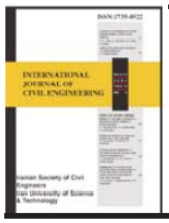

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Technical Note

Aging effect on physical properties of municipal solid waste at the Kahrizak Landfill, Iran

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Abstract

The physical properties of the municipal solid waste (MSW) in Kahrizak Landfill (Tehran, Iran) and its changes due to aging were investigated in this research. A study of the components of the fresh MSW in this landfill showed that more than 60% of it was made from the wastes of foods, fruits, vegetables and organic materials. Next to that, paper/cardboard and plastics, with contributions of 14 % and 11%, comprised the greatest parts of the waste materials. Meanwhile, the results obtained from these studies revealed that the contribution of the organic part has been decreased during the last two decade by about 20% while the plastics and paper/cardboard contribution has been increased by the same amount. In order to investigate the effect of aging on the physical properties of MSW, waste samples of 5.5, 14 and 21 years of age were obtained by excavating the aged waste burial regions of this landfill. A study of the changes in the composition of waste materials through aging also revealed that the portion of paste was decreased from 25% to 40% due to the decomposition process, while the contribution of plastics and fabrics was increased up to 200%. Particle size became finer with the mean size being reduced from 70 mm in the fresh wastes to 20 mm in 21-year-old wastes due to the decomposition process. The moisture content of the fresh waste samples was reported to be more than 150%, which was considerably larger than that of other existing landfills. Along with the increase in the age of the waste samples, the moisture content was decreased by as much as one third of the initial value. Furthermore, since the waste mass became more homogeneous by age, the variation of the moisture content was reduced. The organic content of the 14-year-old waste was found to be 20%, which was less than 0.3 of the initial value. Moreover, the variation of the organic content in the waste samples was directly related to the moisture content of the samples with both parameters being reduced to less than one third of the initial value in the older samples. Investigation of the moisture content and the organic content of the aged samples showed that the burial location had a significant effect on the trend of variations. The average density of the fresh waste was measured to be 3.5 and 7.3 kN/m^3 after production and burial, respectively. It was found that the average density of the fresh waste grew to about 12kN/m^3 as the age was increased.

Keywords: *Municipal solid waste, Aging, MSW compositions, Organic content, Degradation, Kahrizak landfill.*

1. Introduction

Landfilling is still one of the most common and economical methods of municipal solid waste (MSW) management. Correct and safe design and maintenance of landfills need a proper recognition of behavioral parameters and determination of physical, chemical, and mechanical characteristics of the waste materials.

There are numerous reports of failure and destruction of various landfill facilities all around the world (Blight and Fourie [1], Koelsch et al. [2], Merry et al. [3]), showing that comprehensive information does not exist regarding the performance of MSW, especially its long-term performance and it performance in special conditions. Since most landfill facilities are located adjacent to populated cities and residential areas, they have caused homelessness and loss of the lives of hundreds of people living nearby, and the areas themselves have incurred severe financial and environmental damages. Therefore, it seems necessary to explore the behavior of these materials, especially their long-term characteristics.

The compositions and specifications of waste materials in different regions and societies vary according to the consumption culture, economic situation, food habits, seasons, and climatic conditions in those places. Moreover, heterogeneous MSW has a nature varying over time due to the existence of degradable components in it and the occurrence of chemical/physical change processes. As a result, variations of the constituents in different regions, heterogeneity of materials, variable size of components, and time-variant nature of MSW have given a complicated

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behavior to this kind of materials. Surprisingly, some aspects of their mechanical behavior have still remained unknown. Some parameters such as the type and content of constituents, moisture content, degradable materials, density, organic content, and particle size distribution are among the important characteristics and basic properties of the waste materials. They are expected to have significant effects on the behavioral characteristics of waste materials including stability, shear strength, settlement and generally speaking, the long-term behavior of MSW.

The type and amount of constituents in MSW are among the main factors considered as MSW behavioral parameters. With respect to these elements of difference, determining the basic engineering parameters for MSW, such as particle size distribution, density, moisture content, and organic content, has been considered as a rather challenging issue for researchers in designing landfills and their associated structures. Numerous studies have been published so far in relation to the determination of these parameters (Landva et al. [4], Dixson et al. [5], Zekkos et al. [6], Zekkos et al. [7], Oettle et al. [8], Hyun et al.[9]).

In addition to the existing ambiguities in the determination of fresh waste parameters, the behavior of MSW is time-dependent due to the variation in the composition of buried waste caused by the decomposition processes. This can intensify the behavioral complexity of this heterogeneous mass. The long-term behavior of wastes through their aging process is a function of the initial waste composition, conditions and burial system, status of leachate, daily and final conditions of soil cover, and climatic conditions of the region. Therefore, the aged wastes are more difficult to investigate than fresh wastes because of the great variety of parameters involved.

Machado et al. [10] launched some studies on aging waste samples that were up to 15 years old in Metropolitan and Bandeirantes landfills in Brazil. They mainly concentrated on the discussion and determination of such parameters as composition, density, moisture content, permeability, particle size distribution, as well as strength parameters. Chen et al. [11] studied Qizhashan Landfill in China. The waste samples with ages up to 11 years were studied in this landfill. They explored variations in density and porosity parameters as well as settlement, compression and consolidation variables, in addition to discussing the changed composition of the waste due to aging. Reddy et al. [12] focused on variations in the behavioral parameters of wastes during different phases of decomposition. Their work mainly comprised studying the characteristics of the particle size distribution, permeability, compressibility and strength parameters like cohesion and internal friction angle. In another study by Shariatimadari et al. [13], the trend of settlement behavior of two landfills in Iran was investigated about 2.5 years after the wastes had been buried. They also addressed the effects of leachate recycling, waste components, and compression on the settlement behavior.

In this research, an analysis was conducted on the components of Tehran MSW, and the results were compared with some existing information in the technical literature. Based on the analysis of the wastes at different ages, the variation trend of their components was studied up to an age of 21 years. Furthermore, the effect of the age on some important physical parameters used in the design and analysis of the landfills, such as grain size distribution, moisture content, organic content and density, was investigated. The obtained results were compared with those reported by other researchers.

2. Landfill Description

Kahrizak Landfill in Tehran is one of the largest places of waste disposal facilities in Iran and has been operating for 40 years as the final destination for the municipal wastes of Tehran. It is an area of 1200 hectares located 25 km to the south of the city. Some 7,500 tons of MSW produced in Tehran enters this landfill every day. The location of this landfill on the map of Iran is depicted in Fig. 1.

Fig. 1 Situation of Kahrizak Landfill

This landfill is climatically located in an arid area with an average annual rainfall of 183 mm, average relative humidity of 51%, and the annual evaporation of 2370 mm. The mean absolute maximum and minimum temperatures of this location have been recorded as 45°C and -18°C, respectively. Moreover, the mean temperature is reported to be 17°C in this area, while the mean wind speed is 9.7 km/hr and the prevailing winds blow from west to east (Ministry of Energy [14]). From a geological point of view, the area under study is placed on Tehran quaternary alluvial, which includes A series (Hezardarreh formation), B series (Kahrizak formation), C series (Tehran alluvial) and D series (recent alluvium). These deposits are located on a bedrock of upper red formation, including gypsum sand stone, which belongs to the Miocene era and the Karaj formation (Aghanabat[15]). Based on the results of the geotechnical studies conducted within the landfill, this area contains lean clay materials with CL classification and gray to brown color containing silty clay or sand-clay lenses. The thickness of this layer is not greater than 5 m

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in different depths, while the relative density of the layers is moderate to stiff and becomes very stiff to even harder by increasing the depth. The level of underground water in this area stands at the depth of 20 to 25 m (GNCE[16]).

Considering the vast area and the topography of the region, as well as the presence of the natural terrain in the landfill, burial of the waste materials had been done in natural craters and artificial trenches there from the beginning of its operation until the year 2000. Since then, burial of the wastes has been concentrated in one section of the landfill in parallel layers with the thickness of 2 to 3 meters. Currently, the height of the buried MSW in this region of the landfill has already reached to about 60 m. The waste is covered by the layers of soil and construction debris, followed by partial leveling and compaction due to the traffic of trucks over them. The leachate produced from the wastes buried in this region is gravitationally directed toward a low land next to the region. Now, a lake of leachate is formed adjacent to the recent burying location with a depth of about 10 m. This is due to the negligible permeability of the land containing the layers of clay.

3. Material and Methods

3.1. Sampling

By considering the importance of addressing the exact age of the waste for studying the aged samples, the information on this landfill was examined for accessibility to the aged samples. Therefore, it was found that the buried wastes related to the years 2006 (June, July and August), 1998 and 1991 were accessible in three separate positions. The buried samples of the other years were not accessible due to the changes made in the landfill or the little information available about their exact age. So, samples of 5.5, 14 and 21 years were selected for studying the behavior of the aged samples. Observing the date range of the existing newspapers and magazines found in the waste as well as the readable dates printed on the food packs confirmed the exact age of the samples. Furthermore, the existing information denoted that the maximum thickness of the aged wastes was limited to 10 m in most areas. Thus, test pit technique was utilized for sampling these wastes by using a mechanical excavator. Three test pits were dug in the area of each of the aged samples, and at least three samples were extracted from each of them. For this purpose, the test pits were excavated with a depth of 5 m, and all the samples collected from the aged wastes were taken to a depth of 2 to 4 m. The samples of fresh wastes were taken in four steps during a year and in different seasons from the unloading area of the waste trucks at the entrance station of this landfill. The samples were prepared in order to have a sample as homogeneous as possible.

For the determination of the physical properties of the MSW, 4 samples (except in one stage) weighing 30 to 40 Kg were prepared during 4 stages of sampling from the fresh waste, and a total of 15 samples were collected. From every three test pits dug in the place of each aged waste, at least three samples of about 35 to 45 Kg were prepared. Thus, some 10 samples were taken from each of the aged samples, providing a total of 30 samples. The excavated samples were immediately put in plastic bags and gunnies in order to save their moisture, and they were kept at the temperature of 5°C in a refrigerator after being transferred to the laboratory.

3.2. MSW composition

MSW samples usually include different components such as food scraps, fruits and vegetables, garden wastes and landscape, paper and cardboard, wood, plastics, rubber, soil, rock, ceramic, glass, etc. Many researchers have suggested different methods of categorization to determine the components and composition of MSW (Gidarakos [17], Feng [18], Machado[19], Chen et al.[11], Kalantari-Fard and Yang [20], Zekkos et al. [7], Hyun et al. [9]). Physical analysis of the waste samples was carried out in order to examine the waste components. Then, the waste components were separated visually based on the wet weight of each group according to the common methods used in the previous works (Zekkos [21], Karimpour-Fard [22], Oettle et al. [8]). Since the aged waste samples were exposed to an overload pressure as well as physical and chemical changes that were due to the waste decomposition process, the components of the samples were mixed together and it was rather difficult to characterize the samples from their appearance. Therefore, the aged samples were classified into five different groups: 1) glass and metals, 2) rock and ceramics, 3) paper, cardboard, wood and cellulosic products, 4) different types of plastics (hard, soft, foam, PET), fabrics, and 5) paste. A major part of the paste comprised organic, decomposable and inseparable materials with soil and other fine inseparable particles categorized in this group. Machado et al. [10] defined the paste group of MSW as three types of organic materials, namely quickly decomposable (e.g. food scraps), fairly decomposable (e.g. leaves of plants), and hardly identifiable materials.

In order to determine the compositions of the aged wastes, two sample groups, S_1 and S_2, were prepared from each age. Each group was produced by mixing two samples of one test pit with a total weight of about 70 Kg. Once the components of the two groups were characterized and each of the five different constituents was determined, the average values of the constituents in S_1 and S_2 samples were considered as the contribution of components for that sample. Meanwhile, the same method employed for the aged samples was applied to the fresh waste components to determine their contribution. The results of continuous measurements by the laboratory located in the landfill facility were also used. From each series of physical analysis conducted seasonally on the fresh wastes, a minimum of 10 samples with an approximate weight of 50 Kg were randomly obtained from waste-carrying trucks. After characterization and analysis of each sample, the average results of the measurements were presented. Finally the reports included the results of two groups of samples, S_1 and S_2; additionally, the results of four series of seasonal

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measurements of landfill laboratory over waste omponents were obtained.

3.3. Moisture Content

Most published works in the last two decades have reported MSW moisture contents by drying samples at about 60 °C (Siegel et al. [23], Gabr and Walero [24], Zekkos [21], Zekkos et al. [7], Reddy et al. [12]). Instructions of ASTM 2216 [25] were taken into account. It has been suggested that the samples be dried at 60°C to mitigate the decomposition of materials in soils with great amounts of organics. The moisture content of the waste samples in this study was determined based on this standard and calculated using the following equation:

$$\omega_d = \frac{W_i - W_f}{W_f} * 100 \quad (1)$$

where ω_d is the moisture content of the sample (%), W_i denotes the initial weight of the sample (gr), and W_f represents the final weight of the sample after drying(gr).

Four samples, each with an approximate weight of 5 Kg, were prepared to determine their moisture content. They were then placed in an oven of 60 °C for 48 hours. It was observed that the variation in the weight of samples was rather negligible after being kept in the oven for 48 hours.

3.4.Particle Size Distribution

In order to prepare the curve of sample size distribution, two groups, i.e. S_1 and S_2, produced from each age of the wastes, were selected with an approximate weight of 70 Kg. Since adherence of waste components together due to the excessive moisture content of a sample possibly caused some error in the determination of size distribution, the samples were dried prior to this examination. By using a metallic ruler, the separation and determination of sizes were manually done for the parts containing large particle wastes with the size of 100 mm and more. However, particles smaller than 100 mm were separated using a series of standard sieves with the mesh size, ranging from 76.2 mm to 0.075 mm, installed on an electric shaker. Finally, the curve of particle distribution size was presented for each age of the waste based on the average results of both s1 and s2 series of samples.

3.5. Organic Contents

The current work followed the instructions of ASTM 2974[25] (method C) to determine the organic contents of the samples. For this purpose, at least four samples were placed in an oven at a temperature of 110 °C after being dried at 60°C, followed by the determination of their moisture content. When their weight was stabilized in the oven, the samples were prepared for organic content tests. For most of the samples, the weight loss from 60 to 110 °C was measured to be below 4%.

Owing to the 21-liter capacity of the muffle furnace used, the waste sample of 0.8 to 1 Kg was set into a special container with a capacity of 3 liters and placed in the furnace.

The samples were kept at 440°C inside the furnace until they reached a stable weight at this temperature. As observed, the samples reached a stable weight after being inside the furnace for about 3 hours. Based on the programmed system of control in the furnace, the temperature of the samples was thus raised from 25°C to 440°C within 4 hours, and they were kept at the final temperature for 3 hours before being cooled down. The organic content was determined according to the percentage of the weight difference between the sample before and after being placed in the furnace and the remaining weight of the burnt sample.

3.6. Unit Weight

Due to the great effect of the unit weight of MSW on its mechanical behavior, this physical property has been studied by many researchers such as Landva et al. [4], Zekkos [18], Dixson et al. [5], Chen et al. [11], and Hyun et al. [9]. The study by Zekkos et al. [6], which was conducted on the unit weight of wastes, indicated that this parameter was varied from 5 to 16kN/m^3 for the surface layers of landfills and increased with depth.

The local density of the wastes was explored by in-situ density tests. For this purpose, after excavating some test pits for a depth of 1 to 2 meters, the bottom of the test pits was graded for doing the experiments. Then, by using a pick and a shovel, a pit of about 0.6 to 0.8 m in diameter and 0.5 to 0.7 m in depth was dug inside the undistributed waste at the bottom of each excavated test pit. Extracted from the pits, the waste materials were put in plastic and gunny bags in order to be weighed. Afterwards, all the inner surface of the pit was covered with a soft transparent nylon, and its capacity was determined by measuring the amount of water replaced there. After the samples extracted from the pits were weighed, the density of the waste was calculated at each test pit location. The density values were measured twice for each age of the waste.

4. Results and Discussion

4.1. Fresh MSW properties

The results of the component analysis on the fresh wastes in Kahrizak Landfill are given in Fig. 2. An investigation of the contribution of waste components, as shown in this figure, revealed that most of Tehran's MSW was related to food residues and organic materials. This type of waste contained all residues from foods, bread, vegetables, fruits, and garden products. By considering the dry and semi-dry climate of the region and the negligible contribution of landscape and gardens, it becomes clear that these residues comprise less than 5% of the total amount of this part. Meanwhile, more than 85% of the structure of Tehran's MSW contains food, paper/cardboard and plastic residues.

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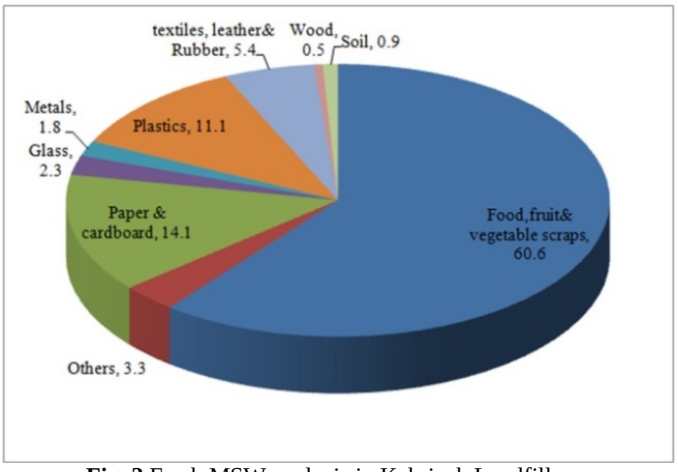

Fig. 2 Fresh MSW analysis in Kahrizak Landfill

A comparison of the contribution of the fresh wastes in this research with the information published by US EPA [26] demonstrated that the total amount of the residues from foods and garden products exceeded 60.6%; however, the contribution of these materials in MSW of US was less than 50% of this value (27.3%). The 14.1% contribution of paper and cardboard in Tehran's wastes was less than half of the contribution of this part in the municipal solid wastes of US (28.5%). The significant differences between the contents of MSW, especially the total contents of degradable and organic materials in this landfill, and those registered in the existing reports in the literature are noteworthy.

The results of the wastes analysis component of 49 landfills from 26 countries (North and South America, Asia, Europe and Australia), as reported by Langer [27], were compared with those of the analysis of the waste components from Kahrizak landfill in Fig. 3. It can be seen that in most samples, the portion of organic materials was larger than that of other compositions with a significant difference in the contribution of each component for various landfills. For example, a contribution range of organic materials from less than 10% to more than 80% is seen in the existing results. A comparison of the waste composition under study with the components of three groups with the highest contribution in most samples revealed that the contribution of organic and plastic materials is relatively greater, and that of paper/cardboard is relatively smaller than the average records.

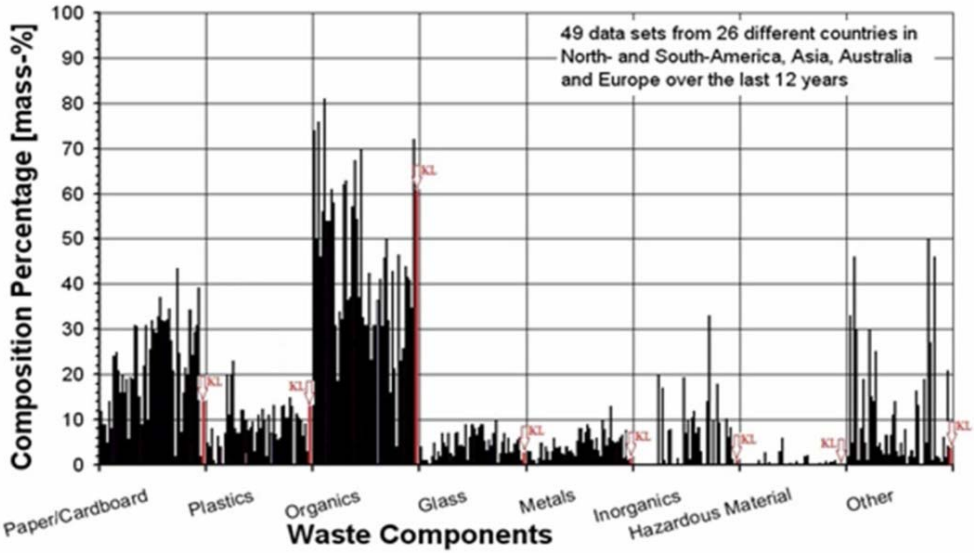

Fig. 3 Percentage of the Waste components at 49 landfills from 26 countries (Langer [27]).
The percentages of Kahrizak wastes components are shown by arrow and "KL" symbols on the graph

Regarding the measurement of the waste density before burial as well as the measurement of the weight and volume of the fresh wastes carried by trucks, the unit weight of the fresh MSW was recorded as 3.0-3.8 kN/m^3 with an average of 3.5 kN/m^3. Meanwhile, the average moisture content and organic content of the fresh waste samples were measured to be 153% and 66%, respectively.

4.2. Variations of MSW properties with age

With respect to the measurement of the fresh waste parameters by the laboratory located at the landfill and other existing information in the documents of Waste Management Organization of Tehran Municipality, it was understood from the results that the components of the fresh wastes had a uniform and nearly linear variation. The main change in the components of Tehran fresh wastes incorporated 20% reduction of food, fruit and vegetables residues (paste) as well as almost the same percentage of increase in the total contribution of plastics and paper/cardboard during the last two decades. Since the aged samples belonged to the wastes buried in 2006, 1995 and 1991, the average values of the variables for the fresh wastes have been reported for these three years. In other words, the values of the reported parameters for the fresh wastes were extracted from the average measurements of these years, some of which were a bit different from those of the fresh wastes for 2012.

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4.3. Compositions

The results of the component analysis of the waste samples at different ages (categorized into five groups of materials) are shown in Fig. 4. It is evident that in all the waste samples, more than 85% of the total waste mass can be categorized under three groups of paste, plastic/fabric and paper/cardboard/wood, while groups five, four and three have shown the greatest contribution in the composition of the waste regardless of the age of the samples, respectively.

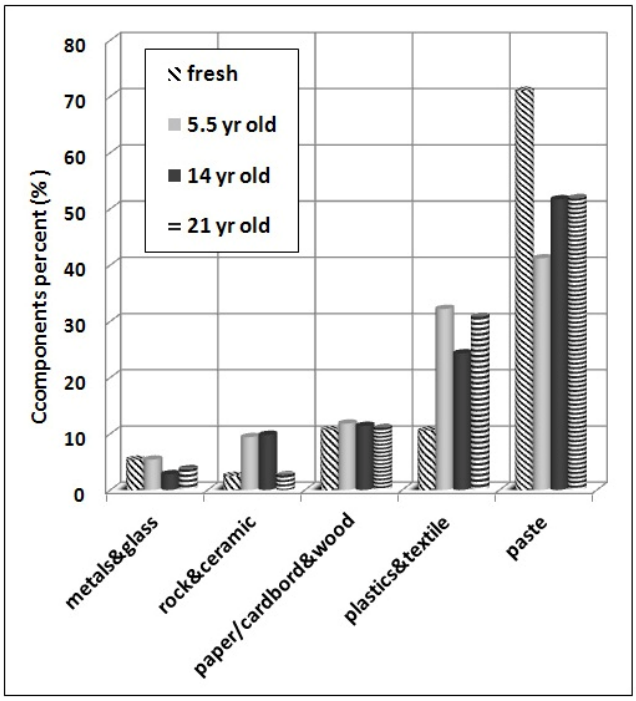

Fig. 4 Components of fresh and aged MSW

The study of variation in the contribution of components demonstrates that the paste content of the samples was decreased by 25-40% as their age was increased. This can be attributed to the degradation and decomposition of organic and degradable materials over time. The increased contribution of paste in 14- and 21-year-old samples in comparison with 5.5-year-old samples and also, the deviation from the general trend of reduction in the organic content of the waste by an increase in their age might be due to the changed burying conditions of the samples, different amounts of initial organic and degradable materials in these samples at the burial time (difference of the fresh waste due to its heterogeneous constituents), and the changed content of soil and inorganic materials in the paste as a result of the changed status of burial. The paste portion of the samples under study is illustrated in Fig. 5 to compare its apparent status upon aging.

The greatest change in the contribution of components is associated with plastics and fabrics such that their contribution in the aged samples is increased up to 200% in comparison with the fresh samples. This is because of the non-degradability and the higher relative stability of this group as well as the decreased contribution of degradable parts over time. The performance of plastics and fabrics as the reinforcement elements of the waste mass as well as their higher compressibility and deformability show that the major variations in their contents over time might have caused significant changes in the mechanical behavior of the waste mass. Machado et al. [28] declared that due to the strain-hardening behavior of the samples, fibrous and plastic materials can serve as reinforcements for the waste mass during a shear test.

Since determining the contribution was the wet base for the waste components, the negligible variations in the components of paper, cardboard and the wood group of the aged samples can be attributed to the significant moisture absorption of these materials after burying, despite their relatively fast rate of decomposition. Moreover, the existence of nylon covers, which did not decay, in most of the MSW inhibited quick decomposition of paper and carton. This is why many parts of them were found almost intact in the aged samples.

The significantly increased percentage of the components in group 2 (soil, stone, and ceramic) in the aged samples was generally due to their non-degradability over time, implying that the significantly increased contribution of this group in the 5.5- and 14-year-old samples was a result of daily and final soil cover mixing with the samples. Zhan et al. [29] investigated the aged wastes of Suzhou Landfill in China and claimed that the organic contents of their samples were decreased, whereas the content of fibers and plastics was increased over time.

4.4. Particle size distribution

Fig. 6 depicts the results of particle size distribution of samples with different ages. As can be observed, by an increase in the age, the constituent particles became smaller and the diagram of particle size distribution approaches the domain of finer particles. This is probably due to the biodegradation and chemical degradation processes which occurred over time and led to the dissociation and fragmentation of the components. In the fresh waste samples, about 50% of the particles were larger than 70 mm, while these dominant sizes reached to 45, 37, and 20 mm for 5.5-, 14-, and 21-year-old waste samples. Furthermore, it can be seen that the coefficient of uniformity (Cu) is increased in the particle size distribution curves for the older samples. Cu is raised from 9 for the fresh samples to 35, 50 and 68 for the 5.5-, 14- and 21-year-old ones, which indicates broadening of particle size distribution curves by an increase in the age of the samples. Evaluation of the reports given in several studies (Landva and Clarck [30], Jessberger [31], Machado et al. [10], Hyun et al. [9], and Reddy et al. [12]) on the particle size distribution curves of the waste samples at various ages showed that nearly the same results as ours were obtained by other researchers in terms of particle size distribution through the aging of samples.

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Fig. 5 Visual status of paste contribution for different samples: (a) fresh waste, (b) 5.5-year-old sample, (c) 14- year-old sample, (d) 21-year-old sample

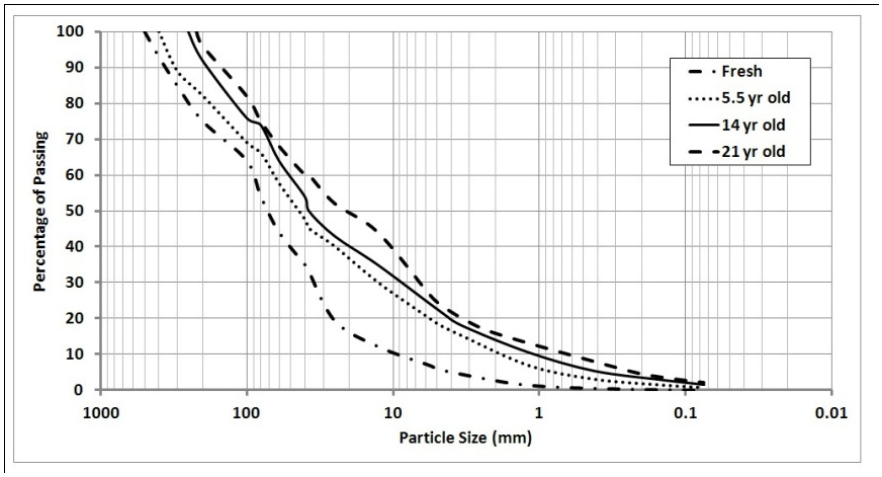

Fig 6. Particle size distribution of MSW samples

4.5. Moisture content

The average moisture contents of the fresh samples and 5.5, 14-, and 21-year-old ones were measured and found to be 153%, 88%, 52%, and 70%, respectively. The moisture contents, as reported by some researchers (Landva and Clarck [32], Coumoulos et al. [33], Geomse et al. [34], Karimpour Fard, [19], and Machado et al. [10]), for fresh wastes are shown in Fig.7, in addition to the moisture content of the samples under study here. A comparison of the moisture contents reveals that the fresh samples in Kahrizak Landfill contain a higher rate of moisture than most existing samples cited in the literature.

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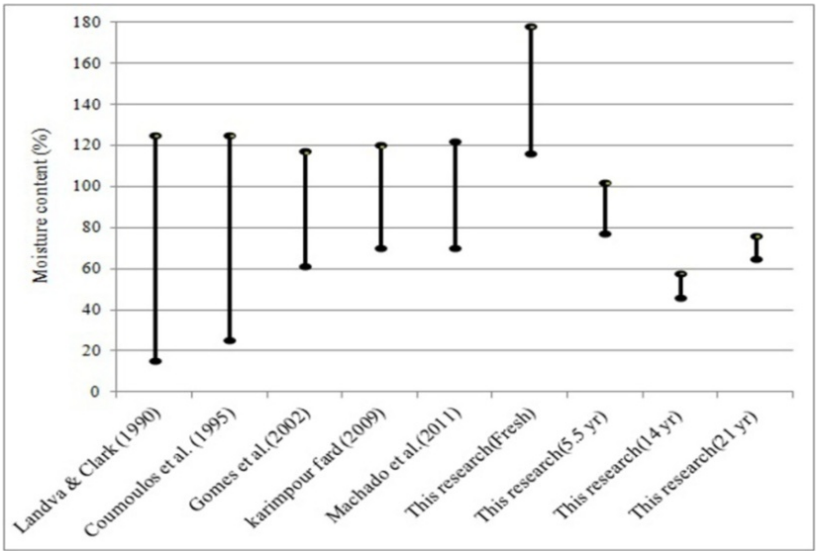

Fig. 7 Range of moisture contents in waste samples of different ages and their comparison with those provided by other researchers [32], [33], [35], [22], [10]

4.6. Organic content

Fig. 8 shows the measurement results of the organic content in the waste samples of different ages. The obtained results were examined based on the average measured organic content for four samples from each of the age groups under study. It indicates that the organic content decreases as the age increases in the samples up to 14 years compared with the fresh samples. The measured increase in the organic content of 21-year-old samples was due to the location of these samples and environmental conditions different from those of 5.5- and 14-year-old samples. The higher moisture of these samples, due to their adjacency to the flowing path of a leachate and their being buried in the lower lands, probably contributed to the increase in the organic content of these samples, even though it accounted for small rates of variation.

The comparative results of the current study regarding the organic content of fresh versus aged waste samples are presented in Fig.9 along with the results reported in the literature. A general investigation of the results shows that the organic content decreased in the waste samples by an increase in the age of the samples. Meanwhile, the organic contents in the fresh and aged waste samples in this study are often greater than the average of other existing records. For the 21-year-old samples located beyond this range, the difference in burying conditions and specifications of the buried fresh wastes seems to play a key role.

Machado et al. [10] studied the organic content of fresh and aged waste samples. They addressed climatic conditions and local moisture content as the main reasons for the increased organic content in some aged waste samples in comparison with those of lower ages. Having compared the results of the organic content and the age of the samples, Zekkos et al. [7] declared that they had noticed no clear correlation between the age of samples and their measured organic content.

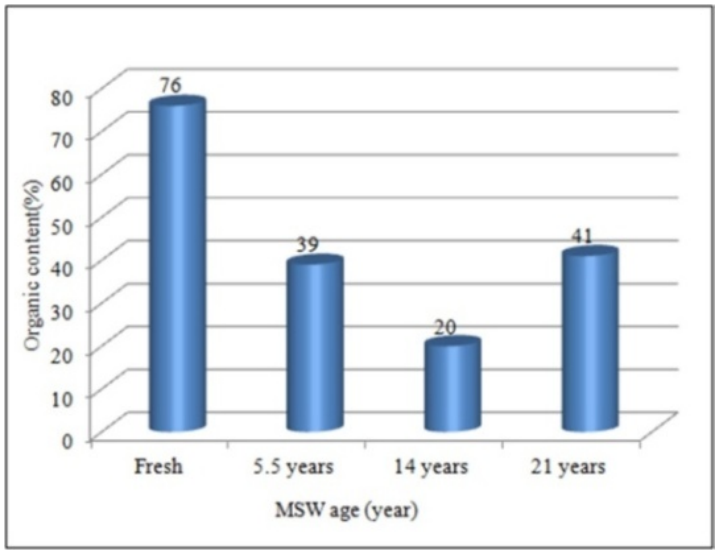

Fig 8. Variation of the organic content of MSW samples at different ages

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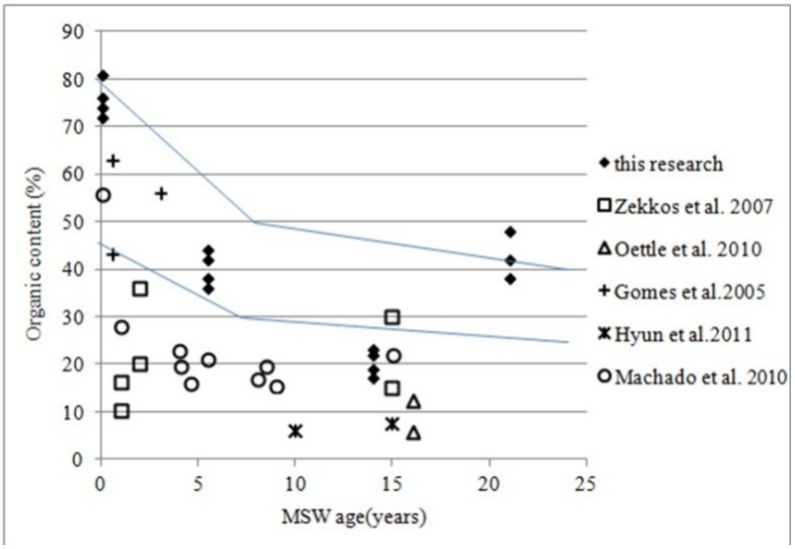

Fig. 9 Comparison of experimentally determined organic content with those reported in the literature [6], [8], [34], [9], [10]

4.7. Unit weight

As with soil, the unit weight of wastes is affected by compaction effort, layer thickness, depth of burial (i.e. over-burden stress), and the amount of liquid present (moisture content). Unlike soil, the unit weight of wastes varies significantly because of the wide variety of their constituents (e.g. size and density), state of decomposition, and degree of control during placement (e.g. thickness of daily cover or its absence) (Dixon et al. [5]).

Kavazanjian [36] reported a unit weight of 6 to 7 kN/m^3 for fresh wastes, and 14 to 20 kN/m^3 for highly decomposed wastes with a great content of soil depending on its compression.

By considering the method of wastes burial in this landfill without using any special compacting equipment, like landfill compactors, and the 2-3 m thickness of each layer of fresh waste, the partial compression of the waste layers was provided just by the traffic of transportation and distribution machinery. The unit weight of the fresh wastes after burial was measured to be 6.2 -8.0 kN/m^3 with an average of 7.3 kN/m^3. Fastel et al. [37] categorized fresh wastes into three groups according to their unit weight: poorly compressed, fairly compressed, and well compressed. Based on this classification, the fresh waste samples under study were placed in the fairly compressed group.

In-situ measurement of the unit weight of the wastes was also made by determining the weight and the volume of the test pits in the aged samples. In this regard, the average unit weights of the 5.5-, 14-, and 21-year-old samples were calculated as 11.4, 12.3 and 11 kN/m^3, respectively. Comparing the densities of the samples at different age groups revealed that in almost similar conditions of overload, the unit weight of aged samples was increased by 50-70 % over that of fresh samples. It seems that this phenomenon is mainly because of the reduced volume of some components including plastics, PET dishes, cans and other parts gradually compressed over time. Moreover, the decomposition of organic and degradable MSW and the decrease in the organic content (quickly or slowly decomposed) over time are considered as other factors accounting for the increase in the unit weight of samples at older age groups. The increased unit weight of the wastes due to the decreased organic content of them clearly implies the existence of a reverse correlation between the organic content and the unit weight of waste materials. As can be seen, the unit weights of 14-, 5.5- and 21-year-old samples and those of fresh samples show a descending trend as the organic content and moisture content of these samples starts an ascending trend. The surface unit weight obtained in this study and its comparison with some of the results published by other researchers are illustrated in Table 1.

As can be observed, the surface unit weight is found to be 5 to 19 kN/m^3 with most of the results being limited to the range of 9 to 15 kN/m^3. Furthermore, in comparison with other landfills, the fresh wastes and the aged wastes in this landfill are rated to be of low and average densities.

Table 1 Surface unit weight measured in this study as compared with other published results[30], [38], [39], [40], [6].

Reference	Unit weight range (kN/m^3)
Landva and Clark(1986),Calrgary landfill	10.6-14.9
Landva and Clark(1986),Vancouver landfill	10.6-12.8
Landva and Clark(1986),Reston landfill	14.8-15.4
Landva and Clark(1986),Ottawa landfill	8.08-13.8
Cowland et al. (1993)	13.7
Machado Santos et al.(1998)	14-19
Pereira et al.(2002)	5
Zekkos et al. (2006),Recommended limit	5.5-15.5
This research(Fresh)	6.2-7
This research(5.5 yr)	11-12.0
This research(14 yr)	11.5-13
This research(21 yr)	10.5-11.4

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5. Conclusion

The following results were obtained from the field studies and experimental work in the laboratory.

1) The component analysis of the fresh wastes in 2012 indicated that food residues, vegetables and garden products, plastics, and paper/cardboard with the respective contributions of 61%, 14% and 11% had a major influence on the waste composition. Also, through a comparison with registered records, it emerged that there existed a relatively higher percentage of early constituents. Meanwhile, studying the trend of variations for these components during the last two decades has been indicative of a 20% reduction in the contribution of the first group along with almost the same increase in the total contribution of the second and third groups.

2) Comparing the components of fresh wastes with those of 5.5, 14- and 21-year-old wastes demonstrated that pastes and plastic/fabrics (fibers) comprised more than three quarters of the waste mass. The contribution of paste was decreased by about 25-40%, while that of plastic/fabrics was increased by some 110-210% in the older wastes due to the decomposition process which occurred in the waste materials. Environmental conditions and the soil cover were the two key parameters which affected the variation of waste components over time.

3) It can be concluded from the particle size distribution of the samples that the distribution becomes wider as the particles become finer in the landfill over time. Thereby, 50% of the materials from fresh wastes and aged wastes with the age of 5.5, 14 and 21years were smaller than 70, 45, 37 and 20, respectively, with the increase in their uniformity distribution coefficient from 10 to 66.

4) The average moisture content in the fresh samples under study was 153%, showing the higher initial moisture content of Kahrizak landfill than those reported in other works. The moisture content of an aged sample was also decreased over time because of the leachate left in it and the chemical reactions in the waste mass. Furthermore, due to the homogenization of the waste mass over time, variations of the moisture content were mitigated in various aged samples in comparison with those of fresh wastes.

5) The organic contents of the waste samples were decreased to less than 30% of its initial value by an increase in the age of the samples. Meanwhile, the reduction of the organic content by the age of the samples is in agreement with the trend observed in most reports in the literature. The examination of variation in 21-year-old samples, in comparison with two other aged samples, indicated that changing the burial conditions had a significant effect on the decomposition rate of organic materials as well as the reduction of moisture content.

6) The average density of the fresh wastes before burying was found to be 3.5 kN/m^3. By taking into account the burying conditions when rated under medium compression category, this value could be raised to 7.3 kN/m^3. In the case of the older wastes, due to the compression of their deformable components, the volume reduction of their voids, and their decreased organic content, their local density was increased to 12.3 kN/m^3. Moreover, the value of the local density showed a reduction along with an increase in the organic content and water content of the wastes.

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