GIS Visualization of Solid Waste Disposal Sites and Environmental Impacts in Kurdistan Region-Iraq

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Abstract: The increase in the quantity of municipal solid waste (MSW) has made environmental problems in the Kurdistan Region (KR)-Iraq. Current study illustrated components and generation rates (GR) of MSW in seven different cities of KR. Geographic information system (GIS) was applied to locate MSW disposal sites, components, and generation rate in the cities. The study reported the maximum GR for MSW in Sulaymaniyah City which was 1.20 Kg/Capita/day and the minimum GR for domestic solid waste in Erbil City was 0.65 Kg/Capita/day. In-addition, the amount of organic waste component (OWC) in Erbil, Halabja, Sulaymaniyah, Semel, Duhok, Qaladize, and Ranya Cities were 79.34 %, 58 %, 65 %, 65 %, 79 %, 75.1 %, and 67.05 %, respectively. The average GR and OWC were calculated to be 0.972 Kg/Capita/day and 71.91%, respectively. Consequently, all MSW disposal sites had great impact to the surrounding areas resulting in air, water, and soil contamination.

Keywords: GIS, Kurdistan Region-Iraq, Landfill, Disposal Sites, Solid Waste.

1. Introduction

Generally, the source of MSW is from residential, commercial, institutional, and industrial sources (Tchobanoglous and Kreith, 2002). MSW management (MSWM) has become a worldwide issue, especially in developing countries. Reduce; reuse, recycling, and recovering are listed in MSW hierarchy management. Moreover, landfilling has been shown to be the most cost-effective MSW disposal process when compared to other using methods, such as composting and thermal processes (Maulood and Aziz, 2016).

Integrated waste management involves a hierarchy of four processes, in order of preference they are: source reduction, recycling, combustion with energy recovery, and disposal through landfilling according to the united state environmental protection agency (USEPA). Burying solid wastes in landfilling is the least solution of the integrated MSWM because of the threatening of the landfill leachate to the surrounded water sources and the soil (Aziz et al., 2018).

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Iraq is considered one of the most populated countries in the Middle East. With a population of around 40 million. MSWM in the country has deteriorated due to rapid economic growth in some cities, rising individual incomes, sectarian conflicts, and high population growth. In 2016, in Baghdad only, the MSW generation is more than 1.5 million tons per year. Alnajjar (2019), indicated that in Iraq, the waste generation is exceeding 1.4 kg/capita/ day. In addition, the generation of solid waste is 31,000 tons per day. (Othman and Kane, 2017) point out that Iraq does not have reliable country-level data on the average solid waste generation per capita. The research should therefore start at the level of the cities and then go to the level of the country. In addition, they referred that city of Sulaymaniyah has about 2.1 million residents, with a city center of about 1 million.

Commonly, in KR-Iraq MSW is disposed of in landfills and dumpsites. There is no proper plan for collection, transportation, and disposal of the MSW in KR as well. Disposal of the MSW in the landfills and dumpsites causes pollution of the environment (Aziz et al., 2018; Aziz and Maulood, 2015; Nawshrwan, 2019; Othman and Kane, 2017; Saeed, 2020). Therefore, the construction of scientific/engineering sanitary landfills is essential and to avoid environmental pollution. In the scientific sanitary landfills formed leachate will collect and treated prior to disposal to the environment. Methane gas will collect as well and it uses as an energy source.

GIS is tools used for optimization, cost, and time of solid waste management in each process and use various alternatives to evaluate and implement the best management practices (Dutta and Goel, 2017). There are numerous phases of solid waste management; the phases are beginning from the step where it is generated until it is delivered to its dumpsite or at a point where it is no more harmful to the environment. It is known that there are two main phases of solid waste management. Phase one is the waste management and statistical representation of solid waste composites in the location where it is generated and the second phase is the management of solid waste at the dumpsite. This covers the MSW characteristics, their statistical and visual representations with the aid of geographical information system GIS from the collection stages. The solid wastes are generated in all cities in the study area however there is a great variant in its types of composites and amount. The concern of solid waste is not only because of the amassed amounts but also mainly because of an insufficient management system (Tınmaz and Demir, 2006). The statistical analysis of the characteristics of this variant will provide the information to easily understand the location’s waste generation nature and characteristics which leads to a proper waste management system and planning. GIS can help consider many factors simultaneously through planning waste management. GIS is a system of computer software and hardware aimed to let users capture, store, manage, query, analyze, display, and retrieve huge volumes of spatially referenced data and associated attribute data collected from a variety of sources (B.Shoba and K.Rasappan, 2013; Shrivastava and Nathawat, 2009). In addition, GIS multifunctional features especially spatial and statistical operations can be used to perform analysis and visualize types of composites and quantity of MSW.

In the extant literature, several researchers were conducted in the MSW filed in different cities of the KR (Aziz et al., 2018; Aziz and Maulood, 2015; Nawshrwan, 2019; Othman and Kane, 2017; Saeed, 2020). But to date, no one has calculated the average GR and average OWCfor the KR. In addition, there is no unique study on the application of GIS on MSW landfills and dumpsites in seven different cities in KR. Consequently, the aims of this study were to 1) Calculate the average GR and average OWC for the first time for the KR, 2) Study and assessment MSW characteristics and dumpsites in KR Cities, 3) Application of GIS on the MSW disposal sites, 4) Documenting the status of MSW landfills and dumpsites for the first time for the KR.

2. Materials and Methods

2.1 Study Area

Seven cities, namely Erbil, Sulaymaniyah, Dohuk, Halabja, Ranya, Qaladize, and Koya, were selected for the study and evaluation of MSW components and dumpsites in the KR in this study, Fig. 1. These cities' choices are relying on the available data on the MSW at different locations in the KR area.

Erbil city is the capital and most populated City in KR in Iraq. and it is population is around 1.3 million. According to Aziz et al. (2011) the generation rate of MSW is 0.65 and Solid Waste Characteristics was measured by Aziz et al. (2011) as shown in Table 1. Solid waste materials in the different quarters of Erbil were collected from various types of households. Seventy-two samples have been collected for 1 year. Through that, the GR and the domestic solid waste characteristics were found.

Sulaymaniyah is one of Kurdistan's three major urban centers, with a population of roughly one million people. At coordinates 35.557, 45.443, the city is about 370 kilometers North-East of Baghdad City. The city is situated in a valley at the foot of Goizha Mountain, spanning approximately 470 km2 and extending southwards to the lower lands of Tanjaro (Othman and Kane, 2017). The topography of the city is hilly and steep making the southern parts of the city at risk of floods and pollution more than higher parts. The city has seen tremendous but poorly planned residential expansion during the past 2 decades (especially after 2003), stretching its boundaries in all directions and putting pressure on many public services including water, sanitation, health, education, and transportation facilities. The city's sewage is discharged into the Tanjaro River, which is located south of the city. The solid waste is dumped near the same river without being treated and is partially covered with earth. Large numbers of small and large industrial areas have started appearing around the river, which then flows into Darbandikhan Lake, contaminating it (Othman and Kane, 2017).

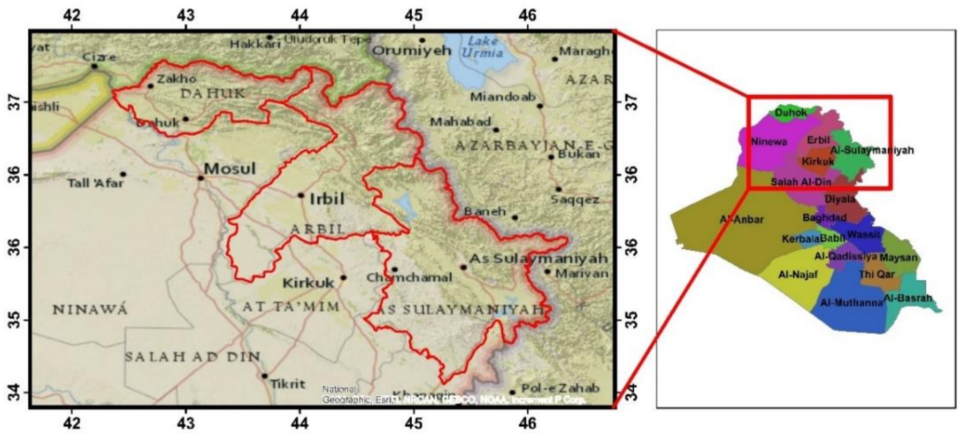

Figure 1: Locations of the study area

Another large Province in KR is Duhok. It is a Kurdish city with a population of 2,111,027 inhabitants, of whom 1,423,080 are the host group, 619,918 IDPs, and 68,029 refugees (Eropean Union et al., 2018). Mountains along the Tigris River surround the city. It is bordered to the north by Turkey, to the west by Syria, to the south-west by the province of Mosul, and to the south-east by the province of Erbil, covering an area of 10,925 km2. Its strategic location, both historical and geographical, location as a joint point among the three parts of KR (Syria, Turkey, and Iraq) makes it a growing tourist industry, agricultural land, and a renowned center for teaching and research. The data for generation rate and characteristics of solid waste was obtained from the General Directorate of Municipalities of

Duhok and Municipalities of Duhok. This data shows that the rate of creation of MSW was 1.18 and 1.03 for both Duhok and Semel cities.

Koya is one of the largest cities in the Erbil Province of the Kurdistan Regional Government, with a population of around 60,000 (Aziz and Khodakarami, 2013). Private company collects solid waste in the area near Hawawan Village on the main road (Koya – Sulaymaniyah).

2.2 Landfills and Dumping Sites Locations

Erbil landfill site (ELS) is located near Kani-Qrzhala Sub-district in Erbil City on the left side of the Erbil–Mosul main road and is approximately 15 km from Erbil City center (Aziz and Maulood, 2015).

The Tanjaro dumping site, located 5 Km south of Sulaymaniyah, is the largest site in the region. Thus, the largest dumping site is very close to the city, and in the years that follow, with the population growth rate, it will be within the city. If so, this is going to be a disaster (Karim et al., 2020).

In Koya, solid waste is managed by a company that is responsible for collecting rubbish and useless materials from residential and industrial areas then landfilling it randomly in a place which is around 5 kilometers away from the center of the city (Haji, 2013) . The waste dumping near Hawawan Village on the main road (Koya – Sulaymaniyah).

Kwashe sanitary landfill is located near the area of Kwashe in Duhok province, which is a mix of industrial and residential zoning. Kwashe is located in the district of Semel, and is approximately 20 km northwest of the capital of the governorate, Dohuk city. The coordinates of the landfill are 36.9745N and 42.8088E.

In Raparin zone, in both districts Ranya and Qaladze the solid waste disposal site is an open dumping area, Hjila is the location of the dumping site in Ranya with longitude 45°123' 4''E and latitude 36°27'.33''N. Koshkalle is the open dumping site in Qaladze with longitude 45°13' 13''E and latitude 36°21'.41''N.

In Halabja, the solid waste disposal site is an open dumping site where is located in the northwest of Halabja city, longitude 45°57'5716''E and latitude 35°12'.07''N, Fig. 2.

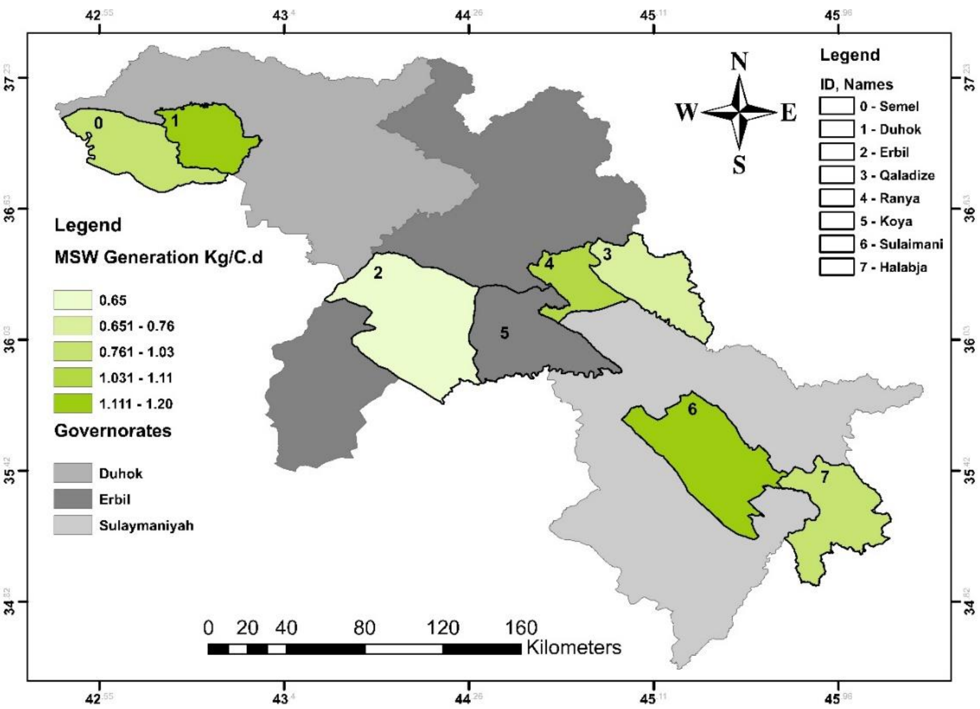

Figure 2: MSW disposal site locations and GR

2.3 Data Collection and Methods

Characteristics of MSW for Erbil, Sulaymaniyah, Duhok, Halabja, Semel, Ranya, Qaladize, Koya Cities in KR-Iraq were collected from related directorates, site visiting, and references. GR and percentage ratio of the MSW components were obtained using the following equations.

$$\mathrm{GR} = \frac{\text{Amount of MSW (kg)}}{\text{Population X Time (day)}} \qquad [1]$$

$$\text{Percentage ratio of MSW component} = \frac{\text{Mass of the MSW componnet (kg)}}{\text{Total mass of MSW (kg)}}\ X\ 1 \qquad [2]$$

GIS were applied to illustrate the locations of the MSW landfills and dumpsites. GR and percentage ratios of the MSW components were presented in a map with the assistance of the GIS, Fig. 2.

3. Results and Discussions

3.1 Solid Waste Characteristics in and Application of GIS

According to the available data gathered about solid waste characteristics in different cities in KR–Iraq. It has been found that the quantity and components of MSW are different from one place to another place due to some effective factors such as population concentration, lifestyle, per capita waste production, cultural, social, and economic status (Othman et al., 2013). The solid waste GR is the main characteristic addressed in this study, and its calculation depended on the population and the quantity of generated waste. The data displayed in Table 1 illustrated that the maximum GR has been observed in Sulaymaniyah City which is 1.20 Kg/Capita/day. While GR for domestic waste in Erbil City was 0.65Kg/Capita/day (Aziz et al., 2011). Recently published works indicated that the amount of MSW disposed of was around 2000 tons/day which showed the GR became more than 1 kg/Capita/day (Aziz et al., 2018). In addition, solid waste GR for other cities such as Duhok, Ranya, Semel, Halabja, and

Qaladze are 1.18 Kg/Capita/day, 1.11 Kg/Capita/day, 1.03 Kg/Capita/day, 1.00 Kg/Capita/day, and 0.76 Kg/Capita/day respectively, Figur 1 and Table 1.

The main components of solid wastes were identified in this research study are organic matter, plastic, metal, paper and cartons, glass, textile, and others, Table 1 and Fig. 3. Organic matter is a major portion in the MSWcontents for all cities which forms 79.34% in Erbil to 58% in Halabja, and it is about 75% for Sulaymaniyah 65% for Semel, 79%,75.71%, and 67.05% for Duhok, Qaladize, and Ranya respectively. However, the least ingredient in the MSW which was found is glass, its percentage between 1% to 5% for both Duhok and Semel respectively. The second major portion of the MSW is different from one city to another city, in the Erbil, Sulaymaniyah, Duhok, and Qaladze cities, plastic is the second major portion of solid wastes which forms 6.25%, 19%, 9%, and 13.18%, respectively. While, in the Halabja and Semel, paper and cartons are the second major portion of solid waste with 15% for Semel and 8.7% for Halabja. In Ranya City textile is the second major portion (11.93%).

Table 1: Solid waste characteristics in KR-Iraq

Cities	Type	Organic (%)	Plastic (%)	Metal (%)	Paper & Cartons (%)	Glass (%)	Textile	Other (%)	GR (kg/ Capita/d)	References
Erbil	Domestic	79.34	6.25	3.60	5.90	3.42	-	1.45	0.65	Aziz et al. (2010)
Sulaymaniyah	MSW	75.00	7.00	1.00	3.00	-	6	8	1.20	(Nawshrwan, 2019; Tahir, 2017)
Duhok,	MSW	79.00	9.00	6.00	4.00	1.00	-	1.00	1.18	General Directorate of Municipalities of Duhok
Duhok, Semel	MSW	65.00	8.00	-	15.00	5.00	-	7.00	1.03	General Directorate of Municipalities of Duhok
Halabja	MSW	58.00	5.30	3.70	8.70	3.00	5.00	16.30	1.00	General Directorate of Municipalities of Halabja
Ranya	MSW	67.05	8.19	3.05	7.12	2.65	11.93	-	1.11	Araz A.H. & Omed A.A, 2019.

Qaladize	MSW	75.71	13.18	0.93	3.73	1.66	4.84	-	0.76	General Directorate of Municipalities of Raparin.

To calculate the average GR in the KR, mass balance was used for the GR of different cities with the corresponding data of the populations for the same cities. The population for 2014 of Sulaymaniyah, Erbil, Duhok, Ranya, Semel, Halabja, and Qaladize Cities were 831219, 904858, 353337, 222984, 175484, 102823, and 73800, respectively (Central Statistical Office (CSO) https://krso.gov.krd/content/upload/1/root/e61.pdf)

$$\text{Average GR in the KR} = \frac{(1.2*831219)+(0.65*904858)+(1.18*353337)+(1.11*222984)+(1.03*175484)+(1*102823)+(0.76*73800)}{831219+904858+353337+222984+175484+102823+73800}$$
$$= 0.972 \text{ Kg/Capita/day}$$

To calculate the average OWCin the KR, mass balance was used for the average OWCof different cities with the corresponding data of the populations for the same cities.

$$\text{Average OWCin the KR} = \frac{(65*831219)+(79.34*904858)+(79*353337)+(67.05*222984)+(65*175484)+(58*102823)+(75.1*73800)}{831219+904858+353337+222984+175484+102823+73800}$$
$$= 71.91\%$$

Finally, it can be noticed that economic and political situations, population increase, investment, etc. affected the GR values. On the other hand, lifestyle, income, education, environmental awareness, religion, residential area, day of the week, etc. influenced the components of the MSW. Figures 2 and 3 illustrate GR and MSW characteristics in different cities in KR-Iraq. GR values were varied from 0.65 to 1.2 Kg/Capita/d for the cities in the study area. Various colors were used for representing the value of GR, Fig. 2. MSW components such as organic, plastic, metals, etc. are shown in the mentioned cities. Different legends were applied for representing the MSW components, Fig. 3.

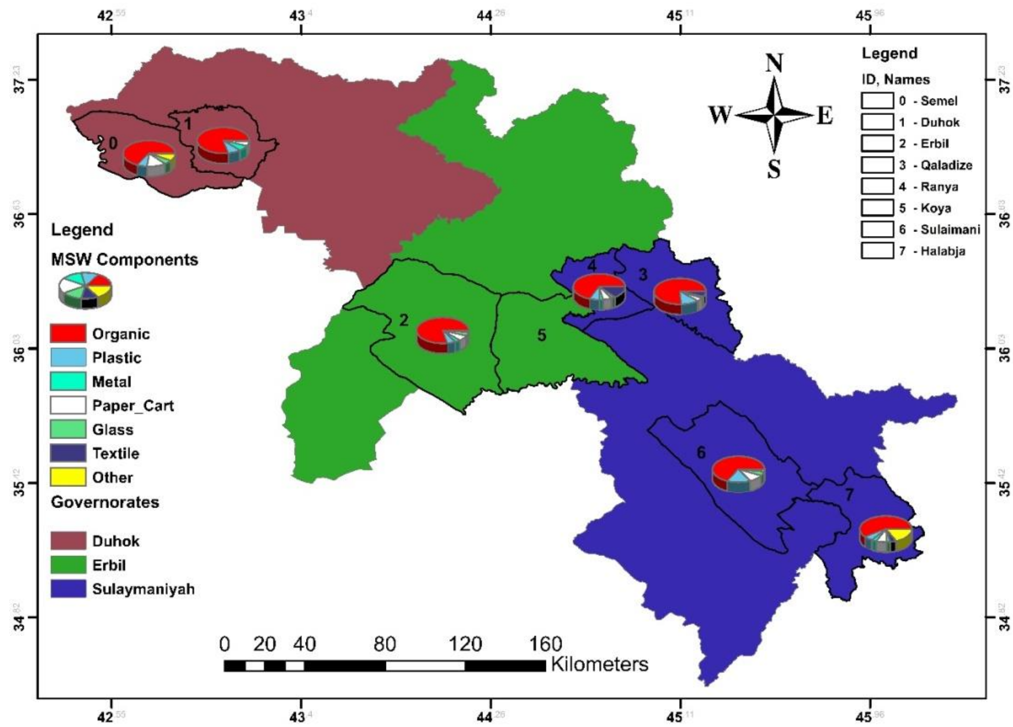

Figure 3: MSW components in the KR cities

3.2 Status of MSW Landfills and Dumpsites in KR-Iraq

Information about Erbil, Sulaymaniyah, Duhok, Halabja, Ranya, Qaladize, and Semel MSW disposal sites are shown in Figures 2 and 3 and Table 2. There are many dumpsites around and near Erbil City such as Khabat, Shamamk, Qushtapa, Harir, Khalifan, Soran, Mergasour, Koya, Barzan, Choman, Pirmam and Shaqlawa. Daily these dumpsites receive all types of MSWs without any appropriate treatment and recycling. The wastes are only buried with soils day by day. This leads to too many environmental and health problems in the surrounding areas near dumpsites (Aziz et al., 2018; Maulood and Aziz, 2016). The main landfill in Erbil City is located at Kani Qrzhal area which is around 15 km far from Erbil City center, Fig. 4. MSW from Erbil city center and surrounding areas such as Kasnazan, Bnaslawa, Permam, Shawes, etc. are disposed at Erbil Landfill Site. Nowadays, a part of metals and cartons collected by the private sectors resulted in decreasing amount of MSW in the Erbil Landfill Site. On the other hand, some recyclable materials are collected by the scavengers at the site. Area of ELS is 37 ha, most parts of the site are covered and the authority planned to open a new landfill. Disposal of MSW at ELS with only covering by soil leads to water, soil, and air pollution (Maulood and Aziz, 2016).

Solid waste GR in Erbil City has been increased due to population growth, rapid urbanization, and migration of Iraqi citizens to the city. This is resulting in an increasing population rate of more than one million.

Components of MSW in Erbil City generally consist of combustible, incombustible, and recyclable materials. Moreover, the average weight percentage of domestic solid waste components is food which is the large portion, plastic, metal paper, glass, and cloth (Aziz et al., 2010).

Figure 4: ELS Visited on a) 28 October 2020, and b) 28 March 2021

In 2015, there were about 5000 factories of varying sizes in the Sulaymaniyah area. Economics growth has conveyed various benefits, for example improving lifestyles and raising living standards across the KR, but it has led to ecosystem degradation and natural resources depletion. The development of the industrial sector in the KR, especially in the city of Sulaymaniyah, is expected to generate tons of various types of waste, containing hazardous waste, which will be illegally dumped in the open dumping area (Tanjaro area) without proper treatment (Tahir, 2017). The Tanjaro dumping site occupies 25 hectares and collects 500 metric tons of MSW on a daily basis, 60 metric tons of silt, and 5 tons of bio-medical waste. The daily amount of silt rises to more than 1000 metric tons between March and June because of drain cleaning in advance of the construction season (Karim et al., 2020). Currently, MSWM in Sulaymaniyah has begun to become a problem, because the amount of waste streams rises every year, and on the other hand, there has been a missing of integrated MSWM, such as reuse and recycling by the government and industry sector.

In Tanjaro (waste pouring area), which was one of the most environmentally dangerous places in Sulaymaniyah, the waste from Sulaymaniyah was not properly handled and dumped. “Activity taken by individuals cause the natural world to be fatally compromised and causes unimaginable destruction” (Yildiz, 2019). Tanjaro has become the source and center of pollution and diseases in the city.

In most cities in KR, especially in the Sulaymaniyah City, massive construction has increased in cement and oil companies in addition to urban expansion. Consequently, they are causing many serious environmental problems and have had a very strong negative effect on the environment (for example groundwater pollution, due to the percolation of leachate from solid waste dump sites and finding its way into the groundwater). A portion of the discarded waste in Tanjaro was burned by irresponsible locals that caused air pollution and another problem that continuously degrades the city’s air quality and can be seen as a haze in the city’s south and southwest. Since the Tanjaro River is flowing alongside the dumping site. The most dangerous things are that farmers use the Tanjaro River to irrigate their farms and then sell their products to local markets. Unfortunately, there is no quality control for it (Karim et al., 2020). Usually, several forms of research have shown that the river is polluted and that it is prohibited to use its water for any domestic use, but it is still utilized (Majid et al., 2018).

Table 2: MSW landfill/ dumpsite detail in KR-Iraq

City	Location	Type*	Level**	E & N	Opened	Area (ha)	MSW amount (tons/day)	Status	Recycling	Distance from City	Reference
Erbil	kani-Qrzhala	Anaerobic	II	36°10′23″N and 43°35′32″E	2001	37	>2000	In operation	Not available	15	Aziz et al. (2012)
Sulaymaniyah	Tanjaro	Anaerobic	I	35.484030N, 45.434365E	2005	25	>1200	In operation	Not available	5	Karem et al (2020)
Duhok	Kashee	Anaerobic	II	36.9745N 42.8088E	2010	14.5	800	In operation	Available	20	Municipalities of Duhok (2020)
Halabja	Hassan Awa	Anaerobic	II	35.1207 N 45.5716 E	2018	1.5	128.86	In operation	Not available	1	General Directorate of Municipalities of Halabja (2019), Karzan et al. (2017)
Ranya	Hajila	Anaerobic	II	36.2733 N 45.1324 E	2010	5.5	286.9	In operation	Not available	1.5	Hamza et al. (2020)
Qaladize	Khas	Anaerobic	I	36.1574 N 45.1324 E	2010	4.5	93.77	Closed	Not available	1.1	General Directorate of Municipalities of Raparin(2020).
	Koshkalle	Anaerobic	II	36.2141 N 45.1313 E	2019	3.5	93.77	In operation	Not available	1.7	
Koye	Hawawan Village	Anaerobic	II	36.0690N, 44.6549E	1995	30	94.148	In operation	Not available	1.1	Municipality of Koya City (2018)

* Anaerobic, semi-aerobic and aerobic landfills
** Based on Malaysian Standards (I: Open dump site, II: MSW disposal with daily cover by soil, III: Semi-aerobic landfill, and IV: Scientific landfill)

Generally, 90% of the open dumpsites in Sulaymaniyah are in an emergency situation, particularly the Tanjaro dumpsite. In order to begin closing and reclaiming those dumpsites, at least one sanitary landfill in the province should begin to operate. Tanjaro's groundwater is polluted and is a domestic source of water for Sharazour and Darbandikhan. From this point of view, the Tanjaro dumpsite is now a life-threatening source that slowly kills the nearby population. The authorities should therefore declare a red alarm for the Tanjaro dumpsite and begin to conclude a contract with eligible international companies to correctly handle and close the dumpsite. If the authorities chose to be quiet about this tragedy, they will be intensively responsible for killing their own country and the next generation.

The population of Duhok Province was about 1557000 at the end of 2018. Households in Duhok District and other districts that belong to the Duhok governorate are served by the door-to-door collection system. So far, they receive the service free of charge. The waste collection services in Duhok and Semel Districts are provided by Artush Private Company on behalf of the municipalities in both districts. According to the contract between the municipalities and the company, the MSW needs to be collected every day in both districts (Saeed, 2020).

Kwashe sanitary landfill is the main landfill in Duhok Province and is located in the district of Semel. The beneficiaries from Kwashe Landfill have been increased significantly since 2014, due to the construction of many IDPs and Refugee camps in the Semel district. Subsequently, it has placed an additional burden on the landfill and increased the negative environmental effects of its current configuration. The Municipality is the government agency responsible for solid waste service provision (Saeed, 2020). Since 2010, Dohuk was the first province in Kurdistan to practice recycling. It engaged a German firm (Eggersman) to construct a facility that separates garbage into materials that can be composted, recycled, or buried (Whitcomb, 2014). The current site consisted of a waste sorting facility with a full working capacity of 320 tons of MSW per day (which represents 40% of the total MSW received, 800 tons/day). In 2014, a buffer tank with a capacity of 3000 m3 was constructed to store the produced leachate from the landfills. In 2017, a leachate treatment plant was constructed to treat the leachate and safely discharge it to the environment. In total, the Kwashe landfill site receives 800 tons/day of MSW which comes from Duhok and Semel Districts (General Directorate of Municipalities of Duhok 2020).

The sorting plant at Kwashe landfill consists of two lines, each with the capacity to sort 250 tons/d. The sorting plant separates metals, plastics, organics, paper-based materials, rubbers, and glasses. The organic materials are processed within the plant, in a composting station. The sorting plant should have the capacity to sort 60% of the total solid waste, and the remaining 40% (unusable waste) should go into the landfill site. Since there are no recycling capabilities within the sorting facility, the sorted materials (including the compost) are then stored and sold for a profit. The remaining non-recyclable waste, approximately, is then deposited into the landfill site. The existing sanitary landfill site has a total area of 25,000 m2 and 3 m deep, Fig. 5. In addition, it has a specified area for future cell extension of 120 000 m2.

Currently, the Kwashe waste area consists of a Materials Recovery Facility (MRF) /sorting plant, one open dumping area for unsorted waste, sanitary landfill, leachate tank, and leachate treatment plant (General Directorate of Municipalities of Duhok 2020).

Akre landfill also belongs to Duhok governorate, it is processing about 250 tons/d. Akre landfill is sited 9 km east of Akre city with allocating of 681846 dunum for sanitary landfill and sorting plants. Since 2011, one sorting plant has been executed with MRF that is a local company. In addition, since

2012, phase 1 of the sanitary landfill has been executed. Area of 10,000 m2 out of 50,000 m2 has been constructed (Eropean Union et al., 2018). There are some other districts that are belong to Duhok province and do not have any sanitary landfill such as Amadia, Zakho and Shekhan Districts.

Figure 5: The current landfill site at Kwashe

Raparin self-administered zone is covered in this research study where is located in KR-Iraq with coordinates of 36.23N and 44.79E, and it has separated from the administration of the province of Sulaymaniyah Governorate. The total area of the Raparin self-administration zone is about 2250 km2, with a population of 369,000 people. It consists of two main districts; Ranya and Pshdar (KRG-Raparin self-administration office 2020). The MSW in Ranya and Pshdar Districts is one of the common environmental issues due to the absence of appropriate MSWM systems, recycling, source separation, and nonscientific disposal method in the Districts. The waste collection process was totally carried out by the municipality, up to September 2014 in both districts. After that, the process has transferred to the private sector under the municipality supervising. The collection process is performed frequently three times a week such as Curbside and Community bin pick up methods in Ranya and Pshdar (KRG-Ministry of Municipalities and Tourism 2020). Additionally, the waste discards in the disposal sites where are open areas, without any treatment and other alternatives such as recycling and incineration in both districts Fig. 6. The total daily quantities of MSW generate in Ranya and Pshdar are 286.90 tons and 93.77 tons, respectively. Moreover, the waste generation rates are 1.108 and 0.761 kg/Capita/day for both of them respectively (Hamza, 2020; Hamza and Ahmed, 2020; Manguri and Hamza, 2021).

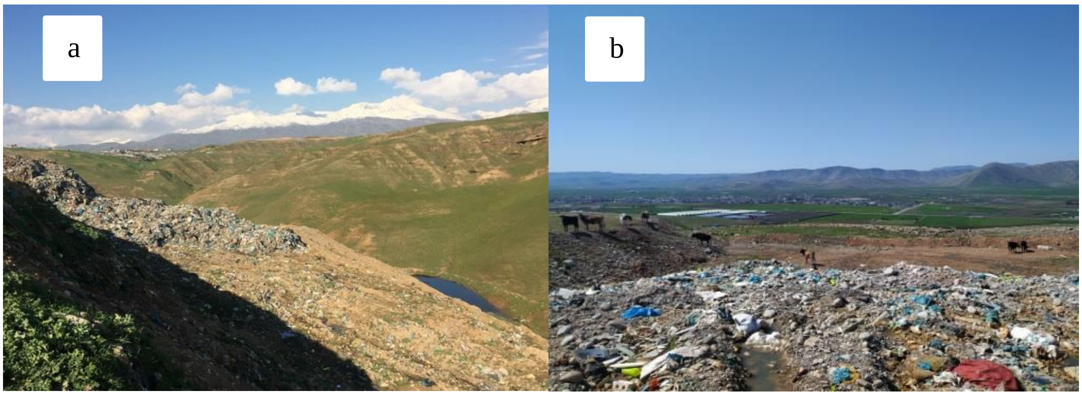

Figure 6: Raparin waste disposal sites, a) Pshdar waste disposal site, b) Ranya waste disposal site

In the present study areas, Halabja Province is considered for evaluating the solid waste management process and waste disposal site situation. The population of Halabja province is approximately 337,000. According to the information are attained from the literature review and Municipality of Halabja, the MSWM process is performed by the private sector which includes these steps, collection, transportation, and disposal process. The solid wastes comprising domestic, industrial, and hospital wastes are being discarded somewhere close to the city (Muhammad and H.Karim, 2016). The GR of MSW in Halabja City approximately is 1 kg/Capita/day (Mohammed et al., 2018). The total amount of wastes which are produced in Halabja are about 128.86 tons/day (General Directorate of Municipality of Halabja, 2019).

The population of Koya City is approximately 60,000 in 2013 and around 91000 in 2019 (Municipality Of Koya 2021). Koya City located in South-East of Erbil Governorate, Koya City has a problem with the disposal of MSW. The city is located between the two lofty mountains of Bawaji and Haibat-Sultan. Economic growth in recent years has led to a remarkable increase in population and consequently in solid waste generation. It is estimated that MSW production of the city is approximately 60 tons/day in 2013 and 94.148 tons/day in 2019.

3.3 Impact of MSW Disposal Sites On the Environment in KR

In all countries, MSWM is a daunting task, with major consequences for human health, environmental protection, sustainability, and the circular economy. The sanitary landfilling approach for final waste disposal remains a widely accepted and used method, but the empirical evidence available on the environmental and health consequences related to waste is not conclusive (Vaverková, 2019). Comparative studies of different MSW treatment methods (Landfilling, incineration, composting, etc.) show that sanitary landfilling or open dumping is common in most countries due to the relatively low cost and low technical requirements among the MSW treatment and disposal technological options (Feng et al., 2018; Gonzalez-Valencia et al., 2016). Evaluation of the effect of landfills on the environment is a crucial subject in the literature and, considering rising environmental issues, has recently received increased attention. The hypothesis is that landfills can be a source of risk and environmental contamination. The main aim of this section is to deal with these issues impacted on environments based on literature research such as the soil contaminations, water pollution, green lands, and although these problems are causing serious health concerns for the inhabitants, they can sometimes, in the worst scenarios.

3.3.1 Soil Contamination

Most of the potential danger from MSW landfills comes from the migration of polluted landfill gas, so it is not possible to disregard the environmental effects of the many landfills around the world. Landfill fires are unexpectedly prevalent (Chavan et al., 2019; Powell et al., 2016) but little attention has been paid to the environmental aspects of landfill fires within the research community. It clears the MSW disposal site in Erbil, Sulaymaniyah, Duhok, Halabja, Ranya, Qaladza, and Koya affected the surrounded environment and contaminated the soil. Aziz and Maulood (2015) reported that surrounded area of the ELS is polluted.

3.3.2 Water Pollution

One of its significant disadvantages is the production of landfill leachate. A huge amount of organic matter, heavy metals, nitrogen compounds, inorganic salts, and phenols can be found in leachates (Aziz et al., 2014; Mojiri et al., 2016; Renou et al., 2008). Leachate could be a potential source of contamination of source and groundwater pollution if not treated and properly disposed of because it could percolate into soil layers, causing significant groundwater pollution (Aziz et al., 2012; Aziz et al., 2010). A focal undesirable feature mainly associated with urban sanitary landfill disposal systems in the development of high polluted leachate that can percolate into the soil and contaminate water supplies and soil (Bashir et al., 2013; Pillai et al., 2014). The age of landfills has a big impact on the fresh landfill leachate created. Deposit age arranges the leachate of the landfill to younger < 5 years, intermediate 5 to 10 years, and matured/stabilized leachate > 10 years (Aziz, 2011). The broad surface and cross-sectional areas of MSW landfill sites produce more landfill leachate output in the surrounding area. The main factors influencing the consistency of landfill leachate are: (1) the composition of MSW disposed of; (2) the nature, operation, and age of the landfill; (3) the availability of moisture and oxygen; and (4) the hydrology of the site. Several studies have shown that as a result of the leaching of the toxic chemical. Landfill leachate is a major source of contaminants (Brennan et al., 2016; Budi et al., 2016; da Costa et al., 2018; Melnyk et al., 2014). Furthermore, leachates contain four main components: nutrient (namely nitrogen), volatile organic compounds, heavy metal (HM), and toxic organic. Compounds (Arunbabu et al., 2017; Budi et al., 2016).

From site visiting and discussion with the authority, it can be noticed that MSW disposal sites affected the surrounded water sources. In Sulaymaniyah, the produced leachate is mixed with the Tanjaro River. Additionally, formed leachate at anaerobic ELS polluted groundwater near the landfill area (Aziz and Maulood, 2015).

3.3.3 Health Problems

On the outskirts of urban areas, solid waste disposal sites are found, turning into child sources of pollution due to the incubation and proliferation of files, rodents, and mosquitoes; which in turn, are disease transmitters that affect the health of the population, which have their organic defenses in a formative and creative state. The impacts evaluated were the potential health and environmental impacts of the dumpsite and also the perspective of the residents on the location of the dumpsite. Abul (2010). investigated the distinction was made between people from nearby and far away. The result indicates that the proximity of the dumpsite nearer to their settlements influenced both residents. It was also noted that chest pain, malaria, and diarrhea are the victims of residents whose homes are less than 200 meters from the dumpsite. However, the chest pain and bad smell from the dumpsite also affect residents whose houses are more than 200 meters, but mostly when the wind blows in their direction. A large variety of health issues, including respiratory symptoms, nose, eye, and skin irritation, gastrointestinal problem, allergies, and psychiatric, have been found in several communities health survey (Berglund et al., 1992; Norsa'adah et al., 2020). Dumpsites closer to residential areas are often feeding places for dogs and cats, according to (Dolk, 1997). These pets take disease with them to nearby homesteads, along with the rate.

Nasty gas, bad view of MSW disposal sites, smoke from the burning of MSW, etc. affected the people health at the surrounded area of the MSW disposal sites in KR.

3.3.4 Methane Gas Formation

While the waste is deposited into a dumping site or landfill, it is known that chemical reactions between the waste and certain gases are produced. Methane gas (CH4) is the best-known one. Methane gas can be used as a source of energy or for heat consumption (Karim et al., 2020). Large biogas emissions are greatly influenced by biological processes that exist in them. If the MSW is disposed of without pretreatment of the landfill, emissions grow during the operation period of the landfill, which are created even after the landfill has been closed (Laner et al., 2012; Shen et al., 2018). Biogas or landfill gas (LFG) is one of the components of biological processes occurring in MSW landfills (Shen et al., 2018). Over the life cycle of the landfill, the rate of biogas production and its composition change. Generation of landfill gas on the basis of a composite bacterial waste decomposition model and a long-term landfill gas behavior model from old waste repositories (Zhao et al., 2017). The key factor influencing LFG quantity are as follows: moisture content, the composition of waste, age of landfill, temperature, etc. LFG production begins in the landfill one to two years after waste disposal and continues for (15-25) years (Thomasen et al., 2019).

Age of MSW dumpsite has a great effect on gas formation. Authors reported that presently ELS in gas formation phase. The expected amount of produced gas for 1,223,834 population (in 2018) at ELS was around 3,839, 669.265 m3 (Aziz and Mustafa, 2018). Uncontrolled formed gas causes problems to landfill sites and the surrounded area. Recently, about 80 pipes were embedded to the ELS for controlling the formed gas, Fig. 7.

Figure 7: Gas collection pipe at ELS (Visited on 28 October 2020)

4. Conclusions

MSW characteristics revealed that more than 50% of the produced solid waste in KR cites is organic/food waste. Normally, GR for MS in KR cities is greater than 1 kg/Capita/day. For the first time in the KR of Iraq, the average GR and average OWC were calculated. Commonly, the scientific recycling process of recyclable materials such as plastic, metals, glass, and papers is not available. MSWM normally is weak. Open dumpsites and landfills generally affected the environment and polluted soil, water, and air. MSW disposal site influenced human health as well. Additionally, the collection of produced methane and achieving energy do not exist in landfills and dumpsites. To protect our environment from pollution, opening new scientific/engineering MSW landfills and upgrading available dumpsites and landfills to scientific landfills are essential. GIS was applied to identify the MSW disposal sites, components, and GR in KR cities. All MSW components are graphically presented with ArcGIS to differentiate between the rate of production and the amount of components based on their types and location of generation.

5. Conflict of Interest statement

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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