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Modeling of Leachate Generation from Landfill Sites

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ABSTRACT

With rapid urbanization and industrialization, Bhutan is developing at a fast pace due to which solid waste generation is increasing day by day and hence its management has become a great issue. One of the management issues that are faced in the management of landfills is the generation of toxic soup from landfills known as leachate which is one of the causes of water and soil pollution. The landfills in Bhutan lack a proper leachate management system and those that have leachate collection tanks are very uneconomical due to unreliable methods being used to determine the leachate generated amount. Leachate generation from municipal solid waste (MSW) landfills by various methods such as Standard, Rational, and Mass balance methods was determined, analyzed the results and ultimately developed a reliable method for determining the amount of leachate generated by a landfill known as "Fusion method". The quantified leachate volume from the study area was 4565.98 m^3 with the annual precipitation amount being 15156.09 m^3 with the developed (fusion) method. Validation of the model was performed on data from Deir Al Balah landfill, Gaza strip, Palestine. The validated amount of leachate generation is about 123,833.08 m^3 by the fusion method, while the actual amount of leachate generated was about 114,351 m^3 from which the percentage difference between the fusion method and the actual amount of leachate generated was found to be only 8.29%, compared to other methods with % error ranged from 10-55 %.

INTRODUCTION

Bhutan is a small developing country with a total area of 38,394 km^2. The country is developing rapidly with exponential population growth and economic progress. The population of the country was estimated to be 771,608 in the year 2020, out of which 45.8% lived in the rural area and 54.2% lived in urban areas (National Statistics Bureau 2018). The National Environment Commission's (NEC) report has pointed out that, with rapid socio-economic growth, increased population, and urbanization, the country is seeing an increase in the volume of solid waste generated. Hence its management is becoming a great issue with many problems evolving (National Environment Commission 2016). One such problem is the generation of toxic soup from landfills known as leachate which is formed when waste is subjected to biological and physiochemical transformation. These are highly toxic and can pollute the land, groundwater, and waterways. Bhutan has about 25 open dumpsite landfills and almost all of them lack a leachate treatment/management system which was mentioned in the BSE report 2016 by the NEC of Bhutan (National Environment Commission 2016).

Leachate is highly polluted and complex wastewater containing high amounts of dissolved and suspended matter generated from percolated water through the waste in landfills. Leachate treatment is very important as it could threaten the surrounding ecosystem when discharged and mixed with groundwater. The increase in municipal solid waste in the country has led to a major issue. (Raghab et al. 2013) explained the formation processes of the leachate generation. Then the anaerobic treatment of leachate was performed using coagulation and flocculation processes. They utilize natural low-cost materials to enhance the chemical treatment process. The result of the study concluded that the treatment was obtained using alum and accelerator (perlite and bentonite). The leachate generation mainly depends on the precipitation and the moisture contained by the waste. The water balance method has been used to determine the rate of leachate generation and found that the estimated amount by the water balance method is coming close to the actual leachate rate, although using closed landfills was reported as a limitation of the study (Baziene et al. 2013). Also, the moisture content of the waste plays a big role in the production of the leachate. It is the moisture content of the waste which results in the production of leachate generated by the waste itself and the amount of precipitated rainfall entered into the waste. Even though, the leachate generation by waste itself depends on a number of factors, moisture content by the waste is one of the major factors which contribute to leachate generation (Hashisho & El-Fadel 2014).

Bhutan does not have a proper waste or leachate treatment system. Since the wastes are dumped from different sources and unseparated, leachate generated will consist of different constituents such as highly toxic chemicals and heavy metals (World Bank 2000). Also, Landfill leachate has been one of the most prominent threats to living beings, especially aquatic animals. Studies have been carried out and studied about the social and environmental risk associated with landfill leachate, its deterioration effects on ecosystems and thus proper quantification of leachate generated from a dumpsite if significant to prevent its pollution effect on ground and water (Ololade et al. 2019).

Various methods are implemented for quantifying the amount of leachate generated by a landfill such as the standard method, rational method, and many other conventional methods. But some conventional methods either overestimate or underestimate the amount of leachate which leads to the design of uneconomical tanks for the leachate collection system. Estimation of leachate generation from MSW landfills in Selangor was performed using the formula $V = 0.15 \times R \times A$ for the calculation of leachate generation. The area (A) of the landfill was calculated using Google Earth and multiplied by annual rainfall (R). Since only two factors are considered, the estimated leachate generated was mostly assumption based. For the calculation of leachate generation, they have selected the closed landfill but most of the landfills are always active. Mainly because of closed landfills the leachate generated by the waste itself was neglected (Ibrahim et al. 2017). Other scenarios could be, the generation of leachate being more and as a result, the tank will overflow during peak season. (Komilis & Athiniotou 2014) have developed a model called as monthly water budget model for the estimation of leachate generation. For the validation of the model, they have used actual leachate generated at the field as they have a record of two years. The main drawback of the model was the negligence of runoff.

This study emphasizes studying various conventional methods and eventually developing a more reliable method and then calculating the leachate generated by a landfill using all of the methods. According to the literature reviews, it was observed that there are a number of parameters that affect the quantification of leachate generation, and all of the above methods that have been reviewed lacked one or more parameters in their method which affects the reliability of the result for calculation of leachate generation. For instance, even if all the parameters are considered for calculation, the complexity increases. Moreover, to obtain some parameters there is a requirement of expensive and complex equipment. Thus, this research aims to develop a model that quantifies the leachate generation considering more onsite parameters and presents less percentage error compared to other methods.

STUDY AREA

Phuentsholing Thromde is located in the south-western foothills of the country with an area of 15.6 sq. km housing a projected population of more than 30,000 including the floating population. The Thromde produces a total amount of 7200 tons of waste annually all being dumped in the only landfill located at Pekarshing (Fig. 1) which is seven km away from the town. Currently, 15-20 tons of waste are dumped at the landfill per day. The waste composition of the landfill is 5% textile, 7% yard, 8% organic material, 6% paper, 12% plastic, 13% Inert Material, 40% Glass, and 9% Metals (Choden et al. 2021).

Through an experimental study, the following data were obtained:

- Field density 14%
- The moisture content of the soil was 12.11%
- The density of the soil was 201.132 $Kg.m^{-3}$
- The total area of the landfill is 3030.49 m^{-2}

With a total of 7.2 km^2 designated area, only 1.2 km^2 area has been used as a landfilling site. The landfill is divided into two parts i.e., an old inactive landfill and a new operational landfill as seen in Fig. 1. The design capacity of the landfill is 24 metric tons per day ($Mt.d^{-1}$) with a design period of 10 years. The landfill is an open dumpsite system. The annual precipitation for the year 2020 is 15,156.09 m^3 for the landfill area.

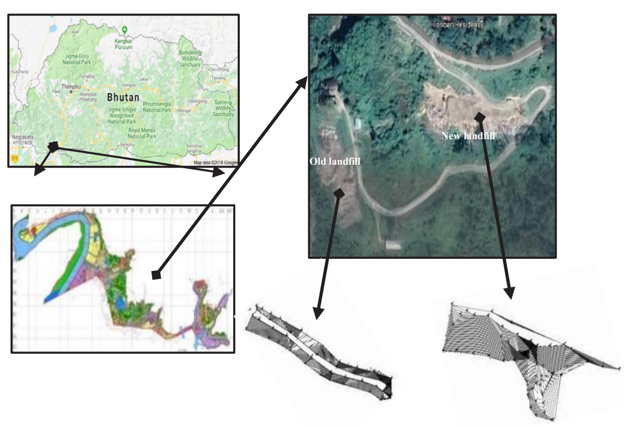

Fig. 1: Pekarshing landfill.

MATERIALS AND METHODS

The methodology emphasizes studying various conventional three methods, eventually developing a more reliable method and then calculating the leachate generated by a landfill using all of the methods. All the conventional methods were carefully studied and a new method (fusion) was developed. The calculation for leachate generation by Pekarshing landfill was done. A model was developed for the quantification process and then the result of the model was compared with conventional results.

Standard Method

A standard method is a simple mathematical model to estimate the amount of leachate generated from municipal solid waste (MSW). It is one of the most used methods or models to estimate the leachate generated in municipal landfills even these days. Many countries in the world adopted this method as it is simple and also has been used for a long time. This method does not consider many parameters. Instead, coefficient 0.15 is taken to consider all the losses in the landfill. The total quantity of leachate is a fraction of the total precipitation (about > 75%) in the active phase and <10% in the closed phase. Peak rate (volume per unit time) is a function of the peak precipitation and height of waste. If the peak precipitation occurs when the waste height/thickness is small, the peak leachate rate is directly proportional to the peak precipitation rate. Whereas if the peak precipitation occurs when the thickness is full of height, the effect is delayed and the peak leachate rate is less than the peak precipitation rate. The relation for the estimation of leachate using this method is shown in equation 1 (Ibrahim et al. 2017).

$$V = 0.15 \times R \times A \qquad \ldots(1)$$

Where;

V is the volume of leachate discharge in a year ($m^3.year^{-1}$).

R is annual rainfall (m).

A is the surface area of the landfill (m^2).

Rational Method

The rational method requires certain parameters to be considered to calculate the amount of leachate generated. The parameters are rainfall precipitation, area of the landfill, and leachate generation coefficient. In the case of coefficient, it is considered based on the nature of the landfill, i.e. if it is a currently used landfill or an old landfill that was disbanded. For an old landfill, the coefficient considered is 0.3 and for a currently operational landfill, the coefficient considered is 0.5. Therefore, the amount of leachate generated is calculated by equation 2 (JICA 2009).

$$Q = Ij \times C \times A \qquad \ldots(2)$$

Where;

Q is the amount of leachate generated.

Ij is rainfall mm/month.

C is the coefficient of leachate generated.

A is the area of the landfill.

Mass Balance Method

This is one of the conventional methods to calculate leachate generation. It takes into consideration the leachate generated by waste itself. In most of the methods, the leachate generated by waste itself is neglected which leads to incorrect estimation. Unlike the other two conventional methods, it considers more parameters like the amount of waste produced, infiltration, and precipitation (Yang et al. 2015).

Equation 3 is used for the calculation of mass balance:

$$L = PI + W_S \qquad \ldots(3)$$

where;

PI is the leachate generated from the precipitation infiltrated and it can be calculated from

$$PI = \sum_{c}^{n} \frac{P \text{ x } (Ic/100) \text{ x } tc}{\rho \text{ x } h}$$

P represents precipitation in mm per month,

I_c represents the ratio of infiltration,

it is the time period of the top cover,

ρ is the density of the waste in tons per m^3 and,

h is the uniform height of the waste in m.

PI is the leachate generated by precipitation infiltered in liter per ton.

Phuntsholing thromde produces waste of 450 to 600 tons of waste per month and the uniform height of the waste is considered 3.5 m. The density of the waste on the landfill was found to be 0.202 tons per m^3 and the soil cover c was done every month. The ratio of infiltration in the year 2020 was found to be 35%.

W_S is the leachate generated by waste itself or the water squeezed from the waste. Now to calculate the W_S we have:

$$W_S = IDM \times \left(\frac{IMCDM}{100} - \frac{FCCDM}{100}\right) \times 1000$$

Where;

- W_S is the leachate produced by waste itself in liter per ton,
- IDM is the initial dry mass which is calculated from

  IDM= $\left(1 - \frac{IMC}{100}\right)$,
- IMC is the moisture content of the waste,

- IMCDM is the initial moisture content of the dry mass calculated as

$$\text{IMCDM} = \frac{\text{IMC}}{1-(\frac{\text{IMC}}{100})},$$

- F_{cc} is the field capacity of the waste in % and, $F_{cc}DM$ is the field capacity of the dry mass i.e., $F_{cc}DM = \frac{\text{Fcc}}{1-(\frac{\text{Fcc}}{100})}$.

Since both the PI and W_S have the same unit i.e., liter per ton, from which we can observe that the factors directly depend on the waste generation and not on the area of the waste covered which is one of the drawbacks of this method. The mass balance method considers more input parameters compared to the other two conventional methods.

Fusion Method

Compared to other conventional methods, this method takes into account, the number of parameters for the calculation of leachate generation. In the standard method and rational method, a certain percentage (15% for standard method, 30-50% for rational method) of precipitation is considered for the leachate generation and in the case of the mass balance method, important parameters such as area of contribution and precipitation are not considered for calculation of the leachate generation.

In this fusion method, all the above problems stated are resolved. It considers all the parameters such as runoff, evaporation, precipitation, leachate generated by waste itself, and area of contribution.

To develop the mathematical model, the water budget equation is used, which states that the continuity equation for water in various phases for a given area is written as:

Mass inflow – Mass outflow = Change in storage

$$V_i - V_o = \Delta S \quad \text{...(i)}$$

Considering the precipitation as the only source of water entering the landfill and other sources like groundwater and spring water are not considered because the location of the landfill should not be near any water source.

$$V_i = P \text{ (precipitation)}$$

It is known that in a given watershed the losses of water are given by runoff (R), evaporation (E), leachate that enters the landfill and comes out (L), and the transpiration (T). Consider the losses due to the transpiration as negligible.

$$V_o = R + E + L$$

Substitute the V_i and V_o in equation i;

$$P - R - L - E = \Delta S \quad \text{...(ii)}$$

Now to understand the change in the storage capacity, field capacity is needed, which is the maximum holding capacity of the waste. When there is no water in the waste, it is known as wilting point. The drainable water between the field capacity and saturation point is the liquid that comes as the leachate which is all shown in Fig. 2.

It can be written as;

ΔS as field capacity – leachate generated by waste itself.

$\Delta S = (\text{Fcc} \times \text{I}) - W_S$; where I is the infiltration which can find out by I= P – R – E

Substituting the ΔS in equation ii;

$$P - R - L - E = (\text{Fcc} \times \text{I}) - W_S$$

Making L the subject we get,

$$L = P - R - E - (\text{Fcc} \times \text{I}) - W_S \quad \text{...(iii)}$$

The above equation iii is known as the fusion formula and it is the formula that is being proposed for the calculation of the leachate generation. Since numbers of parameters are considered in this method, less percentage error could be expected.

Table 1 shows the calculation for leachate generation by various methods and Table 2 shows the calculation for leachate generation using the fusion method at the Pekarshing landfill. The total area of landfill is 3030.49 m^3 and waste generation is 600 tons per month. Leachate generated is 4565.98 m^3 which is 30.13% of precipitation, i.e., 15156.09 m^3 calculated in Table 3.

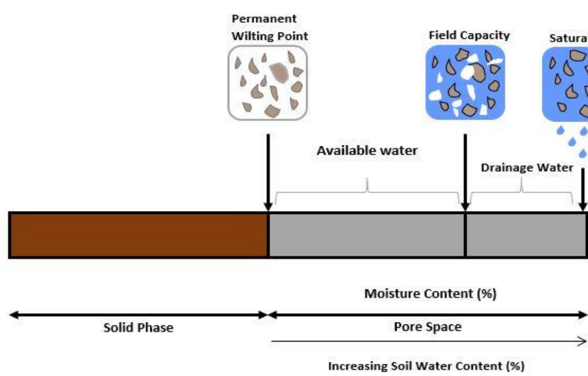

Fig. 2: Field capacity of soil.

Table 1: Leachate amount by various methods.

Method	Estimated Leachate generation in Pekarshing landfill in 2020 [m^3]
Standard Method	2273.41
Rational Method	6095.41
Mass Balance method	2346.35
Fusion Method	4565.98

Table 2: Estimation of Leachate generation by fusion method in Pekarshing landfill.

Sl.No.	Month / Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Rainfall (R)	0	40.8	113.2	207.3	533.1	1549.4	973.2	650.4	826.2	107.6	0	0
2	Area (A_1)	356.32	356.32	356.32	356.32	356.32	356.32	356.32	356.32	356.32	356.32	356.32	356.32
3	Area (A_2)	1191.89	1191.89	1191.89	1191.89	1191.89	1191.89	1191.89	1191.89	1191.89	1191.89	1191.89	1191.89
4	Area (A_3)	204.68	204.68	204.68	204.68	204.68	204.68	204.68	204.68	204.68	204.68	204.68	204.68
5	Area (A_4)	1277.6	1277.6	1277.6	1277.6	1277.6	1277.6	1277.6	1277.6	1277.6	1277.6	1277.6	1277.6
6	Evaporation	0	12.4	22.6	32.8	71.5	67.5	60.3	0	40.8	52.2	0	0
7	Runoff Coefficient (C_1)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
8	Runoff Coefficient (C_2)	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
9	Runoff Coefficient (C_3)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
10	Runoff Coefficient (C_4)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
11	Field capacity	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
12	Water hold by waste in mm (A_1)	0.00	2.26	7.93	15.72	42.23	142.39	86.93	63.74	75.26	3.24	0.00	0.00
13	Water hold by waste in mm (A_2)	0.00	0.55	3.18	7.02	19.84	77.32	46.06	36.42	40.56	-1.28	0.00	0.00
14	Water hold by waste in mm (A_3)	0.00	2.26	7.93	15.72	42.23	142.39	86.93	63.74	75.26	3.24	0.00	0.00
15	Water hold by waste in mm (A_4)	0.00	-0.02	1.59	4.11	12.38	55.62	32.43	27.32	28.99	-2.79	0.00	0.00
16	Actual leachate generation area 1	0.00	4.95	17.36	34.42	92.44	311.67	190.28	139.51	164.72	7.08	0.00	0.00
17	Actual leachate generation area 2	0.00	4.02	23.25	51.37	145.29	566.08	337.21	266.67	296.93	-9.39	0.00	0.00
18	Actual leachate generation area 3	0.00	2.84	9.97	19.77	53.10	179.03	109.30	80.14	94.62	4.07	0.00	0.00
19	Actual leachate generation area 4	0.00	-0.18	12.48	32.29	97.16	436.55	254.53	214.39	227.50	-21.89	0.00	0.00
20	Field capacity	14	14	14	14	14	14	14	14	14	14	14	14
21	Initial moisture content	12.11	12.11	12.11	12.11	12.11	12.11	12.11	12.11	12.11	12.11	12.11	12.11
22	IMCDM	13.78	13.78	13.78	13.78	13.78	13.78	13.78	13.78	13.78	13.78	13.78	13.78
23	FFCDM	16.28	16.28	16.28	16.28	16.28	16.28	16.28	16.28	16.28	16.28	16.28	16.28
24	IDM	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
25	Precipitation [m^3]	0.00	123.64	343.05	628.22	1615.55	4695.44	2949.27	1971.03	2503.79	326.08	0.00	0.00
26	Ws (leachate generated from waste) (Lt^{-1})	21.56	21.56	21.56	21.56	21.56	21.56	21.56	21.56	21.56	21.56	21.56	21.56
27	Total amount of waste generated per month [ton]	450	450	450	450	450	450	450	450	450	450	450	450
28	Leachate from waste [m^3]	9.70	9.70	9.70	9.70	9.70	9.70	9.70	9.70	9.70	9.70	9.70	9.70
29	Total leachate amount (monthly)[m^3]	9.70	21.34	72.76	147.55	397.69	1503.03	901.03	710.41	793.48	-10.42	9.70	9.70

Modeling Using Python Programming

A software is developed using python which directly displays the result of maximum precipitation of the month, total annual precipitation, and the graph showing monthly precipitation vs monthly leachate generation for a year. It has advantages such as:

1. To ease the calculation due to complex input parameters
2. To reduce human error during calculation
3. To cover up the time constraint
4. To make it user-friendly

To develop this software, python programming was used as the software language because it is user-friendly and it contains a wide range of library functions that ease programming. To develop this model, Qt designer is used to enhance programming, and two different types of library functions were also used namely, pyqt5 and matplotlib. Qt Designer is software that is used for making GUI (Graphical User interference) for a developed program. The software that was developed is termed YAKK and it is 58.2 Mb in size. It can be installed in any Windows OS and doesn't need any additional software like Python or PyCharm etc.

Fig. 3 shows the dashboard of software from which a user can choose the method, they want to use for the calculation of leachate generated by a landfill. Upon choosing a method, the next dialogue box will be displayed, where the user needs to input the required parameters. For example, if a user selects a standard method or mass balance method, Fig. 4 and Fig. 5 dialogue box is displayed respectively.

Now the user needs to input the required parameters and then click 'OK' for calculating the amount of leachate generated and the result will be displayed which the user can save for future reference. The displayed result will be as Fig. 6.

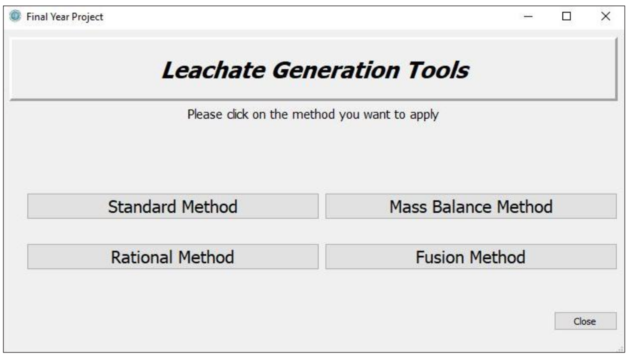

Fig. 3: Main dashboard.

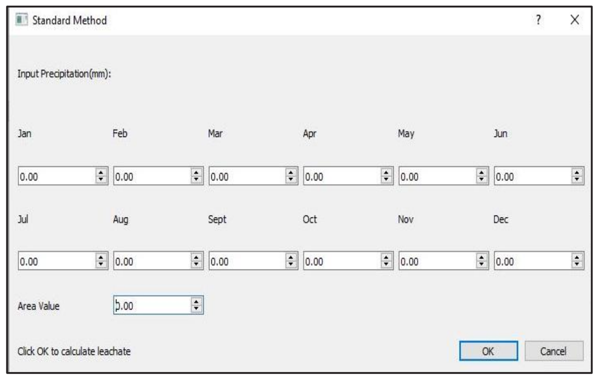

Fig. 4: Standard method dialogue box.

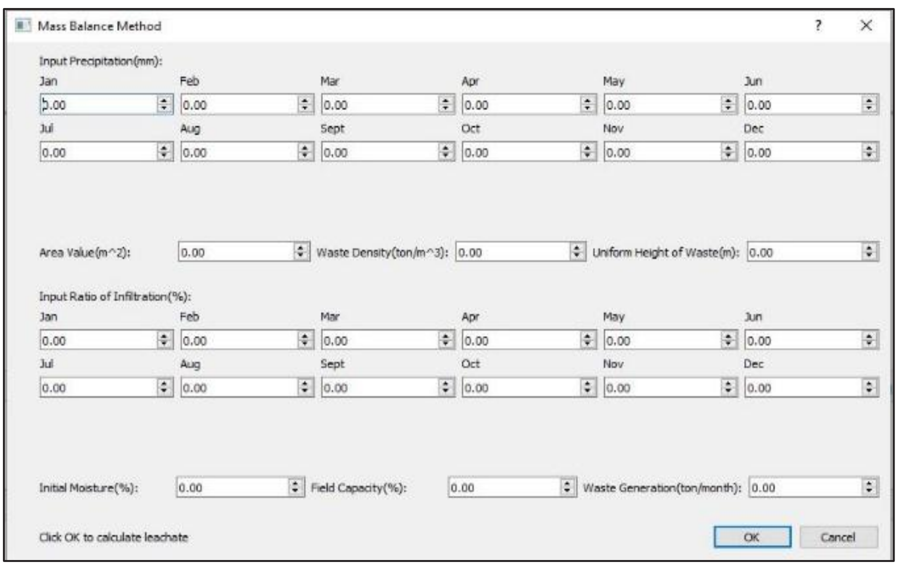

Fig. 5: Mass balance method dialogue box.

Table 3: Estimation of Leachate generation by fusion method in Deir Al Balah landfill.

Year	P [mm]	A [m^2]	R [mm]	E [mm]	L [m^3]	(IMC) [%]	IM - CDM	FC [%]	FF - CDM	IDM	Year	Total amount of waste generated per year [ton]	Leachate generation from waste itself [m^3]	Water hold by waste	Total amount of leachate generated in [m^3]	Cumulative leachate generation
1997	315	35000	54	221	1400.00	20	25.0	16	19.05	0.80	47.62	77000	3666.67	224.00	4842.67	4842.67
1998	217	35000	37	152	980.00	20	25.0	16	19.05	0.80	47.62	88000	4190.48	156.80	5013.68	9856.34
1999	132	35000	22	92	630.00	20	25.0	16	19.05	0.80	47.62	88000	4190.48	100.80	4719.68	14576.02
2000	255	35000	43	179	1155.00	20	25.0	16	19.05	0.80	47.62	95000	4523.81	184.80	5494.01	20070.03
2001	550	35000	94	385	2485.00	20	25.0	16	19.05	0.80	47.62	90700	4319.05	397.60	6406.45	26476.48
2002	391	60000	66	274	3060.00	20	25.0	16	19.05	0.80	47.62	88000	4190.48	489.60	6760.88	33237.35
2003	373	60000	63	261	2940.00	20	25.0	16	19.05	0.80	47.62	84000	4000.00	470.40	6469.60	39706.95
2004	317	60000	54	222	2460.00	20	25.0	16	19.05	0.80	47.62	82000	3904.76	393.60	5971.16	45678.11
2005	346	60000	59	242	2700.00	20	25.0	16	19.05	0.80	47.62	91000	4333.33	432.00	6601.33	52279.45
2006	245	60000	42	172	1860.00	20	25.0	16	19.05	0.80	47.62	105000	5000.00	297.60	6562.40	58841.85
2007	410	60000	70	287	3180.00	20	25.0	16	19.05	0.80	47.62	99000	4714.29	508.80	7385.49	66227.33
2008	373	60000	63	261	2940.00	20	25.0	16	19.05	0.80	47.62	98372	4684.38	470.40	7153.98	73381.31
2009	373	60000	63	261	2940.00	20	25.0	16	19.05	0.80	47.62	101103	4814.43	470.40	7284.03	80665.34
2010	332	60000	56	232	2640.00	20	25.0	16	19.05	0.80	47.62	116234	5534.95	422.40	7752.55	88417.90
2011	386	60000	66	270	3000.00	20	25.0	16	19.05	0.80	47.62	133030	6334.76	480.00	8854.76	97272.66
2012	353	60000	60	247	2760.00	20	25.0	16	19.05	0.80	47.62	133118	6338.95	441.60	8657.35	105930.01
2013	415	60000	70	290	3300.00	20	25.0	16	19.05	0.80	47.62	143273	6822.52	528.00	9594.52	115524.53
2014	376	60000	64	263	2940.00	20	25.0	16	19.05	0.80	47.62	122618	5838.95	470.40	8308.55	123833.09

*P: precipitation A: area, R: Runoff, E: evaporation, L: leachate, MC: moisture content, FC: field capacity, WHC: water holding capacity

Validation of the Model

It is always recommended to validate a model before relying on its accuracy and finding the percentage error. For validation of the Fusion model, the actual amount of leachate generated by a landfill is required along with the necessary parameters but in developing countries like Bhutan, historical data of leachate generated are not found. Moreover, data such as the chemical composition of the leachate and actual leachate generation by landfill are significant. It is necessary for quantifying leachate production and forecasting leachate generation. For this reason, the leachate generation data couldn't be obtained from any landfill in Bhutan as no records are kept by the concerned authority.

So, for the validation of the formula, the data from the Deir Al Balah landfill, Gaza strip, Palestine was used. They have recorded the data for leachate generated by the landfill for 18 years from 1997 to 2014 (Abunama et al. 2017). Their study has a record of required data for the model like field capacity, moisture content of the landfill, evaporation, and runoff data which are necessary parameters in the fusion method.

Using the standard method and rational method the leachate generation at the Deir Al Balah landfill was estimated to be about 51103.5 m^3 and 166407.5 m^3 respectively which gives the percentage error as 53.31% and 45.52% respectively. From the mass balance method, the leachate generation was about 102300.07 m^3 giving an error of 10.54%. By application of the fusion method, the leachate generation at the Deir Al Balah landfill was calculated to be about 123,833.08 m^3 while the actual amount of leachate generated was about 114,351 m^3 as in Table 3. So, the percentage difference between the fusion method and the measured amount was found to be 8.29%.

The results and differences could be more clearly noticed in the following Fig. 7 and 8 graphs are given below. It can be seen that the fusion method has the lowest percentage error i.e. 8.29% followed by the mass balance method with 10.54%, the rational method with 45.52%, and lastly the standard method with 55.31%.

CONCLUSION

The leachate generated in the Pekarshing landfill is 4565.98 m^3 from the dumped waste area of 3030.49 m^2 with rainfall of 5001.2 mm in the year 2020. From the annual precipitation of 15156.09 m^3, the leachate generation was 30.12 % of the total precipitation amount. About 7.2% of the total precipitation was lost in evaporation, 47.5% of the total precipitation was lost as surface runoff, and 15.18% of the total precipitation was water content in the waste itself. The amount of leachate generated in the Pekarshing landfill by the standard method is 2273.41 m^3 and by the rational method is 6029.46 m^3. Fig. 9 shows the comparison of precipitation with quantified leachate amount by various methods.

The following are the main source for the production of leachate generation:

- Higher precipitation leads to higher leachate generation as we can see in Fig. 6.

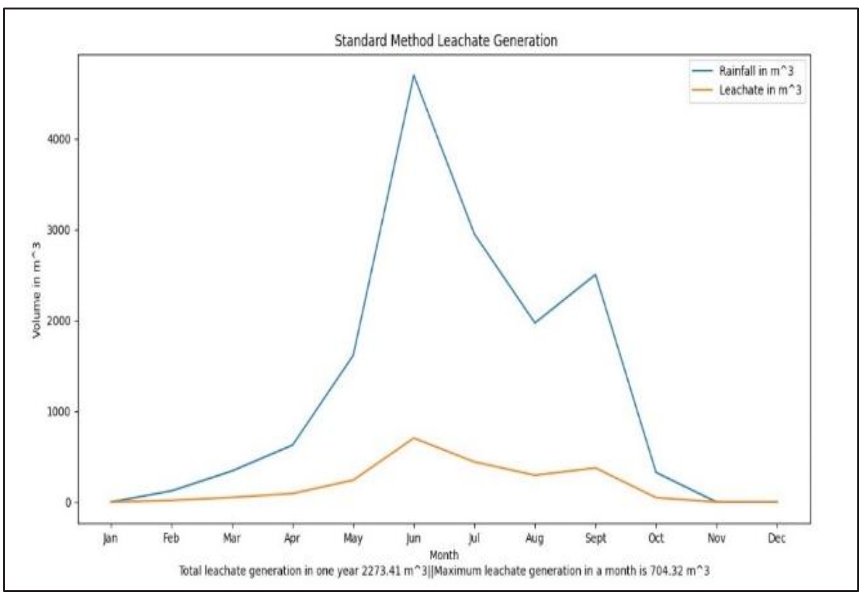

Fig. 6: Final result.

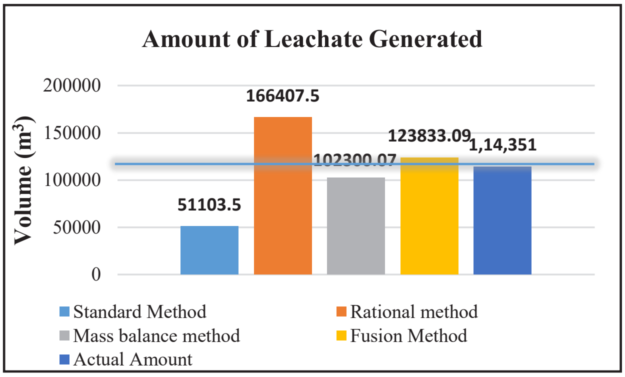

Fig. 7: Estimation of leachate generated by Deir Al Balah landfill by various methods.

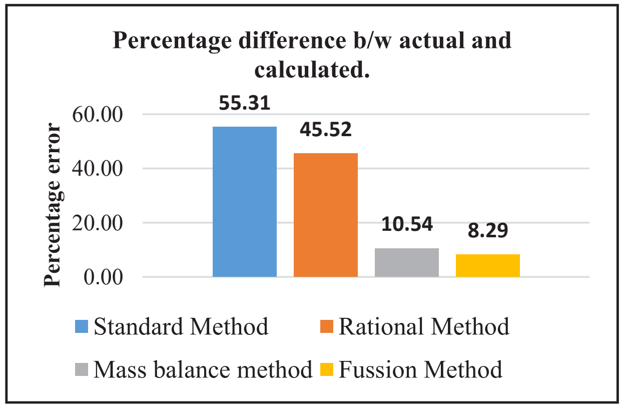

Fig. 8: Difference in percentage error with actual leachate amount.

- When the moisture content of the waste is high it causes higher leachate production.
- Larger the landfill area higher the leachate generation.
- Directly proportional to waste generation and type of waste.
- The field capacity of the waste.

The estimation of leachate generation over time is a complex method mainly because of the factors that influence the leachate generation change over time. With a model developed for the calculation of leachate generation, it will help users to do the calculation faster and easier. The chances of human error are decreased and since the developed formula has less percentage error, we could use it to get a more economic design of leachate management system.

Some of the conclusions drawn from the result of the study are:

1. The generation of leachate depends upon a number of parameters.
2. Precipitation is the main factor contributing to leachate production.
3. Increase in waste generation will result in higher leachate production.
4. It was observed that the fusion method has less percentage error compared to other conventional methods.
5. The composition of the waste affects leachate generation because it affects the field capacity and moisture content of the waste.
6. Fusion methods consider more parameters which makes them more flexible and can be used for other types of landfills.
7. Leachate production could be seen in absence of precipitation too, mainly because of waste compaction and water held by the waste.

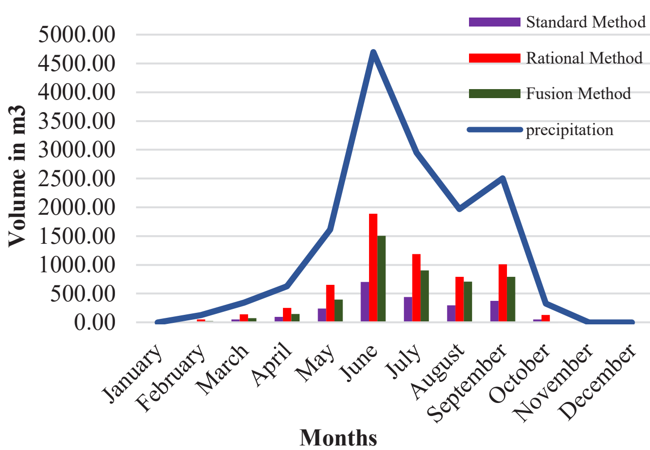

Fig. 9: Comparison of precipitation with quantified leachate amount by various methods.

8. Leachate generation over time increases as the waste generation increases.
9. The landfill system which does not have a leachate management system could pose a great threat to the environment and the people living around it.

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