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Impacts of Heavy Metal Enriched Tailings of Magnesite Mine on Surrounding Water Reservoirs

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Abstract

The prime aim of this study was to assess the physicochemical properties of water reservoirs from magnesite mine surrounding four sites (each direction) on three seasons such as summer, winter, and rainy season. The results attained from the physicochemical analysis states that all the surrounding water reservoir samples have been severely polluted by both essential and non-essential elements. Predominantly the water sample taken from the site I of three seasons has been severely affected by the metal pollutants. The site I water sample unacceptable (mg L^{-1}) physicochemical properties such as turbidity (16.20±1.3; 15.23±1.8; 18.29±1.5), conductivity (2742.30±2.7; 2652.24±2.1; 2785.25±2.1), TDS (2085.13±4.3; 2024.15±2.1; 2113.10±1.2), TSS (712.21±2.1; 692.31±1.12; 711.12±1.5), hardness (765.38±2.4; 738.65±2.1; 781.23±2.9), BOD (208.12±1.7; 201.31±1.2; 212.31±1.5), COD (312.74±0.98; 301.54±1.21; 307.721±1.51), DO (1.12±.39; 1.01±.28; 1.02±0.23), Ca (265.28±1.21; 252.14±1.34; 275.34±1.17), Mg (124.56±1.54; 117.32±1.28; 135.28±1.62), Cl (1248.64±2.69; 1203.17±2.18; 1351.21±1.34), Zn (75.61±1.85; 71.52±1.02; 78.32±1.21), Cd (24.54±0.84; 21.28±0.61; 26.25±0.71), Pb (11.52±0.95; 8.2±0.52; 12.35±0.52), and Cr (3.1±0.054; 2.9±0.063; 3.5±0.21) contents of summer, winter, and the rainy season correspondingly. Among these three seasons, the water sample collected during rainy season possesses more quantity metals than other seasons. These results confirmed that the metal contamination has been spreading from the abandoned magnesite mine tailing. These unacceptable physicochemical properties could cause severe ecological damage to the water ecosystem.

Keywords: Mine tailing, Water reservoir, Metal pollution, Spreading, Permissible limit

1 Introduction

The quality of water is the most essential factor for the healthy survival of the organisms on earth [1-3]. The rapid industrial revolution around the globe for the welfare of human beings creates environmental pollution [4, 5]. It might be related to the growing global population and to fulfill their basic needs the modern agriculture activities and industrial revolution has been taken place around the globe [6]. Nevertheless, in other, this change creates severe environmental pollutions such as air, water, and soil pollution [7]. Among various industrial activities, mining is one of the most significant sectors that provide economy for the growth of the country and offers essential elements required for multiple human welfare activities such as in medical, pharmaceutical, food industries, etc. [8]. Simultaneously the untreated waste dump of mine could create severe environmental pollution. Since this unprocessed abandoned mine tailing has a huge volume of heavy metals such as Cd, Cr, Zn, Pb, Hg, Cu, etc. it might vary based on types of mining [9]. These metal-containing wastes can cause severe damages to the biological things that survive in these polluted metal sites. The mine surrounding sites are more vulnerable in condition to receiving the metal pollutants from the abandoned metal-enriched mine tailings through natural activities such as wind erosion and running rainwater [10-14]. The spreading of these metal contaminations to the nearby farmland could create the possibilities of spreading metal pollutants to humankind and animals by consuming the foods derived from the crops and aquatics cultivated in these metal-polluted sites soil and water [15-18]. These metal pollutants could cause issues in the kidney, nervous system, bone, liver, blood, etc. [19]. Some metals (micronutrients) such as copper, zinc, manganese, iron, etc. are considered essential elements for most of the organisms at low concentrations [20]. Whereas, some other metals (macronutrients) such as calcium, magnesium, sodium, phosphate, and sulphur are required at the proper attention for a healthy life of a human. When these require limits are crossed it could cause mild to severe toxic effects on organisms such as interrupted growth, regular metabolism, reproduction issues, etc. [21]. The remaining familiar metals such as lead, cadmium, nickel, mercury, etc. are considered non-essential elements. Even the very least concentration of these elements is sufficient to cause toxic effects on organisms and collapse the natural ecosystems. These metals have the potential as once it released to the environment from a sequestrated state it might difficult to remove the pollutant from the polluted sites [22]. Furthermore, these metals could persist in the environment for a prolonged period and it has bioaccumulative and biomagnification impacts on the food chain [23]. The microbes that survived in this kind of metal-polluted sites might revolute their resistance mechanisms to survive in these metal-polluted

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sites [24]. These metal resistant microorganisms such as bacteria, fungi, and algae might have the potential to degrade or detoxify the metals and maintain the water and soil properties [26]. These traits could enhance the soil fertility and quality of water. Hence, in this, the physicochemical properties of mine magnesite mine surrounding water reservoirs were studied to assess the spreading of metal pollution from the heap of abandoned magnesite mine tailings as a seasonal study.

2 Materials and Methods

2.1 Study area

The magnesite mine surrounding stagnant water pool sites was chosen for this study located at Salem district of Tamil Nadu, India. This is the open cast mine; thus the minerals extracted ore waste soil has been dumped as a heap. This ore waste dump might contain an impermissible limit of unprocessed heavy metals [19]. Hence, the possibilities of spreading these metal pollutions to adjacent land and water reservoir through weathering activities. The temperature of this region throughout the year has been differing from 67°F to 99°F. Occasionally the weather might be below 63°F or above 104°F and the annual rainfall is 1007.1mm in 144.3 days. The continuous farming activities are conducting by farmers, and the surrounding mine site has been filled with residents recently. Hence the possibility of spreading contamination from the mine tailing is more problematic to the residents and spoils the fertility and quality of the soil and water [27].

2.2 Water sample collection

Around 2 L (each site) of a water sample from four directions of my surroundings (summer, winter, and rainy season) were collected in ethanol wiped glass bottles individually with proper labeling. The collected samples were immediately transferred to the laboratory for physicochemical properties analyses instantly to avoid the loss of detectable minerals in the sample [28].

2.3 Physicochemical parameter analysis

The physicochemical properties such as pH, Conductivity, total suspended solids (TSS), total dissolved solids (TDS), turbidity, hardness, and trace metals or elements such as Ca, Mg, Mn, Cu, Cl, Fl, Cd, Zn, Pb, Fe, and Cr contents of test water samples were studied [21].

2.3.1 In-situ analysis

To get accurate results, specific physical parameters such as turbidity, pH, and the conductivity of the test water samples were studied at the collected site itself by following the typical protocols mentioned in Venkatesan et al. [29].

2.3.1.1 Turbidity analysis

The high sensitive mobile turbidity meter (Aqua TROLL 500 Multiparameter Sonde, USA) was used to analyze the turbidity condition of test samples at the collected site. Simply the water sample was collected in a sample holder of turbidity meter and reserved for a few min until the reading was stable and noted the values [30].

2.3.1.2 The pH analysis

The pocket typed accurate pen pH meter (AQUASOL Pen Type pH Meter- AM-P-PH) was used to record the pH of the water sample on-site. The pH of the water sample reading was noted by immersing the probe of pen pH meter in the water sample and waited for a few minutes to get a steadied pH reading and the probe was periodically washed with deionized water before the next sampling for the accuracy of the results [31].

2.3.1.3 Conductivity analysis

A high sensitive digital conductivity (LABMAN LMCM-20, Mumbai, India) meter was utilized in this study to evaluate the conductivity nature of the test water sample [32]. The known conductivity standard solution was used to calibrate the conductivity probe. The calibrated probe was immersed in the test water sample and recorded the reading after the vanishing of the stability indicator, and the probe was washed intermittently with deionized water for each sample testing.

2.3.2 Ex-situ analysis

2.3.2.1 Total Suspended Solid (TSS) analysis

Under the laboratory condition, the remaining parameters such as TSS and TDS were studied by the standard method (filtration process) [33]. Briefly, a known quantity of test water samples was poured individually on a pre-weighed glass fiber filter (1.5 µm, Diameter 47 mm) and performed the vacuum filtration process for a few minutes. Then the filter was removed and covered with an aluminum foil sheet and dehydrated at 100°C for 2 h in a hot air oven. The dehydrated filter was weighed and attained gain in the filter was measured and denoted as TSS of water sample as mg L^{-1}. In addition to this, the total hardness, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Dissolved Oxygen (DO) were also studied by following the protocol of Natarajan [34].

2.3.2.1 Total Dissolved Solid (TDS) analysis

The gravimetric technique was used to measure the TDS of test water samples. The filtrate (filtered water) of TSS analysis was heated at above 100°C in an oven until the complete evaporation of water. The remaining sediment residues were weighed and represented as TDS in mg L^{-1}.

2.3.2.2 Heavy metal analysis

The heavy metals such as Ca, Mg, Mn, Cu, Cl, Fl, Cd, Zn, Pb, Fe, and Cr contents of test water samples were analyzed as per the protocol of Narayanan et al. [2]. Concisely, about 100 mL of acid conserved water sample was taken in a 250 mL beaker and added 2 mL HNO_3 and HCl (2:1 ratio). Then the flasks were heated at 85°C to concentrate the sample by evaporating the water volume as 1/3 (reduced up to 20 mL). Then the model was quantitatively transferred to a 50 mL volumetric flask and made up the volume with Millipore water. The metal content of this processes sample was analyzed by using Inductively Coupled Plasma - Optical Emission Spectrometry (ICP-OES, 7300 DV, PerkinElmer, Inc. Shelton, CT, USA). ICP-OES standards were used for calibration and reference for metal analysis.

3 Results and Discussion

The ore processed waste dump of magnesite mine soil has enriched with heavy metals, these metal-polluted waste dumps are dumped as a heap in open land without scientific management (Fig. 1). The residents from this study area are facing pollutant issues such as air, water, and soil pollution [35]. The weathering activities such as wind erosion, running rainwater, etc. are spreading metal pollution to the surrounding sites. The surrounding farm sites are been polluted by these metals. The regional water reservoirs such as lakes, ponds, groundwater systems might receive pollution [36-38]. In this study, the physicochemical properties of water samples from four directions of mine surrounding sites on three seasons such as summer, winter, and rainy seasons were studied. Most of the physicochemical parameters such as turbidity, conductivity, TDS, TSS, hardness, BOD, COD, DO, Ca, Mg, Cl, Zn, Cd, Pb, and Cr of four water samples from three seasons were crossing the permissible limits (Table 1 to 3). Among these four sites of three-season the water sample collected from site I has been severely polluted by turbidity (16.20±1.3; 15.23±1.8; 18.29±1.5 mg L^{-1}), conductivity (2742.30±2.7; 2652.24±2.1; 2785.25±2.1), TDS (2085.13±4.3; 2024.15±2.1; 2113.10±1.2), TSS (712.21±2.1; 692.31±1.12; 711.12±1.5), hardness (765.38±2.4; 738.65±2.1; 781.23±2.9), BOD (208.12±1.7; 201.31±1.2; 212.31±1.5), COD (312.74±0.98; 301.54±1.21; 307.721±1.51), DO (1.12±.39; 1.01±.28; 1.02±0.23), Ca (265.28±1.21; 252.14±1.34; 275.34±1.17), Mg (124.56±1.54; 117.32±1.28; 135.28±1.62), Cl (1248.64±2.69; 1203.17±2.18; 1351.21±1.34), Zn (75.61±1.85; 71.52±1.02; 78.32±1.21), Cd (24.54±0.84; 21.28±0.61; 26.25±0.71), Pb (11.52±0.95; 8.2±0.52; 12.35±0.52), and Cr (3.1±0.054; 2.9±0.063; 3.5±0.21) contents of water samples collected during the summer, winter, and rainy season respectively (Table 1 to 3).

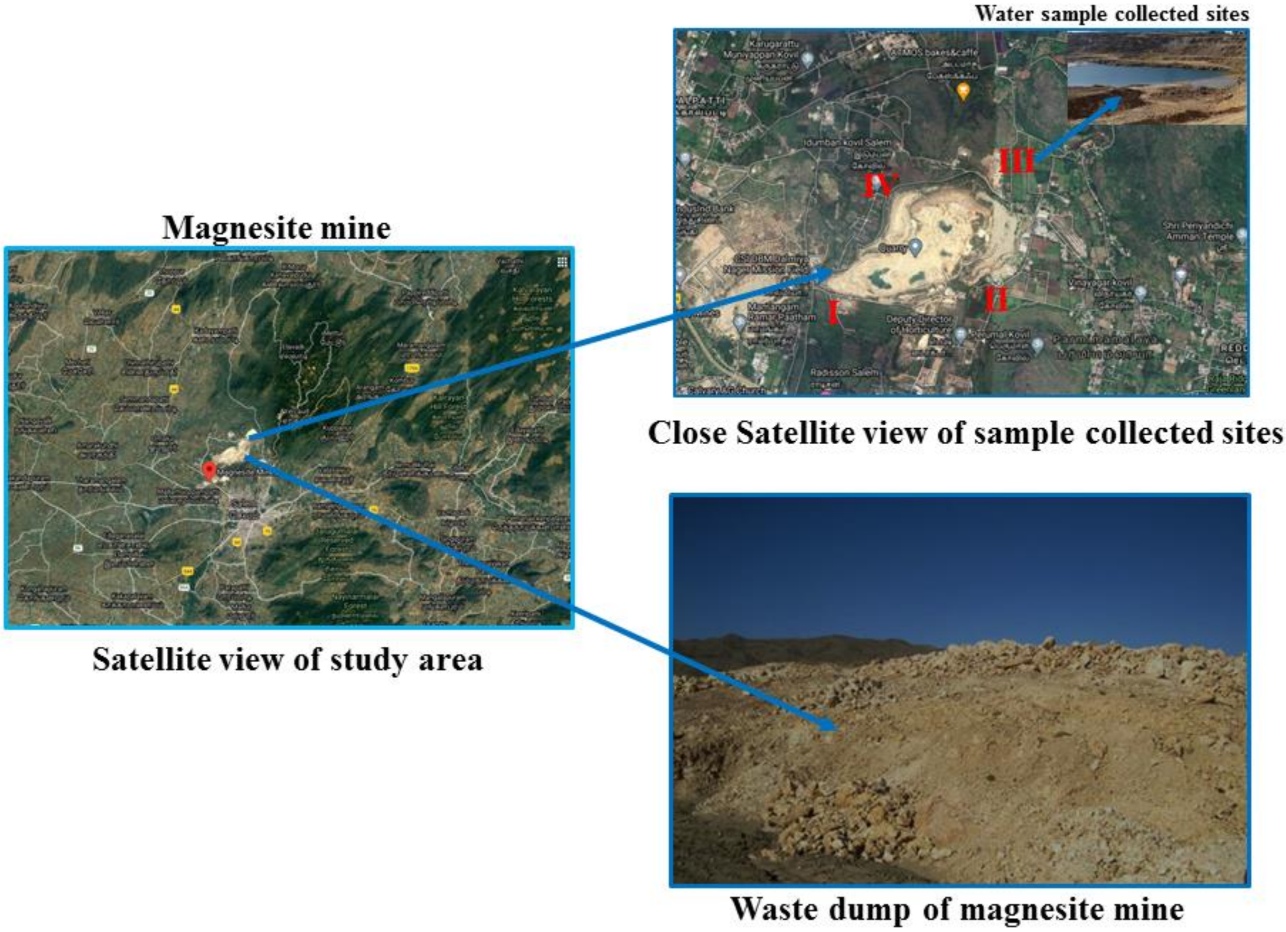

Figure 1: Satellite and live view of sample collected site (the mentioned roman letters indicates sample collected sites and interior image indicates water sample collected site)

The water sample collected during the rainy season has been severely polluted than other season, it might be due to the weathering activities, during the rainy season the rain water running from the accumulated mine waste dump is spreading the metal pollutants from this tailing heap and spread to the surrounding farmland and stagnant water systems such as lakes and ponds [39-42]. These activities increase the physicochemical properties in those sites. The water sample collected during the summer season showed the second position in this study as it has a huge amount of pollutants following the rainy season study [43]. This might be the condensation of elemental concentration in that site by water evaporation and could affect the native fauna [44]. Furthermore, the prolonged metal-polluted stagnant water could affect the groundwater systems too and might be made them as unfit for human consumption and utilization. The metal pollutant could create physiologic and genomic level impacts on microbial and macrobial diversity that survived in these polluted water [45]. The low dissolved oxygen content (1.01 to 1.12 mg L^{-1}), of these sites, might decrease the biological activities due to oxygen depletion and might create odour. The resident farmers and cattle might use this water for irrigation and consumption, respectively [46]. Hence, to avoid the environmental consequences from these polluted water, a suitable eco-friendly remediation technology needed [47]. The natural microbial degradation might be taken place in the polluted sites by native bacteria such as *Thiobacillus thiooxidans, Leptospirillum ferrooxidans, Acetobacter methanolicus, T. intermedius, Bacillus cereus,* Sulfobacillus acidophilus, *Methylobacterium* sp, and *T. ferooxidans*, *Serratia marcescens, Metalogenium symbioticum* 1, *M. symbioticum* 2, *B. alcalophilus, Aminobacter* sp, *Naumaniella neustonica*, *Staphylococcus aureus* 1, *Methylbacillus* sp, *Acenetobacter* sp, *S. aureus* 2, *Pseudomonas aeruginosa*. Fungus such as species of Mucor, Rhizopus, etc. and microalgae such as *scenedesmus* sp. *Chlorella* sp. etc. [2]. The native metal resistant non-pathogenic microbes such as bacteria, fungi, algae could be used for remediation of these polluted water.

Table 1: Physicochemical properties of polluted fresh water samples summer season

Physicochemical parameters (mg L^{-1})	Permissible limits			Water samples			
	ICMR	ISI	CPCB	SI	SII	SIII	SIV
pH	6.5-9.2	6.5-8.5	6.5-8.5	7.35±0.21	7.41±.28	7.37±.21	7.48±0.3
Turbidity (mg L^{-1})	25	10	10	16.20±1.3	8.21±0.34	11.54±0.6	11.25±0.51
Conductivity	-	-	2000	2742.30±2.7	2412.31±3.1	2401.38±2.0	2528.75±2.5
TDS (mg L^{-1})	-	-	-	2085.13±4.3	1721.84±1.2	1851.75±1.5	1651.17±2.1
TSS	-	-	600	712.21±2.1	512.34±1.74	685.89±1.7	603.24±1.7
Total hardness	600	300	600	765.38±2.4	625.50±2.8	641.27±2.0	624.37±1.5
BOD	-	-	30	208.12±1.7	204.31±1.1	195.57±1.9	192.24±1.4
COD	-	-	250	312.74±0.98	301.39±1.5	281.27±2.2	311.24±1.5
DO	-	-	-	1.12±.39	2.52±.37	2.01±.74	2.04±0.18
Ca	200	75	200	265.28±1.21	174.45±1.2	254.36±1.5	207.84±1.4
Mg	-	30	100	124.56±1.54	86.21±.34	105.24±1.51	108.31±0.27
Mn	-	-	-	458.31±1.95	401.54±2.21	408.11±1.21	417.65±1.29
Cu	-	-	1.5	0.8±0.03	0.5±0.002	0.6±0.05	0.8±0.06
Fe	1.0	0.3	1.0	1.1±0.06	1.1±0.03	1.1±0.04	1.1±0.09
Cl	1000	250	1000	1248.64±2.69	1114.35±2.32	1124.21±2.69	1185.24±1.41
Fl	-	1.5	1.5	0.89±0.021	0.75±0.042	0.74±0.056	0.80±0.017
Cd	-	NR	NR	24.54±0.84	20.01±0.52	22.65±0.56	20.21±0.58
Zn	-	15	15.0	75.61±1.85	65.54±1.72	66.74±1.24	65.37±0.74
Pb	-	NR	NR	11.52±0.95	7.25±0.35	8.95±0.56	8.22±0.76
Cr	-	NR	NR	3.1±0.054	2.0±0.012	2.2±0.028	2.2±0.023

Table 2: Physicochemical properties of polluted fresh water samples winter season

Physicochemical parameters (mg L^{-1})	Permissible limits			Water samples			
	ICMR	ISI	CPCB	SI	SII	SIII	SIV
pH	6.5-9.2	6.5-8.5	6.5-8.5	7.30±0.17	7.40±0.17	7.35±0.34	7.52±0.5
Turbidity (mg L^{-1})	25	10	10	15.23±1.8	8.11±0.35	12.11±0.5	11.10±0.75
Conductivity	-	-	2000	2652.24±2.1	2324.54±2.2	2358.24±1.8	2495.21±2.1
TDS (mg L^{-1})	-	-	-	2024.15±2.1	1654.32±1.8	1869.21±1.6	1602.01±2.8
TSS	-	-	600	692.31±1.12	508.75±1.03	665.21±1.4	521.01±0.24
Total hardness	600	300	600	738.65±2.1	620.57±1.6	635.16±1.8	556.28±1.1
BOD	-	-	30	201.31±1.2	186.27±1.8	192.31±1.4	190.17±1.8
COD	-	-	250	301.54±1.21	285.41±1.7	275.17±1.1	302.13±1.1
DO	-	-	-	1.01±.28	2.41±0.75	2.23±0.65	2.0±0.12
Ca	200	75	200	252.14±1.34	172.23±1.5	248.15±1.8	201.12±1.1
Mg	-	30	100	117.32±1.28	95.63±0.27	101.15±1.32	104.76±0.89
Mn	-	-	-	425.61±1.76	395.14±1.36	401.23±1.42	402.23±1.02
Cu	-	-	1.5	0.75±0.04	0.4±0.002	0.5±0.04	0.7±0.04
Fe	1.0	0.3	1.0	1.1±0.02	1.1±0.06	1.1±0.07	1.1±0.02
Cl	1000	250	1000	1203.17±2.18	1019.21±2.1	1098.11±1.11	1102.20±1.21
Fl	-	1.5	1.5	0.68±0.032	0.70±0.23	0.72±0.04	0.82±0.011
Cd	-	NR	NR	21.28±0.61	18.21±0.45	20.21±0.47	18.15±0.23
Zn	-	15	15.0	71.52±1.02	66.27±1.51	62.23±1.17	60.12±0.12
Pb	-	NR	NR	8.2±0.52	5.89±0.62	8.20±0.51	8.01±0.72
Cr	-	NR	NR	2.9±0.063	2.1±0.001	2.0±0.015	2.1±0.032

Table 3: Physicochemical properties of polluted fresh water samples rainy season

Physicochemical parameters (mg L^{-1})	Permissible limits			Water samples			
	ICMR	ISI	CPCB	SI	SII	SIII	SIV
pH	6.5-9.2	6.5-8.5	6.5-8.5	7.48±0.19	7.45±0.21	7.48±0.15	7.56±0.51
Turbidity (mg L^{-1})	25	10	10	18.29±1.5	12.15±0.27	13.24±0.4	13.75±0.39
Conductivity	-	-	2000	2785.25±2.1	2524.51±1.1	2512.17±1.1	2612.01±2.4
TDS (mg L^{-1})	-	-	-	2113.10±1.2	1841.25±1.9	1885.21±1.1	1668.21±1.7
TSS	-	-	600	711.12±1.5	550.11±1.1	691.21±1.5	605.17±1.8
Total hardness	600	300	600	781.23±2.9	641.21±2.1	645.12±1.2	635.64±1.0
BOD	-	-	30	212.31±1.5	207.32±1.4	197.11±1.5	198.26±1.7
COD	-	-	250	307.721±1.51	311.31±1.9	286.2±2.1	320.23±1.1
DO	-	-	-	1.02±0.23	2.14±0.24	2.05±0.23	2.10±0.11
Ca	200	75	200	275.34±1.17	182.1±1.0	258.52±1.8	211.21±1.5
Mg	-	30	100	135.28±1.62	90.17±0.41	108.35±1.42	111.12±0.16
Mn	-	-	-	468.74±1.52	405.21±1.17	412.12±1.31	425.34±1.32
Cu	-	-	1.5	0.9±0.01	0.6±0.03	0.7±0.06	0.9±0.04
Fe	1.0	0.3	1.0	1.2±0.08	1.1±0.07	1.2±0.01	1.2±0.06
Cl	1000	250	1000	1351.21±1.34	1217.11±1.3	1131.2±1.12	1201.14±1.13
Fl	-	1.5	1.5	0.94 ±0.32	0.81±0.024	0.78±0.060	0.86±0.021
Cd	-	NR	NR	26.25±0.71	22.04±0.41	23.15±0.23	22.24 ±0.74
Zn	-	15	15.0	78.32±1.21	66.21±1.32	68.12±1.04	70.28±0.56
Pb	-	NR	NR	12.35±0.52	7.81±0.24	9.01±0.27	8.89±0.54
Cr	-	NR	NR	3.5±0.21	2.2±0.04	2.1±0.036	2.5±0.085

Legend: The mentioned values are mean and standard error of triplicates (±SE). **NR:** No Relaxation. **BOD:** Biological Oxygen Demand, **COD:** Chemical Oxygen Demand, **DO:** Dissolved oxygen, **TDS:** Total Dissolved Solids, **TSS:** Total Suspended Solids. The permissible limit data was adopted from Venkatesan et al. [29]

4 Conclusion

Metals have severely polluted the magnesite mine surrounding water reservoirs might be received from heaped waste dump of magnesite mine through weathering activities. Among three seasonal analyses, the water sample from the rainy season contains a huge amount of heavy metals, especially at collected sample site I. The attained physicochemical properties analyses results states that most of the physicochemical parameters were crossing the permissible limits of Indian standard. There are more possibilities that may occur that the prolonged stagnant of these metal-polluted water might crease water ecosystem damage and might pollute the adjacent farmland. Ultimately it might affect the quality of groundwater. Since the groundwater is one of the major drinking water sources for the resident of mine surrounding sites, hence instant actions need to be taken to avoid the spreading of metal pollution to prevent environmental and human health issues.

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Ethical issue

Authors are aware of, and comply with, best practice in publication ethics specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests and compliance with policies on research ethics. Authors adhere to publication requirements that submitted work is original and has not been published elsewhere in any language.

Competing interests

The authors declare that there is no conflict of interest that would prejudice the impartiality of this scientific work.

Authors' contribution

All authors of this study have a complete contribution for data collection, data analyses and manuscript writing.

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