Journal of Engineering Science and Technology
Vol. 13, No. 11 (2018) 3632 - 3647

ASSESSMENT OF HEAVY METAL CONCENTRATION PRESENT IN SUBSURFACE WATER DUE TO SOLID WASTE DUMPING

K. PRASANNA*, R. ANNADURAI, P. VANAMOORTHY KUMARAN

Department of Civil Engineering, SRM Institute of Science and Technology, Kattankulathur - 603 203, Kancheepuram Dist, Tamilnadu, India
*****Corresponding Author: prasanna.env@gmail.com

Abstract

Landfill and open dumping of solid waste are the two major disposal methods adopted in developing countries like India. The entire Municipal Solid Waste management system includes generation, collection and safe disposal carried out by the respective local bodies. In this study, Pallavaram dumpsite, which is situated on the Thoraipakkam radial road was selected due to its proximity and possible threat to the nearby locality, which includes lakes on either side. This study was undertaken to evaluate the physio-chemical properties of leachate and subsurface water samples collected from 10 locations during Pre-Monsoon and Post-Monsoon periods. It includes the analysis of substantial heavy metal concentrations such as lead, arsenic, chromium, zinc and iron using Inductive Coupled Plasma Mass Spectrometer (ICPMS) and other physio-chemical properties as per Bureau of Indian Standards (BIS). The results of subsurface water analysis revealed that the parameters such as TDS, total hardness, sulphates, chloride, chromium and arsenic were 2103 mg/L, 2136 mg/L, 611 mg/L, 6746 mg/L, 0.82 mg/L and 0.035 mg/L respectively. It was found to be maximum during both the monsoons and the values exceed the permissible limit as mentioned in BIS. It also showed significant variations in the pre and post - monsoon periods. This has a diverse impact on the subsurface water quality, which contributes to health issues rendering it unsuitable for consumption and household activities. Hence, appropriate remedial measures must be taken to avoid further contamination.

Keywords: Heavy metals, Leachate, Physio-chemical properties, Solid waste.

1. Introduction

Our environment, which consists of valuable natural resources like, water, soil, air in the ecosystem are used by all living beings for their survival. Increasing industrialization and population growth pose a severe threat to major compounds of the ecosystem. The subsurface water, which is a scarce resource is being contaminated slowly due to improper methods of disposal of solid waste and lack of maintenance practices by the local bodies.

According to the categories of cities and towns, the disposal methods like secured landfill and open dumping will vary based on the generation of waste and space availability. The most common method of disposal is dumping, which is carried out in most of the municipalities in India for the past 50 years. In the Pallavaram municipality, the solid waste generation ranges from 150 tons in the summer and 190 tons in the winter [1-4].

As stated by Asfaw [5], the uncontrolled dumping of such wastes generates a liquid trickling of the natural and inorganic constituents from the wastes, which is known as leachate. The permeation of the landfill leachate into the subsurface water resources threatens the life of the humans near the dumping site. The percolation of leachate through soil and gradual contact with the subsurface water deteriorates the water quality and the level of concentration of heavy metals increased due to the substances present in the solid waste [6, 7].

The dumping site is located at the Pallavaram municipality, which is 22 km away from the Chennai city, which is said to be the capital of Tamil Nadu state in India. It is in the Kancheepuram district, located on the southern part of Chennai city. Tamil Nadu state is one of the major exporters of leather goods has its tannery units at various locations among which, the units at Pallavaram and Chromepet located in south suburban of Chennai city is very close to the dump site and plays a major contribution to the export sectors from the state [8-11]. Moreover, these units are established about 2 km radius from the dumpsite.

The extent of the municipality in terms of area has been raised from 18 sq. km to 18.7 sq. km along the town limits with 1363 streets and to a total length of about 213 km along with growing population trends. The municipality encompasses 42 wards with a total population of 2.34 lakhs (as per 2011 census). Pallavaram municipality is situated at 12.98° N and 80.18° E with an elevation of 16 meters above mean sea level. The Peri Aeri, which is situated at 12°57'30.73"N and 80° 9'5.7"E was a straddling lake with an area of 200 acres has been wrinkled to 145 acres due to the dumping of solid waste.

Figure 1(a) shows the map depicts the location of the Pallavaram dumpsite [2] and Fig. 1(b) shows the subsurface sampling points near the dumpsite. The Pallavaram-Thoraipakkam radial road laid in 2011, which has been bisecting the lake into two halves.

Over the recent times, 50 % of Municipal Solid Waste from Pallavaram municipality is being transferred to Venkatamangalam, a plant to handle the solid waste, which is about 18 km, from the transfer station situated on the Vandalur-Kelambakkam road.

(a) Map depicting the location of the Pallavaram dumpsite.

(b) Map showing the ground water sampling stations.

Fig. 1. Pallavaram dumpsite and sampling points.

2. Materials and Methods

The methodology adopted for this study, which includes collecting the preliminary details of the dumpsite, identification of sampling points, collection of leachate and subsurface water samples before and after monsoon seasons and to analyse the physio-chemical characteristics and heavy metal concentrations of leachate and subsurface water samples.

2.1. Sample collection

A preliminary study of the dumpsite was conducted in and around the Pallavaram dumping site in order to identify sampling locations for leachate collection as well as subsurface water sources. The coordinates of the sampling locations were measured using hand-held Global Positioning System (GPS) as listed in Table 1 for leachate and Table 2 for the subsurface water sampling locations. The distances vary from 15 m to 810 m from the boundary of a dumping site for various subsurface water sampling points. The sampling points of leachate were identified along the periphery of the dump site with depression and the pathway side for a vehicle moving in the dumpsite. In Tamil Nadu, rainfall is expected only through North East Monsoon, which falls from October to December every year, hence Pre-Monsoon refers to prior to the North East Monsoon, which falls during the months of August and September and subsequently Post-Monsoon refers to the months of January and February of the following year. In the Pre-MN period, 10 leachate samples and 10 subsurface water samples were collected during the month of September 2017 and during the Post-Monsoon period again each 10 samples were collected in the month of January 2018. The depth of subsurface water samples varies from 3 m to 8 m during the Post-MN and subsequently 12 m to 20 m during Pre MN. As mentioned by Tinni et al. [9], the leachate and subsurface water samples were collected in a clean 500 ml sterilized polyurethane bottles with labelling made properly in order to identify the sampling locations. As shown in Fig. 1(b), the locations of subsurface water sampling points are around the dumpsite. The samples of leachate and subsurface water were shown in Fig 2(a) and (b) respectively.

Table 1. Co-ordinates of the leachate sampling locations.

Sample description	Latitude	Longitude
LTS 1	12°57'21.73"N	80° 9'0.84"E
LTS 2	12°57'24.52"N	80° 9'0.15"E
LTS 3	12°57'22.66"N	80° 9'3.34"E
LTS 4	12°57'19.89"N	80° 9'2.49"E
LTS 5	12°57'18.82"N	80° 8'59.66"E
LTS 6	12°57'21.42"N	80° 9'3.56"E
LTS 7	12°57'23.57"N	80° 9'1.15"E
LTS 8	12°57'23.16"N	80° 8'59.64"E
LTS 9	12°57'18.33"N	80° 9'1.84"E
LTS 10	12°57'20.37"N	80° 8'59.32"E

Table 2. Co-ordinates of the subsurface water sampling locations.

Sample description	Latitude	Longitude
GRW 1	12°57'21.09"N	80° 8'57.03"E
GRW 2	12°57'16.41"N	80° 8'52.22"E
GRW 3	12°57'22.50"N	80° 8'53.55"E
GRW 4	12°57'18.35"N	80° 8'50.73"E
GRW 5	12°57'15.17"N	80° 9'8.48"E
GRW 6	12°57'9.18"N	80° 9'3.34"E
GRW 7	12°57'36.76"N	80° 8'59.47"E
GRW 8	12°57'27.51"N	80° 8'49.43"E
GRW 9	12°57'6.09"N	80° 8'53.62"E
GRW10	12°57'10.16"N	80° 8'34.55"E

(a) Leachate samples.

(b) Subsurface water samples.

Fig. 2. Pallavaram dumpsite and sampling points.

2.2. Testing and analysis

The temperature of the samples was measured onsite. Standard techniques for the examination of water and wastewater as prescribed by the American Public Health Association were used for the analysis. The pH was measured by using pH meter. Also, the turbidity and electrical conductivity were measured by using the nephelo-turbidity meter and conductivity meter [12-15]. The Total Dissolved Solids measurement was carried out as per IS 3025 Part 16 gravimetric method and the measurement of the Total Suspended Solids was made by using the hot air oven, muffle furnace and Whatman filter paper. The Biochemical Oxygen Demand (BOD) measurement was carried out by using BOD incubator and BOD bottles as prescribed by IS 3025 part 44 [16]. Based on studies by Pandey et al. [17] and Brindha et al. [18], the measurement of Chemical Oxygen Demand (COD) was done as per IS 3025 Part-58 by using UV method. The heavy metal analysis of iron, lead, chromium, copper, zinc, nickel and arsenic were determined using Inductive Coupled Plasma Mass Spectrometer (ICPMS) as per IS 3025 (Part 65) UV method [7, 8]. According to Tinni et al. [9] and Manjunatha et al. [10], the measurement of sulphate was carried out by the precipitation of magnesium sulphate ($MgSO_4$) in HCl medium gravimetrically. The measurement of chloride was carried out by titration of silver nitrate solution ($AgNO_3$) against ammonium chloride (NH_4Cl) [11, 19-21].

3. Results and Discussion

From the analysis carried out in the leachate and the subsurface water samples from the dump site, the following inferences were drawn.

3.1. Characteristics of leachate samples

In the leachate analyses, the values of pH in the Pre-MN varies from 6.18 - 8.06 and 7.32 - 8.1 in the period. The electrical conductivity varies from 1210 -2762 µS/cm in the Pre-MN and 879 - 2029 µS/cm in the Post-MN period. The results of the total hardness vary from 547 mg/L to 835 mg/L in the Pre-MN and 234 - 739 mg/L in the Post-MN period. The total suspended solids vary from 1439 mg/L to 6567 mg/L in the Pre-MN and 1271 mg/L - 4298 mg/L in the Post-MN period. The BOD values vary from 308 mg/L to 1657 mg/L in the Pre-MN and 297 mg/L- 444 mg/L in the Post-MN period. The sulphate ion concentration ranges from 15.4 mg/L to 69.4 mg/L in the Pre-MN and 10.1 mg/L- 28.5 mg/L in the Post-MN period. The chloride ion concentration ranges from 1095mg/L to 3646 mg/L in the Pre-MN and 1229 mg/L - 2270 mg/L in the Post-MN period. The physio-chemical characteristics are higher than the subsurface water samples and it may have a direct impact in altering the quality of water due percolation rate and soil properties.

Obviously, theses analysis will help to check the subsurface water characters and the range of increased concentration due to various monsoon periods. The collected 10 leachate samples in and around the dumping site during the Pre-MN and the Post-MN seasons were analysed for 5 major heavy metal concentrations namely lead (Pb), chromium (Cr), iron (Pb) arsenic (As), zinc (Zn). Tables 3 and 4 show the heavy metal concentration of the leachate during the Pre-MN and Post-MN seasons respectively. The concentration of lead (Pb) in leachate samples varies from 0.015 mg/L to 0.12 mg/L in the Pre-MN and 0.008 mg/L to 0.09 mg/L during the Post-MN period. The arsenic present in leachate samples varies from

0.014 mg/L to 0.06 mg/L in the Pre-MN and 0.004 - 0.07 mg/L in the Post-MN period. The chromium concentration present in the leachate samples varies from 0.35 mg/L to 1.43 mg/L in the Pre-MN and 0.13 mg/L - 1.03 mg/L in the Post-MN period. The concentration of iron varies from 0.09 mg/L to 0.52 mg/L in Pre-MN season and subsequently 0.09 mg/L - 0.6 mg/L in the Post-MN period. The concentration of zinc in the leachate samples varies from 0.08 mg/L to 0.46 mg/L in the Pre-MN season and 0.08 mg/L - 0.47 mg/L in the Post-MN period. The results obtained from the analysis predicts that there is a significant effect on the subsurface water due to leachate percolation in both the seasons. The results are not comparable with any standards since there are no such guidelines for comparing the characters and its limitation as in the case of water quality standards. It shows that the levels are more when compared with the subsurface water samples for the same heavy metal concentrations.

Table 3. Heavy metal concentration of leachate in the Pre-Monsoon.

Sample	Pb (mg/L)	As (mg/L)	Cr (mg/L)	Fe (mg/L)	Zn (mg/L)
LTS 1	0.021	0.02	0.42	0.52	0.19
LTS 2	0.033	BDL (DL:0.001)	1.16	0.41	0.11
LTS 3	0.024	0.014	1.28	0.39	0.27
LTS 4	0.11	BDL (DL:0.001)	0.35	0.25	0.08
LTS 5	0.09	0.033	1.43	0.19	0.17
LTS 6	0.053	0.04	0.48	0.18	0.2
LTS 7	0.015	0.02	0.44	0.35	0.21
LTS 8	0.036	BDL (DL:0.001)	0.81	0.26	0.46
LTS 9	0.12	0.06	1.43	0.19	0.31
LTS 10	0.019	BDL (DL:0.001)	0.48	0.09	0.23

Table 4. Heavy metal concentration of leachate in the Post-Monsoon.

Sample	Pb (mg/L)	As (mg/L)	Cr (mg/L)	Fe (mg/L)	Zn (mg/L)
LTS 1	0.016	0.07	0.31	0.28	0.35
LTS 2	0.045	0.042	0.68	0.15	0.42
LTS 3	0.037	BDL(DL:0.001)	0.13	0.33	0.21
LTS 4	0.029	0.013	1.03	0.17	0.08
LTS 5	0.013	0.004	0.77	0.6	0.47
LTS 6	0.033	0.011	0.29	0.21	0.33
LTS 7	0.012	BDL(DL:0.001)	0.41	0.26	0.19
LTS 8	0.008	0.038	0.93	0.3	0.30
LTS 9	0.011	0.009	0.65	0.25	0.44
LTS 10	0.09	BDL(DL:0.001)	0.48	0.09	0.13

3.2. Characteristics of subsurface water samples

The pH of the subsurface water samples ranges from 7.08 - 8.78 in the Pre-MN season and 7.11 - 7.82 in the Post-Monsoon season. The pH range 6.5 - 8.5 is generally suitable for drinking purposes. Figure 3 depicts the variation of pH range in the Pre-MN and Post-MN in the year 2017-18**.** However, only two samples in Pre-MN period are beyond the permissible limit and very close too to the limitations and that will not have any impact on the quality. Higher values of pH in the subsurface water damage the mucous membrane present in eyes, nose, mouth, abdomen, anus, etc., when it is consumed for long period.

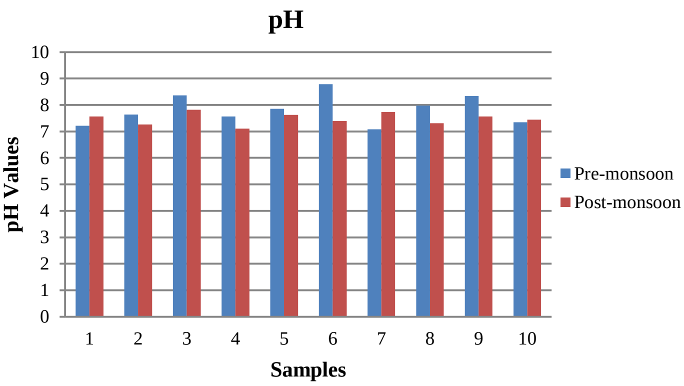

Fig. 3. pH values of the subsurface water samples in Pre-MN and Post-MN seasons during the year 2017-18.

The Electrical Conductivity (EC) of the subsurface water samples ranges from 1058 - 2910 µS/cm in the Pre-MN and from 1328 - 2136 µS/cm in the Post-MN. Figure 4 shows the variations of EC in Pre-MN and Post-MN periods. In the Pre-MN, the amount of dissolved mineral (ions) in a few subsurface water samples is slightly higher and there are no other standards for comparison especially for EC.

The total hardness of the subsurface water samples ranges from 619 mg/L to 2136 mg/ L in the Pre-MN and 398 mg/L - 872 mg/ L in the Post-MN. Figure 5 shows the variations of total hardness in Pre-MN and Post-MN periods, which is above the permissible limit of 300 mg/L as per IS 10500:2012 Drinking Water Quality Standards and hence, it is not recommended for drinking purposes. The effect of high total hardness may be due to industrial activities very near to dump site. Comparing to Pre-MN period the total hardness level is reduced in Post-MN. The subsurface water samples are said to be very hard especially during Pre-MN season. Significantly high levels of hardness may cause corrosiveness to water distribution systems, accumulation of calcium salts in arteries and cause urinary tract infections.

The Total Suspended Solids (TSS) in the subsurface water ranges from 1.10 mg/L to 12.07 mg/L in the Pre-MN and 1.03 mg/L - 6.49 mg/L in the Post-MN. Figure 6 depicts the variations in the TSS in Pre-MN and Post-MN periods. Since the permissible limit of TSS is 200 mg/L, the samples are much below the permissible limit and there is no significant effect on water quality due to TSS. Similarly, the Total Dissolved Solids in both Pe-MN and Post-MN for 10 samples is shown in Fig 7. It shows that the TDS ranges from 1063 mg/L to 2671 mg/L during Pre-MN and from 1117 mg/L to 2103 mg/L during Post-MN period. All the samples are beyond the permissible limit of 500 mg/L and it requires suitable treatment before consumption. However, the TDS limit can go up to 2000 mg/L, when there is no alternate sources as mentioned in BIS 10500-2012.

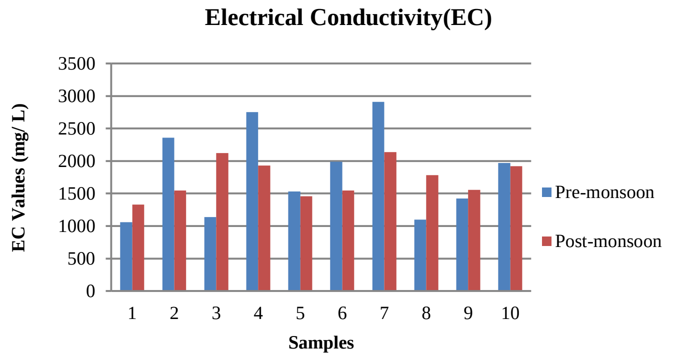

Fig. 4. Electrical Conductivity of the subsurface water samples in Pre-MN and Post-MN seasons during the year 2017-18.

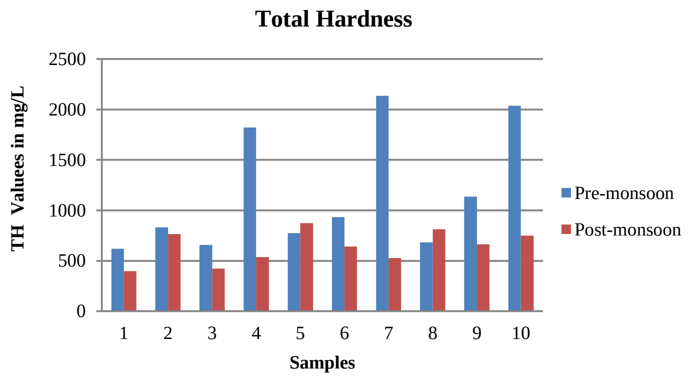

Fig. 5. Total Hardness of the subsurface water samples in Pre-MN and Post-MN seasons during the year 2017-18.

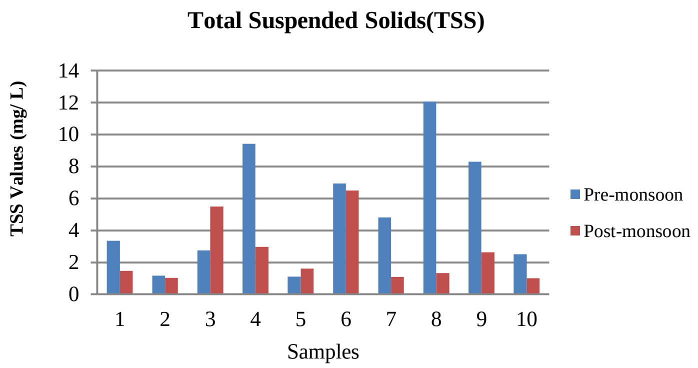

Fig. 6. Total Suspended Solids of the subsurface water samples in Pre-MN and Post-MN seasons during the year 2017-18.

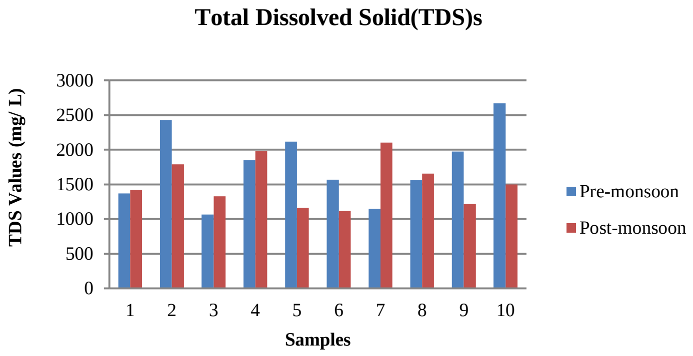

Fig. 7. Total Dissolved Solids concentration in the subsurface water samples in Pre-MN and Post-MN seasons during the year 2017-18.

The BOD values of the subsurface water samples range from 11.01 - 64.6 mg/L in the Pre-MN and 4.8- 47.4 mg/L in the Post-MN period. Figure 8 depicts the variation of BOD in Pre-MN and Post-MN periods. It was observed that all the BOD values are above the permissible value, that is, it should be zero in drinking water since the subsurface water sources are directly consumed for residential purposed. The sulphate concentration in the subsurface water ranges from 38.5 mg/L to 611 mg/L in the Pre-MN season and it varies with 13.2 mg/L - 456.6 mg/L in the Post-MN season. It was observed that 4 samples in Pre-MN period and 3 samples in Post-MN are beyond the permissible limit of 200 mg/L and all other samples are within permissible limits.

Figure 9 depicts the variations in the sulphate concentration in Pre-MN and Post-MN periods**.** The possible source of sulphate (SO_4^{2-}) from the tanneries is from ammonium sulphate, sodium sulphate, chrome sulphates, which are among the chief chemicals used in the tanning process and leaching of the effluents into the groundwater could have led to contamination of groundwater. The chloride ion concentration present in the subsurface water varies from 127.1 mg/L to 6746 mg/L in the Pre-MN season and 130 mg/L - 3972 mg/L in the Post-MN season.

Figure 10 depicts the variations of chloride level in Pre-MN and Post-MN periods. It was observed that most of the samples both in Pre-MN and Post-MN are beyond the permissible limit of 250 mg/L and only 2 samples in Pre- MN and 3 samples in Post-MN are within the allowable limits. The main source of chloride is due to more usage in the liming process and other raw materials used for the processing of leather, which generates a significant amount of waste, which is dumped illegally contributing to the rise in the amount of chloride ion concentrations. The heavy metal concentration of subsurface water samples during Pre-MN and Post-MN periods are listed in Tables 5 and 6 respectively.

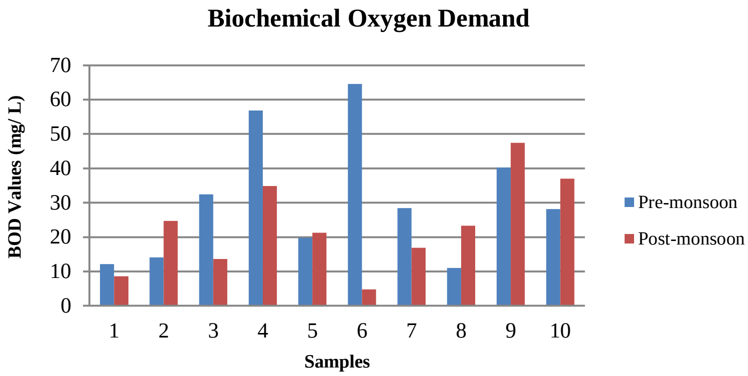

Fig. 8. Biochemical Oxygen Demand of the subsurface water samples in Pre-MN and Post-MN seasons during the year 2017-18.

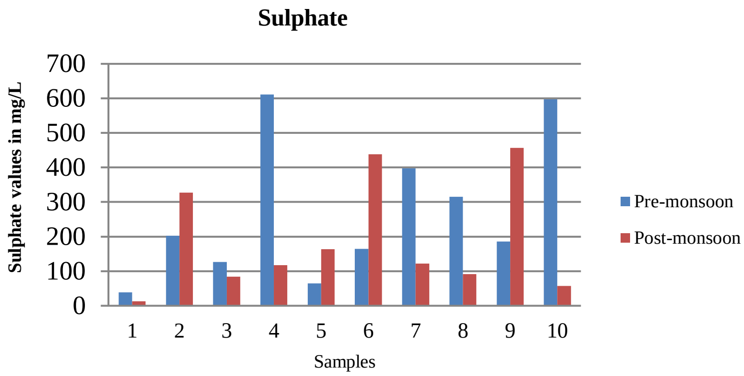

Fig. 9. Sulphate concentration of the subsurface water samples in Pre-MN and Post-MN seasons during the year 2017-18.

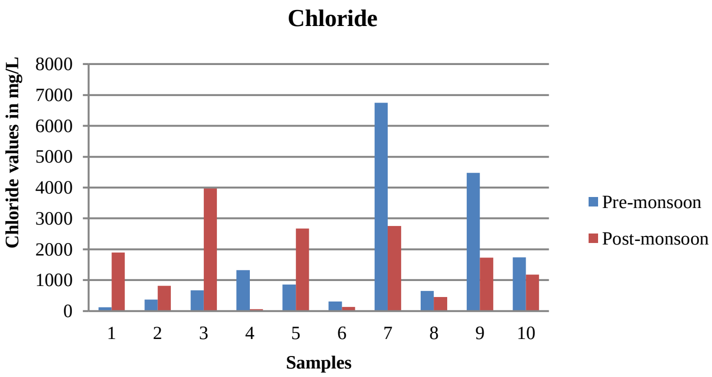

Fig. 10. Chloride concentration of the subsurface water samples in Pre-MN and Post-MN seasons during the year 2017-18.

Table 5. Heavy metal concentration of subsurface water in the Pre-MN.

Sample	Pb (mg/L)	As (mg/L)	Cr (mg/L)	Fe (mg/L)	Zn (mg/L)
GRW 1	0.061	0.018	0.04	0.05	0.34
GRW 2	0.019	0.035	0.27	0.07	0.36
GRW 3	0.038	BDL(DL:0.001)	0.53	0.31	0.32
GRW 4	0.025	0.01	0.11	0.25	0.42
GRW 5	0.001	0.028	0.82	0.125	0.19
GRW 6	0.013	0.015	0.47	0.16	0.48
GRW 7	0.002	BDL(DL:0.001)	0.08	0.132	0.3
GRW 8	0.012	0.035	0.74	0.02	0.21
GRW 9	0.026	0.019	0.41	0.19	0.22
GRW10	0.013	0.024	0.35	0.22	0.21

Table 6. Heavy metal concentration of subsurface water in the Post-MN.

Sample	Pb (mg/L)	As (mg/L)	Cr (mg/L)	Fe (mg/L)	Zn (mg/L)
GRW 1	0.04	0.016	0.17	0.02	0.31
GRW 2	0.062	0.012	0.02	0.04	0.28
GRW 3	0.015	0.005	0.30	0.21	0.26
GRW 4	0.026	0.003	0.14	0.18	0.33
GRW 5	0.012	0.027	0.47	0.115	0.16
GRW 6	0.01	BDL(DL:0.001)	0.22	0.17	0.32
GRW 7	0.028	0.017	0.08	0.05	0.21
GRW 8	0.02	0.031	0.1	0.012	0.19
GRW 9	0.011	0.011	0.37	0.16	0.15
GRW10	0.04	BDL(DL:0.001)	0.24	0.11	0.16

3.2.1. Lead (Pb)

The concentration of lead (Pb) in the subsurface samples varies from 0.001 mg/L to 0.061 mg/L in the Pre-MN and 0.01 mg/L - 0.062 mg/L in the Post-MN period. The permissible lead (Pb) is 0.1 mg/L as per Standards of Drinking Water (IS: 10500- 2012). Figure 11 depicts the variations of lead (Pb) in subsurface water samples during Pre-MN and Post-MN periods. The lead levels in all the samples are within the permissible limits. However, the dumping products such as paint, ceramics, pipes and plumbing materials, solders, gasoline, batteries, ammunition, and cosmetics, etc., which contain lead may cause significant increasing levels, will become threats to the subsurface water quality in future. Some of the health effects are anaemia, sometimes coma or even sudden death.

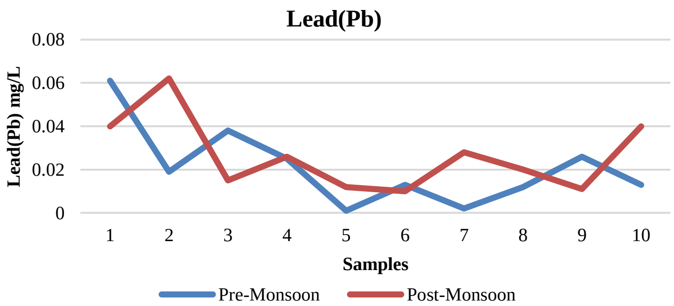

Fig. 11. Lead (Pb) present in the subsurface water samples in Pre-MN and Post-MN seasons during the year 2017-18.

3.2.2. Arsenic (As)

The concentration of arsenic (As) in the subsurface water samples varies from 0.01 mg/L to 0.035 mg/L in the Pre-MN and ranges with 0.003 mg/L - 0.031 mg/L in the Post-MN season. Figure 12 depicts the variations in arsenic (As) concentration during Pre and Post-MN periods. The permissible limit of arsenic (As) is 0.01 mg/L as per IS 10500:2012. It was observed that 7 subsurface samples during Pre-MN season and 5 samples during Post-MNshows that A levels are beyond the allowable limit. This may be due adverse effects of mineral compounds disposed in the dump site.

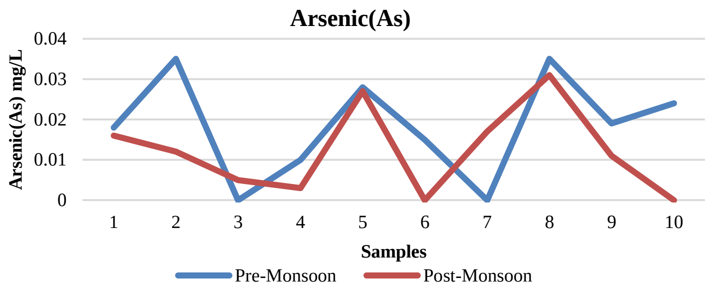

Fig. 12. Arsenic (As) present in the subsurface water samples in Pre-MN and Post-MN seasons during the year 2017-18.

3.2.3. Chromium (Cr)

The concentration of chromium (Cr^{6+}) in the samples varies from 0.08 mg/L to 0.82 mg/L in the Pre-MN and similarly 0.02 mg/L - 0.47 mg/L during Post-MN period. The permissible limit of hexavalent chromium (Cr^{6+}) is 0.1 mg/L as per BIS, Drinking Water Quality (IS 10500:2012). The results show that all the Cr levels are beyond the permissible limit except samples 1 and 7 in both the monsoon periods. This may be due to the leather industries established around the dump site, which produces the products by the tanning process, which uses chromium. Figure 13 depicts the variation in the chromium concentration during the pre and Post-MN periods. The tannery units use chromium (Cr^{6+}) for the process of conversion of skin to leather in order to improve the quality of the tanning process. The tannery effluent, when released into the soil, undergoes oxidation of Cr into toxic hexavalent form of chromium.

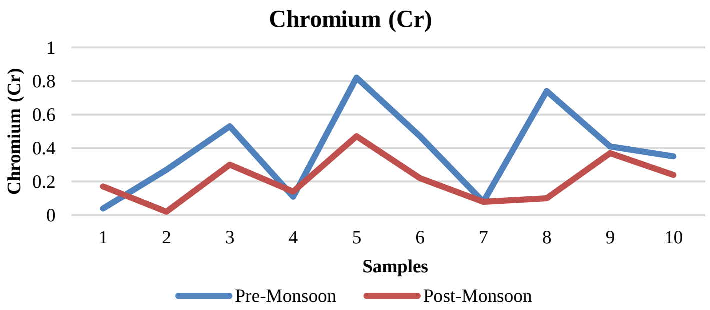

Fig. 13. Chromium present in the subsurface water samples in Pre-MN and Post-MN seasons during the year 2017-18.

3.2.4. Iron (Fe)

The concentration of iron in the subsurface water varies with 0.02 mg/L - 0.31 mg/L in the Pre-MN season and varies with 0.02 mg/L - 0.21 mg/L in the Post-MN. The results show that all the concentration levels of Fe are within the permissible limit of 0.3 mg/L except one sample in Pre-MN that is sample 3, which is slightly more, that is 0.31 mg/L. Figure 14 depicts the variation in the iron (Fe) concentration during the Pre-MN and Post-MN periods. Hence, it does not have any significant effect on subsurface water quality.

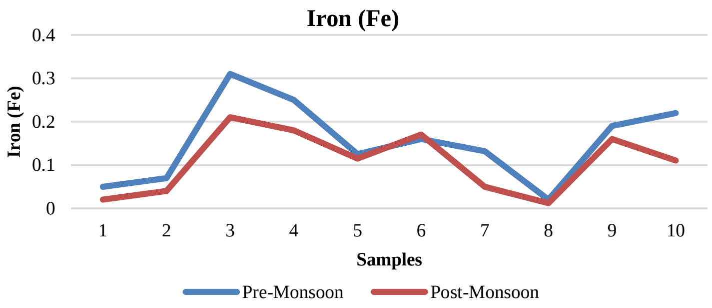

Fig. 14. Iron (Fe) present in the subsurface water samples in Pre-MN and Post-MN seasons during the year 2017-18.

3.2.5. Zinc (Zn)

The concentration of zinc in the subsurface water varies from 0.19 mg/L to 0.48 mg/L in the Pre-MN season and from 0.16 mg/L to 0.33 mg/L in the Post-MN season and all values are within the permissible limit of 5 mg/L as per IS 10500:2012. Figure 15 depicts the variations of zinc (Zn) concentration in the samples during the Pre-MN and Post-MN periods. Hence, it does not have any influence on the subsurface water quality.

A comprehensive result of physio-chemical characteristics and heavy metal concentration of the subsurface water samples is listed in Table 7 and the maximum and minimum values for 10 samples taken during Pre-MN and Post-MN seasons is shown. The results are compared with the permissible limits and the parameters beyond the limitations are highlighted.

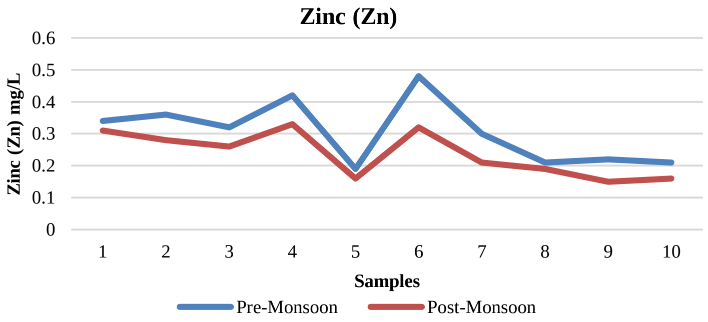

Fig. 15. Zinc (Zn) present in the subsurface water samples in Pre-MN and Post-MN seasons during the year 2017-18.

Table 7. Min / Max Value of the subsurface water samples in the Pre-Monsoon and Post-Monsoon.

Parameters	Min/max value of the subsurface water in the Pre-MN	Min /min value of the subsurface water in the Post-MN	Permissible limits as per IS 10500:2012
pH	7.08 - 8.78	7.11 - 7.82	5.5 - 8.5
EC (µS/cm)	1058 - 2910	1328 - 2136	-
Total hardness (mg/L)	619 - 2136	398 - 872	300
TSS (mg/L)	1.1 - 12.07	1.01 - 6.49	0 - 200
TDS (mg/L)	1063 - 2671	1117 - 2103	0 - 500
BOD (mg/L)	4.06 - 64.6	4.8 - 47.4	NIL
Sulphate (mg/L)	38.5 - 611	13.2 - 456.6	200
Chloride (mg/L)	127.1 - 6746	62 - 3972	250
Lead (mg/L)	0.001 - 0.061	0.01 - 0.062	0.2
Arsenic (mg/L)	0.01 - 0.035	0.03 - 0.031	0.01
Chromium (mg/L)	0.04 - 0.82	0.02 - 0.47	0.1
Iron (mg/L)	0.02 - 0.31	0.02 - 0.3	0.3
Zinc (mg/L)	0.01 - 0.48	0.008 - 0.27	5

4. Conclusion

The major five heavy metals such as lead (Pb), arsenic (As), chromium (Cr), Iron (Fe), zinc (Zn) and other physio-chemical characteristics like colour, pH, turbidity, electrical conductivity, total hardness, Total Suspended Solids, Total Dissolved Solids, Biochemical Oxygen Demand, assessed for subsurface water samples with respect to seasonal variations. It was observed that the characteristics of the subsurface water such as total hardness, TDS, sulphates, chlorides, BOD, chromium (Cr), arsenic (As) and few samples of iron (Fe) are beyond the permissible limits as mentioned in Bureau of Indian Standards (BIS) during the Pre-MN season and Post-MN. It shows that contamination is a threat to the quality of water in the areas surrounding the dumpsite due to permeation of leachate generated from the dumpsite depletes the subsurface water quality making it unfit for drinking purposes. Persistent exposure to iron, chromium, lead concentrations has a significant impact on the urinary tract, weakness of the immune system, respiratory system in humans, liver disease, heart attack, diabetes, etc. The higher concentration of chromium in both Pre-MN and Post-MN may be due to the impact of waste from the tannery units within the radius of the Pallavaram municipality. Suitable remedial measures may be taken by the authorities to avoid further contamination and to improve the quality of subsurface water in future by closing the dump site since the development and increase in residential activities will face a major problem in upcoming years.

Nomenclatures

$AgNO_3$	Silver nitrate
As	Arsenic
Cr	Chromium
Cr^{6+}	Hexavalent chromium
Cr III	Chromium oxide
Fe	Iron
HCl	Hydrochloric acid
$MgSO_4$	Magnesium sulphate

NH_4Cl	Ammonium chloride
pH	Hydrogen-ion activity
Zn	Zinc

Abbreviations

APHA	American Public Health Association
BOD	Biochemical Oxygen Demand
BIS	Bureau of Indian Standards
COD	Chemical Oxygen Demand
GPS	Global Positioning System
ICPMS	Inductively Coupled Mass Spectrometer
MSW	Municipal Solid Waste
Pre-MN	Pre-Monsoon
Post-MN	Post-Monsoon
TSS	Total Suspended Solids
TDS	Total Dissolved Solids
UV	Ultra Violet

References

1. Raman, N.; and Sathiyanarayanan, S. (2011). Quality assessment of ground water in Pallavapuram municipal solid waste dumpsite area nearer to Pallavaram in Chennai, Tamilnadu. *Rasayan Journal of Chemistry*, 4(2), 481-487.
2. Karpagam, V.; and Ramesh, K. (2015). Assessment of groundwater quality of Chrompet industrial area by water quality index method. *International Journal of Engineering Technology, Management and Applied Sciences*, 3(7), 123-132.
3. American Public Health Association (APHA) (2005). Standard methods for examination of water and wastewater (21st ed). Washington D.C.: American Public Health Association.
4. Ramesh, K.; and Thirumangai, V. (2014). Impacts of tanneries on quality of groundwater in Pallavaram. Chennai metropolitan city. *Journal of Engineering Research and Applications*, 4(1), 63-70.
5. Asfaw, A. (2014). Heavy metals concentration in tannery effluents, associated surface water and soil at Ejersa area of East Shoa, Ethiopia. *Merit Research Journal of Environmental Science and Toxicology*, 1(8), 156-163.
6. Ali, Z.; Malik, R.N.; and Qadir, A. (2013). Heavy metals distribution and risk assessment in soils affected by tannery effluents. *Chemistry and Ecology*, 29(8), 676-692.
7. Bureau of Indian Standards. (1987). Methods of sampling and test (physical and chemical) for water and wastewater. Part 1 sampling. CHD 32: Environmental Protection and Waste Management. *IS 3025-1*, New Delhi, India.
8. Vijayalakshmi, P.; and Abraham, M. (2017). Adverse effects of physico-chemical parameters of solid waste disposal on ground water quality- A case study. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, 8(3), 151-163.
9. Tinni, S.H.; Islam, M.A.; Fatima, K.; and Ali, M.A. (2014). Impact of tanneries. Waste disposal on environment in some selected areas of Dhaka City

Corporation. *Journal of Environmental Sciences and Natural Resources*, 7(1), 149-156.

10. Manjunatha, G.; Basavarajappa, B.E.; and Puttaiah, E.T. (2012). Physio-chemical parameters and groundwater quality status of villages of Sira Taluk, Tumkur District, Karnataka. *International Journal of Latest Research in Science and Technology*, 1(4), 423-426.
11. Balan, I.N.; Shivakumar, M.; and Kumar, P.D.M. (2012). An assessment of ground water quality using water quality index in Chennai, Tamil Nadu, India. *Chronicles of Young Scientists*, 3(2), 146-150.
12. Prasanna, K.; and Annadurai, R. (2016). Study on ground water quality in and around Perungudi solid waste dumping site in Chennai. *Rasayan Journal of Chemistry*, 9(2), 287-293.
13. Central Leather Research Institute *(*CLRI). (1990). Central leather research institute report on capacity utilization and scope for modernization in Indian tanning industry. Central Leather Research Institute, Chennai.
14. Ramesh, K.; and Seetha, K. (2013). Hydrochemical analysis of surface water and groundwater in tannery belt in and around Ranipet, Vellore district, Tamil Nadu, India. *International Journal of Research in Chemistry and Environment*, 3(3), 36-47.
15. Govindarajan, M.; and Senthilnathan, T. (2014). Ground water quality and its health impact analysis in an industrial area. *International Journal of Current Microbiology and Applied Sciences*, 3(7), 1028-1034.
16. Bureau of Indian Standards (2012). Drinking water specification (2nd revision). *IS 10500*, New Delhi.
17. Pandey, R.K.; Mishra, K.P.; and Tiwari, R.P. (2017). Characterization of municipal solid waste and evaluation of subsurface water quality in the vicinity of dumping sites. *International Journal for Research in Applied Science & Engineering Technology*, 5(10), 425-431.
18. Brindha, K.; Elango, L.; and Rajesh, V.G. (2010). Occurrence of chromium and copper in groundwater around tanneries in Chrompet area of Tamil Nadu. *Indian Journal of Environmental Protection*, 30(10), 818-822.
19. Tiwari, M.K.; Bajpai, S.; Dewangan, U.K.; and Tamrakar, R.K. (2015). Assessment of heavy metal concentrations in surface water sources in an industrial region of central India. *Karbala International Journal of Modern Science*, 1(1), 9-14.
20. Paul, D. (2017). Research on heavy metal pollution of river Ganga: A review. *Annals of Agrarian Science*, 15(2), 278-286.
21. Assubaie, F.N. (2015). Assessment of the levels of some heavy metals in water in Alahsa Oasis farms, Saudi Arabia, with analysis by atomic absorption spectrophotometry. *Arabian Journal of Chemistry*, 8(2), 240-245.