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Effect of Municipal Solid Waste Leachate on Ground Water Quality of Thiruvananthapuram District, Kerala, India

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Abstract The study aimed to assess the effect of Municipal Solid Waste (MSW) leachate on ground water quality by using water quality index (WQI) in Thiruvananthapuram corporation area, Kerala, India. Ground water samples were collected from dug wells 1 kilometer around the MSW dumping site and control samples from 10 kilometer away from the site both in two seasons (pre monsoon and post monsoon) for analysis of physicochemical and microbiological parameters. The characteristics of leachate of the MSW were also studied. Ground water near the MSW dumping sites were found to be more polluted than the control sites in both seasons. From this study, it is evident that the leachate from the MSW dumping site plays a major role in polluting the ground water in the area. The nitrate (88 mg/l) and total dissolved solids (TDS) (726 mg/l) concentration in ground water is in alarming state that should be taken into consideration before using for drinking purpose. The ground water near the MSW dumping site was also contaminated by fecal coliform (8 CFU/100ml) which makes unsuitable for drinking purpose.

Keywords: *ground water, pollution, leachate, municipal solid waste, water quality index*

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1. Introduction

Water is a precious resource and it has to be treated as such. The challenge in Kerala is mainly the management of water and waste management. The strategy should be one of sustainable integrated management of water in all areas. Water needs to be conserved and valued. However in several parts of the world, humans do not have any access to safe drinking water, due to the fact that water is contaminated. Access to safe drinking water remains an urgent necessity, as 30 % of urban and 90% of rural Indian population still depend completely on untreated surface or groundwater resources [4].

Waste deposited in landfills or in refuse dumps immediately becomes a part of the prevailing hydrological system. Fluids derived from rainfall, snowmelt and groundwater, along with liquids generated by the waste itself through processes of hydrolysis and solubilisation, caused by an entire series of complex biochemical reactions during degradation of organic wastes, percolate through the deposit and mobilise different components within the waste. This leachate, the liquid drains from the dump, chiefly organic carbon largely in the form of fulvic acids migrate downward and contaminate the groundwater [28].

The natural aquatic resources are inflicting serious and varied pollution in aquatic environment resulting in water quality and depletion of aquatic biota. It's thus necessary that the quality of drinking water ought to be checked at regular intervals as a result of the use of contaminated drinking water, human population suffers from a range of water borne diseases [24]. Degradation end products of waste components like food, paper and textiles consumes oxygen thereby changing the oxidation-reduction potential of the liquid present and probably influence quality of different constituents. Percolating rainwater provides a medium in which waste, particularly organics, can undergo degradation into less complicated substances through biochemical of organic chemistry reactions involving dissolution, hydrolysis, oxidisation and reduction, processes controlled to a large extent within landfills and dumps by microorganisms, primarily bacteria. Due to the decomposition of organic matter, leachate derived from landfills or dumps comprises primarily dissolved organic carbon, for the most part within the form of fulvic acids [8]. The solubility of metals in leachate is enhanced through complexation by dissolved organic matter. The solubility of organic contaminants (e.g. solvents) in waste may also be slightly enhanced through the presence of high levels of organic carbon in leachate. Hydrophobic compounds may be mobilised through leachate, as they adsorb to organic carbon in solution [25].

In unsealed landfills above an aquifer, waters percolating through landfills and refuse dumps often accumulate or 'mound' within or below the landfill. This is often because of production of leachate by degradation processes operative inside the waste, additionally to the rainwater percolating down through the waste [30]. The raised hydraulic head developed promotes downward and outward flow of leachate from the landfill or dump. Downward flow from the landfill threatens underlying groundwater resources whereas outward flow may result in leachate springs yielding water of a poor, often dangerous quality at the periphery of the waste deposit. Observation of leachate springs or poor water quality in adjacent wells/boreholes measure indicates that leachate is being produced and is moving. Leachate springs represent a major risk to public health, therefore their detection in situation assessment is vital so as to prevent access to such springs [19].

Leachate migration is also affected by the type of waste deposited. Compaction of waste before deposition reduces its permeability, whereas regular application of a topsoil cover between the loadings of waste to landfills induces layering. These characteristics in evitably bring about to preferential flow paths through landfills. Johnson et al. [18] found, for instance, that residence times for rainwater entering a landfill varied from a period of a few days to several years. This is often mirrored within the frequently temporal nature of leachate "springs", which might seem in wet seasons however afterwards; disappear in dry seasons to leave patches of discolored soil [17].

Thiruvananthapuram the capital city of Kerala is one among the most populated cities in the state. As per census (2011), the entire population of Trivandrum city is 752,490. The Municipal Solid Wastes (MSW) generated by the people are disposed in open dumps, thus posing huge threat to the quality of ground water. MSW leachate contains variety of chemicals like inorganic and complex organic chemicals, detergents and metals [9]. The dumping site is in an extremely populated area with no proper maintenance and therefore the people are using ground water for their daily usage. Hence, this work was undertaken to study the effect of open dump landfills and the leachates emanating from these landfills on surrounding ground water quality.

2. Materials and Methods

2.1. Study Area

The study area comprises 10 km radius of the municipal solid waste dumping site of Thiruvananthapuram Corporation in Kerala, India. The corporation dumps its waste in open area which is in the midst of the heavily populated city around two lakhs people. The drinking water source of the people around the dumping site is mainly ground water from dug wells which prone to pollution by the leachate. The people in the area are suffering from different water borne diseases especially children. The study area lies between 8°28'44.61''N, 76°57'12.13''E(S3)., 8°28'47.54''N, 76°57'18.39''E (S2), and 8°28'46.36''N, 76°57'21.97''E (S1) near the municipal solid waste dumping site and remaining three control stations(8°28'5.92''N, 76°57'7.88''E (S5)., 8°28'2.42''N, 76°57'9.44''E(S6) and 8°27'57.15''N, 76°57'17.16''E(S7) which are nearly five kilometers away from the sampling site. The location of Municipal Solid Waste (MSW) dumping site of Thiruvananthapuram is 8°28'48.19''N 76°57'8.86''E(S4).

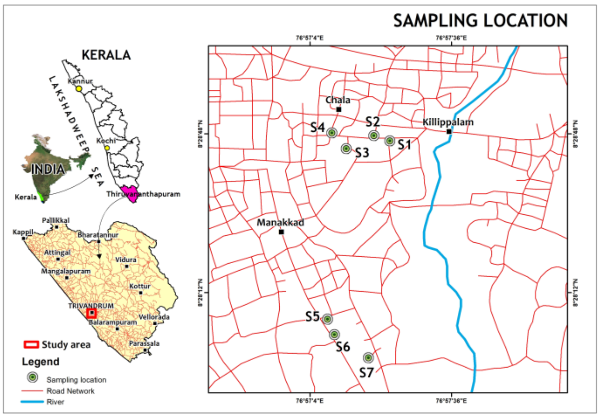

Figure 1. Sampling location

2.2. Sample Collection and Analysis

A preliminary survey was conducted to evaluate the effect of leachate and ground water quality on human health. Six sampling sites were selected, three sites near to the MSW dumping site and the remaining three control sites which is five kilometers away from the MSW site. Samples were taken during pre monsoon and post monsoon 2013. Water samples from dug well (Six numbers) and leachates were collected in plastic bottles and glass containers for microbiological analysis. Collected samples were placed in icebox and transported to laboratory within 3 hours for analysis.

The samples were analysed for various parameters as per standard methods for the examination of water and waste water [3]. The results obtained were compared with the drinking water standards as specified by WHO [29] and Indian Standards [6].

The depth of wells varies from 3-5 meters from ground level. The soil type mainly of sandy loam in the area.

2.3. Microbiological Analysis

The fecal coliforms were estimated using M-FC Agar at 44.5°C for 24 hrs employing membrane filter technique [3] and the colonies were identified as bluish green in color.

2.4. Water Quality Index

Water quality index (WQI) represents water quality assessment through the determination of physico-chemical parameters of Ground water; it can act as an indicator of water pollution because of natural inputs and anthropogenic activities [31]. WQI is one of the most effective tools to provide feedback on the quality of water to the policy makers and environmentalists. It provides a single number expressing overall water quality status of a certain time and location. It is actually the categorization counting the combined influence of different important water quality parameters; as it is calculated based on the concentration of several important attributes [27].

For computing water quality index three steps were followed. In the first step, each of the nine parameters has been assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes. The maximum weight of 5 has been assigned to the parameter nitrate due to its major importance in water quality assessment [23]. Magnesium which is given weight of 2 as magnesium by itself may not be that harmful [3].

In the second step, relative weight (Wi) was computed from the following equation:

$$\text{Wi} = \text{wi} + \sum_{i=1}^{n} \text{wi}$$

Where (Wi) is the relative weight, (wi) is the weight of each parameter and ‘n’ is the number of parameters. The Calculated Water Quality Index of drinking water in different sites during pre monsoon and post monsoon 2013 are given in the Table 1 to Table 4.

In the third step, a quality rating scale (qi) for each parameter was assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the BIS and the result is multiplied by 100:

$$\text{qi} = (\text{Ci} / \text{Si}) * 100$$

Where **qi** is the quality rating, **Ci** is the concentration of each chemical parameter in each water sample in mg/*l*, and **Si** is the BIS (Bureau of Indian standards) water standard for each chemical parameter in mg/l according to the guidelines of the BIS, 2012 and WHO, 2006.

For computing the **WQI**, the **SIi** was first determined for each chemical parameter, which is then used to determine the **WQI** as per the following equation

$$\text{SIi} = \text{Wi} * \text{qi}$$

$$\text{WQI} = \sum \text{SIi}$$

SIi is the sub index of Ith parameter, qi is the rating based on concentration of ith parameter and **n** is the number of parameter. The computed WQI values are classified into five types “excellent water”, “good water”, “poor water” “very poor water” and “water unsuitable for drinking” as shown in the Table 5.

2.5. Statistical Analysis

The data obtained on the physicochemical parameters of the ground water was subjected to correlation analysis. The correlation was carried on statistical software SPSS version 18.

3. Results

3.1. Physicochemical Characteristics

The results from the analysis of water samples collected during premonsoon and post monsoon of 2013 are presented in Figure 2 and Figure 3.

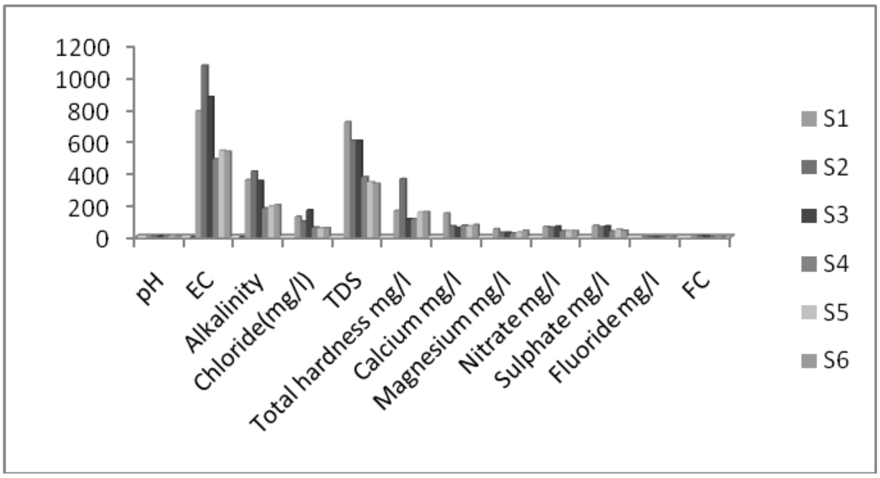

Figure 2. Physicochemical parameter of water samples during Premonsoon season

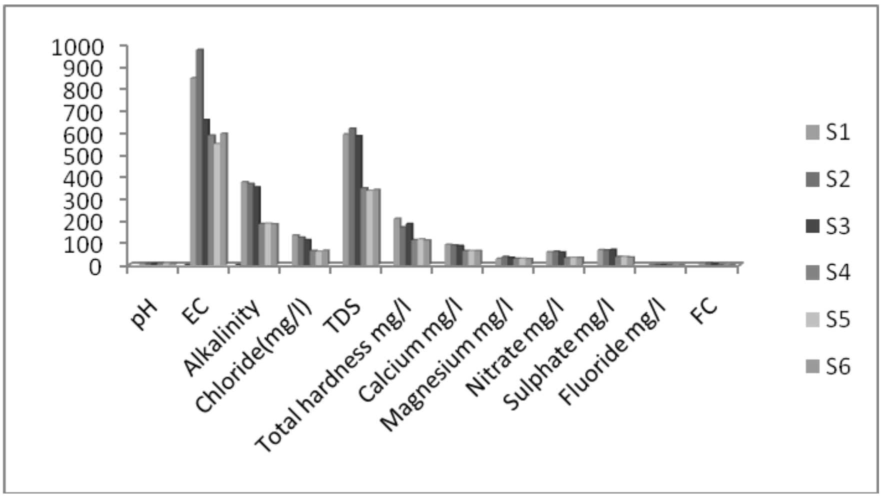

Figure 3. Physicochemical parameter of water samples during Post monsoon season

In pre monsoon, pH of the water was in the range from 6.86 to 7.29. Maximum pH was observed in sampling station 4 and minimum was observed in the station 3. Similarly, during post monsoon, the pH of samples ranged from 6.59 to 7.69. The conductivity of the samples varied between 424 µS/cm to 1075µS/cm during premonsoon and between 391 µS/cm to 975µS/cm during post monsoon. Maximum conductivity was observed in station 2 during premonsoon and station 3 during post monsoon. Minimum conductivity was observed in station 4 during premonsoon and in station 5 during post monsoon.

Total dissolved solids in samples range from 286 mg/l to 726 mg/l during premonsoon and from 258 mg/l to 614 mg/l during post monsoon. Maximum TDS was observed in sample 1 during premonsoon and in station 2 during post monsoon. Minimum TDS was observed in station 6 during premonsoon and in station 5 during post monsoon. Total hardness of the samples ranged from 98 mg/l to 365 mg/l during premonsoon and 56 mg/l to 148 mg/l during post monsoon. Maximum total hardness was observed in sample 1 during premonsoon and in post monsoon. Minimum total hardness was observed in station 5 during premonsoon and in station 6 during post monsoon season. Calcium concentration ranged from 38.6 mg/l to 148.2 mg/l during premonsoon and from 44.2 mg/l to 112.6 mg/l during post monsoon. Maximum Calcium was observed in sample 1 during premonsoon and in post monsoon seasons. Minimum Calcium was observed in station 3 during premonsoon and in station 4 during post monsoon.

Magnesium range from 28.4 mg/l to 86.8 mg/l during premonsoon and from 18.2 mg/l to 126 mg/l during post monsoon. Maximum magnesium was observed in station 1 during premonsoon and in station 2 during post monsoon. Minimum Mg was observed in station 4 during premonsoon and in station 4 during post monsoon. Nitrate ranged from 32.4 mg/l to 88 mg/l during premonsoon and from 24 mg/l to 76 mg/l during post monsoon. Maximum nitrate was observed in sample 3 during premonsoon and in station 2 during post monsoon. Minimum nitrate was observed in station 3 during premonsoon and in station 2 during post monsoon. Sulphate ranged from 38 mg/l to 82.4 mg/l during premonsoon and from 32 mg/l to 78.4 mg/l during post monsoon. Maximum sulphate was observed in sample 1 during premonsoon and in station 3 during post monsoon. Fluoride ranged from 0.56 mg/l to 0.76 mg/l during premonsoon and from 0.44 to 0.88 mg/l during post monsoon. Maximum fluoride was observed in sample 1 during premonsoon and in post monsoon season. Minimum fluoride was observed in station 6 during premonsoon and in station 5 during post monsoon. Total and fecal coliform ranged from 1CFU/100ml (control stations) to 8 CFU/100ml (near MSW stations).

Alkalinity ranged between 188 mg/l to 412 mg/L CaCO3 during premonsoon and between 185.3 mg/l - 375.8 mg/L CaCO3 during post monsoon. The maximum alkalinity was observed in station 2 during premonsoon and station1during post monsoon. Minimum alkalinity concentration was observed in station 3 during premonsoon and in station 6 during post monsoon. Chloride ranged from 48 mg/l to 170 mg/l during premonsoon and from 54 mg/l to 142 mg/l during post monsoon. Maximum chloride concentration was observed in station 3 during premonsoon and in station 1 during post monsoon. Minimum chloride concentration was observed in station 5 during premonsoon and in post monsoon season.

3.2. Leachate Characteristics

The leachates from the municipal solid waste dumping site were analyzed for pH, conductivity, alkalinity, chloride, nitrate, Chemical Oxygen Demand (COD) and sulphate. The results were shown in the Figure 4.

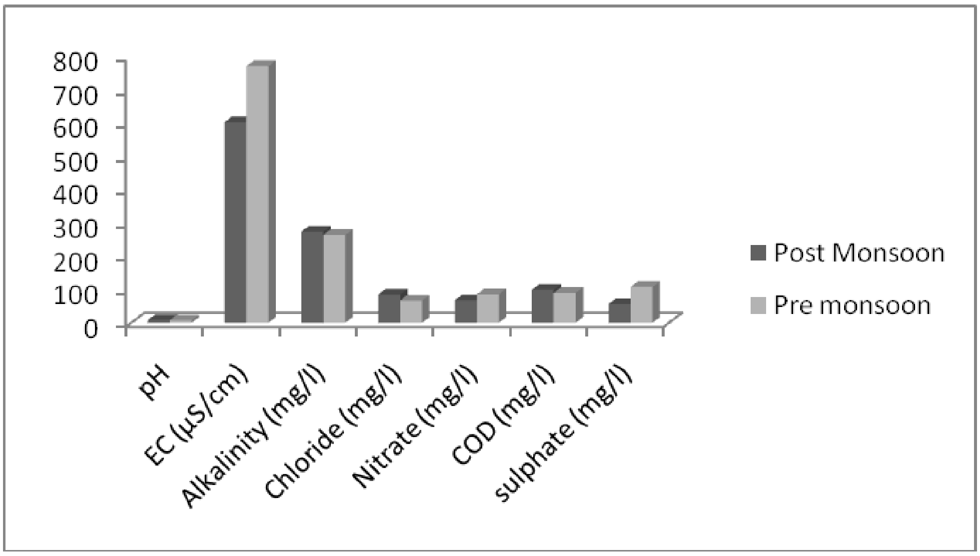

Figure 4. Leachate characteristics of the MSW

3.3. Water Quality Index (WQI)

The water quality index of ground water is presented in the Table 1 to Table 4. The WQI of Ground water in stations near MSW dumping stations during pre monsoon is 101.9 and in control stations were 64.9. The WQI of Ground water in stations near MSW dumping stations during post monsoon were 97.6 and that of control stations were 58.7.

Table 1. The Water Quality Index of Ground water in stations near MSW dumping yard during pre monsoon

Parameters	Concentration of parameters (mg/l) (Ci)	Weightage (wi)	Relative weight (Wi)	Standard Concentration (mg/l) (Si)	Quality Rating (qi)	Sub Index (SIi)
TDS	643.00	4	0.13	500	128.6	17.1
Chloride	132.00	3	0.10	250	52.8	5.3
Total hardness	214.00	3	0.10	300	71.3	7.1
Calcium	92.00	2	0.07	75	122.7	8.2
Magnesium	36.00	2	0.07	30	120.0	8.0
Nitrate	64.30	5	0.17	45	142.9	23.8
Sulphate	68.00	4	0.13	200	34.0	4.5
Fluoride	0.68	4	0.13	1	68.0	9.1
Alkalinity	374.00	3	0.10	200	187.0	18.7
					WQI= 101.9	

Table 2. The Water Quality Index of Ground water in control stations pre monsoon

Parameters	Concentration of parameters (mg/l) (Ci)	Weightage (wi)	Relative weight (Wi)	Standard Concentration (mg/l) (Si)	Quality Rating (qi)	Sub Index (SIi)
TDS	352.00	4	0.13	500	70.4	9.4
Chloride	58.00	3	0.10	250	23.2	2.3
Total hardness	142.00	3	0.10	300	47.3	4.7
Calcium	72.00	2	0.07	75	96.0	6.4
Magnesium	32.00	2	0.07	30	106.7	7.1
Nitrate	39.00	5	0.17	45	86.7	14.4
Sulphate	42.00	4	0.13	200	21.0	2.8
Fluoride	0.61	4	0.13	1	61.0	8.1
Alkalinity	192.00	3	0.10	200	96.0	9.6
					WQI= 64.9	

Table 3. The Water Quality Index of Ground water in stations near MSW dumping stations during post monsoon

Parameters	Concentration of parameters (mg/l) (Ci)	Weightage (wi)	Relative weight (Wi)	Standard Concentration (mg/l) (Si)	Quality Rating (qi)	Sub Index (SIi)
TDS	598.00	4	0.13	500	119.6	15.9
Chloride	124.00	3	0.10	250	49.6	5.0
Total hardness	189.00	3	0.10	300	63.0	6.3
Calcium	89.00	2	0.07	75	122.7	8.2
Magnesium	33.00	2	0.07	30	120.0	8.0
Nitrate	59.00	5	0.17	45	131.1	21.9
Sulphate	68.00	4	0.13	200	34.0	4.5
Fluoride	0.72	4	0.13	1	72.0	9.6
Alkalinity	365.00	3	0.10	200	182.5	18.3
					WQI= 97.6	

Table 4. The Water Quality Index of Ground water in control stations during post monsoon

Parameters	Concentration of parameters (mg/l) (Ci)	Weightage (wi)	Relative weight (Wi)	Standard Concentration (mg/l) (Si)	Quality Rating (qi)	Sub Index (SIi)
TDS	342.00	4	0.13	500	68.4	9.1
Chloride	64.00	3	0.10	250	25.6	2.6
Total hardness	114.00	3	0.10	300	38.0	3.8
Calcium	64.00	2	0.07	75	85.3	5.7
Magnesium	28.00	2	0.07	30	93.3	6.2
Nitrate	32.00	5	0.17	45	71.1	11.9
Sulphate	36.00	4	0.13	200	18.0	2.4
Fluoride	0.58	4	0.13	1	58.0	7.7
Alkalinity	186.00	3	0.10	200	93.0	9.3
					WQI= 58.7	

Table 5. Water quality classification based on WQI value [29]

WQI Value	Water Quality
<50	Excellent
50 – 100	Good water
100 – 200	Poor water
200 – 300	Very poor water
>300	Water unsuitable for drinking

4. Discussion

The study conducted in two seasons Pre monsoon and post monsoon of seven different sites in Thiruvananthapuram corporation area, three of them are near to the dumping site and the rest is five kilometers far away from the dumping site to know the difference in ground water and the impact of leachate. Due to urbanization and heavy industrialization the ground water of our country becomes unpleasant for drinking [20].

In pre monsoon and post monsoon, pH of all the stations in Trivandrum city was found within the range of Indian standards (6.5-8.5). pH have negative correlation with sulphate during premonsoon. Electrical Conductivity (EC) and Total Dissolved Solids (TDS) are basic indicators of the total mineral contents of water and may be related to problems such as excessive hardness, corrosive characteristics or other mineral contamination [16]. The conductivity values of groundwater samples have maximum in pre monsoon (1075µs/cm).

The Total dissolved solids (TDS) of six stations were higher than the standards in pre monsoon. In post monsoon also TDS was high in all the stations near the MSW dumping site. TDS and Electrical conductivity has high positive correlation in pre and post monsoon. Craun et al. [10] reported that increase TDS concentrations in drinking water cause of cancer, coronary heart disease, arteriosclerotic heart disease and cardiovascular disease.

An improvement of knowledge is however essential to make the water services more powerful and to reinforce the policy for the access to safe water in the country [11]. Nitrates and nitrites may themselves be carcinogens or may be converted in the body to a class of compounds known as the nitrosamines, compounds that are known to be carcinogens [14]. Nitrites are relatively short-lived because they are quickly converted into nitrates by bacteria which exist in the air. Nitrites react directly with haemoglobin in human blood to produce methemoglobin, which destroys the ability of blood cells to transport oxygen [1].

The Total Hardness (TH) is an important parameter of water quality whether it is to be used for domestic, industrial or agricultural purposes. Total hardness of the all the stations near the dumping site was above the Indian standards for drinking water in both season. A study by Pocock et al [21] revealed that hardness of drinking-water cause cardiovascular disease. Total hardness has significant correlation ($p<0.05$) with Total Dissolved solids (TDS) and pH in pre and post monsoon. The calcium concentration in all the stations near MSW dumping site was above the standards in both season. But in the stations five km away from MSW dumping site was within limits in both season. In case of magnesium, four stations have high amount of magnesium concentration than the standards in pre monsoon.

The concentration of chloride was well within limits of Indian standards [6] and WHO [26] in both seasons. A report showed that people drinking chlorinated water over long periods have a 21% increase in the risk of contracting bladder cancer and a 38% increase in the risk of rectal cancer [14]. The strong contents in chlorides could be only of organic origin, because the ion chloride accompanies the ion nitrate in the case of groundwater pollution by domestic waste [26]. The factors which control the fluoride concentration include the climate of the area and the presence of accessory minerals in the rock mineral assemblage through which the ground water is circulating [22]. In the present study the concentration of fluoride was within the permissible limits of WHO [29,30] in both seasons. Negative correlations of calcium and magnesium with fluoride may be expected due to the low solubility of fluoride in natural groundwater [13].

Behnke [5] determined that surface sources of ground water nitrate contamination related to man's activities include domestic sewage, agricultural practices, and high-density animal confinement. Nitrate in drinking water may be associated with increased risk of bladder and ovarian cancer, genotoxic at chromosomal level and insulin dependent diabetes [12]. Nitrate concentration in samples near the MSW dumping site is found very high than the Indian standards (45mg/l). But in control stations, they were well within limits. Fecal coliform is a sub-group of coliform bacteria, which live and reproduce in the gut of humans and other warm-blooded animals. Most fecal coliform bacteria are harmless, but a few can cause mild to serious illness.Most waterborne pathogens are introduced into drinking-water supplies in human or animal faeces, do not grow in water and initiate infection in the gastrointestinal tract following ingestion [39,30]. In all the stations, faecal coliform exceeds the standards for drinking water [6,29,30] which put the groundwater unfit for drinking but lack of other drinking water sources people are forced to drink the water.

Water Quality Index (WQI) is one of the most effective tools to provide feedback on the quality of water to the policy makers and environmentalists. It provides a single number expressing overall water quality status of a certain time and location [2]. The WQI of control water samples was 64.9 and 58.7in pre and post monsoon respectively (Table 2 and Table 4) which categorizes the ground water in the “good water” category as per the water quality classification based on WQI value. But in the samples near the MSW dumping site were found to be as high as 101.9 and 97.6 in pre and post monsoon season respectively (Table 1 and Table 3) which categorizes the ground water in the “poor water” category as per the water quality classification based on WQI value. But the presence of fecal coliforms in the water samples make them unfit for drinking.

5. Conclusion

The ground water qualities of the water near the Municipal solid waste dumping sites are of poor quality since contaminated by the leachate. Preventive management is the preferred approach to drinking-water safety and should take account of the characteristics of the drinking-water supply from catchment and source to its use by consumers. Drinking-water quality management are often outside the direct responsibility of the water supplier, a collaborative multiagency approach be adopted to ensure safe drinking water.

New landfill construction methods are designed to prevent pollution of groundwater. Landfills are now built with liners to prevent leachate from seeping through soil into aquifers. Leachate collection systems store the liquid away from the water table. Clay caps prevent rainwater runoff from carrying pollutants from the landfill into the groundwater.

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References

[1] Akinbile C.O. and Yusoff, M.S., 2011. Environmental Impact of Leachate Pollution on Groundwater Supplies in Akure, Nigeria, International Journal of Environmental Science and Development, 2(1):81-86.

[2] Amadi, A. N., P.I Olasehinde, Okosun, E.A and Yisa, J., 2010. Assessment of the Water Quality Index of Otamiri and Oramiriukwa Rivers. Physics International. 1 (2): 116-123.

[3] APHA., 2012 Standard methods for the examination of water and waste water, 22ndEdn, American Public Health Association, Washington.

[4] Ashwani, K.T. and Abhay, K.S., 2014. Hydro geochemical investigation and Groundwater Quality assessment of Pratapgarh District, Uttar Pradesh. Journal Geological Society of India, 83:329-343.

[5] Behnke, J., 2003. A summary of the biogeochemistry of nitrogen compounds in ground water. Journal of Hydrology. 27:155-167.

[6] Bureau of Indian Standards., 2012. IS 10500:2012, Drinking Water-Specification, Second Revision. Government of India, New Delhi.

[7] Census., 2011. Census of India, Registrar General & Census Commissioner, India.

[8] Christensen, J.B., D.L.Jensen, C.Gron, Filip, Z and Christensen, T.H., 1998. Characterisation of the dissolved organic carbon fraction in landfill leachate-polluted groundwater. Water Research. 32(1):125-135.

[9] Cocchi, D and Scagliarini, M., 2005. Modelling the Effect of Salinity on the Multivariate Distribution of Water Quality Index. Journal of Mathematics and Statistics.1 (4): 268-272.

[10] Craun, G.F. and Mccabe, L.J., 1975. Problems associated with metals in drinking water. Journal of the American Water Works Association. 67: 593.

[11] Diodato, N., L. Esposito, G.Bellocchi, L.Vernacchia, Fiorillo, F and Guadagno F.M., 2013. Assessment of the Spatial Uncertainty of Nitrates in the Aquifers of the Campania Plain (Italy). American Journal of Climate Change. 2: 128-137.

[12] Faisal, I., A.Shafaqat , M.T.Hafiz, , B.S.Muhammad , F. Mujahid, I. Usman and Muhammad, M.N., 2013. Assessment of ground water contamination by various pollutants from sewage water in Chakera village, Faisalabad. International Journal of Environmental Monitoring and Analysis.1 (5): 182-187.

[13] Hem., 1991. Study and interpretation of the chemical characteristics of natural water. US Geochemical Survey Water Supply, Scientific Publishers, India: 2254.

[14] Howard, D., 2007. Chemical Speciation Analysis of Sports Drinks by Acid–Base Titrimetry and Ion Chromatography: A Challenging Beverage Formulation Project. Journal of Chemical Education. 84(1):124.

[15] Huang, T., Z.Pang and Edmunds W.M., 2012. Soil profile evolution following land-use change: Implications for groundwater quantity and quality. Hydrological Process. 27(8):1238-1252.

[16] Jain, C.K., A. Bandyopadhyay and Bhadra A., 2010.Assessment of ground water quality for drinking purpose, District Nainital, Uttarakhand, India. Environmental Monitoring and Assessment. 166: 663-676.

[17] Jefferis, S.A., 1993. Old landfills: perceptions and remediation of problem sites. In: R.W. Sars by (Ed.) Waste Disposal by Landfill: 93-106.

[18] Johnson, C.A, G.A. Richner , T. Vitvar, , N. Schittli and Eberhard M., 1998. Hydrological and geochemical factors affecting leachtae composition in municipal solid waste.

[19] Muhammad S., Rosli Saad & Marwan., 2013. Leachate Migration Delineation using 2-D Electrical Resistivity Imaging (2-DERI) at Gampong Jawa, Banda Aceh.EJGE. 18: 1505-1510.

[20] Parihar, S.S., A. Kumar, R.N .Gupta, M. A. Pathak, Shrivastav and Pandey A.C., 2012. Physico Chemical and microbiological analysis of underground water in and ground Gwalior city, M.P. India. Research Journal of Recent Science. 1(6): 62-65.

[21] Pocock S.J., A.G. Shaper, Cook D.G., 1980. British Regional Heart Study: geographic variation in cardiovascular mortality, and the role of water quality. Br Med J. 280: 1243-1249.

[22] Rahman, S. (2002). Groundwater quality of Oman. Groundwater Quality, London. 122-128.

[23] Ramakrishniah, C.R., C. Sadashivam and Ranganna, G., 2009. Assessment of Water Quality Index for the Groundwater in Tumkur, Karnataka State, Indian. Electronic Journal of Chemistry. 6(2): 523 530.

[24] Raman, N. and Sathiyanarayanan, D., 2011. Quality Assessment of Ground Water in Pallavapuram Municipal Solid Waste Dumpsite Area Nearer to Pallavaram in Chennai, Tamilnadu. Journal of Chemistry. 4 (2): 481-487.

[25] Riediker, S., J.F. Suter and Giger, W., (2000). Benzene- and naphthalene-sulphonates in leachates and plumes of landfills. Water Research. 34(7): 2069-2079.

[26] Saadi, S., D.Khattach and Kharmouz, M., 2014. Geophysics and physico chemical coupledapproach of the groundwater contamination.Application in pollution by the landfillleachate of Oujda city (Eastern Morocco). *Larhyss Journal*.19: 7-17.

[27] Sengupta, M. and Dalwani, R., 2008. Determination of water quality index and sustainability of an urban water body in Shimoga town, Kornataka, Proceedings of Taal 2007: The 12th World Lake Conference: 342-346

[28] Ugwu, S.A. and Nwosu, J.I., 2009. Effect of Waste Dumps on Groundwater in Choba using Geophysical Method. Journal of Applied Sciences and Environmental Management. 13(1): 85-89.

[29] WHO (a)., 2006. Guidelines of drinking water quality Recommendation: the 3rd edition. Geneva: World Health Organisation. 2nd ed. Geneva.

[30] WHO (b)., 2006. Protecting Groundwater for Health: Managing the Quality of Drinking-water Sources. Edited by O. Schmoll, G. Howard, J. Chilton and I. Chorus. ISBN: 1843390795. Published by IWA Publishing, London, UK.

[31] Yisa, J. and Jimoh, T., 2010. Analytical Studies on Water Quality Index of River Landzu, American Journal of Applied Sciences, 7(4): 453-458.