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ASSESSMENT SOME OF THE GEOTECHNICAL PROPERTIES OF MUNICIPAL SOLID WASTE AT SORAN WASTE DUMPING SITE, KURDISTAN REGION OF IRAQ

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ABSTRACT

The majority of waste disposal (landfill) sites are made up of the municipal solid waste (MSW), that requires a proper management and engineering design of the landfill sites is must; otherwise they hurt the environment. The geotechnical properties of MSW are essential factors in the overall stability of landfills. The aim of this research is to assess the strength properties of MSW from a main dumping site in Soran city, Kurdistan region of Iraq. For this purpose, seven Shelby tube samples of MSW were collected at the different locations and depths of the dumpsite. Natural moisture content (NMC) and unconfined compressive strength (UCS) tests were performed on the collected samples. Results revealed that the MSW samples collected in the middle of the dumpsite had higher NMC and lower UCS than the samples collected at the edge sides of the dumpsite due to higher waste quantity in the middle of the dumpsite. Hence, the strength properties of MSW decreased with increasing waste quantity. In addition, the NMC and UCS of the MSW samples increased with increasing depth. Eventually, the unconfined compression results verified the stability of the landfill.

KEYWORDS: Dumping site; Geotechnical properties; Landfills; Municipal solid waste (MSW); Natural moisture content (NMC); Unconfined compressive strength (UCS), Waste disposal sites

1. INTRODUCTION

Municipal Solid Waste (MSW) is a type of solid waste material that can be found in the environment (Kumar & Mittal, 2019). MSW materials are rising at an exponential rate, and disposal necessitates an excessive amount of land (Kumar & Mittal, 2019). The amount and quality of MSW is based upon a number of factors, including style of living, standard of living, population, food habits, the extent of commercial and industrial operations in the area, residents' cultural traditions, and weather (Singh et al., 2008). Long-term dumping of unmanaged municipal wastes and rising toxicity of urban waste as a result of rapid industrialization make municipal waste utilization conceivably harmful (Anikwe & Nwobodo, 2002).

Landfill is one of the most prevalent techniques for disposing of solid wastes (Bassam et al., 2006; Huang & Fan, 2016; Khodary et al., 2018; Sadhasivam et al., 2020). Geotechnical engineers have faced difficulties

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with the design of landfills and waste disposal facilities (Machado et al., 2010). The geotechnical engineers play an important role in the design and construction of environmental control measures at waste dumping sites (Datta, 2012). To build a framework for geologically and environmentally sensitive landfills, site-specific geological, hydrogeological, and engineering criteria are required. A landfill's average active life span is between 25 and 50 years. Moreover, the landfill's environmental repercussions persist for hundreds of years. As a result, proper assessment of the essential structural features is required when adjusting a landfill area (Yılmaz & Atmaca, 2006).

Many features of waste management facilities and landfills are influenced by the properties of MSW. Because MSW makes up the majority of a landfill, the strength characteristics and physical features of the MSW determine the overall stability of the landfill slopes. On the side, the components of the waste, that influences the MSW's geotechnical behavior, is influenced by a number of aspects including disposal technique, climate, local culture and habits (Machado et al., 2010). It is considered that the decomposition of organic matter in waste alters the constitution of the MSW's solids mixture. Thus, the geotechnical behaviors of MSW are likely to be substantially different than those of fresh MSW (undegraded case) (Reddy et al., 2011). Because MSW has intricate engineering characteristics and landfills can readily become unstable due to external reasons; landfill stability is the most important engineering task in landfill implementation (Huang & Fan, 2016). As a result, it is critical that landfill design and stability assessments can be carried out in each area depending on local circumstances and MSW geotechnical characteristics (Machado et al., 2010). Numerous features of landfill lining framework design and implementation such as stability problems, are influenced by the waste body's mechanical behavior. The ability to evaluate potential failure mechanisms and so design landfill engineering systems requires knowledge of the anticipated variations of waste mechanical characteristics (Dixon & Jones, 2005).

The geotechnical characteristics of MSW might vary significantly from one area to the next because of the differences in waste components, climatic factors, operating techniques, testing methodologies, and other factors (Feng et al., 2017). Numerous problems in landfills have arisen due to the complex behavior of MSW (Machado et al., 2010). For that purpose, several studies (Dixon & Jones, 2005; Durmusoglu et al., 2006; Feng et al., 2017; Machado et al., 2010; Reddy et al., 2009, 2011, 2015; Vilar & Carvalho, 2004) have been reported on the geotechnical properties of MSW in order to provide a clearer vision of the physical and mechanical behaviors of MSW materials.

The disposal of solid waste could be a significant environmental issue in the Kurdistan region of Iraq because it is not managed appropriately (Mohammed et al., 2018). One of the waste dumping sites in Kurdistan is Soran dumping site in Erbil province, which is not managed in an environmentally engineered system. Therefore, the Soran dumping site has the potential to consistently pollute the environment severely. The stability of a landfill system is controlled by the behavior of the geotechnical properties of MSW. This paper presents the assessment of the geotechnical properties of MSW in Soran waste dumping site and determines its strength properties.

2. METHODOLOGY

2.1 Location and site of the study area

Soran is a city in Erbil Governorate in the Kurdistan Region of Iraq bordering Iran and Turkey. It is located to the north east of the Kurdistan Region of Iraq, and is located about 110 km north east of Erbil and 65 km west of the Iranian border. Today Soran city has a population of approximately 150,000, and it is estimated to reach 180,000 in the next 5 years. Figure 1 shows the location of Soran city on the geographical map. The site of the study area is located between Soran city and Rawanduz city, around 700 to 800 m away from the Rawanduz river. The area of the waste dumping site is about 61700 m², and it lies at the coordinates of 36°37'28.09" N and 44°31'33.36" E. The distance from Soran city center to the Soran dumping site is 4.89 km, which is very close and almost considered as a part of the city as shown in Figure 2. The average age of the Soran waste dumping site is 12 years, and the average daily waste dumping is more than 125 tons. The waste that was dumped at this site was not disposed of in the form of properly designed landfills. The waste was dumped without any leachate containment linear system or gas collection system. Figure 3 shows a part of the waste dumping site investigated in this study.

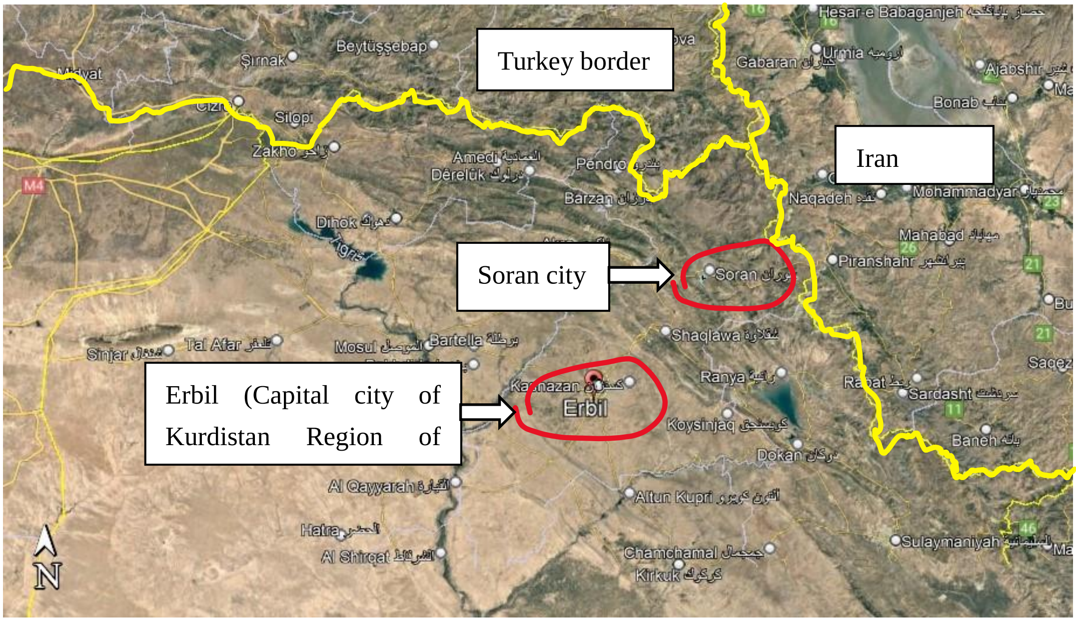

Fig.(1):- Soran city location

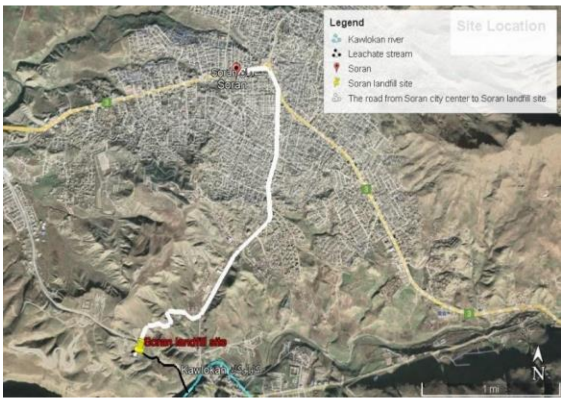

Fig.(2):-Road from Soran city center to Soran dumping site (white line)

Fig.(3):- Soran waste dumping site

2.2 Sample preparation

Soran waste dumping site fraction that includes 10 years MSW, was investigated in this study. The heterogeneous mixture of MSW samples were collected at the site. Seven samples of MSW were taken at the dumping site as presented in Table 1. The samples were collected at the edge of two sides of the dumpsite and middle of the dumpsite. The first two samples were collected at the edge of the dumpsite in the south direction at depths (0-1) m and (1-2) m from the surface of the dumpsite, labeled R1 and R2, respectively. In addition, three samples were collected at the middle of the dumpsite at depths of (0-1) m, (1-2) m, and (2-3) m from the surface of the dumpsite, labeled S1, S2, and S3, respectively. The other two samples were collected at the edge of the dumpsite in the east direction at depths (0-1) m and (1-2) m from the surface of the dumpsite, labeled T1 and T2, respectively.

The MSW samples were collected in Shelby tubes using a backhoe loader as shown in Figure 4. The Shelby tubes were 50 mm in diameter and 600 mm in height. After setting up the tubes in the earth, the backhoe compressed the tubes into the ground until the MSW samples (mixed of municipal solid waste and soil) got into the tubes.

Table (1):- Municipal solid waste (MSW) sampling

Sample	Location	Depth (m) from the surface of the dumpsite
R1	Edge of the dumpsite in the south direction	0 - 1
R2	Edge of the dumpsite in the south direction	1 - 2
S1	Middle of the dumpsite	0 - 1
S2	Middle of the dumpsite	1 - 2
S3	Middle of the dumpsite	2 - 3
T1	Edge of the dumpsite in the east direction	0 - 1
T2	Edge of the dumpsite in the east direction	1 - 2

Fig.(4):- Collection of municipal solid waste (MSW) samples

2.3 Laboratory investigation

A set of laboratory tests was carried out in this study to determine some of the geotechnical properties of MSW. Natural moisture content and unconfined compressive strength (UCS) test was conducted on the MSW samples to detect the strength property of the waste. Tests were carried out according to the American Society of Testing and Materials (ASTM) standards as listed in Table 2.

Table (2):- Standard-Testing Procedures

Test	ASTM
Moisture content	D 2216
Unconfined compression	D2166

3. RESULTS AND DISCUSSION

3.1 Geotechnical characterization of MSW

The characteristics of MSW have been evaluated in the study area of Soran waste dumping site. The natural moisture content (NMC) and strength characterization of MSW samples at different depths in the study area were investigated. Figure 5 shows NMC of the MSW samples investigated in this study. Figure 5 shows that the NMC of all the MSW samples ranged between 27.22 % to 37.50 % and it varies based on the sample location and depth. The NMC of the sample taken at the middle of the dumpsite was higher than that of the edges of the sides of the dumpsite. For example, the NMC of S1 sample, which was taken from the middle of the dumpsite at depth of 0-1 m was 20% higher than NMC of R1 sample, which was taken from the edge of the dumpsite in the south direction at the same depth. In addition, Figure 5 shows the NMC of the investigated samples slightly increased with increasing depth. For example, the NMC of the samples taken at the middle of the dumpsite increased from 33.52% (S1) to 37.5% (S3) when the depth of the samples increased from (0-1) m to (2-3) m. This trend in NMC of the dumpsite samples was due to an increase in the amount of waste that causes more generation of leachate. Further, the increase in NMC might also be due to the particle disintegration causing a decrease of pore spaces and increase in MSW's moisture holding capacity (Reddy et al., 2015). A literature study presented higher moisture content ranging between 30.0 % and 68.9 % (Feng et al., 2017).

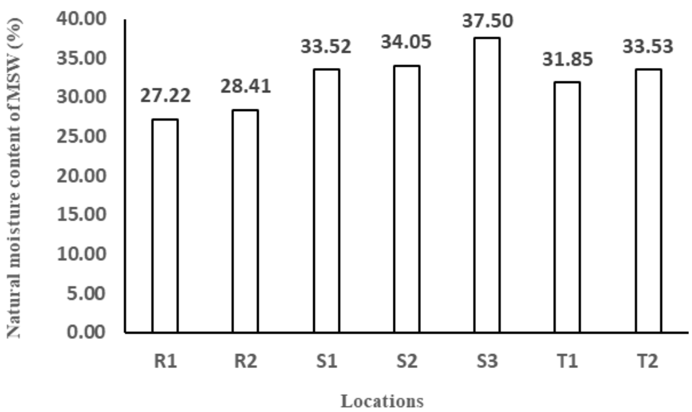

Fig.(5):-Natural moisture content of MSW samples

The unconfined compressive strength (UCS) tests were performed on the MSW samples in accordance with ASTM-D 2166. Figure 6 shows the typical setup of the UCS test. The results of the UCS tests for the MSW samples were shown in Figure 7. The samples were brought to the lab as undisturbed samples utilizing the Shelby tube then subjected to an unconfined compression test. As shown in the test results, UCS of MSW at the edge of the dumpsite in the south direction was 96 kPa for R1 sample, and increased to 139 kPa for R2 sample. Also, the UCS of MSW at the edge of the dumpsite in the east direction was almost the same as for R1 sample (i.e., UCS of the T1 sample was 98 kPa), and increased to 121 kPa at point T2 (1-2) m. In addition, the UCS of MSW samples taken at the middle of the dumpsite was 50 kPa at depth (0-1) m (i.e., S1 sample), increased to 87 kPa at depth (1-2) m (i.e., S2 sample), and increased to 115 kPa at depth (2-3) m (i.e., S3 sample). The results of the unconfined compressive strength test indicate that the UCS of MSW samples increased with increasing depth which might be due to experiencing longer-term degradation in lower layers. In addition, the UCS of MSW samples taken in the middle of the dumpsite were lower than those taken from the edges, and this might be due to less quantity of the waste at the edges of the dumpsite. Fatahi et al., (2015) improved the geotechnical properties of MSW using fly ash and quicklime, and obtained consistent results for the untreated MSW. The UCS of MSW was 102 kPa, which is close to the UCS values of this study.

Fig.(6):- UCS test setup

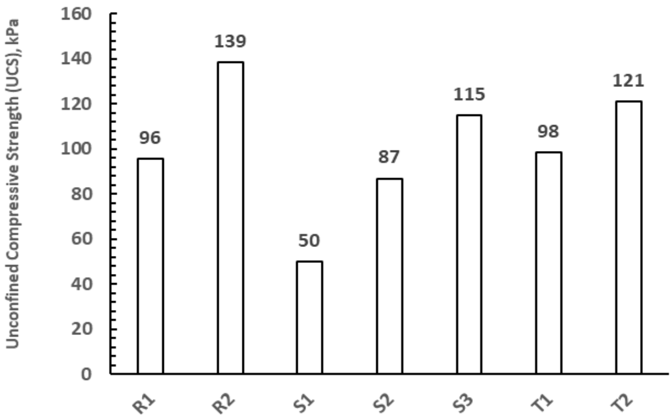

Fig.(7):- Unconfined compressive strength of MSW samples

3.2 Evaluation of the landfill stability

Stability is one of the most important factors in the construction and operation of landfill sites (Fang et al., 2011). The stability of landfills is strongly related to the engineering behavior of the waste (Sheng et al., 2021). A key consideration in the geotechnical assessment of landfills is waste materials which are extremely variable. Design cases involving the waste body must take into account both the distinct nature of the waste and the lack of knowledge on its material engineering characteristics (Dixon & Jones, 2003). Figure 8 shows the typical profile of the waste slope of Soran waste dumping site.

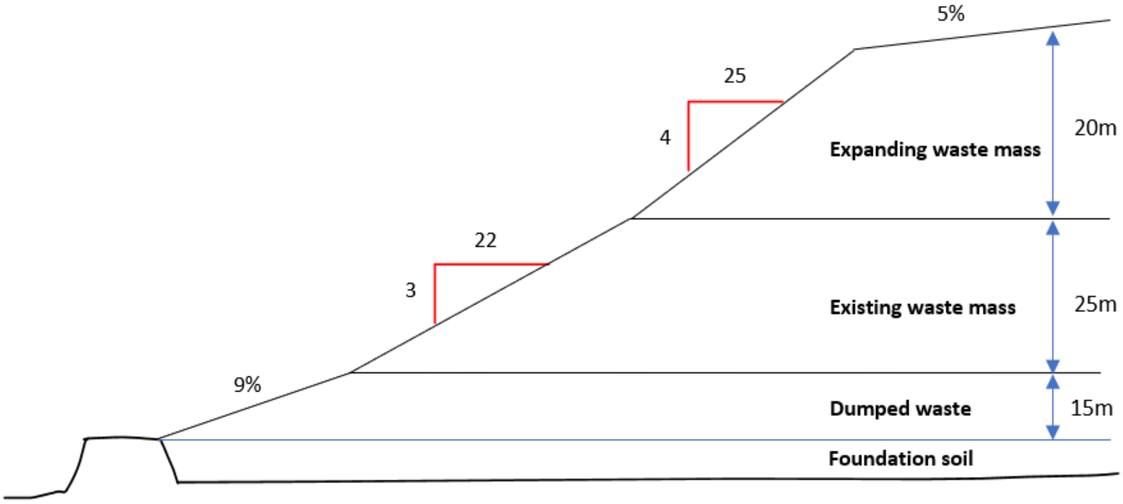

Fig.(8):-Typical waste slope profile

Evaluating the stability of landfill slopes necessitates studying of the geotechnical properties of MSW and the structural characteristics of the waste body. According to the compressive strength of the MSW, the stability of a landfill can be assessed as following:

In the unconfined compression test, the cylindrical specimen loaded axially (compressive axial stress σ_1) without a lateral support, which means that the minor principal stress σ_2 and σ_3 (confining pressure) are zero. Therefore, the maximum shear stress τ_{max} can be calculated by the below equation:

When $\sigma_2 = \sigma_3 = 0$;

$$\tau_{max} = 0.5\,\sigma_1$$

$\tau_{max} > Sy$ Failure occurs (Budhu, 2011; Murthy, 2003)

When τ_{max} = maximum shear stress

σ_1 = compressive axial stress

Sy: Yielding stress

The yielding stress (Sy) of the MSW specimens has been determined in the stress-strain relationship curves of the unconfined compression test. On the curves, yield point represented the yielding stress of the specimens.

Normally, the primary objective of a slope stability analysis is to calculate a factor of safety (FS) against failure of the slope. Factor of safety (FS) is the ratio of the absolute strength of a structure (resistance strength) to actual applied stress, and it can be calculated as follows:

$$FS = \frac{Sy}{\tau_{max}}$$

When FS = factor of safety

Sy = yielding stress

τ_{max} = maximum shear stress

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Table 3. presents the data of compressive axial stress σ_1, maximum shear stress τ_{max}, yielding stress (Sy) of the MSW specimens, FS, and failure surface of the slope. The results show that the waste slope is stable because maximum shear stress is lower than the yielding stress, and hence the factor of safety is greater than one at all of the points. However, S2 sample shows that the slope of that region is in critical condition as FS is near to 1.0. In another side, the slope stability issues of a landfill body are more complicated than those of a soil or rock mass due to the different composition and time dependability of MSW. Therefore, further research on landfill stability, taking into consideration other characteristics of the waste and other factors of stability (elevation, age, excess pore pressure by leachate, etc.,), is needed to confirm these results.

Table(3):- Stress parameters

MSW samples	σ_1 (kPa)	τ_{max} (kPa)	Sy (kPa)	FS = (Sy/ τ_{max})	Slope failure surface
R1	96	48	56	1.17	3:22
R2	139	69.5	80	1.15	3.22
S1	50	25	32	1.28	4:25
S2	87	43.5	44	1.01	4:25
S3	115	57.5	63	1.10	4:25
T1	98	49	60	1.22	3:22
T2	121	60.5	100	1.65	3:22

4. CONCLUSIONS

This article presents the results of laboratory experiments on some geotechnical properties of municipal solid waste (MSW) materials from the Soran waste dumping site, Erbil province, Kurdistan Region of Iraq. MSW samples collected at various locations and depths at the dumping site, were tested to determine the geotechnical properties of the MSW and concluded the following:

The natural moisture content (NMC) of MSW at the middle of the dumpsite was higher than that at the edges of the dumpsite.

Higher NMC in the middle of the dumpsite might be due to particle disintegration causing the decrease in pore spaces and increase in the capacity of MSW to hold moisture.

The unconfined compressive strength (UCS) at the middle of the dumpsite was lower than that at the edges of the site due to difference in waste quantity. However, UCS of MSW increased with increasing depth due to higher degradation level in lower layers.

According to the unconfined compression test results, the landfill is stable. However, further research is necessary on the evaluation of its stability.

REFERENCES

Anikwe, M. A. N., & Nwobodo, K. C. A. (2002). Long term effect of municipal waste disposal on soil properties and productivity of sites used for urban agriculture in Abakaliki, Nigeria. *Bioresource Technology*, *83*(3), 241–250. https://doi.org/10.1016/S0960-8524(01)00154-7

Bassam, R., Tuffaha, R., Haddad, M., & Engineer, E. (2006). Impacts of Solid Waste Leachate on

tss480h@cive.soran.edu.iq
jamal.kakrasul@soran.edu.iq
sherwan.qurtas@soran.edu.iq

Soil and its Simulation to Ground Water at Nablus Area. In *An-Najah National University*. An-Najah National University.

Budhu, M. (2011). Soil Mechanics and Foundations. In J. Welter (Ed.), *JOHN WILEY & SONS, INC.* (3rd Editio, Vol. 6, Issue August). Don Fowley. website: www.wiley.com/college/budhu

Datta, M. (2012). Geotechnology for Environmental Control at Waste Disposal Sites. *Indian Geotechnical Journal*, *42*(1), 1–36. https://doi.org/10.1007/s40098-012-0002-x

Dixon, N., & Jones, D. R. V. (2003). Stability of Landfill Lining Systems : Report No . 2 Guidance. *R&D Technical Report P1-385/TR2*, *2*.

Dixon, N., & Jones, D. R. V. (2005). Engineering properties of municipal solid waste. *Geotextiles and Geomembranes*, *23*(3), 205–233. https://doi.org/10.1016/j.geotexmem.2004.11.002

Durmusoglu, E., Sanchez, I. M., & Corapcioglu, M. Y. (2006). Permeability and compression characteristics of municipal solid waste samples. *Environmental Geology*, *50*(6), 773–786. https://doi.org/10.1007/s00254-006-0249-6

Fang, R., Guo, Z., & Feng, T. (2011). Analysis of stability and control in landfill sites expansion. *Procedia Engineering*, *24*, 667–671. https://doi.org/10.1016/j.proeng.2011.11.2715

Fatahi, B., Khabbaz, H., & Fatahi, B. (2015). Improving Geotechnical Properties of Closed Landfills for Redevelopment Using Chemical Stabilization Techniques. In *Ground Improvement Case Histories* (Issue March). https://doi.org/10.1016/b978-0-08-100191-2.00008-3

Feng, S. J., Gao, K. W., Chen, Y. X., Li, Y., Zhang, L. M., & Chen, H. X. (2017). Geotechnical properties of municipal solid waste at Laogang Landfill, China. *Waste Management*, *63*, 354–365. https://doi.org/10.1016/j.wasman.2016.09.016

Huang, Y., & Fan, G. (2016). Engineering geological analysis of municipal solid waste landfill stability. *Natural Hazards*, *84*(1), 93–107. https://doi.org/10.1007/s11069-016-2408-8

Khodary, S. M., Negm, A. M., & Tawfik, A. (2018). Geotechnical properties of the soils contaminated with oils, landfill leachate, and fertilizers. *Arabian Journal of Geosciences*, *11*(2). https://doi.org/10.1007/s12517-017-3372-7

Kumar, A., & Mittal, A. (2019). Utilization of municipal solid waste ash for stabilization of cohesive soil. In *Lecture Notes in Civil Engineering* (Vol. 31). Springer Singapore. https://doi.org/10.1007/978-981-13-7010-6_12

Machado, S. L., Karimpour-Fard, M., Shariatmadari, N., Carvalho, M. F., & Nascimento, J. C. F. d. (2010). Evaluation of the geotechnical properties of MSW in two Brazilian landfills. *Waste Management*, *30*(12), 2579–2591. https://doi.org/10.1016/j.wasman.2010.07.019

Mohammed, K., Karim, S. H., & Mohammed, S. A. (2018). The Influence of Waste Disposal Site on The Water and Soil Quality in Halabja Province, Kurdistan, Iraq. *Science Journal of University of Zakho*, *6*(1), 11. https://doi.org/10.25271/2018.6.1.404

Murthy, V. N. S. . (2003). Geotechnical Engineering-Principles and Practices of Soil Mechanics and Foundation Engineering. In *Taylor & Francis* (Vol. 6, Issue October). Taylor & Francis.

Reddy, K. R., Hettiarachchi, H., Gangathulasi, J., & Bogner, J. E. (2011). Geotechnical properties of municipal solid waste at different phases of biodegradation. *Waste Management*, *31*(11), 2275–2286. https://doi.org/10.1016/j.wasman.2011.06.002

Reddy, K. R., Hettiarachchi, H., Giri, R. K., & Gangathulasi, J. (2015). Effects of Degradation on Geotechnical Properties of Municipal Solid Waste from Orchard Hills Landfill, USA. *International Journal of Geosynthetics and Ground Engineering*, *1*(3), 1–14. https://doi.org/10.1007/s40891-015-0026-2

Reddy, K. R., Hettiarachchi, H., Parakalla, N., Gangathulasi, J., Bogner, J., & Lagier, T. (2009). Hydraulic Conductivity of MSW in Landfills. *Journal of Environmental Engineering*, *135*(8), 677–683. https://doi.org/10.1061/(asce)ee.1943-7870.0000031

Sadhasivam, N., Sheik Mohideen, A. R., & Alankar, B. (2020). Optimisation of landfill sites for solid waste disposal in Thiruverumbur taluk of Tiruchirappalli district, India. *Environmental Earth Sciences*, *79*(23), 1–20. https://doi.org/10.1007/s12665-020-09264-0

Sheng, H., Ren, Y., Huang, M., Zhang, Z., & Lan, J. (2021). Vertical Expansion Stability of an Existing Landfill: A Case Study of a Landfill in Xi'an, China. *Advances in Civil Engineering*, *2021*. https://doi.org/10.1155/2021/5574238

Singh, U. K., Kumar, M., Chauhan, R., Jha, P. K., Ramanathan, A. L., & Subramanian, V. (2008). Assessment of the impact of landfill on groundwater quality: A case study of the Pirana site in western India. *Environmental Monitoring and Assessment*, *141*(1–3), 309–321. https://doi.org/10.1007/s10661-007-9897-6

Vilar, O. M., & Carvalho, M. D. F. (2004). Mechanical properties of municipal solid waste. *Journal of Testing and Evaluation*, *32*(6), 438–449. https://doi.org/10.1520/jte11945

Yılmaz, A., & Atmaca, E. (2006). Environmental geological assessment of a solid waste disposal site: A case study in Sivas, Turkey. *Environmental Geology*, *50*(5), 677–689. https://doi.org/10.1007/s00254-006-0241-1