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# Impact of Municipal Solid Waste on Characteristics of Water Resources in and around Guntur city

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## ABSTRACT

This survey was conducted in Guntur district Andhra Pradesh during the year 2022-2023 to study the impact of municipal solid waste on water resource characteristics in and around Guntur city. Water samples were collected near the landfill sites from various sources like bore wells, lakes or ponds and irrigation channels. Irrigation through underground water sources was very common in the areas of Guntur city. This study was carried out to know the physico-chemical, chemical and bio chemical properties of water samples collected near landfill sites. These water samples were collected from five different landfill sites *viz,* Budampadu, Naidupeta, Etukuru, Mangalagiri and Jindal power plant at 300 and 600 meters distances, respectively. Physico-chemical properties like pH, EC and chemical properties like chlorides, calcium, magnesium, carbonates and bicarbonates and bio chemical properties like BOD and COD were also analyzed. This study showed that the impact of municipal solid waste on water resource characteristics had greater impact on water samples near 300m distance from landfill site. All physico-chemical, chemical and bio chemical properties showed the highest values at 300m distance from landfill site compared to water samples collected from 600m distance.

**Keywords:** *Guntur, Land fill site, Municipal solid waste and Water Characteristics.*

Generally, waste is categorized into solid and liquid waste. Urban solid wastes are the discarded leftovers of our advanced consumer society that contain organic and inorganic waste materials which are produced by various activities of the society and are a major cause of pollution. Current global waste generation levels are approximately 1.3 billion tonnes per year and are expected to increase approximately 2.6 billion tonnes annually by 2025.

Improper dumping of solid wastes pollutes all the important components of the living environment (*viz*., air, land and water) both locally and globally. The problem is seen more in developing nations like India when compared to developed nations, Mismanagement of municipal solid waste can have negative effects on the environment, pose a risk to the public's health and lead to other socioeconomic issues (Jha *et al*., 2011).

The amount of solid garbage produced annually in Indian cities has climbed from 6 million tonnes in 1947 to 48 million tonnes in 1997, 65 million tonnes in 2009 and 80 million tonnes in 2019 and is anticipated to rise to 300 million tonnes by 2047 (TEDDY, 2016). According to recent estimates, India produces 450–600 g of garbage per person per day (Gosh and Kansal, 2014).

In Andhra Pradesh, after bifurcation of the state rapid growth and urbanization in and around Guntur and Vijayawada cities were observed. Guntur is one of the fast growing city in Andhra Pradesh after the bifurcation of the state. The city is the biggest economic hub with both public and private sector undertakings like textile industries, cement manufacturing industries, mining and quarrying industry sectors and different jute manufacturing, tobacco processing, pharmaceutical industries and many more private companies are located in and around the city generating huge amounts of waste. As per recent estimates of GMC, Guntur generates about 200 to 250 tonnes of solid wastes daily. In Guntur, solid waste is being disposed at 4 different land filling sites. Very small quantities of wastes are recycled as composts and remaining waste is dumped in land fill sites. In view of this, the present investigation was undertaken to evaluate the impact of municipal solid wastes on water resources.

## MATERIAL AND METHODS

The present study area was located in Guntur district, Andhra Pradesh bounded on the North by Krishna District, on the West by Palnadu

District, on the South by Bapatla District and on the East by Krishna River. It is situated between 16$^{O}$17'57.18" Northern Latitude and 80$^{O}$25'55.06" Eastern Longitude. The city has witnessed rapid industrialization and has been identified as one of the fastest growing cities, economically and demographically. Water samples were collected from groundwater sources near Budampadu, Etukuru, Naidupeta, Mangalagiri and Jindal power plant landfill sites as per standard procedures (APHA, 1985). Stoppered glass bottles of two litre capacity were used for collecting water samples. Each bottle was washed with dilute HCl and then was rinsed with distilled water. A clean water sampler was introduced into the well with the help of rope and water was taken out. Prior to sampling the bottle was rinsed thoroughly with the water drawn. pH and EC were measured immediately and samples were stored at 4°C until use, for physico-chemical analysis (APHA, 1985). The samples were labeled and were used for analysis of pH, EC, carbonates and bicarbonates, chlorides, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), calcium and magnesium. Necessary precautions were taken in collection and preservation of water samples for analysis.

## RESULTS AND DISCUSSION

The data obtained from the analysis of different parameters of water samples are presented in the tables from 1 to 3 and illustrated in figures from 1 to 6.

### Water Reaction (pH)

The data present in the table 1 revealed that the pH of the underground water samples collected at 300 meters distance from different land fill sites of Bundampadu, Naidupeta, Etukuru, Mangalagiri and Jindal power plant ranged from 7.28-7.43, 7.72-7.78, 7.03-7.35, 7.65-7.72 and 7.29-7.76, respectively. Whereas water samples collected at distance from 600 meters have pH ranged from 7.36-7.42, 6.73-6.98, 7.49-7.63, 7.78-7.90 and 7.45-7.88, respectively. Among the landfill sites the highest pH range (7.78-7.90) was observed in Mangalagiri landfill site which was found to be moderately alkaline to alkaline followed by Jindal power plant (7.45-7.88) and lowest was observed in Naidupeta (6.73-6.98). Etukuru surface samples ranged from slightly alkaline to moderatleyalkaline. All water samples collected from different sources were neutral to alkaline in condition.

All the underground water samples collected near landfill sites contained pH in the range of 6.5-8.4 which was the standard limit for irrigation given by FAO (1985).Similar results were observed by Sridhar *etal.,* (2013), Nagarajan *etal.,* (2012) and Rajkumar*etal.*(2010). This Alkalinity is due to the function of $CO_3^{2-}$, $HCO_3^-$ and $OH^-$ ions. This is also due to hardness and excess dissolved salts. This may be attributed to the decrease in the concentration of free volatile acids due to anaerobic decomposition, as fatty acids can be partially ionized and contribute to higher pH values.

### Electrical Conductivity (EC)

The highest EC was observed in the water sample collected near the Naidupeta landfill site ranging from 3.90-4.10 dS $m^{-1}$ with a mean value of 3.96 dS $m^{-1}$. The lowest EC was observed near the budampadu landfill site which ranged from 0.72-0.78 dS $m^{-1}$. The EC of water sample collected from different landfill sites *viz.,* Budampadu, Naidupeta, Mangalagiri, Ethkuru and Jindal power plant ranged from 0.78-0.84, 3.90-4.10, 1.70-1.85, 0.98-1.23, 0.76-1.22 dS $m^{-1}$ with mean values of 0.81, 3.96, 1.78, 1.08, 0.89 dS $m^{-1}$ at 300 meters distance from landfill site. The underground water samples collected from landfill sites were non saline to moderately saline in nature because EC values ware less than 2 $dSm^{-1}$ according to FAO (1985).

The electrical conductivity was due to the presence of electrolytes which dissociate into cations and anions and also due to the dissolved ions such as bicarbonates, chlorides, sodium, potassium, magnesium and sulphate. The higher conductivity values obtained around the dumpsite indicated the effect of landfill on water quality in the form of leachate outcome and inorganic pollution at this specific site.

Kamboj and Choudhary (2013) made a study on ground water quality near Gazipur dumping site at Delhi, India in which the conductivity ranged between 1.22 and 2.94 $dSm^{-1}$ and they reported that very high EC observed in the groundwater due to downward transfer of leachate into groundwater. Esmail *et al.,*2009) revealed same results in the dumping site at Ibb landfill at Al Sahool of Yemen and they found that the EC values ware higher at the vicinity of the dumpsite and reduced with the distance from the landfill site. This was due to the effect of the leachate seepage into boreholes.

**Chlorides**

The data pertaining to the chlorides in underground water samples at different landfill sites in and around Guntur city are presented in table 2.

The chloride content in the underground water samples recorded mean values of 3.0, 8.4, 4.7, 3.4, 5.3 mg $L^{-1}$ at 300 meters distance from landfill sites. The chloride content in the underground water samples recorded mean values of 2.8, 7.8, 4.1, 2.8, 4.3 me $L^{-1}$ at 600 meters distance from landfill sites. The Highest value was observed at the Naidupeta landfill site water sample at 300 meters distance which ranged from 8.2-8.6 me $L^{-1}$and least at 300 meters observed at Budampadu landfill site ranged from 3.0-3.2 me $L^{-1}$. The Lowest chloride content was observed in the Budampadu landfill with mean value of 2.8 me $L^{-1}$ at 600 meters distance. Results showed that the most of the underground water samples collected near different landfill sites contained chloride content above the critical limits (4 me $L^{-1}$) and at Budampadu land fill site it was below critical limit (4 me $L^{-1}$) according to FAO (1985).

This was in accordance with the findings of Rajkumar *et al.* (2010) who studied the ground water contamination due to municipal solid waste disposal in Erode city, Tamil Nadu and reported that the concentrations of chloride was found higher at the dumping site as compared to non-dumpsite. High chloride concentration in the water samples near the dumping site as compared to non-dumpsite is mainly due to presence of high concentration of chlorides in landfill leachate which migrates to the underground water table from the municipal solid waste dumping site as reported by Jhamnani and Singh, (2009). Department of National Health and Welfare (1978) reported that chloride in ground water may result from both natural and anthropogenic sources such as run-off containing salts, the use of inorganic fertilizers, land fill eachates, septic tank effluents, animal feeds, industrial effluents, irrigation drainage. An excess of chloride in water is usually taken as an index of pollution and considered as tracer for groundwater contamination (Loizidou and Kapetanios 1993).

The chloride values in the water samples may be due to the dissolution of rocks surrounding the aquifer and probably due to the leakage of sewage and anthropogenic pollution (agricultural activities). High concentration of chloride gives salty taste to water and may result in hypertension, osteoporosis, renalstones, andasthma(McCarthy, 2004).The high chloride content in groundwater is from pollution sources such as domestic effluents, fertilizers, septic tanks, and leachates (Mor *et al*. 2006).The chloride levels in natural water are an important consideration for the selection in public water supplies (Subramanian, 2000).Omofonmwan and Eseigbe, 2009 reported that the chloride can get into ground water from solidwaste when it comes in contact with the rainwater and gain entry.

**Carbonates**

The data pertaining to the carbonates, bicarbonates calcium and magnesium in underground water samples at different landfill sites in and around Guntur city are presented in table 2.

The carbonates content in the water samples at different landfill sites due at 300 meters distance from Budampadu ranged from 2.3-2.4 meq $L^{-1}$, followed by Naidupeta (3.4-3.6 me $L^{-1}$) Ethkuru (1.6-1.9 me $L^{-1}$ ),Mangalagiri (0.9-1.1 me $L^{-1}$ ) and Jindal power plant (1.3-1.1.6 me $L^{-1}$). The carbonates content in the water samples at different landfill sites observed at 600 meters distance from Budampadu ranged from 2.0-2.2 me $L^{-1}$, followed by Naidupeta (2.6-2.8 me $L^{-1}$), Ethkuru (2.3-2.6 me $L^{-1}$) Mangalagiri ( 0.7-0.8 me $L^{-1}$) and Jindal power plant (0.8-1.0 me $L^{-1}$), Results showed that the underground water samples collected near different landfill sites contain carbonates content above the critical limit (0.1me $L^{-1}$) according to FAO (1985). Sanjana (2022) reported that carbonates are above critical limits in Visakhapatnam city.

**Bicarbonates**

The bicarbonate content in the underground water samples recorded mean values of 8.8, 22.1, 14.0, 15.7, 16.8 me $L^{-1}$ at 300 meters distance from different landfill sites. The chloride content in the underground water samples recorded mean values of 8.4, 14.5, 11.7, 14.4, 17.3 me $L^{-1}$ at 600 meters distance from landfill sites. At 300 meters distance the highest value was observed at the Naidupeta landfill site ranging from 20.9-22.8 me $L^{-1}$and the lowest was observed at Budampadu landfill site ranged from 8.7-8.9 me $L^{-}$

1. The lowest bicarbonate content was observed in the Budampadu landfill (8.4-8.5 me $L^{-1}$ ) at 600 meters distance. Results showed that the underground water samples collected near different landfill sites contained bicarbonate content above the critical limit(10 me $L^{-1}$) except the Budampadu landfill water samples, according to FAO (1985).

Similar reports were given by Sridhar *et al.,* (2013). The primary source of bicarbonate in groundwater isthe dissolved carbon dioxide in the rain water that enters the soil to dissolve more carbon dioxide. The high concentration of bicarbonate in wells near the dumpsite is suspected to be as a resultof the presence of carbonate rock in the area as reported by Badmus *et al.,* (2014).

**Calcium**

The highest calcium content was observed in Naidupeta landfill site water sample at 300meters distance which range from 6.49-6.62 me $L^{-1}$ with a mean value 6.54 me $L^{-1}$. followed by Jindal power plant water sample at 300meters distance observed that 6.30-6.75 meq $L^{-1}$ was the range and had a mean value 6.53 me $L^{-1}$ and the lowest at the 300 meters distance ranged from 4.23-4.66 me $L^{-1}$ and had a mean value The calcirm cenlut at 300m distance from landfill sites was higher and it ranged from 5.12-5.20, 6.49-6.62, 5.09-5.22, 4.23-4.66, 6.30-6.75 me $L^{-1}$ respectively at Budampadu,Naidupeta,Ethkuru, Mangalagiri and Jindal power plant. At 600 meters distance from landfill sites calcium ranged from 4.86-4.96, 6.10-6.23, 4.56-4.83, 4.19-4.34, 5.89-6.18 me $L^{-1}$.

Results showed that the underground water samples collected near different landfill sites contains calcium content within the critical limit of 20 me $L^{-1}$ according to FAO (1985).

Similar results were reported byKamboj and Choudhary(2013). The principal source of Ca in groundwater is considered to be silicate mineral groups like plagioclase, pyroxene and amphibole among igneous and metamorphic rocks and limestone, dolomite and gypsum among sedimentary rocks. Disposal of sewage and industrial wastes are also important source of calcium. For irrigation water is 40 to 120 meqaccording to WHO standards. Calcium content is very common in ground water because they are available in most of the rocks abundantly and also due to contribution from the urban solidwaste leachate. The presence of $Ca^{2+}$ ions in drinking water may result in hardness of water as reported by Adetunde *et al*.,(2011).

**Magnesium**

The magnesium content in the water samples at different landfill sites at 300 meters distance from budampadu ranged from 3.96-4.02 me $L^{-1}$ with mean value 3.99 me $L^{-1}$, followed by Naidupeta (5.18-5.21 me $L^{-1)}$ Ethkuru (4.19-4.44 me $L^{-1}$) and Mangalagiri (3.34-3.46 me $L^{-1}$) The magnesium content in the water samples at different landfill sites at 600 meters distance from Budampadu ranged from 3.66-3.83 me $L^{-1}$ with a mean value 3.73 me $L^{-1}$, followed by Naidupeta ( 4.66-4.92 me $L^{-1}$ with a mean value 4.75 me $L^{-1}$) Ethkuru (3.69-3.86 me $L^{-1}$ with a mean value 3.77me $L^{-1}$), Mangalagiri (3.18-3.30 me $L^{-1}$) and Jindal power plant (5.32-5.73 me $L^{-1}$ with a mean value 5.48 me $L^{-1}$). All landfill sites except Naidupeta landfill site recovded magnisum within the critical limit (5 me $L^{-1}$) according to FAO (1985).

Similar results were reported by Kamboj and Choudhary(2013). If magnesium concentration in drinking water is more than the permissible limit, it causes unpleasant taste to the water. The prescribed limits for magnesium for irrigation water are 6 to 24 me $100g^{-1}$ according to WHO standards. The presence of magnesium in the leachate is due to the disposal of construction waste along with MSW (Al-Yaqout, 2003). There are no adverse health effects due to presence of magnesium in drinking water as compared to calcium. But the negative effects of $Mg^{2+}$ ions in drinking water may result from their ability to cause hardness of water as reported by Adetunde *et al.,* 2011. The results are in line with the findings of Raman and Sathiya, (2008) who studied the magnesium concentration in the water samples collected from Pallavaram solid waste landfill site in Chennai. Shinde *et al*., (2014) made a quality assessment of ground water samples near a municipal solid waste open dumpsite at Sangola city, Solapur district and they quoted that the moderately high concentration of magnesium near dumping site deteriorates its quality for drinking and other domestic purposes.

**Chemical OxygenDemand (COD)**

The biochemical properties COD and BOD collected from different landfill sites in and around

Guntur city are presented in table 3.

COD of the underground water samples collected from different landfill sites *Viz.,* Budampadu, Naidupeta, Ethkuru, Mangalagiri, Jindal power plant ranged from 118-121, 128-142, 110-119, 112-130 and 115-143 mg $L^{-1}$ at 300 meters distance from landfill sites respectvally. The highest values ranged from 128-142 mg $L^{-1}$ with a mean value of 135 mg $L^{-1}$ at 300m distance. At 600 meters distance from landfill site the COD of water samples was found to be in the range 98.6-117.3, 108-121, 110-119, 101-106, 112-130, 103 and 128 mg $L^{-1}$. The Lowest COD was observed in the Budampadu landfill site at 600m distance.

As distance increased from landfill sites the COD values decreased. The maximum values of chemical oxygen demand might be due to high concentration of leachate and organic matter at the dumping site; while the minimum value of chemical oxygen demand might be due to low organic matter at the non-dumpsite soils. Results indicated that the COD values of underground water samples collected near different landfill sites were less than the critical limit of 500 mg $L^{-1}$ according to FAO (1985). Similar findings were reported by Han *et al.,* (2016) and Evangelin *et al.,* (2014). Yadav and Kumar (2011)also reported that high COD value in groundwater shows the presence of oxidizable organic materials that had leached from domestic refuse in the dump site. The presence of COD indicates the high organic strength. This indicates that majority of the organic compounds are biodegradable (Fatta *et al*. 1999). Similar findings were also observed by Sanjana (2022).

**Biological OxygenDemand (BOD)**

The highest BOD in water samples was observed in Naidupeta landfill site site ranged from 110-121 mg $L^{-1}$ and had a mean value 116 mg $L^{-1}$at 300 meters distance from landfill site while the lowest BOD value was observed at Ethkuru water sample at 600 meters distance from the landfill site. The highest BOD at 600 meters distance was observed at Naidupeta landfill . The mean values of different landfill sites at 300m distance of Budampadu, Naidupeta, Ethkuru, Mangalagiri and Jindal power plant were 107, 116, 94.3, 11, 102 mg $L^{-1}$. At 600 meters distance from different landfill sites, the observed mean values were 91.2, 105, 83.5, 102, 91.0 mg $L^{-1}$ for Budampadu, Naidupeta, Ethkuru, Mangalagiri,Jindal Power plant and at 600 meters distance from the Budampadu and Jindal power plant landfill site, the BOD values were below critical limit (100 mg $L^{-1}$) and remaining landfill site water samples were more than the critical limits (100 mg $L^{-1}$) according to FAO (1985).

The leachate generated at the landfill site carries considerable amount of organic matter percolated through the soil and entered into ground water showing increase in biological oxygen demand value at the dumpsite. The presence of high BOD indicates the high organic matter

Similar reports were given by Evangelin *et al.* (2014) and Hameed *et al.,* (2018) and Sanjana (2022). The presence of high BOD indicates the high organic matter. This indicates that majority of the organic compounds are biodegradable (Fatta *et al*., 1999)

## CONCLUSION

The pH of the water samples collected from different landfills reported that the underground samples ranged from neutral to alkaline condition. The pH of water samples near the landfill sites were higher than at distance from landfill site. The EC of water samples were non-saline in nature except the Naidupeta sampels.

Chemical properties of water samples like chlorides, calcium, magnesium, carbonates and bicarbonates were observed more at 300 meters distance from landfill site. The chloride content was above the critical limites are except Budampadu landfill site. All the landfill sites showed excess carbonates which were above the critical limits and the bicarbonates more critical limits were observed in some landfill sites (FAO, 1985). Calcium and magnesium, COD & BOD contents were observed higher near the landfill sites.

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**Table 1. Physico - chemical properties of ground water samples near different landfill sites of Guntur city**

| Name of the site | Distance from landfill site(m) | pH | EC (dS $m^{-1}$) | |
|---|---|---|---|---|
| | | Range | Range | Mean |
| Budampadu | 300 | 7.28-7.43 | 0.78-0.84 | 0.81 |
| | 600 | 7.36-7.42 | 0.72-0.78 | 0.76 |
| Naidupeta | 300 | 7.72-7.78 | 3.90-4.10 | 3.96 |
| | 600 | 6.73-6.98 | 3.00-3.41 | 3.16 |
| Ethkuru | 300 | 7.03-7.35 | 1.70-1.85 | 1.78 |
| | 600 | 7.49-7.63 | 1.49-1.82 | 1.66 |
| Mangalgiri | 300 | 7.65-7.72 | 0.98-1.23 | 1.08 |
| | 600 | 7.78-7.90 | 0.69-0.93 | 0.79 |
| Jindal power plant | 300 | 7.29-7.76 | 0.83-1.22 | 0.91 |
| | 600 | 7.45-7.88 | 0.76-1.12 | 0.89 |

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**Table 2. Chemical characteristics of different underground water samples near waste dumpies sites of Guntur city**

| Name of the site | Distance From landfill site(m) | $Ca^{2+}$( me $L^{-1}$) | | $Mg^{2+}$( me $L^{-1}$) | | $CO_3^{2-}$( me $L^{-1}$) | | $HCO_3^-$( me $L^{-1}$) | | $Cl^-$ (me $L^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean |
| Budampadu | 300 | 5.12-5.20 | 5.10 | 3.96-4.02 | 3.99 | 2.30-2.40 | 2.30 | 8.70-8.90 | 8.80 | 3.0-3.2 | 3.0 |
| | 600 | 4.86-4.96 | 4.90 | 3.66-3.83 | 3.73 | 2.00-2.20 | 2.10 | 8.40-8.50 | 8.40 | 2.7-2.9 | 2.8 |
| Naidupeta | 300 | 6.49-6.62 | 6.54 | 5.18-5.21 | 5.19 | 3.40-3.60 | 3.50 | 20.9-22.8 | 22.1 | 8.2-8.6 | 8.4 |
| | 600 | 6.10-6.23 | 6.16 | 4.66-4.92 | 4.75 | 2.60-2.80 | 2.60 | 14.5-14.6 | 14.5 | 7.8-7.9 | 7.8 |
| Ethkuru | 300 | 5.09-5.22 | 5.15 | 4.19-4.44 | 4.31 | 1.60-1.90 | 1.70 | 13.8-14.3 | 14.0 | 4.4-5.2 | 4.7 |
| | 600 | 4.56-4.83 | 4.68 | 3.69-3.86 | 3.77 | 2.30-2.60 | 2.40 | 11.6-12.1 | 11.7 | 4.0-4.3 | 4.1 |
| Mangalgiri | 300 | 4.23-4.66 | 4.47 | 3.34-3.46 | 3.48 | 0.90-1.10 | 0.90 | 15.6-15.9 | 15.7 | 3.3-3.6 | 3.4 |
| | 600 | 4.19-4.34 | 4.26 | 3.18-3.30 | 3.23 | 0.70-0.80 | 0.70 | 14.2-14.6 | 14.4 | 2.7-3.0 | 2.8 |
| Jindal power plant | 300 | 6.30-6.75 | 6.53 | 5.43-5.60 | 5.53 | 1.30-1.60 | 1.20 | 16.6-17.2 | 16.8 | 4.8-5.7 | 5.3 |
| | 600 | 5.89-6.18 | 5.96 | 5.32-5.73 | 5.48 | 0.80-1.00 | 0.90 | 17.1-17.5 | 17.3 | 3.9-4.6 | 4.3 |

**Table 3. Bio chemical characteristics of different landfill ground water near sites of Guntur city**

| Name of the site | Distance from landfillsite (m) | COD (mg $L^{-1}$) | | BOD (mg $L^{-1}$) | |
|---|---|---|---|---|---|
| | | Range | Mean | Range | Mean |
| Budampadu | 300 | 118-121 | 119 | 103-110 | 107 |
| | 600 | 98.6-117.3 | 109 | 87.3-96 | 91.2 |
| Naidupeta | 300 | 128-142 | 135 | 110-121 | 116 |
| | 600 | 108-121 | 115 | 101-107 | 105 |
| Ethkuru | 300 | 110-119 | 113 | 90.0-98.1 | 94.3 |
| | 600 | 101-106 | 109 | 81.5-86.0 | 83.5 |
| Mangalgiri | 300 | 112-130 | 121 | 108-115 | 111 |
| | 600 | 101-115 | 109 | 99.3-107 | 102 |
| Jindal power plant | 300 | 115-143 | 132 | 93.0-113 | 102 |
| | 600 | 103-128 | 116 | 78.0-102 | 91.0 |

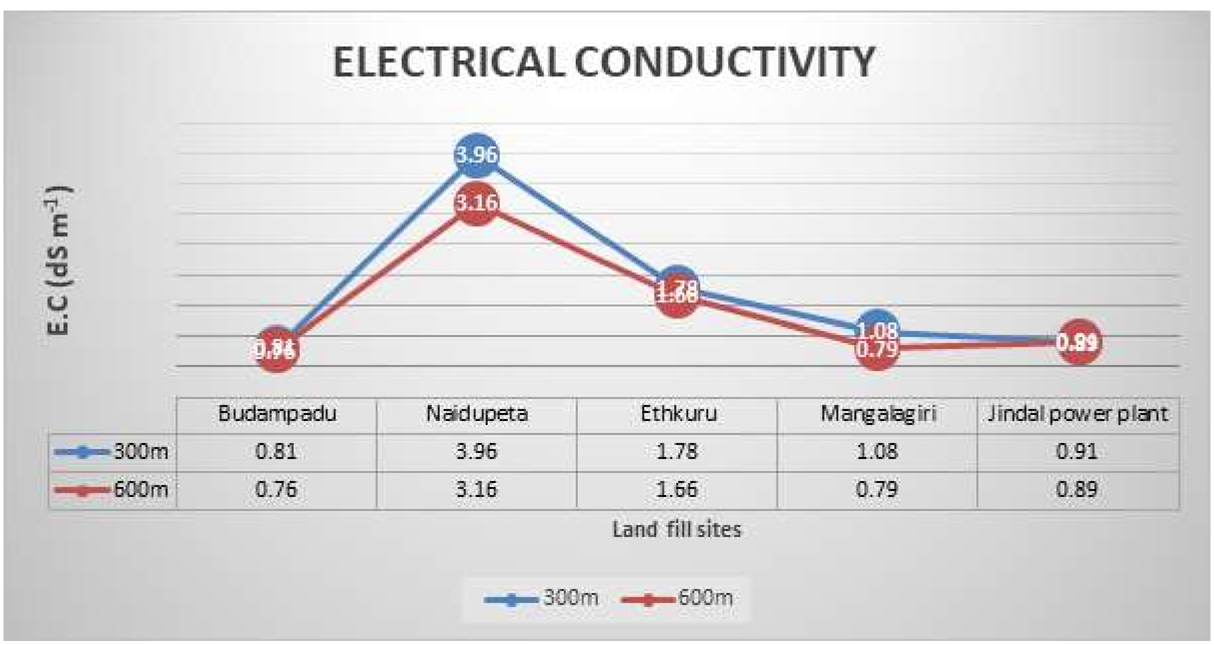


**Fig.1 Electrical conductivity (dS $m^{-1}$) of ground water samples collected near different landfill sites**

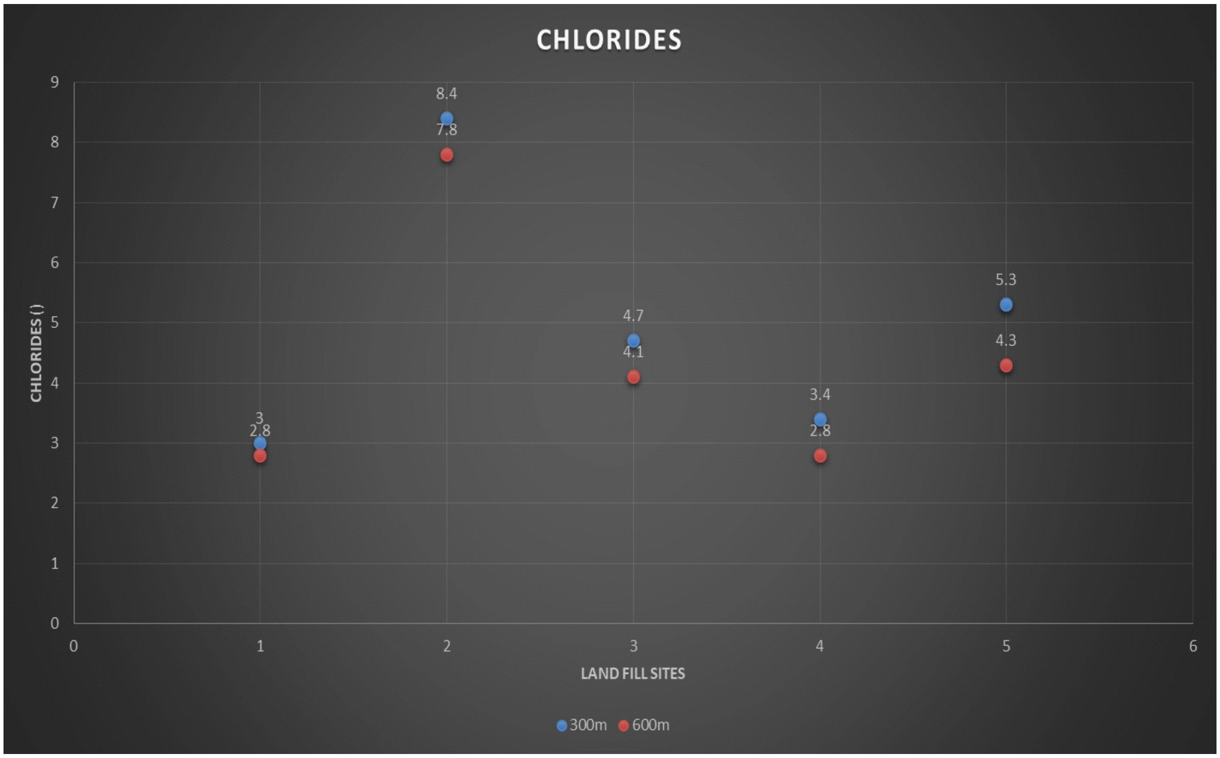


**Fig. 2Chloride (me L$^{-1}$) of ground water samples collected near different landfill sites**

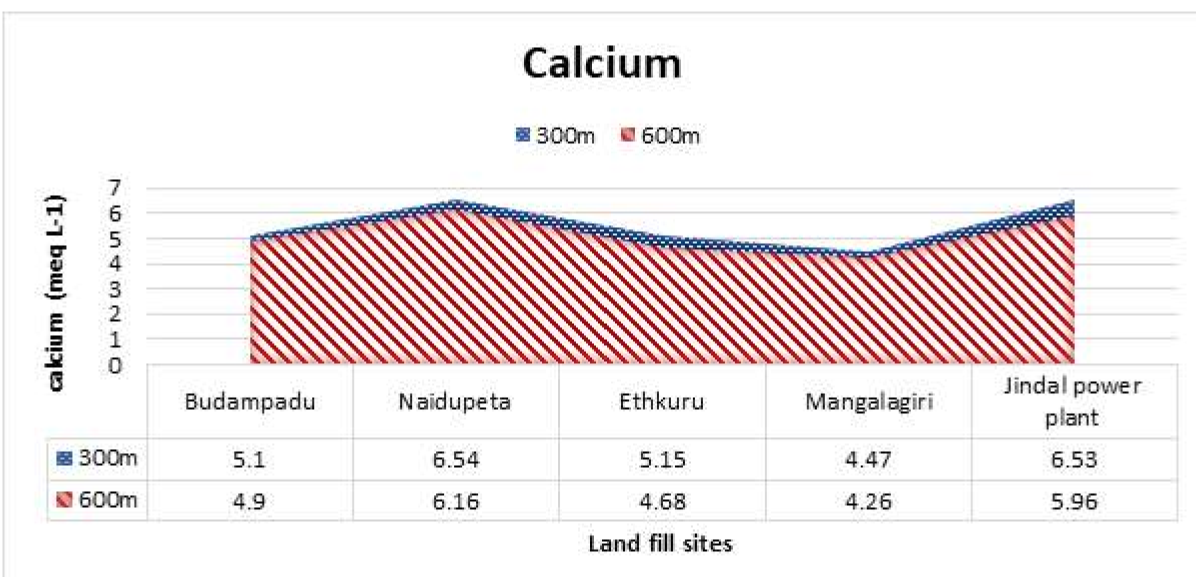


**Fig 3. Calcium (meq L$^{-1}$) of underground water samples collected near different landfill sites**

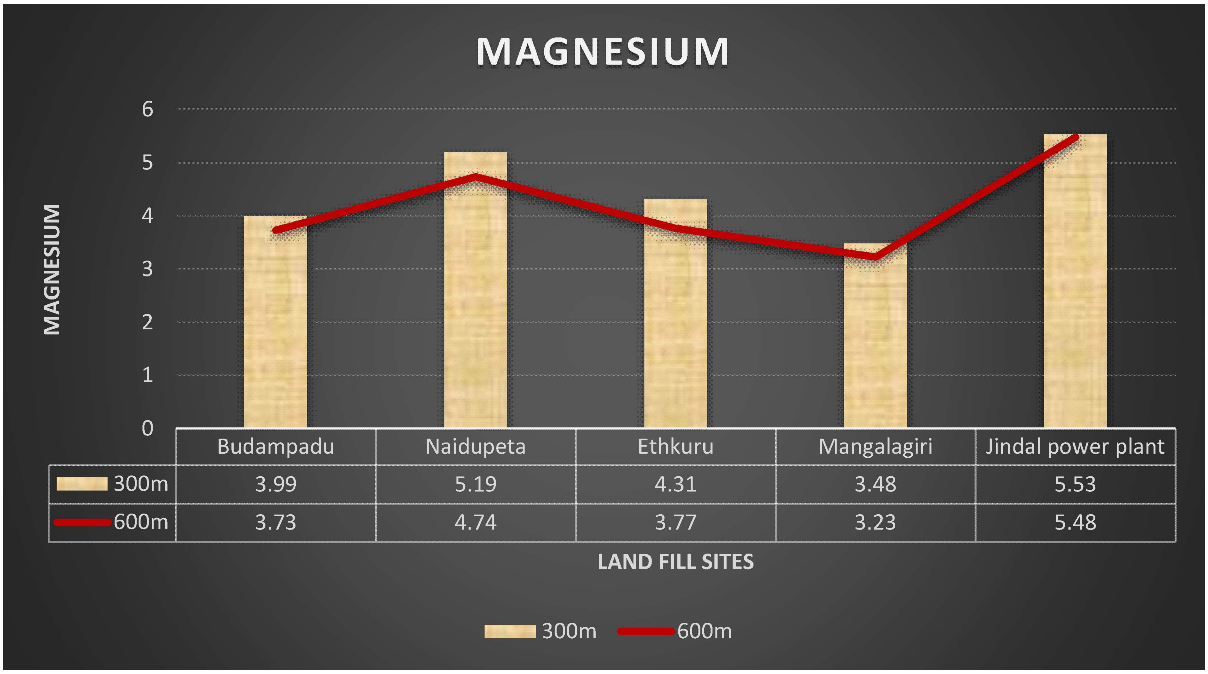


**Fig 4. Magnesium (me $L^{-1}$) of underground water samples collected near differ ent landfill sites**

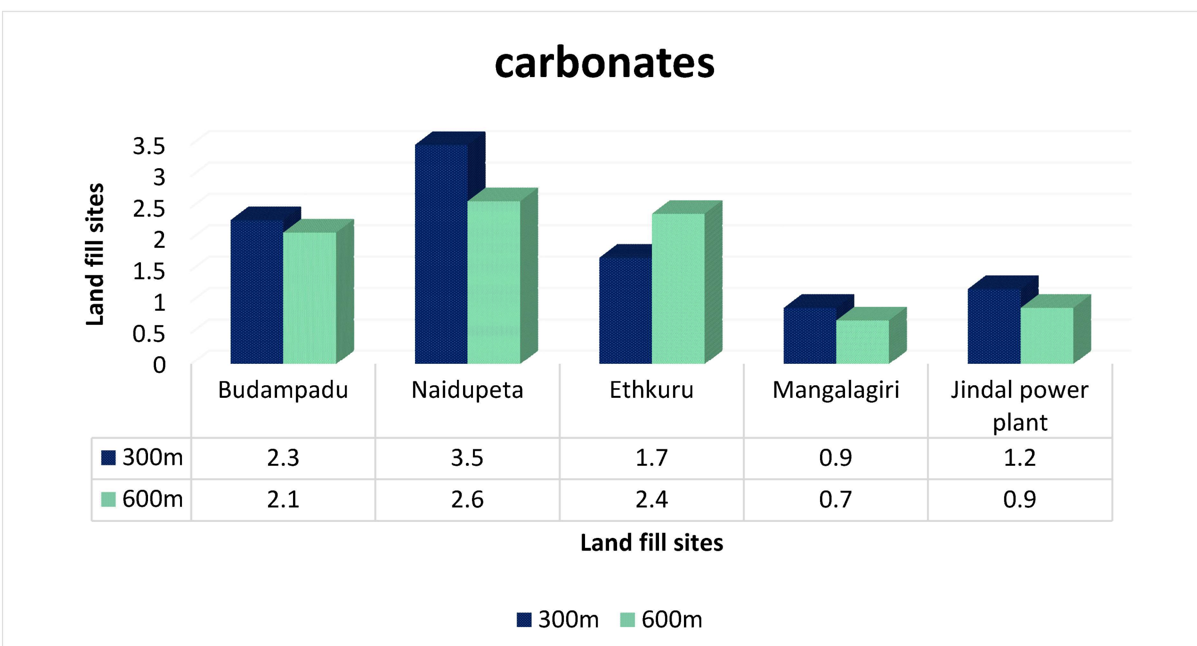


**Fig. 5. Carbonates (me $L^{-1}$) of underground water samples collected near different landfill sites**


| | Budampadu | Naidupeta | Ethkuru | Mangalagiri | Jindal power plant |
|---|---|---|---|---|---|
| 300m | 8.8 | 22.1 | 14 | 15.7 | 16.8 |
| 600m | 8.4 | 14.5 | 11.7 | 14.4 | 17.3 |

**Fig. 6. Bio carbonates (meq L$^{-1}$) of underground water samples collected near different landfill sites**


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