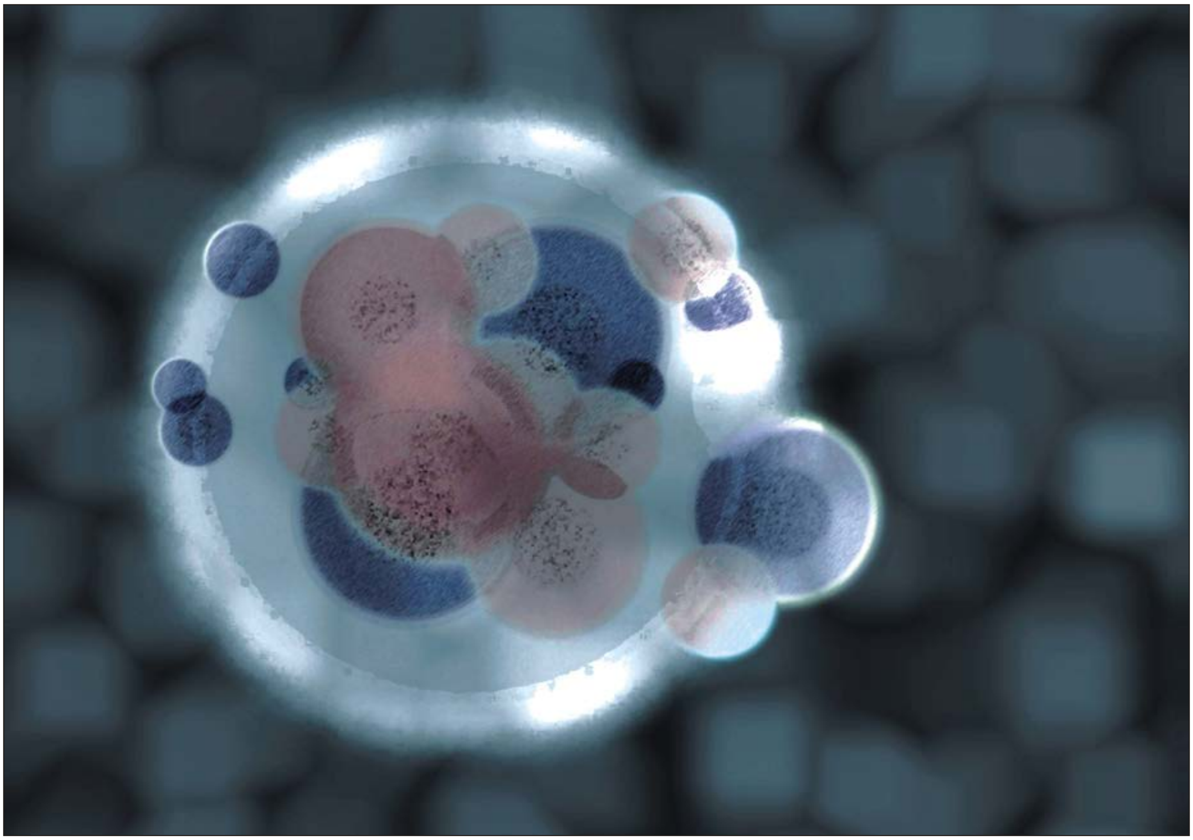

Journal of Biological Sciences

ISSN 1727-3048

science alert

ANSInet
an open access publisher
http://ansinet.com

Journal of Biological Sciences 10 (2): 107-111, 2010
ISSN 1727-3048

Direct Evaporation from the Waste Body and its Influence on Leachate Generation in Landfills in Arid Areas

[1]M.A. Abdoli, [2]Hans Gunter Ramke and [1]Hossein Ghiasinejad
[1]Faculty of Environment, Tehran University, Iran
[2]Faculty of Environmental Engineering, University of Lippe-Hoexter, Germany

Abstract: In this study, a newly established test was performed to determine a correlation between pan evaporation and waste surface evaporation. A container with diameter of 120 cm and height of 60 cm was used for determining the evaporation in field conditions in Kahrizak Landfill in Tehran based on the container weight loss. A class and a evaporation pan was also installed in the vicinity to determine evaporation from water surface. A correlation could be seen in the results and also a certain diminishing by time pattern in evaporation from the waste was also observed. A governing equation was also provided to calculate direct evaporation from waste using pan evaporation values. The correlation showed with acceptable precision with 0.5 mm day^{-1} error. A comparison also made with the previous researches in Germany showed higher values for maximum evaporation per day (8 mm day^{-1} instead of 5 mm day^{-1}) and higher maximum possible values for evaporation (180 mm instead of 20 mm). The current study showed that the evaporation can have a significant impact on the amount of leachate produced in the landfills in arid areas and implementing the current tool will lead to more efficient design of leachate treatment in landfills or better decision making for operation of landfills.

Key words: Landfill, evaporation, leachate, waste, hydrology

INTRODUCTION

Evaporation form soil surface and water surface is a well known phenomena in hydrology and agriculture science (Chow *et al*., 1998). In different theories regarding leachate generation in landfills this concept is well developed to calculate the quantity of penetrated water to the waste body in different methods (Schroeder *et al*., 1994; Zeh and Witt, 2002).

On the other hand, direct evaporation from the waste body is not regarded as an important factor in generation of leachate. Even the theories developed for special condition in arid areas where the evaporation rates are high, similar methods to hydrology science is applied, assuming that the direct evaporation from the waste has negligible effect on the Leachate generation in comparison to hydrologic attributes of waste body in landfill (Vorster, 1994; Blacky, 1989; Parsons, 1995).

No reference has been found during the research that depicts the reason for such ignorance, but the main reasons can be figured out as following:

- Research activities and consequently scientific literature about leachate generation in arid and semi arid regions are quite limited. This is due to the fact that the investments in such researches were done in developing countries (EU, USA, Japan) where the high rate of precipitation is the major concern in leachate generation
- One may consider that if we apply a daily soil cover or a synthetic cover over then a direct evaporation from waste is of negligible importance

During the current research led to presented results in this study, it is shown that the latter reason cannot be relevant as the rate of evaporation is quite high (and the highest) in first 24 h. On the other hand, if one would like to use compaction systems it is possible to delay the application of daily soil cover for some days that may lead to drastic decrease in leachate generation in the landfill.

It is a common practice to be observed especially in Middle East that the leachate treatment facilities are not required at all (Yaqout and Hamoda, 2003).

This experience shows the discussable effect of high evaporation rates on the leachate generations. Based on similar experiences, studies were performed to determine the direct evaporation tests (in 5×5 m cells) from waste body in University of Braunschweig-Germany (Ramke, 1991), it shows that the maximum evaporation possible from the waste body is limited to 5 mm day^{-1} and the total amount cannot be exceeded by 20 mm in long run without any rewetting (Ramke, 1991).

Corresponding Author: M.A. Abdoli, Faculty of Environment, Tehran University, Iran

In this passage an original method is used to understand the direct evaporation from the waste based on local situation in Tehran as a representative for areas with arid and semi-arid climatic conditions.

MATERIALS AND METHODS

Two main tests are performed for the current research:

- Class A (US National Weather service) an evaporation recording
- Direct evaporation from waste body test (DEW test)

The tests are performed in the Kahrizak Landfill (altitude = 51°, 20', latitude = 35° 27' degrees) near Tehran City. The DEW test is performed from 12th of April to 3rd of July 2008. The pan evaporation recordings for the same time are also used in the study.

Also, for purpose of checking the compliance of the data the evaporation results from the nearest weather station (Emam Khomeyni Station) was also obtained and used in data interpretation according to National Weather Organization (2008) of Iran.

The method for recording daily evaporation was based on standard evaporation pan positioned nearby the test area in the administrative building of Kahrizak municipal solid waste processing to provide required safety and access to the equipments.

The readings were performed twice a day in 6 am to 6 pm as the standard procedure and refilling was taken place.

The DEW test was performed based on current experience in Germany. In the test in Braunschweig University lysimeters were used to achieve total hydrologic balance of landfills that some of them were used to study evaporation specifically.

In current research a smaller (shallower) container is used as only the surface evaporation is considered to be evaluated and the data would also be used to determine the water balance of test cell in next phases.

The containers for the test has 60 cm diameter and 60 cm depth (based on the German experience it was much higher than the maximum evaporation depth). The fresh (Already entered to the landfill) was placed and compacted to the container to density of 900 kg m^{-3} which corresponds to high range of the density of compacted waste in modern landfills (Yildiz *et al.*, 2004). Then the specimens were placed in open ambient prone to direct sunlight and wind.

The weight loss of specimen was recorded on daily basis for 90 days as the recording stops. The reason for using 90 days is that it is the maximum possible time that one may expect that the waste would be left uncovered in the landfill or compost facilities. The DEW test container is shown in Fig. 1.

Fig. 1: The container used for DEW test (60 cm (height) ×60 cm (diameter))

Five specimens were used to determine evaporation properties the municipal waste in Tehran to achieve acceptable level of accuracy.

RESULTS AND DISCUSSION

A general trend was expected to be achieved during the test based on previous experience in Germany in wet climate condition:

- The evaporation from the waste has a relationship with direct evaporation from the standard pan; if the evaporation in the standard pan decreases the evaporation from the waste should follow this decrease
- Evaporation from the waste should be decreased in the time if no rewetting (precipitation) taken place
- Evaporation from the waste should be deceased after a period of time and no evaporation should take place after that (the surface of the waste should be totally dry)

Some of the above-mentioned trends were also observed during the test. Figure 3 shows the evaporation of the first container during the DEW test.

As it is clear from the Fig. 2, one of the trends which were decreasing of evaporation because of water depletion can be observed in time. This was expected against the fact that we have a very wet waste in Tehran (similar to other developing countries situation), but the long time considered for the test period was enough for water depletion even in a waste with high moisture content.

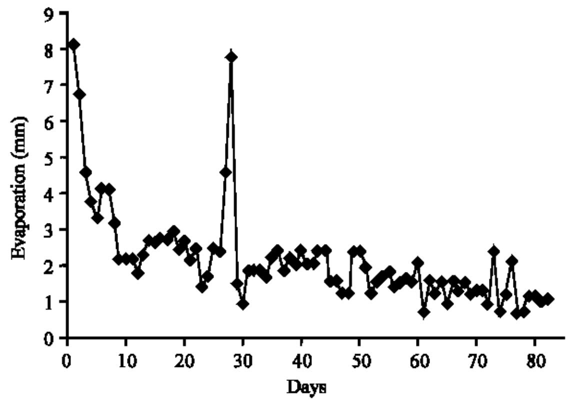

Fig. 2: The result of DEW test for first specimen

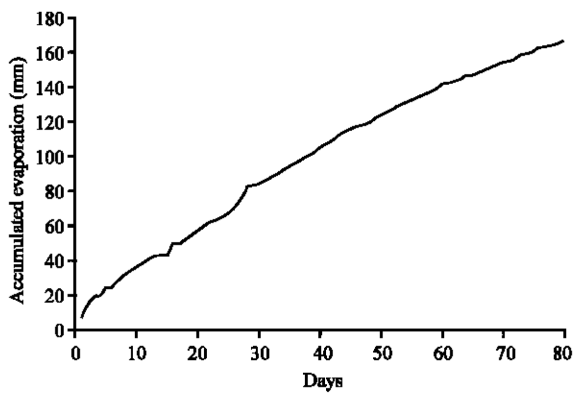

Fig. 3: The result of DEW test for first specimen-accumulated evaporation

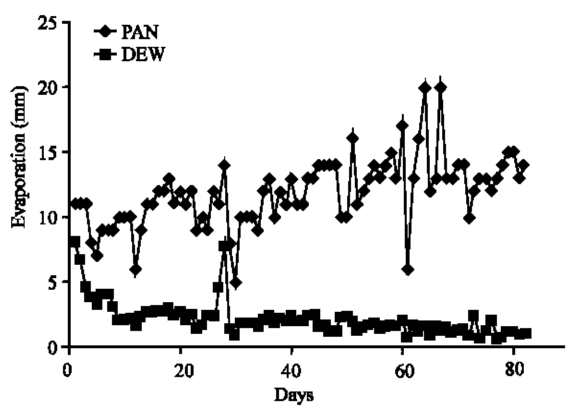

Fig. 4: The result of DEW test for first specimen via pan evaporation values

Another issue can be noticed when an accumulated evaporation curve is prepared as Fig. 3.

As it is shown in Fig. 4, it is clear that the maximum potential for evaporation is not limited in the Tehran waste. The accumulated evaporation is around 160 mm after 80 days and it is continuing for longer period. An estimation of this limit will be given based on extrapolation in following parts of the passage.

Another important trend is the relationship between the pan evaporation and DEW test results. It is clear that in Fig. 2 the undulations in the curve can only be interpreted by the natural changes in evaporation during the test. To perform this comparison the pan evaporation values is shown via DEW tests in Fig. 4.

A total compliance is observable from the comparing pan and DEW evaporation values. It is also understood that, although the trends are quite the same but the DEW evaporation will decrease over the time while the pan evaporation values are increasing. This can be explained by depletion of the water on the surface of the waste and lack of capillary suction in the waste as discussed also in other researches (Ramke, 1991).

Based on the results produced by DEW test, a formulation developed to predict the evaporation from waste to be used as a basis for decision making on operation of landfills and also estimation of leachate. This formulation would also be so helpful in moisture adjustment activities in compost facilities.

As discussed earlier, there is a relationship between pan evaporation DEW. While, there is higher pan evaporation, direct evaporation from the waste would also be expected but the evaporation from waste surface will decrease in time because of water depletion in the surface and lack of capillary properties in the waste. Therefore, a general Pseudo-First Order kinetic equation is selected for modeling the phenomena:

$$DEW = k_1 E e^{-k_2 t} \quad (1)$$

Where:

DEW : Direct evaporation from waste surface (mm)
k_1 : Constant of initial evaporation
k_2 : Constant for evaporation attenuation during the time (1 day^{-1})
E : Pan evaporation (mm)

As it is clear we would have two constant factors in the equation. The set of data used from DEW tests were used when the DEW and E for each day was available. In each set of the data, the part which was recorded before any precipitation (rewetting) was used to determine the factors. As there is three parameters were involved and also two constant variables were considered, a try and error method with goal to minimize the absolute cumulative error was used to determine the constants.

The final equation can be described as following:

$$DEW = 0.72 E e^{-0.069t} \quad (2)$$

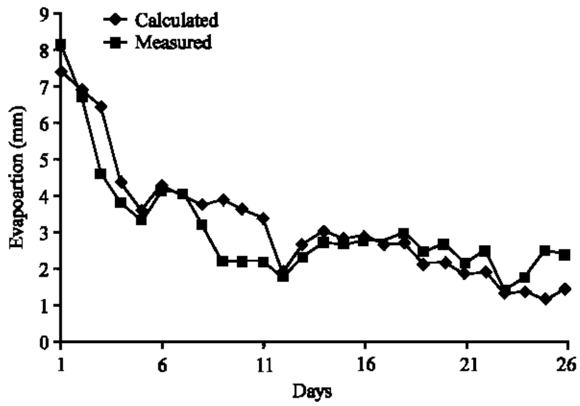

Fig. 5: Comparison between measured and calculated DEW

The accumulative absolute error for this equation in available data set was calculated to be 14.4 mm in 26 days which means that average absolute error for daily evaporation is 0.55 mm which implies 18%. In Fig. 5, a comparison between calculated data and real data from DEW test is shown.

A lower degree of error can be achieved if we divide the set of data to different phases. It is clear that in the first days a rate of DEW decrease is much higher later days. So, if we divide the equation 2 to three phases for example day 0-5, 5-12 and more than 12 and calculate the K values for each of them separately, then the error will decrease dramatically.

As mentioned earlier four other tests were performed on different specimens. Same methodology was pursued for other four specimens and the concluding equations were produced as following:

$$DEW = 0.68Ee^{-0.07t} \quad (3)$$

$$DEW = 0.71Ee^{-0.072t} \quad (4)$$

$$DEW = 0.69Ee^{-0.079t} \quad (5)$$

$$DEW = 0.65Ee^{-0.1t} \quad (6)$$

If we use an average of 5 tests results for K_1 and K_2 the following equation is produced:

$$DEW = 0.69Ee^{-0.078t} \quad (7)$$

This equation can be used to predict DEW form waste in most part of Iran. The only research performed to assess the direct evaporation from is done from Germany as discussed in several cases in the study. The results from current research confirm the trends in evaporation rates which were consolidated by former research, but the values of thresholds vary significantly. The maximum rate of DEW was assessed to be less than 5 mm day^{-1} while in current research a value of 8 mm day^{-1} is achieved. On the other hand, the maximum value for evaporation is estimated to be 20 mm in former research while in our tests we observed up to 180 mm accumulative evaporation. One should also has this fact in mine that as the methodology for evaluation of the evaporation is different in these two researches that may be responsible for some parts of difference. Generally, as the dimension of the test cells in Germany were bigger less evaporation is expected from them. Based on current research a tool to assess the direct evaporation of the waste body is developed that shows considerable difference to dominant trends developing countries. This may be because of high moisture content of waste which contributes to evaporation during the time and also stronger sunlight radiation in arid areas.

To have a better understanding of the evaporation effect on the leachate generation rates, we could consider a landfill with average pan evaporation of 12 mm, only after 65 days the DEW will be less than 0.1 mm. What we can deduce from that is in the arid areas, the evaporation will not stop before 2 months if no rewetting has taken place which is quite different from areas with wet climate. This also shows us the importance of evaporation in landfill operation. For example if we consider a landfill with 1Ha operative front (if a thin layer operation is considered that is quite common for a medium size landfill) and 12 mm pan evaporation if for 3 days no landfill cover is applied, the amount of 226 m^3 potential reduction in the volume of the leachate will take place on daily basis. This may lead to considerable reduction in the size of leachate treatment facilities.

Current analysis can be completed by additional test regarding different phases of evaporation and the effect of very high evaporation rates (for example in South of Iran). At the current level of studies, different phases on evaporation can be observed although further research needs to be done regarding the boundaries of different phases and their relationship with pan evaporation value. Current equation in hand can is determined based on specific condition of the Kahrizak landfill site in South of Tehran but it is believed that it can be applicable in any other area with highly wet municipal waste and positive evaporation budget.

ACKNOWLEDGMENTS

This research was financially supported by President Deputy for Strategic Planning and Control, (former Iranian

Management and Planning Organization) and Organization of Material Recycling and Composting of Tehran city. The writers also express their gratitude to Mr. Engineer Alimohammdi for further financial support and dedication to this research.

This article is a part research for developing a model for prediction of the leachate production in landfills in arid and semi arid areas which is financially supported by the abovementioned sponsors.

REFERENCES

Blacky, N.C., 1989. landfill leachate production and use of computer model. Proceedings of 2nd International Landfill Symposium, (ILS'89), CISA, Environmental Sanitary Engineering Center, Cagliari, Italy, pp: 1-15.

Chow, V., D. Maidment and L. Mays, 1998. Applied Hydrology. McGraw-Hill Book Co., New York, pp: 80-98.

National Weather Organization, 2008. Daily Registered Data in Emam Khomeyni Weather Station. NWO., Iran.

Parsons, R., 1995. Water balance method to predict leachate generation: Geohydrological experience. Proceedings of 2nd International Landfill Symposium, (ILS'95), CISA, Environmental Sanitary Engineering Center, Cagliari, Italy, pp: 275-284.

Ramke, H.G., 1991. Hyraulische beurteilung und dimensionierung der basisentwasserung von deponien fester siedlungsabfalle-wasserhaushalt, hydraulischenennwerte, berechnungsverfahren. Doctoral Thesis, Technical University of Carlo-Wilhelmina in Braunschweig.

Schroeder, P.R., T.S. Dozier, P.A. Zappi, B.M. McEnroe, J.W. Sjostrom and R.L. Peyton, 1994. The hydrologic evaluation of landfill performance (HELP) model: Engineering documentation for version 3. EPA/600/R-94/168b, September 1994, US. Environmental Protection Agency Office of Research and Development, Washington, DC. http://el.erdc.usace.army.mil/elmodels/pdf/help3doc.pdf.

Vorster, K., 1994. A mathematical model for the flow of water through a landfill. Doctoral Thesis, University of the Witwatersrand

Yaqout, A.F. and M.F. Hamoda, 2003. Evaluation of landfill leachate in arid climate: A case study. Environ. Int., 29: 593-600.

Yildiz, E.D., K. Ünlü and R.K. Row, 2004. Modeling leachate quality and quantity in municipal solid waste landfills. Waste Manage. Res., 22: 78-92.

Zeh, R.M. and K.J. Witt, 2002. Water balance models and programmes-comparisons and calculation results. http://www.uni-weimar.de/cms/uploads/media/Water_balance_models_and_programmes_-_Comparisons_and_calculation_results_01.pdf.