OPEN DUMPING OF MUNICIPAL SOLID WASTE – IMPACT ON GROUNDWATER AND SOIL

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Abstract

Municipal Solid Waste Management has become one of the major problems in urban and semi-urban areas. Improper MSW disposal and management causes all types of pollution: air, soil, and water. Indiscriminate dumping of wastes contaminates surface and ground water supplies. Health and safety issues also arise from open dumping.

The report starts with various approaches to manage municipal solid waste and a plan to implement an integrated solid waste management for a town. In this one week, statistical study was performed at the dumping yard (near Thandemvalsa Village) which is located 12 km away from Srikakulam town. The total number of waste collection trucks and average quantity of generated solid waste from different locations of Srikakulam were calculated and collected data from municipal office is presented.

The focus of this study is to assess the contribution of waste dumping in soil contamination and in groundwater pollution. Collected surface soil samples from the open waste dumping area and controlled site (away from dumping yard) were examined and found variation in the soil composition. On the other hand, ground water samples were collected from the nearby village bore wells and open wells, were analyzed and observed contamination of groundwater up to certain limit. In-order to control contamination of air, water and soil, landfill was designed as a disposal method.

Index Terms: Municipal Solid Waste Management, Soil & Groundwater pollution, open dumping and Landfill

I. INTRODUCTION

The threat of environmental pollution has been lingering the human world and is still growing fast due to excessive population growth in developing countries. Municipal solid waste (MSW) normally termed as garbage or trash is an unavoidable consequence of human activity. Population growth and economic development lead to enormous amounts of solid waste generation by the dwellers of urban areas (Krishnamurti and Naidu, 2003). Urban MSW is usually generated from human settlements, small industries and commercial activities (Singh et al., 2011). Solid waste from hospitals and clinics is an additional source of MSW. Most of the countries do not have any specific technique of managing hospital and clinical wastes. So, they are mixed with MSW and pose a threat to human population and surrounding environment (Pattnaik and Reddy, 2009).

Unsuitable disposal of MSW causes all types of pollution: air, soil, and water. Indiscriminate dumping of wastes contaminates surface and ground water supplies. In urban areas, MSW clogs drains, creating stagnant water for insect breeding and floods during rainy seasons. Open burning of MSW contributes significantly to urban air pollution. Open dumping is quite common in developing countries due to low budget available for waste disposal. It also poses serious threat to groundwater.

Health and safety issues also arise from improper MSWM. Insect and rodent vectors are attracted to the waste and can spread diseases such as cholera and dengue fever. Using water polluted by MSW for bathing, food irrigation and drinking water can also expose individuals to disease organisms and other contaminants.

In India, dumping on land is the most common method of waste disposal, because it is the cheapest method of waste disposal, still, this requires large area and proper drainage. The land disposal of municipal and industrial solid waste is potential cause of groundwater contamination. Unscientifically managed dumping yards are prone to groundwater contamination because of leachate production. Leachate is the liquid that seeps from solid wastes or other medium and have extracts with dissolved or suspended materials from it.

The volume of leachate depends principally on the area of the landfill, the meteorological and hydro-geological factors and effectiveness of capping. It is essential that the volume of leachate generated be kept to a minimum and ensures that the access of groundwater and surface water is minimized and controlled. The volume of leachate generated is therefore expected to be very high in humid regions with high rainfall, or high run off and shallow water table (Chapman. D 1992). Leachate from the solid waste dump has a significant effect on the chemical properties as well as the geotechnical properties of the soil. Leachate can modify the soil properties and significantly alter the behavior of soil (Ebrahim Panahpour, 2011).

II. METHODS AND MATERIALS

Study Area

The study area is located about 12 km away from the Srikakulam town (18°34′49.57″N, 83°94'94.14"E), in Andhra Pradesh state, India. The volume of waste being dumped at the dump yard was 27tonnes/day in 2017. The waste dumped at this site includes domestic waste, e.g. kitchen waste; paper, plastic, glass, cardboard, cloths. Construction and demolition waste consisting of sand, bricks and concrete block are also dumped. Further waste from the poultry market, fish market, slaughterhouse, dairy farm and non-infectious hospital waste is also dumped. The site is a non-engineered low lying open dump, a huge heap of waste up to a height of 12-20 m. The waste is dumped irregularly without segregation, except the rag pickers who rummage through the garbage and help in segregating it.

Figure I: Dumping Yard - Thandemvalsa Village, Srikakulam

Field Survey and Quantification of Solid Waste

The methodology used for calculating the per capita waste quantification for Residential, Commercial and street sweeping at Srikakulam town is as follows:

Residential: The per capita survey in residential area has been calculated at 6 randomly selected wards. The 10 houses in each ward have been identified based on high income, low income and poor group of people. Plastic bags have been supplied to the identified households for collecting waste. After 24 hours, the waste is collected and weighed with weighing machine. The quantified waste has been divided with the number of family members to get the individual contribution of waste. The survey was carried out for 3 continuously days at all the wards. The average per capita has been considered for further calculations.

Commercial: Six wards were selected randomly for per capita survey at commercial centers. The bins identified are depending on the type of centers like thick commercial complexes, thin commercial areas and streets containing market yards. The capacity of each bin or heap of MSW at all the 10 collection points and the number of fillings of each bin in a day has been calculated and the average value is projected for further calculations.

Street Sweeping: The street sweeping data was collected on each day by weighing the heaps on a road length having 1 km stretch. Same procedure was adopted at various centers like commercial/residential etc. The data projected is based on the road length survey.

Primary Survey results: The methodology adopted for collecting MSW samples in this ULB is as per CPHEEO manual based on the type of area such as residential, commercial, industrial, market and slum. To assess the waste generation levels primary survey was also carried out in selected wards of Srikakulam town. Around six typical wards were selected and data related to number of persons in each ward, the waste generation in terms of residential, commercial and street sweeping waste details were collected on a day to day basis. Waste Characterization was also carried during the survey.

Sampling and Analytical Methods

Since there is no proper solid waste treatment and disposal, at the dump yard, there is a possibility of contamination to soil and groundwater in and around the site. So, a soil sample from the dump yard and soil away from the dump yard are collected for testing and comparison. Similarly, to check whether the ground water is being contaminated or not, the ground water samples were collected from a neighboring village (2 km) and tested.

The analysis was done as per the standard methods. Various Physico-chemical parameters examined in water samples include, pH, electrical conductivity (EC), total dissolved solids (TDS), total alkalinity (TA), total hardness (TH), calcium, magnesium, potassium, iron, chlorides, turbidity, Nitrates. Similarly soil samples were tested for pH, water soluble salts, organic matter, nitrogen, phosphorus, potassium, iron, water soluble chlorides, water soluble sulphates, calcium carbonate. The results were compared with BIS standard limits.

Soil samples were collected from the dumpsite, by removing the surface debris and subsurface soil dug to a depth of about 30cm and 1m with a hand auger. 5 Kg of soil sample was taken into the sterile containers and labeled. The soil samples were carried to Andhra university laboratory and analyzed for soil chemical properties. The water samples were carried to Zilla.Parishad laboratory and analyzed.

III. RESULTS AND DISCUSSION

Quantification of Solid Waste

With the help of local bodies and the field survey, the amount of waste that is being generated in the Srikakulam town was quantified and found that 60% is from Residential buildings. The other main contributions are from Street sweepings & Drain cleaning (10%) and Commercial Establishments (9%) followed by Market Waste (5%) and Hotels & Restaurants (5%). The least contribution is the construction & demolition waste (<1%), because construction & demolition waste is being used for filling low laying areas by the public.

Table I: Amount of solid waste generated from different sources of Srikakulam town

S. No	Type of waste	Waste Generated in (Mton/day)	Waste Generation (%)
1	Residential & Commercial	16.2	60
2	Market Waste	1.35	5
3	Street sweepings and Drain cleaning	2.89	10.7
4	Hotels & Restaurants	1.35	5
5	Marriage/Function halls	0.58	2.14
6	Commercial Establishments	2.51	9.29
7	Hospitals/Health centers	0.47	1.71
8	Construction Waste	0.19	0.71
9	Institutions	0.77	2.86
10	Temples	0.31	1.14
11	Chicken, Beef, Mutton & Fish stalls	0.38	1.43
	Total	27	100

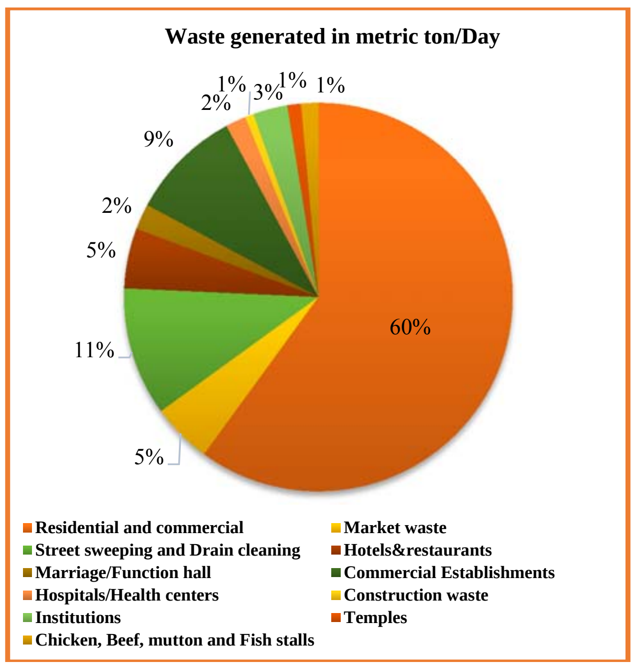


Figure II: Pie chart showing various source contributions to MSW of Srikakulam town

GROUNDWATER ANALYSIS

The various ground water quality parameters are shown in the below Table II.

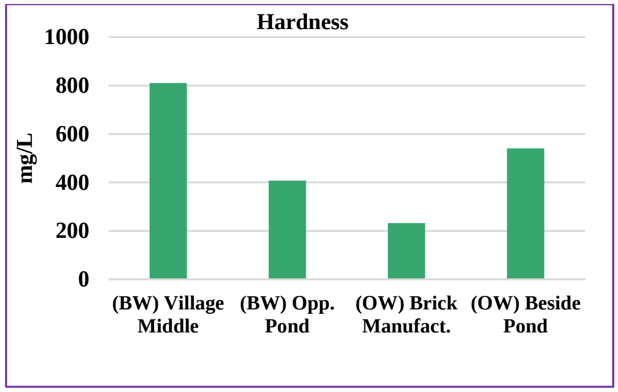
Table II: Groundwater analysis of 4 groundwater samples collected from Bore wells (BW) and open wells (OW)

Location / Parameter	Village Middle (BW)	Opp. Pond (BW)	Opp. Brick Manufacturing (OW)	Beside Pond (OW)
PH (6.5-8.5)	7.12	6.98	7.54	7.14
EC micromhos/cm (200-2000)	3340	1563	648	2130
TDS (500-2000 mg/L)	2171	1015	421	1384
Total Alkalinity as $CaCO_3$ (200-600 mg/L)	480	332	208	412
Total Hardness as $CaCO_3$ (300-600 mg/L)	810	408	232	540
Fluorides (1.0-1.5 mg/L)	0.62	0.85	0.87	0.92
Chloride (250-1000 mg/L)	700	232	100	428
Calcium (75-200 mg/L)	91	36	38	41
Iron as Fe (0.3 mg/L)	0.04	0.01	0.01	0.02
Turbidity (5-10 NTU)	0.6	0.8	0.4	0.5
Magnesium (50-150 mg/L)	174	90	47	121
Nitrates as NO_3^- (45 mg/L)	65	45	10.4	15.7
Remarks	Not Satisfactory	Satisfactory	Satisfactory	Satisfactory

The pH of different groundwater samples near the dumping site was ranged 6.98 - 7.54, which were within the desirable limit of BIS. The total alkalinity found in the water samples near municipal dumping site ranged from 208 mg/L - 480 mg/L, with the maximum value at the Village Middle and still within the permissible limits.

Hardness:

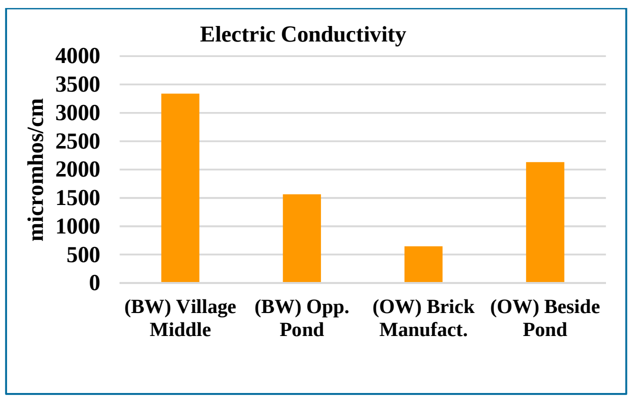
The total hardness was found in range of 232 mg/L - 810 mg/L. The maximum value of 810 mg/L was recorded at the Village Middle, bore well, which is above the standard permissible limit of BIS (600 mg/L). The concentration of calcium in the groundwater samples was found from 36 mg/L to 91 mg/L, less than the permissible limit of 200 mg/l of BIS.



Graph I: Total Hardness present in various groundwater samples

Electric Conductivity (EC):

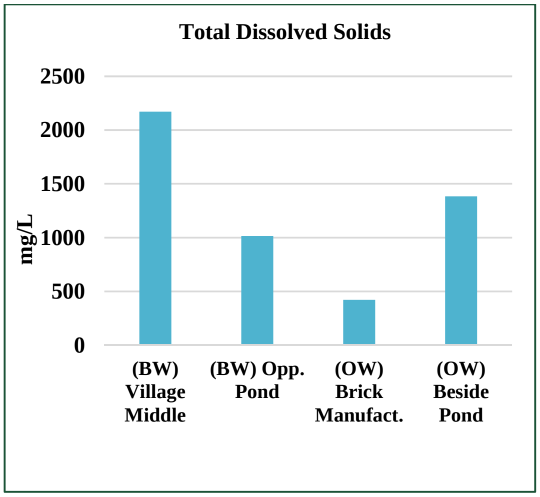
The conductivity around the study site was found to be in range between of 648 µmhos/cm - 3340 µmhos/cm. Highest value of conductivity (3340) µmhos/cm. was found at the Village Middle (bore well water sample).



Graph II: EC of groundwater samples collected from four locations

Total Dissolved Solids (TDS):

Total dissolved solids (TDS) refers to the matter dissolved in water with high content is inferior and may be polluted. In the present study, TDS ranged from 421 mg/L to 2171 mg/L. Highest value of TDS (2171 mg/L) was found at the sampling site, Village Middle, which is above the desirable and permissible limits (500 -2000 mg/L) of BIS.

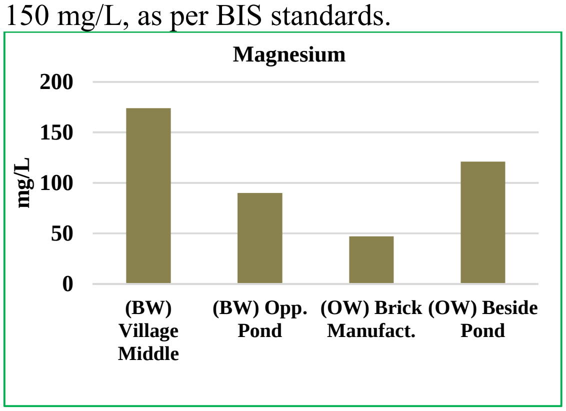


Graph III: Total Dissolved Solids present in groundwater samples

The high amounts of EC and TDS observed in the groundwater imply a downward transfer of leachate into groundwater as previously mentioned by Mor et al. (2006) and Longe and Enekwechi (2007). Higher the TDS lower the palatability of water and may possibly cause gastro-intestinal irritation in human and laxative effects particularly upon transits (WHO, 1997).

Magnesium:

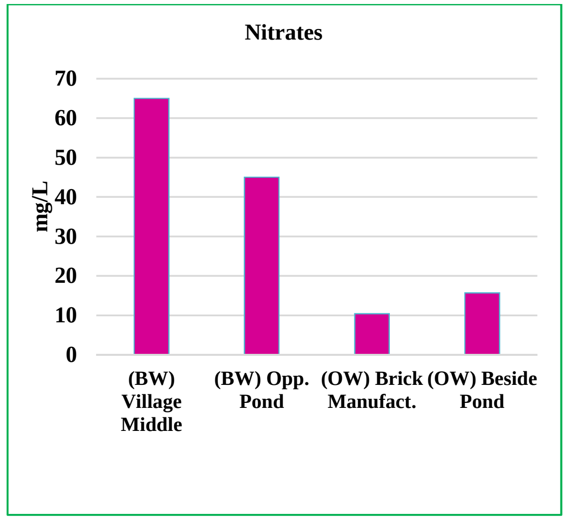
Magnesium values were found in the range of 47 mg/L as minimum at Opp. Brick manufacturing unit (open well) and 174 mg/L as maximum at Village Middle (bore well). Magnesium concentration is above the permissible limit of 150 mg/L, as per BIS standards.



Graph 10: Amount of Magnesium found in groundwater samples

Nitrates:

High concentration of nitrate causes Methemoglobinemia (blue baby syndrome) in infants. Nitrate was recorded in the range of 10.4 mg/L - 65 mg/L. The maximum value of 65 mg/L was found at the Village Middle, bore well, which is above the standard permissible limit of BIS (45 mg/L).



Graph V: Nitrate concentrations in groundwater samples

In the case of chloride concentrations, the minimum and maximum values were 100 mg/L and 700 mg/L at sampling sites; Opp. Brick manufacturing unit and Village Middle respectively. Even though the maximum value of 700 mg/L is below the permissible limit of BIS, it is above the maximum allowable concentration given by WHO guidelines. In this study the fluoride concentrations (0.62 to 0.92 mg/L) of groundwater samples were within the permissible limits of BIS drinking water standards. In the same way Iron (0.01 – 0.04 mg/L) and Turbidity values (0.4 – 0.6 NTU) were within the permissible limits of both BIS standards and WHO guidelines of drinking water.

Finally, out of four Groundwater water samples, three are within the limits and satisfactory. But one sample from bore well (middle of the village) is not satisfactory as it is contaminated. Especially, EC, TDS, Hardness, Magnesium and Nitrates are above the standard limits found in bore well water located at the middle of the village. This clearly shows that there is some type of contamination happening due to open dumping of solid waste without any pre-treatment or safe disposal. This might be due to the leachate produced from the solid waste dumped openly.

SOIL TESTS:

From the analysis of soil samples collected from the dumping yard and away from dumping yard, the results were obtained for 10 parameters and presented in the below table.

Table III: Characteristics of two soil samples collected from and away of dumping yard

Parameter	Soil from Dumping yard (%)	Soil away from Dumping yard (%)
pH	8.40	7.96
Water soluble salts	2.40	0.340
Organic matter	1.980	0.060
Nitrogen	1.360	0.108
Phosphorus	0.750	0.028
Potassium	0.015	0.002
Iron	0.009	0.002
Water soluble chlorides	0.990	0.004
Water soluble Sulphates	0.008	0.001
Calcium carbonate	0.170	0.005

From the above table it is clear that the soil from the dump yard contains higher amounts of certain parameters than the soil away from the dump yard. Especially, organic matter, nitrates, and phosphorus that are more in dump yard soil sample are beneficial to the plant growth or for cultivation. But due to improper solid waste management, this nutrient rich soil is mixed up with several other contaminants such as soluble salts, plastics, heavy metals and so on. This makes the soil not fit for cultivating purposes.
Proper segregation, recovery, treatment and safe disposal either composting or sanitary landfill will provide nutrient rich organic soil for cultivating crops and for plantation purposes.
On the other hand, due to open burning, another problem is air pollution. So, due to improper solid waste management, there will be a great effect on surrounding environment (air, land and water).

DESIGN OF LAND FILL

Available solid waste per day = 27000 ton/day
Assume height and width of a cell is 10 ft and 100 ft
Slope of working face is 3:1
Assume that the waste is compacted initially to an average specific weight of 600, 800, and 1000 lb/yd^3
The daily cover thickness is 0.5 ft

1) Daily volume of the deposited solid waste

a) For 600 lb/yd^3

$$V_d = 27000 \text{ ton/day} \times 2000 \text{ lb/ton} \times \frac{yd^3}{600\, lb}$$
$$V_d = 90000 \text{ yd}^3$$

b) For 800 lb/yd^3

$$V_d = 27000 \text{ ton/day} \times 2000 \text{ lb/ton} \times \frac{yd^3}{800\, lb}$$
$$V_d = 67500 \text{ yd}^3$$

c) For 1000 lb/yd^3

$$V_d = 27000 \text{ ton/day} \times 2000 \text{ lb/ton} \times \frac{yd^3}{1000\, lb}$$
$$V_d = 54000 \text{ yd}^3$$

2) Length of each daily cell

a) For 600 lb/yd^3

$$L = \frac{V_d \times 27\frac{ft^3}{yd^3}}{B \times H}\pi r^2$$
$$L = \frac{90000\times 27}{100\times 10}; \quad L = 2430ft$$

b) For 800lb/yd^3

$$L = \frac{67500\times 27}{100\times 10}; L = 1822.5ft$$

c) For 1000lb/yd^3

$$L = \frac{54000\times 27}{100\times 10}; \quad L = 1458ft$$

3) Cell surface areas

a) For top of the cell

$A_{T600} = L \times B$= 2430×100= 243000 ft^2
A_{T800} = 1822.5 × 100 = 182250 ft^2
A_{T1000} = 1458 × 100 = 145800 ft^2

b) For the face of the cell

$$A_{F600} = 2430 \times \sqrt{10^2 + (3\times 10)^2} = 76843.89 \text{ ft}^2$$
$$A_{F800} = 1822.5 \times \sqrt{10^2 + (3\times 10)^2} = 57632.92 \text{ ft}^2$$
$$A_{F1000} = 1458 \times \sqrt{10^2 + (3\times 10)^2} = 46106.33 \text{ft}^2$$

c) For the side of the cell

$$A_s = 100 \times \sqrt{10^2 + (3\times 10)^2} = 3162.3 \text{ ft}^2$$

4) Volume of soil for daily cover

$$V_c = Daily\ cover\ thickness \times (A_T + A_F + A_S)$$

V_{C600} = 0.5×(243000+76843.89+3162.3) = 161503.095 ft^3
V_{C800} = 0.5×(182250+57632.92+3162.3) = 121522.61 ft^3

$V_{C1000} = 0.5\times(145800+46106.33+3162.3)$
$= 97534.31\ ft^3$

5) Ratio of waste to cover soil

a) For 600 lb/yd^3

$$R_{W.C} = \frac{90000\times27}{161503.095} = 15.04:1$$

b) For 800 lb/yd^3

$$R_{W.C} = \frac{67500\times27}{121522.61} = 14.99:1$$

c) For 1000 lb/yd^3

$$R_{W.C} = \frac{54000\times27}{97534.31} = 14.94:1$$

IV. CONCLUSION

The dumping site near Thandemvalsa Village, Srikakulam, was found susceptible to the ground water contamination through leaching action. The concentration of various Physico-chemical parameters such as conductivity, total dissolved solids (TDS), alkalinity, total hardness, magnesium, chloride, and nitrate were recorded higher at the Village Middle (bore well water sample).

Despite the fact that the concentration of several other parameters in ground water is within permissible limits yet it is important and is thought provoking as the ground water should have been free from any kind of contamination. Even though most of the Physico chemical parameters were within the permissible limits of BIS standards, some of them are above the maximum allowable limits of WHO guidelines.

The collected solid waste must be segregated, treated and disposed in an environmentally acceptable manner. So, safe disposal of solid waste leads to safe human health and healthy environment. Moreover, segregated solid waste can be used to recover precious metals, generate electricity and produces nutrient rich soil. For better disposal of solid waste, a Landfill was designed.

As a result, there is a need of integrated municipal solid waste management of the Srikakulam dumping site to prevent ground water contamination and the regular monitoring of the ground water in and adjoining areas of landfill dumping site is also required.

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