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ORIGINAL ARTICLE

A Study on the Landfill Leachate and its Impact on the Groundwater Quality of the Vellakal Village, Madurai, Tamilnadu.

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ABSTRACT
Tamil Nadu has emerged as the state with the highest level of urbanization (43.86%) in the country according to 2011 census. The urban population requires a wide range of urban services including water supply, sewerage and solid waste management. In most cities, the solid waste is dumped in open dumps without proper lining which affects the environmental media such as air, water and land. So, the present study was focused on the impact of leachate percolation on ground water quality. Leachate and ground water samples were collected from Vellakkal landfill sites in Madurai city, Tamil Nadu, India, to study the possible impact of leachate percolation on groundwater quality. Concentrations of various physicochemical parameters including heavy metals (Cd, Cr, Cu, Ni, Pb, and Zn) were determined in leachate samples and are reported. The concentrations of Cl-, TKN, Ammonia Nitrogen, COD were found to be in considerable levels in the leachate samples particularly near to the landfill sites, likely indicating that groundwater quality is being significantly affected by leachate percolation. Further they were proved to be the tracers for groundwater contamination in Bomban nagar and Vellakkal village. The presence of contaminants in groundwater particularly near the landfill sites warns its quality and thus renders the associated aquifer unreliable for domestic water supply and other uses.
Keywords: *Solid waste management, Groundwater contamination, Landfill Leachate .*

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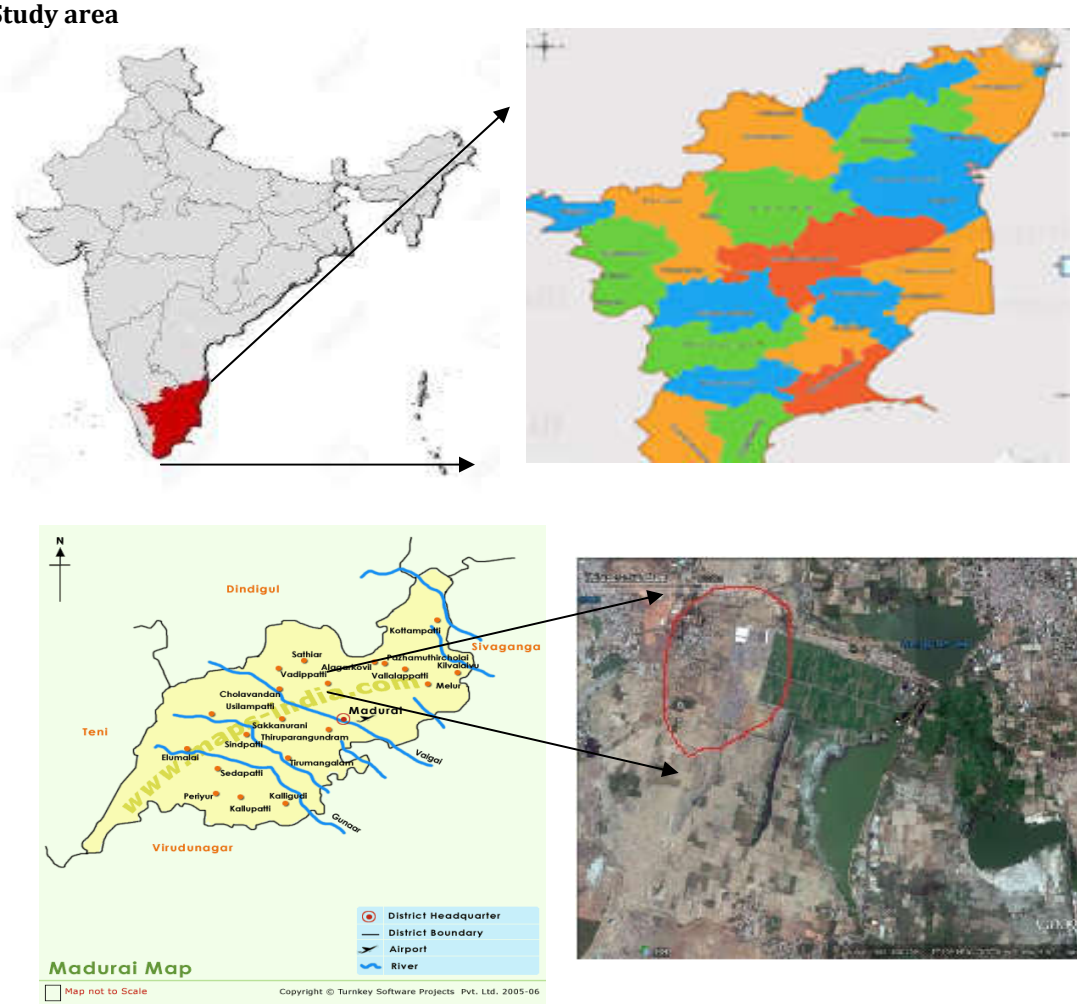
INTRODUCTION

Landfills have been identified as one of the major threat to groundwater resources [1] not only in India but throughout the world [2]. More than 90% of the Municipal Solid Waste (MSW) generated in India is directly dumped on land in an unsatisfactory manner [3].The solid waste placed in landfills or open dumps are subjected to either groundwater underflow or infiltration from precipitation or any other possibility of infiltration of water. During rainfall, the dumped solid wastes receivers water and the by-products of its decomposition move into the water through the waste deposition. The liquid containing innumerable organic and inorganic compounds is called 'leachate'. This leachate accumulates at the bottom of the landfill and percolates through the soil and reaches the groundwater [4]. Areas near landfills have a greater possibility of groundwater contamination because of the potential pollution source of leachate originating from the nearby dumping site. Such contamination of groundwater results in a substantial risk to local groundwater resource user and to the natural environment. The impact of landfill leachate on the surface and groundwater has given rise to a number of studies in recent years and gained major importance due to drastic increase in population [5]. There are many approaches that can be used to assess the groundwater and surface water contamination. It can be assessed either by the experimental determination of the impurities or their estimation through mathematical modeling [6]. In the present study, the impact of leachate percolation on groundwater quality was estimated from an unlined landfill site at Vellakkal of Madurai District, Tamil Nadu, India. Various physicochemical parameters including heavy metals were analyzed in the leachate and in groundwater samples to understand the possible link of groundwater contamination. The effect of depth and distance of landfill from groundwater sources were also studied and some remedial measures were discussed to reduce further contamination of groundwater.

MATERIAL AND METHODS

Study area



Madurai city is the head quarters of Madurai District, Tamil Nadu, India .The city's population is **1,017,865**, and lies between Latitude: 9°55.041′ N Longitude: 78°7.1772′ E. The average altitude of the region is about 144 m above the mean sea level The city is located to the southwest of Chennai and to the north of Kanniyakumari. The picturesque hills of Nagamalai and Sirumalai are situated to the northwest of Madurai. The city is nestled on the productive basin of the Vaigai River which flows across the city and splits it into two equal parts. The Vaigai River flows from the north to the south. The territory surrounding the city is used mostly for farming operations and this is supported by the Periyar Dam. The city covers a total area of 20.01 sq miles or 51.82 sq km. Madurai has moderate-dry weather throughout except during the monsoon seasons. It also experiences heavy rains primarily during the periods of monsoon with an average annual rainfall of 840 mm. The depth of groundwater table in Madurai city varies from 5 to 25 m with respect to ground level. In Madurai City garbage is generated at the rate of 406 gram per day per head accumulating to a massive quantum of 548 Metric Ton per day. This is slightly higher when comparing similar level of cities where the per capita generation of waste is around 400 grams per day and the reason for the excess rate of creation of waste is due to the heavy influx of floating population which is estimated to be around 3 lakhs. Out the accumulated garbage released by the houses, shops, daily and weekly markets, commercial establishments, hotels, hospitals and industries, garbage generated from the house account of 64%. Household wastes contains mainly residual vegetables and food which could be easily disposed. But the scientific disposal of solid waste such as plastic, paper discharged by the commercial establishments, without affecting the environment remains to be a great challenge. The existing SWM system lacks adequate infrastructure facilities to implement SWM system as per MSW Rules2016. Accordingly, the project has been prepared with a view to rehabilitate and augment the existing Municipal Solid Waste Management system through an integrated approach. The project proposal envisage processing and disposal of Municipal Solid Waste generated in Madurai City. Bio-degradable waste is proposed for aerobic composting with a processing facility of capacity of 300 MT/

day at the Vellakkal Recyclable waste is proposed for environmentally safe disposal through a Sanitary Landfill with a capacity of 296 MT/day. Recyclable waste shall be salvaged for revenue generation. Landfill space optimization (reduction) is biodegradable and non-recyclable such as rubber, soiled cloth and similar waste to State Govt. operated Cement Industries in the region for use as supplemental raw material in the incinerator. Through this project, the coverage has increased from 80% to 98%, door to door collection has been increased from 65 % to 95%. The crude method of dumping municipal solid waste has been overcome by way of scientific disposal of waste. The user charges imposed for the domestic collection adds to Rs. 5.00 crores per annum. Besides, the number of complaints related to SWM has reduced by over 95% [7].

Sampling technique adopted

Once leachate enters a storage facility or contacts air,it is subject to physical, chemical and biological reactions that can change the composition of the leachate. Therefore, the best representative sample must be collected as close to the leachate generation point as possible, ideally as soon as the leachate leaves the waste. The leachate collection location should be selected with this objective in mind. Typically, leachate is collected using grab samples, i.e., single samples taken at specific times. (SW Jackson, Suite 320, Topeka, Kansas)**.** Leachate is generated on account of the infiltration of water into dumpsites and its percolation through waste as well as by the squeezing of the waste due to self weight. Water that penetrates into landfill picks up the soluble constituents from the wastes and may enter either the ground water or the surface water and thus act as a vehicle, carrying potentially toxic matter from the landfill to the water sources. The important factors that influence leachate quality are waste composition, elapsed time, temperature, moisture and available oxygen.In general, leachate quality of the same waste type may be different in landfills located in different climatic regions. Dumpsite operational practices also influence the leachate quality. Significant quantity of leachate is produced from the active phases of a landfill under operation during the monsoon season. Leachates which emerge out of the dumpsite percolate down to the aquifer. Characterization of the leachate is necessary in the assessment of ground water contamination near disposal site. The leachate samples were collected from MSW yard located near Vellakal village. To evaluate the environmental impacts associated with solid waste landfilling, leachate and groundwater quality near the landfills were analyzed. The results of physico-chemical analyses of leachate confirmed that its characteristics were highly variable with severe contamination of organics, salts and heavy metals. It was also found that groundwater in the vicinity of the landfills did not have severe contamination, although certain parameters exceeded the WHO and EPA limits. These parameters included conductivity, total dissolved solids, chlorides, and Fe. The results suggested the need for adjusting factors enhancing anaerobic biodegradation that lead to leachate stabilization in addition to continuous monitoring of the groundwater and leachate treatment processes. In an effort to study the extent of the groundwater contamination in Bomban nagar and Vellakkal four observation wells were selected to collect groundwater samples .The ground water depth comes in between 80 to 200 mts. The geomorphological study of the region indicates that most of the area where the landfill sites are located is found to have deep pediments. The region also consists shallow and buried pediments in other parts. The groundwater samples were collected during February after the extraction of water from borewells.

Analytical methods

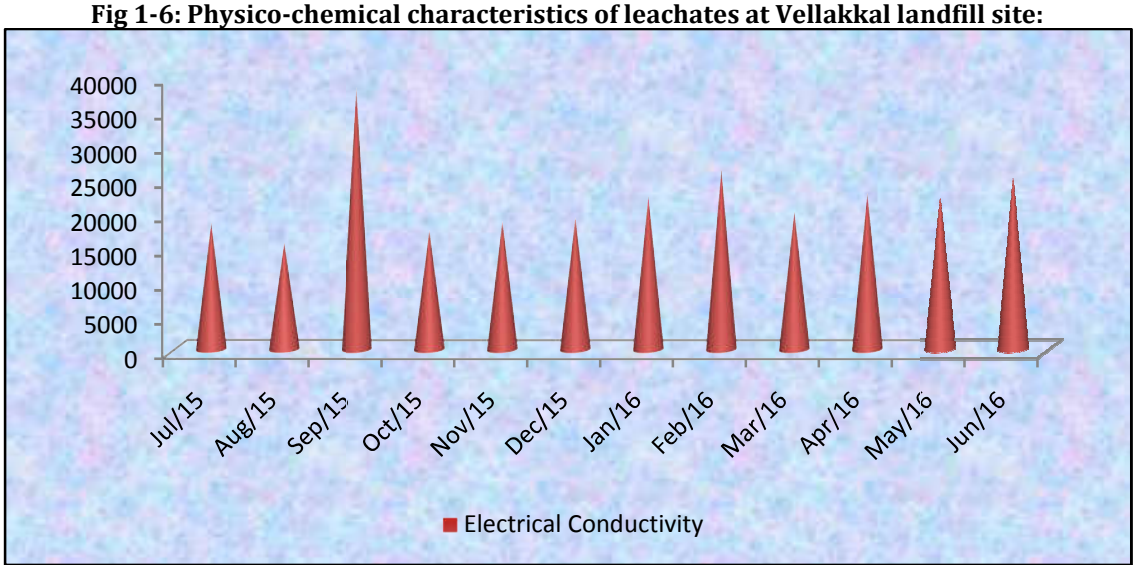
Samples were immediately transferred to the laboratory and were stored in refrigerator at 4°C. The sampling wells were selected based on the availability of the wells around the landfill sites and to represent the whole area [8]. The analysis was started without any delay using the standard procedure prescribed by the American Public Health Association (APHA,). The leachate samples were analyzed for EC,TSS, TDS, Chloride, COD, TKN, Ammonia Nitrogen, and heavy metals (Tcr,Cu,Zn,Pb,Ni,Cd).The ground water samples were tested for drinking water parameters prescribed by CPCB which include, total dissolved solids (TDS), total alkalinity (TA), total hardness (TH), Phosphate(P), fluoride (F^-), nitrate (NO_3^-)and Zinc. Estimation of COD for leachate was done by reflux titrimetry, while TA, TH, and Cl^- were estimated by titration, Fluoride was estimated by SPANDS, while NO_3^-, Phosphate were determined using UV spectrophotometer. The concentrations of cadmium (Cd), copper (Cu), chromium (Cr), iron (Fe), nickel (Ni), lead (Pb) and zinc (Zn) were determined using a Thermofisher Atomic Absorption Spectrometer (AAS). The limit of detection (BDL) of these elements was 0.001 mg/L. The depth of groundwater table was also measured in each well using water level recorder. It varied between 5 and 25 m with respect to the ground surface. All the experiments were carried out in triplicate and the results were found reproducible within ±3% error. The data were statistically analyzed by setting up and calculating a correlation matrix for the various parameters using Statistical Package for Social Sciences (SPSS**)**.

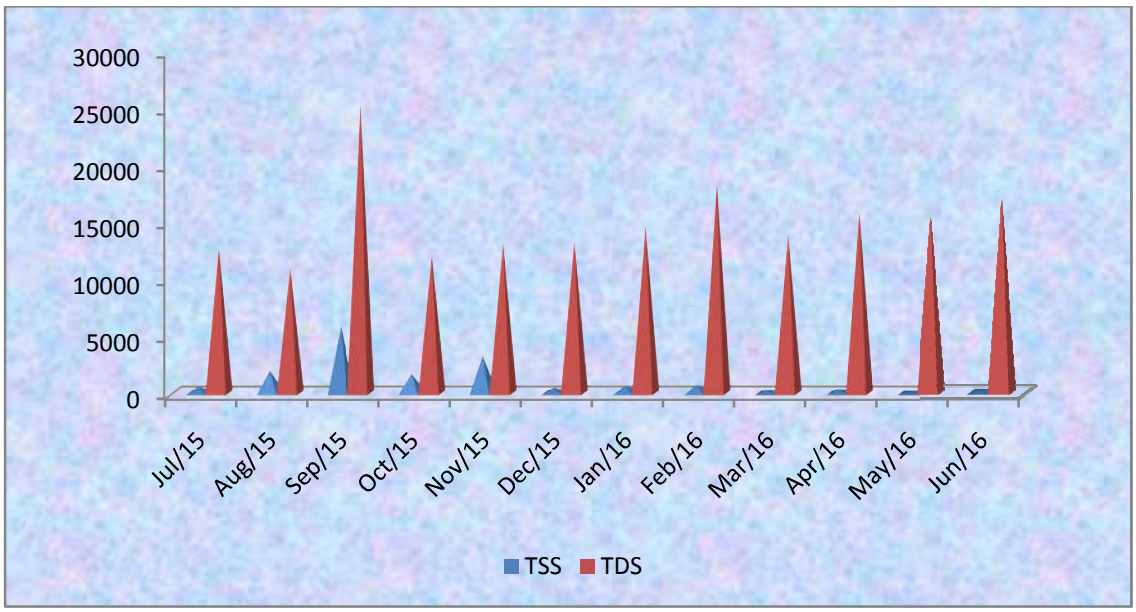
RESULTS

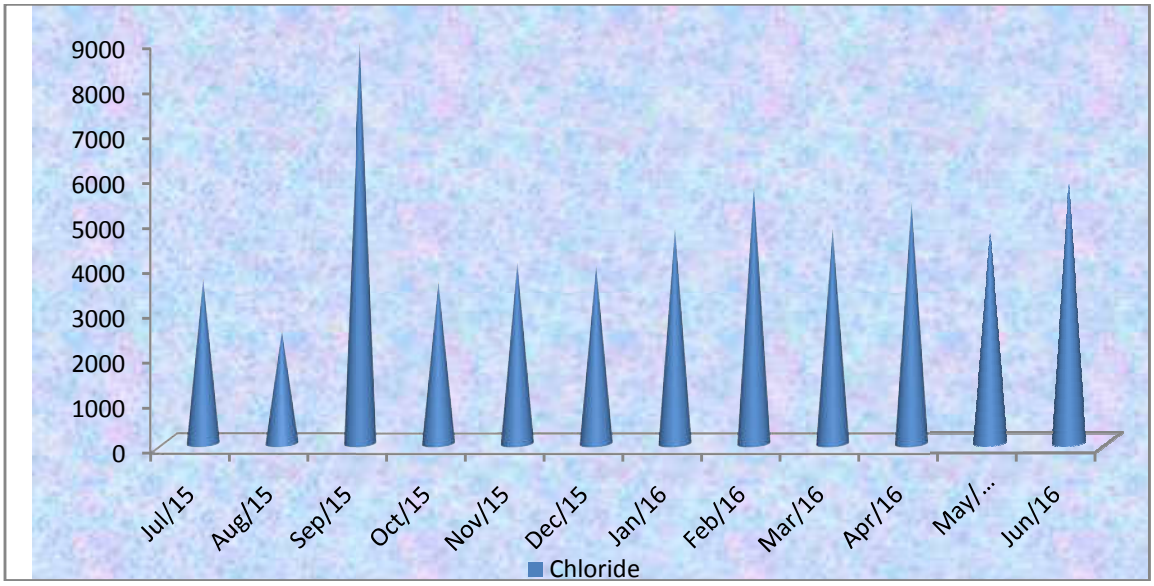
Leachate characteristics

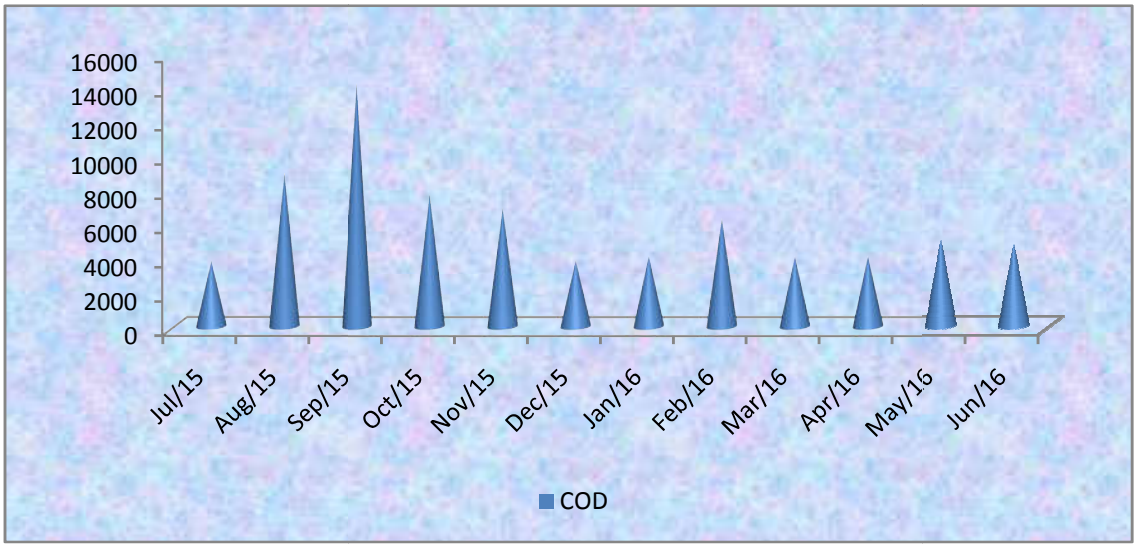
Physico-chemical characteristics of the leachate depend primarily upon the waste composition and water content in total waste (Mohan and Gandhimathi). The characteristics of the leachate samples collected from Vellakkal landfill sites are presented in Table 1. The EC value of lechate of Vellakkal landfill site was 38100,the TDS (25424 mg/L), and COD (14145 mg/L) values were high in the leachate samples during September 2015. Among the nitrogenous compounds, ammonia nitrogen (1036 mg/L) TKN (1266 mg/L was present in high concentration during September 2015. A high concentration of Cl^- (8984 mg/L) was also observed in the leachate samples. Groundwater chemistry of a region may also be influenced by complex contamination sources and geochemical processes [11]. The contamination levels are high in the wells near to the landfill sites. Table 3

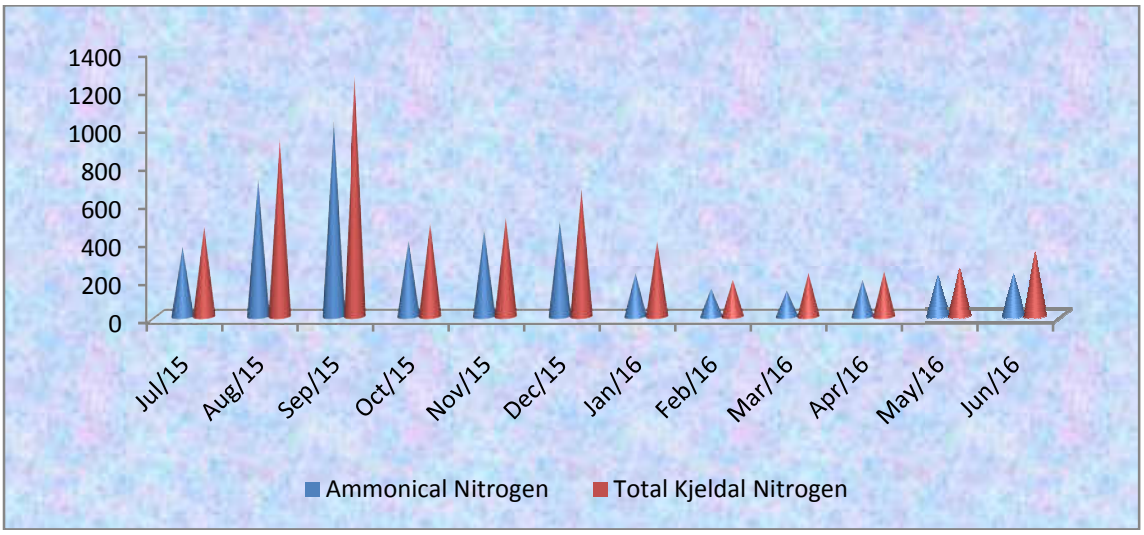
Fig 1-6: Physico-chemical characteristics of leachates at Vellakkal landfill site:

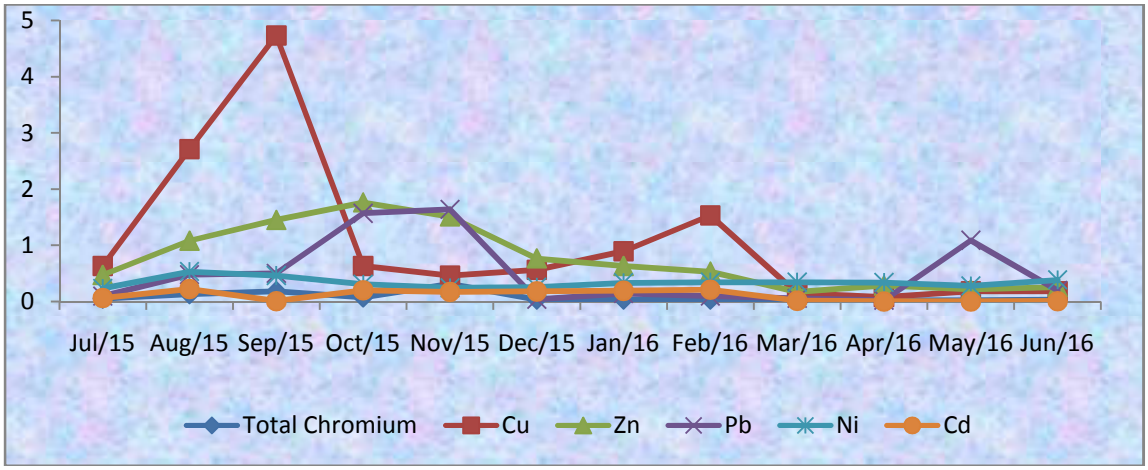












*All in mg/L except EC (µS/cm).

Table 1: Study of Leachate parameters with Indian (BIS) standards

Parameters	Units	Minimum	Maximum	Average ±SD	BIS Standards (Max. allowable limit)*
EC	µmhos/cm	15590	38100	22177.2 ±5908.7	---
TSS	mg/L	118	5960	1345.8±1733.3	100
TDS	mg/L	11090	25424	15336.2±3812.	2100
Chloride	mg/L	2518	8984	4837.3±1618.6	1000
COD	mg/L	3871	8960	6151.4±3032.4	250
$NH_4^+N^2$	mg/L	140	1036	387.8±268.4	50
TKN	mg/L	196	1266	501.6±321.9	100
Cr	mg/L	<0.03	0.31	0.1±0.1	2.0
Cu	mg/L	0.15	4.73	1.1±1.4	3.0
Zn	mg/L	0.17	1.76	0.8±0.6	5.0
Pb	mg/L	0.023	1.64	0.5±0.6	0.1
Ni	mg/L	0.23	0.53	0.5±0.1	3.0
Cd	mg/L	<0.001	0.22	0.1±0.1	2.0

*Source Municipal solid waste Management Regulations-2016

Table 2: Study of ground water quality near landfill site:

Parameter	Units	Near Admin building	Bomban nagar Ist Street	Bomban nagar IInd Street	Bomban nagar North Street
TDS	µmhos/cm	3218	2398	2498	798
TA	mg/L	390	424	272	284
TH	mg/L	1680	1340	1420	300
Nitrate	mg/L	17.9	10	16	1.22
Phosphate	mg/L	2.47	1.26	0.15	0.18
Fluoride	mg/L	1.29	2.54	2.51	1.52
Zinc	mg/L	0.025	0.028	0.010	0.002

DISCUSSION

There were four wells were selected for sampling which located around leachate discharge site and the distances were 75,100,175 and 1000 meters respectively. Well number one (MSW Administration building) located nearer and well number four (Bomban nagar North Street) located far. Higher value of EC,TDS,TA,TH and Fluoride were recorded and Nitrate ,Phosphate and Zinc found to be within the limit. The extent of contamination level of groundwater quality due to leachate percolation depends upon a number of factors like chemical composition of leachate, rainfall, depth and distance of the well from the pollution source (the landfill site in the present case). Groundwater samples of different depths and distances from landfill sites were analyzed in the present study to understand the level of combination [4]. From the analysis, it is evident that the concentrations of contaminants were found to be high in the sampling sites which are near to the landfills. Interestingly, the groundwater contamination drops fast

with increase in the distance of sampling sites from the landfill sites. The percolation of leachate was further found to become gentler. However, this aspect needs further investigations by drilling more wells of varying depths for having a proper correlation between distance and percolation depth.
Although, the concentrations of few contaminants did not exceed drinking water standard even then the groundwater quality represent a significant threat to public health. Strictly speaking one should avoid using groundwater drawn from the wells located in proximity of the waste dumping sites. If this is unavoidable, deeper drilling and frequent analysis of water samples are desirable. Efforts should be made to supply clean water through pipelines from distant sources.

Table 3: Comparison of groundwater quality parameters with Indian (BIS) and International (WHO) standards

Parameters	Units	Minimum	Maximum	Average ±SD	BIS Standards (Max. allowable limit)	WHO Standards (Max. allowable limit)	Wells nos. exceeding Max. allowable limit		Undesirable effect
							As per BIS standard	As per WHO standards	
TDS	µmhos/cm	798	2498	2228 ±884.14	500	500	1,2,3,4	1,2,3,4	Gastro -intestinal irritation
TA	mg/L	272	424	342.5 ±65.75	200	120	1,2,3,4	1,2,3,4	
TH	mg/L	300	1680	1185 ±526.19	300	300	1,2,3	1,2,3	Scale formation
Nitrate	mg/L	1.22	17.9	11.28 ±6.50	45	45	--	--	Blue baby
Phosphate	mg/L	0.15	2.48	1.015 ±0.95	5.0	5.0	---	--	Gastrointestinal disorders
Fluoride	mg/L	1.29	2.54	1.965 ±0.57	1.2	1.5	1,2,3,4	2,3,4	Fluorosis
Zinc	mg/L	0.002	0.028	0.016 ±0.012	15.0	5.0	--	--	

CONCLUSION

The moderately high concentrations of TDS, TH, Fluoride and TA etc. in groundwater were found near landfill which deteriorates its quality for drinking and other domestic purposes. Further, the presence of P, NO_3^- and Zinc shows found as tracer with relation to leachate percolation. As there is no natural or other possible reason for high concentration of these pollutants, it can be concluded that leachate has significant impact on groundwater quality in the area near to landfill site. The quality of the groundwater was found to improve with the increase in depth and distance of the well from the landfill site. Although, the concentrations of few contaminants do not exceed drinking water standard even then the groundwater quality represent a significant threat to public health.

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