mahanagara Palike, and the rural villages of Bangalore comprise the reservoir's catchment area. This catchment region includes the urban areas of Bidadi, Rajajinagar, Peenya, and Kumbalgod. The Vrishabhavathi River transports stormwater in the catchment area between urban, semi-urban, and rural regions, as well as industrial and home sewage. In the catchment's rural areas, intensive farming generates agricultural waste that enters the reservoir. According to the report, the reservoir and its sediments are heavily contaminated. Records from the rain gauge at Byramangala were used to calculate the average monsoon rainfall, 551.69 mm, and the 789 mm average rainfall yearly. The reservoir's yearly inflow varies between 23.92 M3 at the minimum and 114.5 × 10^9 M3 at the maximum. The canal's withdrawal is noted as 34.97M cum, and up to 5.42M cum in reservoir losses are recorded. According to the reservoir's data, the FRL was 24.10 m3, the water spread area was 430.25 ha, the living storage was 22.01 m3, and the dead storage was 2.09 m3 at the sluice's sill level. The reservoir's right flank features a large crested spillway. The spillway is 150.5 meters long, with a 0.9-meter flood lift, and can discharge 230 cubic meters. Figure 1 shows the Byramangala reservoir's satellite image. The earthen-type bund built for the Byramangala reservoir has a measured depth of 22.85 meters at its deepest point. The bund's length is 2286 meters, and its top width is 3.66 meters. The reservoir's sill level is 22.85 meters, its FRL is 32 meters, and its MWL is 32.9 meters. The reservoir has two waterways: the Canals on the opposite Banks. The lengths of the left and right bank canals are 26.4 & 8.4 km, respectively. Their respective command areas are 444 and 1330 hectares. As seen in Fig. 2, the reconnaissance survey indicates that the application of sewage water has contaminated the soil throughout the command area.

[Fig.2: The Research Area's Geology and Geomorphology include the Presence of Contaminated Water in the Left Bank Channel.

The Vrishabhavathi flows across the laterite profile at the head reaches in a southerly direction. The stream flows over a deep, chemically worn saprolite profile from its headwaters to the N130 parallel. It passes through a sequence of banded gneissic strata downstream, going southeast into Kumbalagodu, N0 13 runs parallel to the road bridge (E 77º 27': N 15º52'20"). The creek cuts it. Crosses granitic gneiss that dips sharply to the east beyond Kumbalagodu [1]. A parallel sequence of simple dykes that are trending from northwest to southeast passes through the granitic gneisses on the left bank. These simple dykes Tank Cross crosses the right bank in the lower reaches of the creek at Byramangala. Showing distinct indications of offsetting indicates that the NE-SW faulting system is responsible for training this section of the stream flow. Regional boundaries delineate the water split that separates the Arkavathi river system from the Vrishabhavathi [1]. N-S cracks where dykes are present. On the southeast slope above topographic point 926 meters northeast of Peenya, the primary Vrishabhavathi stream originates. It passes through Bruhat Bangalore Mahanagara Palike's Rajajinagar on its way south (BBMP). The first and second order streams' flow courses, as well as the Vrishabhavathi River's original channel in some areas, have been modified by the area's urbanisation [2]. The mainstream's current location features distinct scenery. It drains several subsidiary drainages and preserves a well-carved landscape downstream. The most prominent tributary is Nagarabhavi Torai. Urbanisation has interfered with the traditional drainage course upstream near Kumbalagodu, preventing the stream system from displaying a unique and cohesive pattern [1]. In the downstream section of Kumbalagodu, evidence suggests that the stream system is structurally controlled. Between Ampapura and Kumbalagodu, a deep rock-cut valley has been carved through the main stream. Figure 3 displays the map of the land cover and use.

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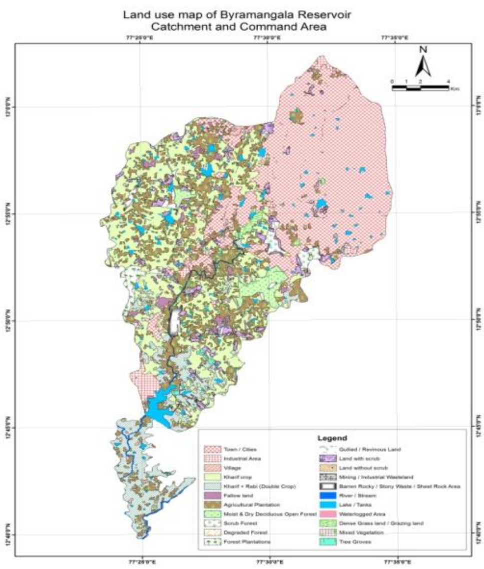
III. METHODOLOGY

At several points within the reservoir, its catchment, and command regions, water samples have been taken in April 2018 (pre-monsoon), September 2018 (monsoon), and December 2018 (post-monsoon). The samples have been examined bacteriologically and physico-chemically. Samples of water from the soil and water have been collected at tube wells located across the study region to identify the source of the water. Water samples collected from various locations were subjected to physicochemical and biological studies, utilising the methods recommended by APHA (1994). The pH, proportion, macronutrients, and micronutrients of organic carbon in the soil samples were all examined. Heavy metals and their absorption from soil to vegetation are analysed using soil and vegetation samples gathered from command areas and the catchment. The spatial analyses of the collected water and soil particle samples were conducted without using GIS-ArcInfo Software. The water and soil quality indexes for the samples gathered in the catchment and command regions were determined after the water samples were examined for irrigation water requirements.

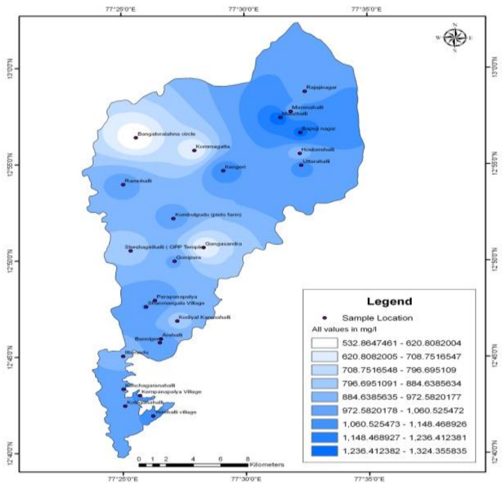


[Fig.3: Land use along with Land Cover Map of Byramangala Reservoir Catchment, also Command Area]

IV. RESULTS AND DISCUSSION

At 42 sites throughout the catchment or command area, groundwater and surface water samples were investigated during three seasons. The Byramangala reservoir catchment and the command area's surface and groundwater are contaminated at different places, according to the findings of physico-chemical and bacteriological investigations. The groundwater tests revealed high levels of sodium, calcium, magnesium, chlorides, sulphates, nitrates, bicarbonates, and hardness, all exceeding allowable limits. The surface water samples had very high BOD, COD, total coliform, and faecal coliform levels. Concentrations involving heavy metals in surface and ground water were also measured. The Byramangala reservoir's surface water samples contained heavy metals, including copper, zinc, lead, nickel, and iron. The waters of the river Vrishvabhavathi reach the reservoir. Table 3 displays the findings of the seasonal study of water samples from the ground and the surface. Figure 5 shows the TDS spatial distribution in the groundwater samples. According to a chemical analysis, the findings show that Lower quantities of available phosphate, potash, or organic carbon are found in soil samples taken throughout the command area or catchment.

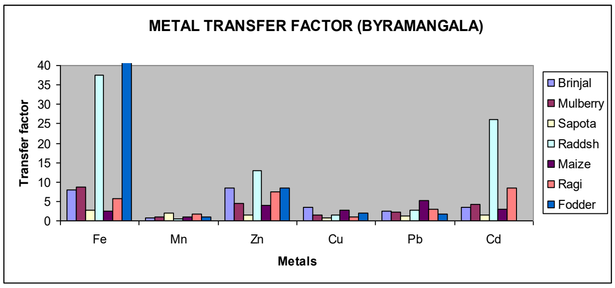
In some areas, the metal concentrations, including Fe, Mn, Zn, Cu, Pb, or Cr, in the vegetation and soil of the command area exceed allowable limits. Table 2 displays the findings of the concentration of heavy metals in farmed plants. The metal transfer factor from soil to vegetation for each metal has been calculated and documented in Table 1 and Figure 5. The average concentrations of metals It was also discovered that the natural elemental trace amounts of 500 (Fe), 15(Zn), 3(Zn), 0.5(Ni), 1(Cr), 1(Pb), & 0.03(Cd) in fresh water were 2,8,3,5,4,8, and 20 times lower than the levels of 1015 (Fe), 115 (Zn), 16(Cu), 4(Ni), 3 (Cr), 8 (Pb), or 0.5 (Cd) in lake water (µg/l).



[Fig.4: The Ground Water Samples' Spatial Distribution of TDS Reservoir Catchments and Command Area]

Table 1: Each Metal's Metal Transfer Factor from Soil Towards Vegetation

Heavy Metal	Brinjal	Mulberry	Sapota	Raddish	Maise	Ragi	Fodder
Fe	7.9	8.8	2.7	37.6	2.38	5.73	71.43
Mn	0.71	1.1	1.9	0.56	0.87	1.78	0.91
Zn	8.5	4.59	1.4	12.89	3.92	7.34	8.54
Cu	3.6	1.52	0.63	1.5	2.77	1.11	1.98
Pb	2.56	2.15	1.14	2.78	5.33	2.86	1.66
Cd	3.48	4.33	1.6	26.04	3.03	8.33	-



[Fig.5: Each Metal's Metal Transfer Factor from Soil to Vegetation]

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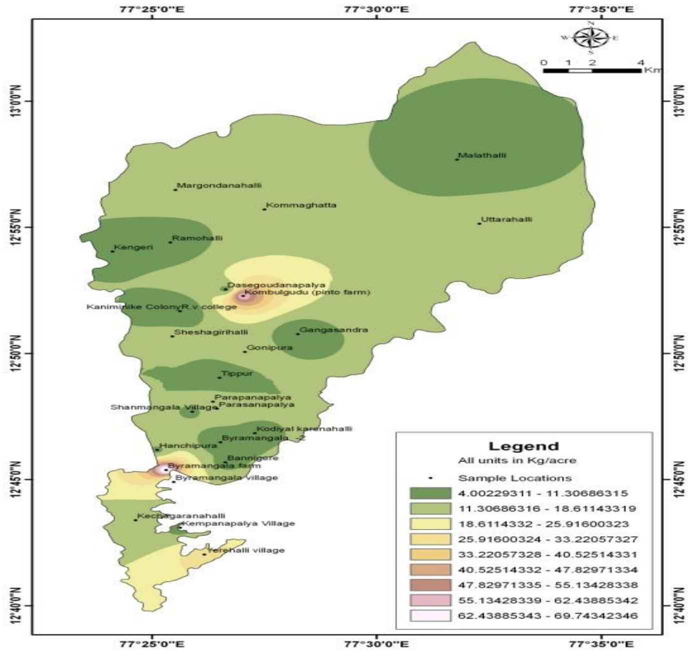

[Fig.6: Distribution of Available Phosphorus within Catchment & Command Area Soil Samples]

Table 2: Results of the Presence of Heavy Metals in Vegetables of the Byramangala Command Area

Sl. No	Name of the Sample or Vegetation		Iron (Fe) in µgm/Kg		Manganese (Mn) in µgm/Kg		Zinc (Zn) in µgm/Kg		Copper (Cu) in µgm/Kg		Chromium (Cr) in µgm/Kg		Lead (Pb) in µgm/Kg		Cadmium (Cd) in µgm/Kg	
			IS	Result	IS	Result	IS	Result	IS	Result	IS	Result	IS	Result	IS	Result
1	Brinjal	Soil	500	78.83	50	48.39	49	1.9	30	2.31	20	0	1.8	0.94	2.2	0.273
		Root	500	1978.08	50	34.7	49	28.05	30	8.55	20	0	1.8	0.25	2.2	0.95
		Leaf	500	623.4	50	14.3	49	16.15	30	4.9	20	0	1.8	0.6	2.2	0.05
		Fruit	500	41.85	50	7.45	49	23.15	30	8.5	20	0	1.8	1.25	2.2	0.7
2	Mulberry	Soil	500	5.71	50	35.13	49	2.57	30	3.09	20	0	1.8	0.72	2.2	0.003
		Root	500	2142.12	50	37.2	49	11.8	30	3.7	20	0	1.8	1.55	2.2	0.45
		Stem	500	50.25	50	9.45	49	37.85	30	4.7	20	0	1.8	0.65	2.2	0.05
		Leaf	500	151.7	50	39.1	49	17.75	30	3.7	20	0	1.8	0	2.2	0
3	Sapota	Soil	500	26.01	50	27.68	49	6.56	30	6.94	20	0	1.8	0.96	2.2	0.093
		Root	500	1680.72	50	52.6	49	13.7	30	3.05	20	0	1.8	1.85	2.2	0
		Stem	500	70.3	50	10.95	49	9.2	30	1.15	20	0	1.8	1.3	2.2	0.15
		Leaf	500	30.55	50	27.2	49	15.8	30	4.4	20	0	1.8	1.1	2.2	0
		Fruit	500	33.3	50	4.05	49	5.45	30	0.55	20	0	1.8	0	2.2	1.1
4	Radish	Soil	500	12.53	50	53.88	49	1.47	30	1.96	20	0	1.8	1.06	2.2	0.048
		Leaf	500	473.95	50	30.35	49	32.4	30	5.55	20	0	1.8	2.95	2.2	0
		Fruit	500	1669.36	50	27.5	49	18.95	30	2.95	20	0	1.8	6.95	2.2	1.25
5	Maize	Soil	500	16.31	50	70.52	49	3.02	30	1.46	20	0	1.8	0.63	2.2	0.033
		Stem	500	53.4	50	13.7	49	12.8	30	7	20	0	1.8	3.36	2.2	0.1
		Leaf	500	135.45	50	61.4	49	29.6	30	6.55	20	0	1.8	0	2.2	0.65
		Fruit	500	38.9	50	20.55	49	47.45	30	4.05	20	0	1.8	6.1	2.2	1.3
		Fruit1	500	69.55	50	7.4	49	11.85	30	10.45	20	0	1.8	0	2.2	0.75
6	Ragi	Soil	500	7.01	50	54.53	49	1.98	30	2.92	20	0	1.8	0.68	2.2	0.036
		Root	500	7800.4	50	51.95	49	18.85	30	9.7	20	0	1.8	1.95	2.2	0.65
		Stem	500	40.2	50	31.75	49	14.55	30	2.2	20	0	1.8	6.8	2.2	0.3
		Leaf	500	163	50	97.5	49	22.55	30	3.25	20	0	1.8	0.2	2.2	1.35
		Fruit	500	70.4	50	45.1	49	39.75	30	6.15	20	0	1.8	5.9	2.2	0
7	Fodder	Soil	500	5.1	50	59.76	49	2.1	30	2.04	20	0	1.8	1.92	2.2	0
		Root	500	5795.4	50	54.85	49	17.95	30	6.9	20	0	1.8	3.2	2.2	0.4
		leaf	500	364.3	50	40.7	49	20.55	30	4.05	20	0	1.8	0.6	2.2	0
8	Sugarcane	Leaf	500	119.05	50	65.65	49	10.7	30	1.4	20	0	1.8	2.95	2.2	0
9	Banana	Root	500	1525.02	50	677.75	49	29.85	30	8.9	20	0	1.8	2.4	2.2	0.95
		leaf	500	335.05	50	141	49	22.9	30	0.6	20	0	1.8	0.4	2.2	0

Table 3: Seasonal Variation of Water Quality Parametres in the Byramangala Catchmentand Command Areas (Min-Max Values)

I	Parameters	Ground Water			Surface Water (Reservoir and Stream)		
	Season	Pre-monsoon	Monsoon	Post monsoon	Pre-monsoon	Monsoon	Post monsoon
1	pH	7.3-8.1	7.75-8.2	7.08- 7.81	8.05-8.39	7.2-8.53	7.11- 8.5
2	Temperature°(C)	29	26	24	29	26	24
3	DO (mg/lt)	3.7-5.9	5.9-6.8	2.4- 4.7	1.4-5.9	1.1-3.9	1.2-4.1
4	BOD (mg/lt) for 5 days	less than1.0 – 21.6	less than1.0-15.4	1.7-18.2	15.8 – 158.9	12.3-148.4	17.4-150.7
5	COD, mg/lt	3.6- 42.5	less than1.0-35.7	5.2-40.9	56.8-286.3	41.2-278.3	32.1-292.3
6	TSS, mg/lt	Less than1.0-8.9	less than1.0-5.7	less than1.0 – 7.8	12.4-66.6	11.1-68.5	15.9-71.5
7	Turbidity, NTU	0-6.9	0-5.2	0- 6.7	3.9-33.6	3.0-55.2	3.8-45.3
8	TDS, mg/lt	819- 2439	771-1956	796- 2247	902-1735	798.5-1631	815-1695
9	Conductivity, micromhos/cm @25 C	1498-2752.9	1123-2430.4	1227 – 2488.3	1278-2713	1128-2545	1112 - 2391
10	Sodium as Na, mg/lt	98.9- 224.4	82.9-201.3	91.6-211.9	127.5-192.3	72.5-180.3	91.5- 91.53
11	Potassium as K, mg/lt	6.1 – 57.49	4.2-47.0	5.4-51.0	1.3-45.8	3.93-42.1	2.1 – 32.9
12	Calcium as Ca, mg/lt	50.2 – 221.4	33.2-168.7	61.79 - 202.4	72.1-171.4	57.3-165.4	65.2 – 151.9
13	Magnesium as Mg, mg/lt	19.5 – 96.2	13.9-68.4	24.40 - 98.2	12.2-79.4	16.2-86.3	10.7- 81.5
14	Total Hardness as $CaCo_3$, mg/lt	176.3 – 791.52	152.7-624.5	224.5 – 735.19	250-720.7	214.2-668.6	232.1- 715.4
15	Total Alkanility, as $CaCo_3$, mg/lt	178.4 – 645.2	274.0-612.3	264.0 – 612.3	312.5 – 582.3	283-683.5	302.5-539.2
16	Chlorides as mg/lt	90.7 – 329.4	101.5-278.9	112.5 –302.4	159-290.8	92.3-282.4	129.9-272.5
17	HCO_3 as mg/l	270.4- 625.9	285.4-747.1	293.6- 703.9	314.2 – 710.4	261.4-669.7	278.6- 632.1
18	Fluorides as F, mg/lt	0.56 – 1.9	0.28-1.7	0.41–2.1	0.02-1.15	0.02-1.10	00.5--1.18
19	Nitrates as No_3, mg/lt	5.9- 76.8	0.97-98.8	4.5- 87.8	7.8-97.6	7.2-88.4	7.5-81.60
20	Phosphorous as Po_4, mg/lt	less than0.05	Less than0.05	less than0.05	3.1-8.9	3.0-7.4	3.4-9.1
21	Sulphates as So_4, mg/lt	14.4 – 78.5	9.5-68.4	13.5 -71.9	9.2-55.9	7.0-45.2	8.2-40.5
22	Hexa valent–Chromium as Cr6+, mg/lt	less than0.01	less than0.01	less than0.01	0.01-0.02	0.01-0.02	0.01-0.07
23	Iron, as Fe, mg/lt	0.09 – 7.2	0.04-3.0	0.05 – 8.1	0.08 – 0.57	0.05-0.38	0.09-0.39
24	Copper, as Cu, mg/lt	less than 0.02-0.04	0.02-0.04	less than 0.02-0.04	0.02-0.19	0.02-0.14	0.02-0.21
25	Lead, as Pb, mg/lt	less than0.01-0.11	<01-0.19	less than0.01-0.13	0.01-0.41	0.01-0.38	0.01-0.33
26	Nickel as Ni, mg/lt	<01-0.11	< 0.01-0.09	less than0.01-0.10	0.09-6.2	0.07-5.1	0.08-6.1
27	Zinc, as Zn mg/lt	0.02 – 0.19	0.02-0.25	0.02 – 0.16	0.04-0.81	0.02-0.77	0.03-0.71
28	Total-Coliform/100ml	0-32700	0-9600	0-12700	34-307 $X10^4$	12-228$X10^4$	42 – 208$X10^4$
29	Faecal-Coliform/100ml	0-14300	0-5800	0-9300	6-202 $X10^4$	8-182$X10^4$	7-195$X10^4$

A. Nanotechnology Methods for the Removal of Heavy Metals

The electronics sector began to utilise carbon-based nanoparticles due to their exceptional electrical and thermal properties. However, carbon-based nanoparticles have emerged as viable alternatives for wastewater treatment due to their other remarkable qualities, which include a large surface area, straightforward physical or chemical modification, and the ability to eliminate both types of contaminants. The two primary forms of carbon-based nanomaterials that are mostly covered here are those based on carbon nanotubes and those based on graphene.

Carbon Nanotubes After decades of intensive research, carbon nanotubes (CNTs) are believed to possess multiple outstanding properties, including mechanical, thermal, electrical, vibrational, and optical properties. Numerous papers have discussed its use in wastewater treatment to remove heavy metals. The type of Carbon nanotubes is a carbon-based material with diameters of roughly 1-3 nm and lengths ranging from hundreds to thousands of nanometers. They fall into two types: multi-walled CNTs (MWCNTs) and single-walled CNTs (SWCNTs). Carbon nanotubes are preferable when treating heavy metal wastewater because of their large specific surface area, rapid adsorption kinetics, and elevated adsorption capacity. Carbon nanotubes (CNTs) are thought to have a diversity of exceptional properties, such as optical, electrical, vibrational, mechanical, & thermal properties, following decades of intensive research. Numerous papers have discussed its use in wastewater treatment to remove heavy metals. They are classified compared to CNTs with multiple walls (MWCNTs) and those with just one wall (SWCNTs). Carbon nanotubes are preferable when treating heavy metal wastewater because of their large specific surface area, rapid adsorption kinetics, and high adsorption capacity. According to reports, Superior adsorption capacities with Mn (VII), Tl (I), Cu (II), Pb (II), Cr (VI), in addition to metals, are demonstrated by carbon nanotubes. The bulk of carbon nanotubes' possible adsorption active sites are found on their outside surface, interstitial channels, exterior groove sites, and internal sites.

A homogeneous cluster in single-walled carbon nanotubes (SWNTs) with relatively open ends has four distinct adsorption sites: an external groove site, an interstitial channel, an internal site, and an external surface. CNTs' surfaces are commonly modified chemically, heated, or endohedral filled with functional groups like -COOH, -NH2, -OH, etc.,

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to increase their capability for heavy metal adsorption. For example, it has been shown that simply changing the oxidants, such as KMnO4, HNO3, H2SO4, and NaOCl, can significantly enhance the adsorption capacity of CNTs. According to Mohamed et al., Hg (II) was removed using a functionalized-CNT absorbent. Pre-oxidised CNTs were combined with glycerol and allyl triphenyl phosphonium bromide to create a deep eutectic solvent (DET) for the new functionalised CNTs. The results of the batch adsorption experiment indicated that a pH of 5.5 and a contact period of 28 minutes were ideal. The matching maximum, the manufacture, use, and mechanism of modified carbon nanotubes have all been covered in Xu et al.'s comprehensive investigation of heavy metal adsorption within wastewater, which becomes possible by functionalised carbon nanotubes. Better nano composites could be created by combining carbon nanotubes with other supports. For instance, Zhan et al. developed a one-pot solvothermal approach for producing a new Fe3O4/carboxylic multi-walled CNTs hybrid with magnetic amino functionalisation [3]. In batch adsorption studies, the new CNT-based nanocomposite demonstrated a very high separation efficiency towards Cu(II) due to the synergistic interaction between the amino groups and the CNTs. Using the Langmuir model, the maximal adsorption capacity against Cu (II) can be determined as 30.49 mg·g−1. A magnetic field from outside may extract the effluent from the adsorbent.

While utilising CNTs to eliminate heavy metals in wastewater has several advantages, there are also disadvantages. To begin with, CNTs are too costly to be used on a commercial scale. It takes much effort to build efficient and reasonably priced CNTs. Furthermore, CNTs are typically challenging to extract from wastewater after adsorption, which increases the risk of secondary pollution and treatment costs. Lastly, there is a strong need for research on the toxicity of CNTs.

Nanoparticles of graphene: Graphene is an essential carbon-based nanomaterial that might be used to remove heavy metals from wastewater. My first access to a 2D atomic crystal is this one. Due to its numerous exceptional qualities, including electrical and thermal conductivity, mechanical strength, stiffness, and elasticity, it is widely used in various fields. Heavy metals in wastewater can also be extracted using graphene-based nanomaterials, like food-reduced graphene oxide (RGO) and graphene oxide (GO). The elimination of heavy metals is made possible by the different oxygen-containing functional groups found in graphene oxide (GO), an oxidation product of graphene. These groups include carbonyl, carboxyl, hydroxyl, & epoxide functional groups. Functional groups, including -OH, - COOH, etc., easily change the graphene oxide (GO) reduction because it is more prone to defects than pristine graphene. Illustrations of some of graphene's structures. Along with other exceptional qualities, these graphene-based nanomaterials are capable of removing heavy metals because of their enormous specific surface areas. High negative charge density, different functional groups (including -CH(O)CH-, -OH, or -COOH, etc.), and extremely hydrophilic properties.

V. CONCLUSIONS

A significant source of tank pollution is industrial waste. Without adequate treatment, the trash is dumped into bodies of water, making the reservoir water unsafe for human consumption. The types of industries and waste disposal practices are among the elements that influence water pollution. Numerous businesses are located in the catchment area and dispose of their wastewater next to the river without first treating it. The reservoir is contaminated once these pollutants enter the water bodies, rendering the water unfit for human use. The most crucial element is that industries that violate these regulations must be penalised, and the unlawful disposal of industrial wastewater must be stopped. Every industry shall provide the required treatment unit at the wastewater disposal source before it is ultimately released into the reservoir to comply strictly with the effluent disposal system.

Reducing intensive farming around the community is also crucial for the reasons above. Groundwater is frequently observed as one of the sources of pollution entering the Byramangala reservoir; therefore, groundwater pollution must be stopped at its source. Chemical fertilisers mainly cause groundwater pollution. Consequently, it is advised that crops be fertilised using biofertilisers instead of chemical fertilisers based on organic fertilisers.

Urbanisation in the Catchment area significantly contributes to groundwater pollution. Sewage is being dumped into roadside drains as a result of rapid urbanisation, contaminating groundwater and immediately entering aquatic bodies [1] Additionally, the sewerage system should be well-designed, the septic tanks and soak pits should be sealed, sewers should be installed across the study area, and domestic sewage in these urbanising areas should be treated. Industrial solid waste should be transported and disposed of at designated disposal facilities rather than close to a water source.

Even with every item safeguard in place, public education regarding the dangers of pollution is crucial. Industry-public interaction should be incorporated into public awareness initiatives for the research area to educate the public and lessen the issue of additional pollution. Door-to-door rubbish collection should be vigorously enforced in all of these regions.

Water samples from the watershed and command area have been subjected to physicochemical and bacteriological analyses, which show that the water is highly contaminated in some places where industrial effluents were directly released. Heavy metal concentrations were also found in surface and groundwater that were beyond acceptable limits. Micro and macronutrients, as well as organic carbon, are low in the obtained soil samples. In the command area, vegetation and soil samples fed fresh reservoir water had levels of heavy metals exceeding allowable limits.

Pollution from point and non-point sources should be decreased, and a less expensive and energy-intensive nanotechnology treatment approach may be employed. Applications of nano-hydroxy hepatite (nha) chemical as a

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single entity of the nano fertilisers of size less than 20nm to immobilise the concentration of Pb and Cd contaminants, as well as the use of microbes for intracellular alongside extracellular synthesis of nanoparticles with different chemical composition, size/shape, and controlled mano disparity, can be economically viable and environmentally friendly strategies for effectively immobilising the heavy metals in the soil. Additionally, immobilising agents such as nano-scale zero-valent iron, bentonite-Nzvi, nanoalumina, and nanocarbon dendrimers can be employed. All nano-immobilising agents demonstrated considerable efficacy in lowering the amount of DTPA extractable-Cd & Pb.

Urban lakes are a source of water and a hub for leisure activities. A lake catchment management plan that addresses issues like erosion and deforestation is crucial. Sewage from homes and businesses is treated locally.

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DECLARATION STATEMENT

After aggregating input from all authors, I must verify the accuracy of the following information as the article's author.

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