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Comparison of Ground Water Quality with Leachate from Municipal Solid Waste Dumpsites

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ABSTRACT

Vijayawada city of Andhra Pradesh, India is a rapidly growing city both technologically and demographically. A sudden growth of population coupled with poor infrastructure and inadequate waste management services is bound to create problems in the public health sector. A long-term ground water quality monitoring at Municipal Solid Waste (MSW) dumpsites is important to the protection of aquifer. The effect of dumpsites on ground water is often detrimental and the cumulative effects may not be visible for many years. Ground water and leachate near the two major dump sites of Vijayawada were used for monthly monitoring to identify the impacts.

Introduction

The open-dumping and land filling are the two common disposal options for getting rid of the waste produced in most parts of the world. Unorganized, indiscriminate and unscientific dumping of Municipal Solid Wastes in open dumps is very common disposal method in many Indian cities which cause adverse impacts to the environment (Mahar, 2007). These solid wastes are generally preferred to be disposed in low lying areas called dumpsites. Failure of liners and/or leakage of the leachate collection systems are the primary causes of such leachate seepage and infiltration into groundwater (Lee and Jones Lee, 1994). Abolfazl *et al.*, (2008) and Akoteyon *et al.*, (2010) studied that most of the sites are not intended and engineered towards sanitary landfill for the purpose of solid waste disposal. El-Fadel *et al.*, (1997), Dsakalopoalous *et al.*, (1998), Jhamnani *et al.*, (2009), Longe and Balogun (2010) identified that the land filling of municipal solid waste is a common waste management in many parts of the world. Singh *et al.*, (2009) analysed that in the developing countries several unregulated landfills exist adjacent to large cities, releasing harmful contaminants to the underlying aquifer. The landfill leachate contains a high concentration of organic matters and inorganic ions, including heavy metals (Baun et al., 2000). Thus it is well known from the literature that the landfill leachate may cause a serious environmental problem caused to discharge heavy metals continuously, if it is not under control (Abu-Rukah and Al-Kofahi, 2001; Nanny and Ratasuk, 2002; Huan-Jung et al., 2006 & Mor et al., 2006).

In the present study, the impact of leachate percolation on groundwater quality was estimated from two unlined dump sites of Vijayawada in order to find out the variations in the water quality. The leachate samples were compared with the ground water samples for some of the selected parameters like Temperature, pH, Total Dissolved Solids, Electrical Conductivity, Chlorides, Sodium, Potassium, Fluorides, Nitrates, phosphates, Dissolved Oxygen, Biological Oxygen Demand and Chemical Oxygen Demand, to find out the extent of contamination of ground water due to leachate.

Study Area

Vijayawada is the second largest city in Andhra Pradesh after Visakhapatnam, located on banks of river Krishna. It is considered as the agricultural and commercial capital of Andhra Pradesh. The Vijayawada city with a population of 1,048,240 (2011 Census) generates waste of 650 Tons/Day. The present study has been carried out at two Municipal Solid Waste (MSW) dumpsites at Pathapadu and Ajith Singh Nagar in Vijayawada city. The ground water quality was monitored at these two Municipal Solid Waste dump sites at Vijayawada city. Of the two dumpsites selected Pathapadu dumpsite was larger and older compared to Ajith Singh Nagar. The dumping of waste at both the dumpsites and open burning continues in Vijayawada. The dump sites are an eyesore, inviting public indignation with open burning and leachate overflowing.

Materials and Methods

Description of Ground Water Stations

Gurunanak Colony Site

The Station-I selected was at a residential area of Gurunanak colony in Vijayawada city. The Station-I was considered to be a control station which was at a distance of 14.2 Km from the Pathapadu dump site and 10.7 Km from Ajith Singh Nagar dumpsite respectively.

Pathapadu Site

The site was sloping towards southern side, embracing an area of 7 acres. The Stations II, III and IV were selected at a distance of 180 meters, 200 meters and 600 meters, respectively from the dumpsite. The Stations II and III were located in the downstream region from the dump and along the direction of the ground water flow i.e. from north to south.

Ajith Singh Nagar Site

The site is sloping towards southern side. Northern side of the site is used for MSW dump and also for the compost

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facility and waste to energy facility. Two Stations V and VI were selected for the present study at a distance of 150 meters and 180 meters from the dumpsite.

Leachate from the leachate collection trench near the two major dump sites (Pathapadu and Ajith Singh Nagar dumpsites) of Vijayawada was collected and used for monitoring on a monthly basis for a period of two years (i.e. from June 2012 to June 2014). The leachate collection trenches at the two dumpsites were named as two sample stations i.e., LS-I near Pathapadu dumpsite and LS-II near Ajith Singhnagar dumpsite.

Ground water from five bore wells located near the two major dump sites of Vijayawada were used for the ground water monitoring on a monthly basis for a period of two years (i.e. from June 2012 to June 2014). The ground water of six sampling stations along with two leachate samples was monitored monthly. The water and leachate were tested using standard methods for physical, chemical and biological parameters. Standard APHA analysis procedures were used to analyze the water quality parameters.

Results

Temperature

In investigating the relationship between the characteristics of leachate Temperature and its impact on ground water it was observed that the distance of the dumpsites from the bores varied but the mean Temperatures in ground water at the five stations remained similar that ranged between 29.17 and 29.78°C (Fig. 1) excluding the control area. But at Station-I (control station) the two year mean Temperature of ground water was less than the other stations (Fig. 1) indicating that there was leachate percolation at the other stations which raised the water Temperature due to the decomposition of organic matter in the water added by leachate. The mean of leachate Temperature (which was 28.72°C at LS-I and 28.86°C at LS-II) at both the stations was found to be less than the ground water Temperature (Fig. 1). As the leachate was exposed to atmospheric conditions, the Temperature of leachate might be low when compared to the ground water. The leachate Temperature was high during summer season compared to rainy and winter seasons. But the ground water Temperature was comparatively high in rainy than the other seasons**.**

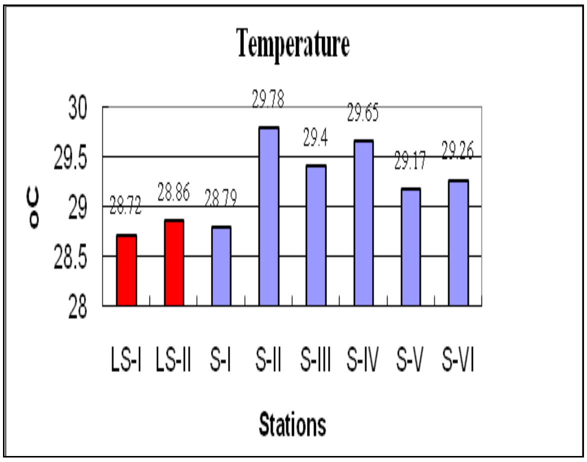

Figure 1. The comparison of mean of Temperature in Ground water and leachate

pH

In the present study the mean pH of ground water ranged between 7.31 and 7.49 (Fig. 2). Maximum value was recorded at Station-III and minimum value at Station-II **of** ground water both near Pathapadu dumpsite (Fig. 2). As the variation was very less it can be considered as pH to be nearly same at all the stations. None of the samples of ground water samples were found to have exceeded the BIS desirable limit of (6.5-8.5) for pH of drinking water. The mean of ground water pH was found to be less than the pH of leachate which was 7.89 at LS-I and 7.97 at LS-II (Fig. 2). This might be due to the dilution of infiltrated leachate in the ground water. For ground water highest pH values were recorded in rainy season for three Stations I, IV and V. The same trend was also observed in leachate, where the pH was also observed to be high during rainy season than other seasons. High pH values observed during rainy season might be due to the presence of high amounts of carbonates and bicarbonate substances leached from the dumpsite to the ground water. But the ground water samples collected from Stations II and III were found to have high pH during summer season. Only at Station-VI the pH was high during winter season. The pH values varied very a little among the ground water samples collected during the study period.

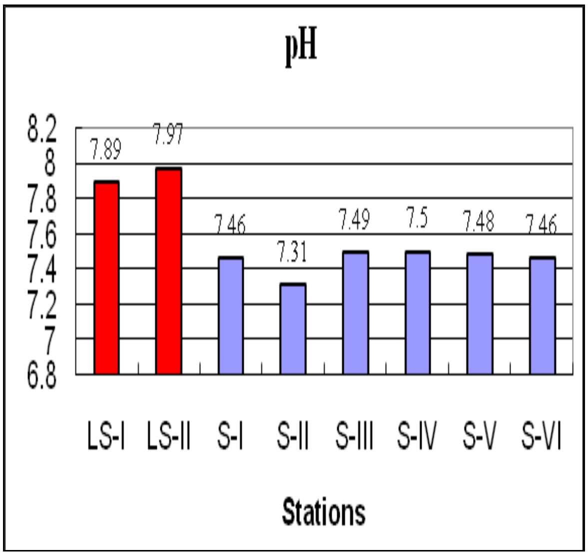

Figure 2. The comparison of mean of pH in ground water and leachate

Total Dissolved Solids (TDS)

In the present investigation, mean Total Dissolved Solids in ground water ranged between 2505.88 and 4155.42 and the Total Dissolved Solids Station-I (i.e., control station) was 520.41 mg/L (Fig. 3). The Total Dissolved Solids of ground water at all the six stations was higher than the BIS desirable limit of 500 mg/L (Fig. 3). The Total Dissolved Solids of leachate was far above than the Total Dissolved Solids of ground water, which were 8589.46 mg/L at LS-I and 8292.46 mg/L at LS-II (Fig. 3). The leachate infiltrated from LS-I might have contributed to high Total Dissolved Solids in ground water at Stations III and IV. The direction of flow of ground water was from North to South and the Stations III and IV were also located in the same direction which might have contributed to high Total Dissolved Solids values in these stations. It was also assessed from the study that the Total Dissolved Solids of ground water was high during summer season, and the similar trend was observed in leachate collected from Pathapadu dumpsite. At Ajith Singh Nagar dumpsite the pH of leachate was high during rainy season. This might be due to the flow of contaminants from the other sources from the adjacent colony at Ajith Singh Nagar dumpsite due to rainfall.

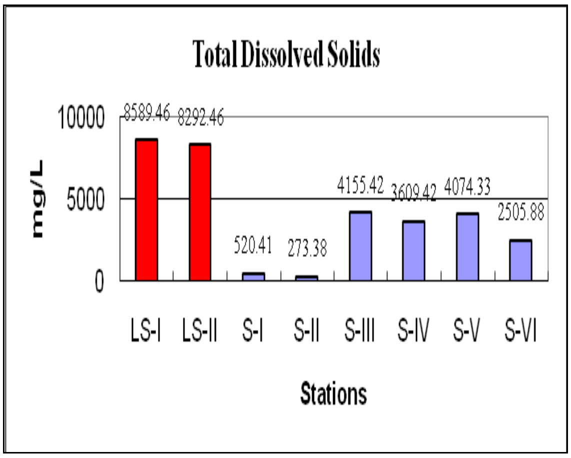

Figure 3. The comparison of mean of Total Dissolved Solids in ground water and leachate

Electrical Conductivity

As the Electrical Conductivity of ground water was directly related to the Total Dissolved Solids concentration, it ranged between 3721.35 and 6195.89 µmhos/cm and found to be less at the control area i.e., Station-I (Fig. 4). The Electrical Conductivity of leachate was 12820.1 at Pathapadu dumpsite i.e., LS-I and 12376.8 at Ajith Singh Nagar dumpsite i.e., LS-II (Fig. 4). High Electrical Conductivity was recorded in ground water from two Station-III which was near to the Pathapadu dumpsite and Station-V which was near to Ajith Singh Nagar dumpsite (Fig. 4). As the Station-III was located in a downstream region that might have contributed to high Electrical Conductivity and Station-V was adjacent to the Ajith Singh Nagar dumpsite that might be the reason for high Electrical Conductivity at this station. Leachate percolation and improper leachate collection also might have contributed to high Electrical Conductivity at the two stations, indicating high concentration of various salts and minerals.

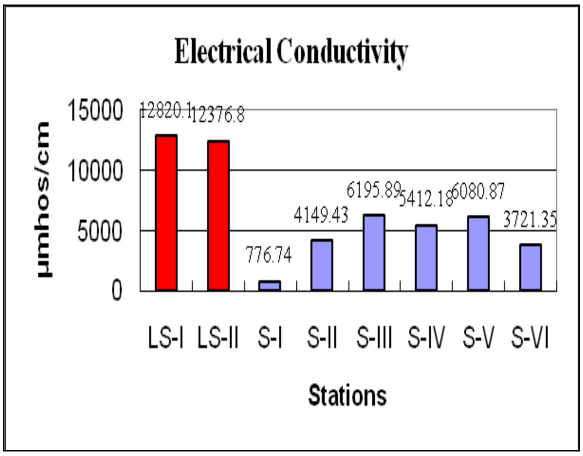

Figure 4. The comparison of mean of Electrical Conductivity in ground water and leachate

Total Hardness

The study revealed that the ground water of at the study area was very hard and was found to be high at Station-III at the Pathapadu dumpsite (Fig. 5) located in a downstream region to dumpsite and along the direction of ground water flow i.e. from North to South. A comparatively less Hardness was identified at Station-I which was a control area and was far away from the dumpsites (Fig. 5). The Total Hardness of leachate was higher than the ground water and identified to be similar at both the dumpsites. In ground water collected from Stations I, II and III the Total Hardness was high during rainy season than winter and summer seasons. But at rest of the stations of ground water, the Total Hardness was high during summer and winter seasons. In leachate collected from both the dumpsites, the Total Hardness was high during summer season followed by winter and rainy seasons. All the samples of ground water exceeded the BIS desirable limit of 300 mg/L for drinking water (Fig. 5). On comparing the Control Station with the other stations it was observed that dumpsite leachate might have highly contributed to Total Hardness to ground water at the stations near dumpsites.

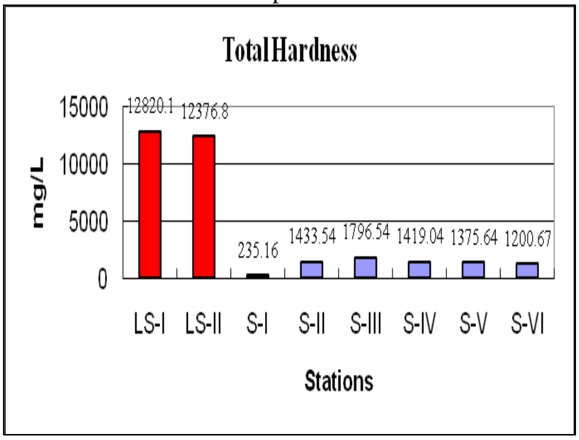

Figure 5. The comparison of mean of Total Hardness in Ground water and leachate

Total Alkalinity

Maximum concentrations of Alkalinity in ground water were recorded at Station-II (586.83 mg/L) while lowest value at Station-I (151.16mg/L). The ground water samples were detected to have Alkalinity higher than the desirable limits of 200 mg/L. An increase in Alkalinity value in the study area is ascribed to dilution due to rainfall. The standard desirable limits of Alkalinity in portable water is 200 mg/L (BIS-10500, 1991) but ground water samples have high Alkalinity values than prescribed by BIS (Fig. 6). High values of Alkalinity in the water samples indicate pollution of organic nature and give an unpleasant taste. In the absence of alternate source of water, Alkalinity up to 600 mg/L is permissible (BIS, 1991). In leachate samples collected from Pathapadu dumpsite i.e., LS-I the Alkalinity was very high than the samples collected from the Ajith Sigh Nagar dumpsite i.e., LS-II, indicating that the leachate is undergoing methanogenic phase in which the leachate becomes almost stabilized as Alkalinity pH of the leachate indicates biochemical activity at its peak (Fig. 6).

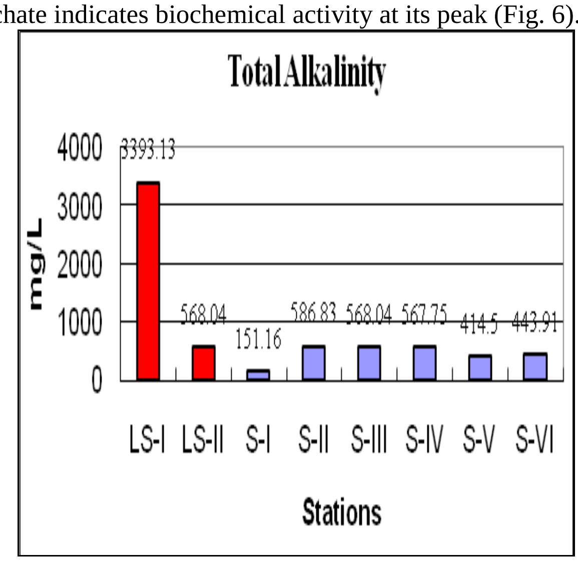

Figure 6. The comparision of mean of Total Alkalinity in ground water and leachate

Fluorides

The mean of Fluoride concentrations in ground water of the study area varied between 0.12 to 1.82 mg/L. At two stations i.e., Stations III and IV the Fluoride concentration exceeded the BIS desirable limit of 1 mg/L and only at one station i.e., Station-IV the Fluoride concentration exceeded the WHO permissible limit of 1.5 mg/L. It is also significant to mention that the ground water collected from Station-IV was having Fluoride concentrations higher than the concentrations found in the leachate collected from both the dumpsites. This might be due to the geological conditions at Station-IV that might have contributed to high Fluorides in ground water. At all the stations the Fluoride concentration was detected to be high during summer season followed by winter and rainy seasons.

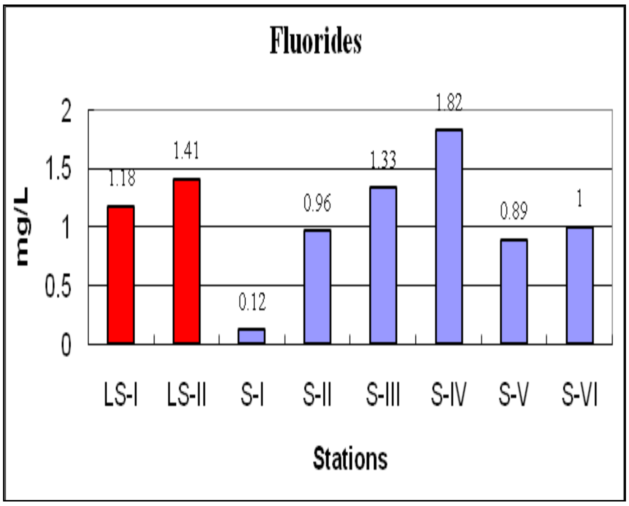

Figure 7. The comparison of mean of Fluorides in ground Water and leachate

Sodium

The mean concentration of Sodium in ground water ranged between 173.62 to 898.42 mg/L (Fig. 8). The maximum concentration was at Station-IV and minimum concentration was detected at Station-I of ground water (Fig. 8). All the ground water samples exceeded the BIS desirable limit of 200 mg/L indicating that the water is unfit for the purpose of drinking and irrigation. Elevated concentrations of Sodium were detected in leachate samples at both the dumpsites which were higher than the concentrations found in ground water (Fig. 8). A seasonal trend of high concentration of Sodium was observed at three stations (i.e. I, V, VI) during summer season followed by winter and summer seasons due to dilution effect, whereas the concentrations were high during winter season followed by rainy and summer seasons at Stations II and IV. And only at Station-III the concentration of Sodium was high during summer season followed by rainy and winter seasons. This might be due to infiltration of leachate at Station-III which was very near to the Ajith Singh Nagar dumpsite than other stations.

Potassium

The mean concentrations of Potassium in ground water ranged between 18.03 and 85.3 mg/L with maximum concentration detected at Station-II which was near to Pathapadu dumpsite having high Potassium concentration in leachate and minimum concentration recorded at Station-I (Control Station) of the study area (Fig. 9). The fall in the Potassium concentration in ground water with increasing distance from dumpsite indicated the effect of leachate infiltration.

In leachate the mean Potassium concentrations exceeded the FEPA desirable limit of 100 mg/L (Fig. 9).

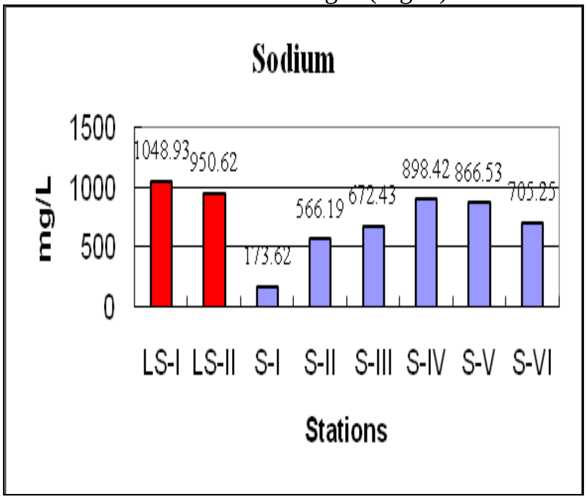

Figure 8. The comparison of mean of Sodium in ground Water and leachate

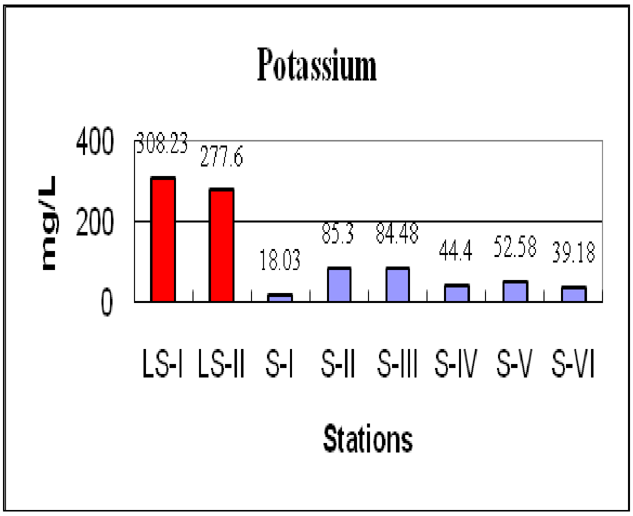

Figure 9. The comparison of mean of Potassium in ground water and leachate

Chlorides

The mean concentration of Chloride in ground water was greatest at Station-V and least at Station-I (Fig. 10). The concentrations of Chloride in ground water exceeded the BIS desirable limit of 250mg/L at all the stations indicating leachate percolation from the dumpsites, except at Station-I which was a control station. The concentration of Chloride in leachate also exceeded the BIS desirable limit of irrigational discharge i.e. 600 mg/L at both the dumpsites (Fig. 10). The Chloride concentrations in ground water were high at Stations I and II during rainy season followed by winter and summer seasons, whereas the concentrations were high during rainy season followed by summer and winter seasons at Stations III and V. And at Stations IV and VI the concentration of Chlorides was high during winter season followed by summer and rainy seasons. The study of ground water on a seasonal basis also revealed that the concentration of Chlorides was high at Station-V in rainy season located near to the Ajith Singh Nagar dumpsite. This might be due to its nearest distance from the dumpsite.

Nitrates

At all the stations the mean concentrations of Nitrates in ground water were within the BIS desirable limit of 45 mg/L for drinking water (Fig. 11). The mean concentrations of Nitrates in leachate have exceeded the FEPA standard of 20 mg/L (Fig. 11). The concentrations of Nitrates in leachate were much more than the Nitrate concentrations observed in ground waters. This might be due to the dilution and dispersion of plume of Nitrates in ground water at the study area.

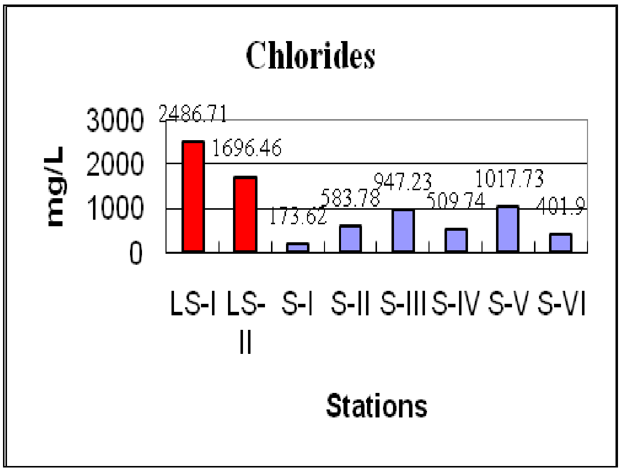

Figure 10. The comparison of mean of Chlorides in ground water and leachate

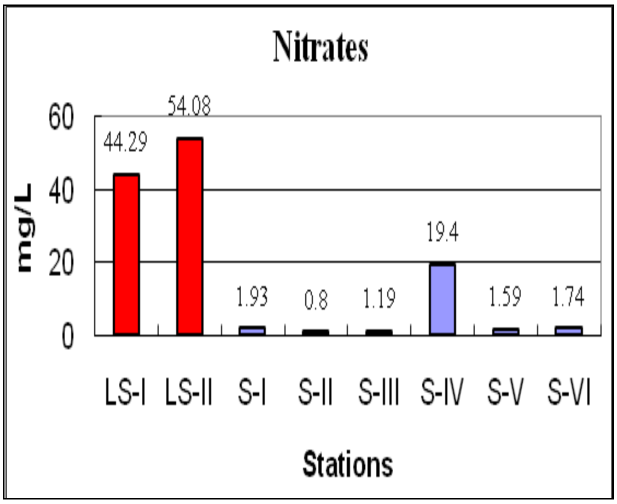

Figure 11. The comparison of mean of Nitrates in ground water and leachate

Phosphates

The mean concentrations of Phosphates in ground water ranged between 0.07 to 0.6 mg/L (Fig. 12). The mean concentrations of Phosphates were high in leachate samples than the ground water but within the FEPA desirable limit of 50 mg/L (Fig.12).

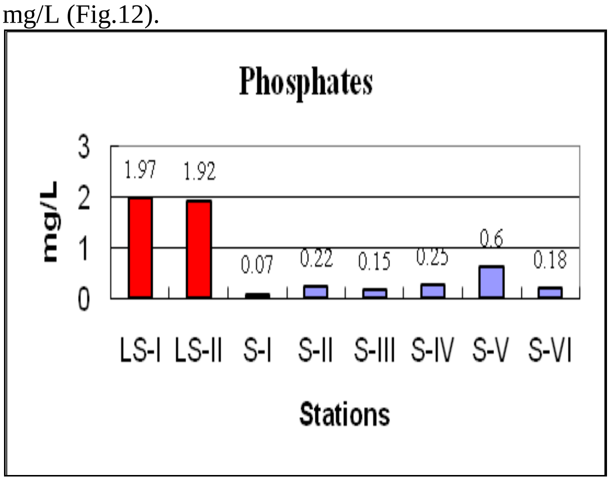

Figure 12. The comparison of mean of Phosphates in ground water and leachate

Dissolved Oxygen

The Dissolved Oxygen concentrations increased from Station-I and Station-VI indicating that the concentration increased with increasing distance from the dumpsite (Fig. 13). The mean concentrations of Dissolved Oxygen at all the stations were not meeting the BIS desirable limit of 6 mg/L for drinking water except at Control Station. The Dissolved Oxygen was absent in leachate samples collected at both the dumpsites indicating the heavy organic load in the leachate (Fig. 13).

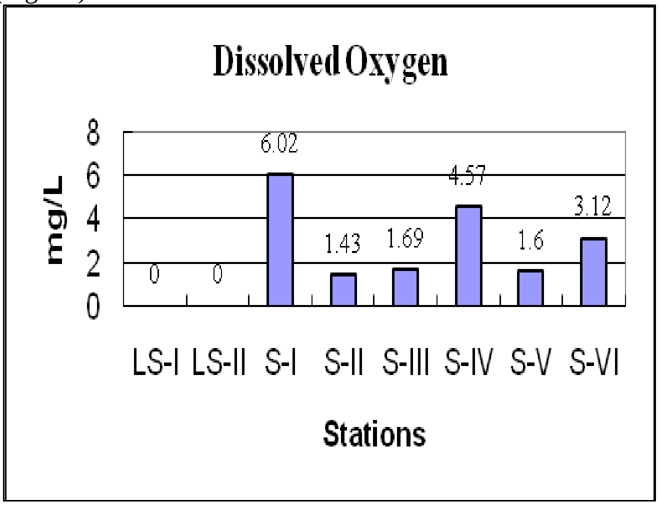

Figure 13. The comparison of mean of Dissolved Oxygen in Ground water and leachate

Biological Oxygen Demand

The concentration of Biological Oxygen Demand in ground water was in range of 0.13 to 1.36 mg/L at all the stations, indicating that all the stations were within the BIS desirable limit of 2 mg/L for drinking water (Fig. 14). But the mean concentrations of Biological Oxygen Demand in leachate was higher than the BIS desirable limit for irrigational discharge i.e., 100 mg/L, indicating much higher organic load in the leachate at both the dumpsites, that might have reduced due to dispersion in ground water (Fig. 14).

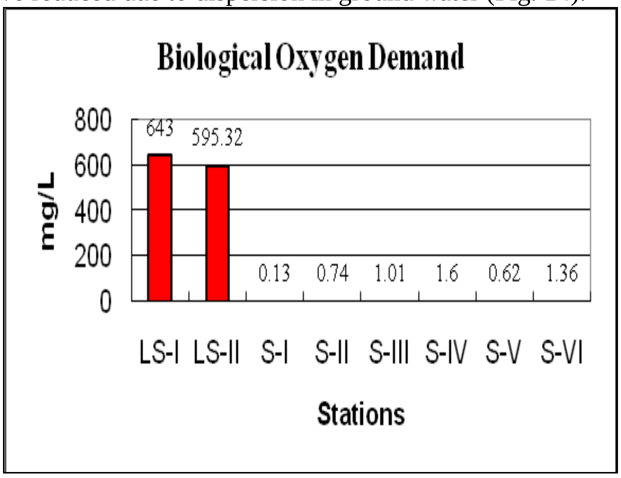

Figure 14. The comparison of mean of Biological Oxygen Demand in ground water and leachate

Chemical Oxygen Demand

The concentration of Chemical Oxygen Demand in ground water was in range of 1.86 to 8.75 mg/L at all the stations. But the mean concentrations of Chemical Oxygen Demand were higher than the FEPA allowable limit of 75 mg/L in the leachate at both the dumpsites. The similar trend of low Chemical Oxygen Demand levels was observed in ground water samples, although there were considerably high concentrations in leachate samples indicating the dispersion of organic load in the ground water.

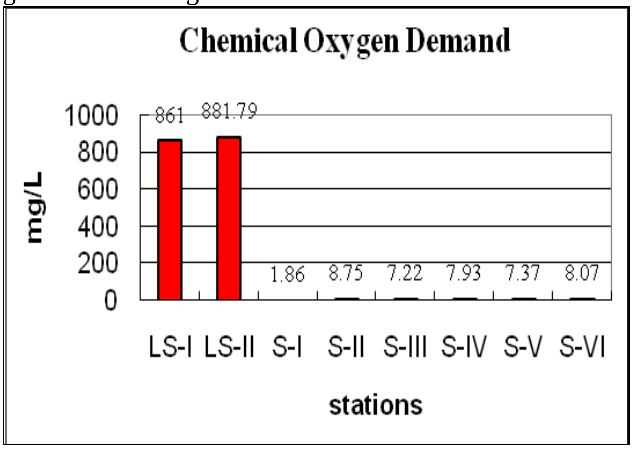

Figure 15. The comparison of mean of Chemical Oxygen Demand in ground water and leachate

Discussion

The ground water Temperatures were in agreement with the studies made by different researchers at MSW sites in Nigeria (Akinbile and Yusoff, 2011 in Akure, Saidu, 2011 in Minna of Niger state, Afolayan *et al.*, 2012 in Solous). The mean temperature of leachate at both the stations was observed to be less than the ground water temperature during the present study period. This may be due to the bio-chemical activity happening in the ground water which might have increased the ground water temperature. . The alkaline pH can be considered due to mineralization of carbonates, bicarbonates and hydroxides in the well-established methanogenic phase of landfill (Maqbool *et al.,* 2011& Robinson, 2007). Bhalla *et al.,* (2012) also reported higher pH values of 9.3 to 9.8 in the leachate samples which confirmed that the leachate was stabilized and was from semi-aerobic landfill (Bashir *et al.,* 2010). In the present study, the Total Dissolved Solids in ground water was very much higher than the BIS specified limit of 500 mg/L. High concentrations of Total Hardness in leachate have contributed to high hardness in ground water. Similar levels of hardness were reported by other studies done by Mor *et al.,* (2006) and Raman and Sathinarayanan (2011). The alkaline nature of leachate indicated a more stabilized methanogenic phase that has also contributed to high Alkalinity in ground water. The ground water quality near Pathapadu dumpsite was observed to be more affected than at Ajith Singh Nagar dumpsite. This might be due to the topography of the dumpsite and the stations being located in the low lying area to the dump. But the concentrations of Fluorides in leachate at Ajith Singh Nagar dumpsite were more than the Pathapadu dumpsite. The high concentrations of Sodium in leachate at LS-I have contributed to high concentrations of Sodium in ground water at Station-IV. The concentration of Nitrates in leachate was very high compared to the concentrations in ground water. This might be due to the dilution in concentrations in ground water during leachate infiltration. The pollution due to Chloride was observed to be high at Station-V near Ajith Singh Nagar dumpsite and low at Pathapadu dumpsite. A comparison of stations near dumpsites with the Control Station-I revealed that the leachate contamination of the ground water was chiefly due to dumpsite during the study period. The absence of DO in and high concentrations of BOD and COD in leachate indicated organic load.

The leachate at LS-I (Pathapadu dumpsite) was comparatively more polluted than LS-II (Ajith Singh Nagar dumpsite). The parameters like Temperature, pH, Total Dissolved Solids, Electrical Conductivity, Calcium Hardness, Total Alkalinity, Silicates, Sodium, Potassium, Chlorides and Biological Oxygen Demand were high at LS-I (Pathapadu Dumpsite) than LS-II (Ajith Singh Nagar Dumpsite). While parameters like Total Hardness, Fluorides, Nitrates, Chemical Oxygen Demand and metals like Lead, Nickel and Zinc were high in leachate of LS-II (Ajith Singh Nagar Dumpsite) than LS-I (Pathapadu Dumpsite). As the LS-II was Ajith Singh Nagar dumpsite that was located in a residential zone, these domestic waste waters got mixed with leachate resulting in high concentration of pollutants.

Conclusion

Open dumping is still in practice at Vijayawada. This is unscientific. Within a very short time the adverse impacts of the dump on the ground water quality will be vogue. Proper lining must be provided for these dumpsites in order to prevent percolation of leachate to the ground water. The leachate collection system established at Pathapadu is not effective and scientific. It should be replaced with 'state of the art technologies'. The bore wells dug for the public usage were voluntarily abandoned by public because of odours, unacceptable colour of the water and frequent sedimentation in the collected waters. All these indicate that the public have realized the threat of contamination of ground water. A continuous monitoring station for ground water and leachate quality must be established on permanent basis on the lines suggested in Municipal Solid Waste (Management and Handling) Rules, 2000.

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