Waste Management 86 (2019) 49–53

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Production of municipal solid waste and sewage in European refugees' camps: The case of Lesvos, Greece

Anastasia Katsouli, Athanasios S. Stasinakis *

Water and Air Quality Laboratory, Department of Environment, University of the Aegean, 81100 Mytilene, Greece

ARTICLE INFO

Article history:
Received 22 July 2018
Revised 13 December 2018
Accepted 24 January 2019
Available online 28 January 2019

Keywords:
Solid waste
Wastewater
Production
Refugee crisis
Environmental footprint
GHG emissions

ABSTRACT

Since 2015, Lesvos Island (Greece) is a key entry location for people seeking asylum in the EU. This article presents information for the production of municipal solid waste and sewage in the asylum seekers reception sites of Moria and Kara Tepe for the period between May 2016 and April 2017. According to the results, the annual produced municipal solid waste and sewage in the refugees' camps were 1464 tons and 95,550 m^3, respectively. Taking into account the population served, the average daily per capita generation of municipal solid waste was 0.88 kg per asylum seeker and day, significantly lower than that calculated for the permanent population the same period (1.39 kg per inhabitant and day). The daily production of sewage was 54 L per asylum seeker and day, while the corresponding value for the permanent population was 211 L per inhabitant and day. The total methane emissions from solid waste and sewage production in studied refugees' camps were estimated to 178.6 tons per year or 35.5 kg CH_4 per asylum seeker and year. Further investigation is needed for the characterization of the produced solid waste and sewage in order to assure the sustainable design and operation of these sites.

1. Introduction

Following the refugee and migration crisis in the Aegean Sea in 2015 where nearly 857,000 asylum seekers arrived in the Aegean islands by sea (UNCHR, 2018), two asylum seekers reception sites (commonly known as refugees' camps) were constructed in Lesvos Island at the areas of Moria and Kara Tepe. These camps are located in a distance of 8 and 6.5 km from the city centre, respectively, and according to the UN Refugee Agency, it is estimated that 506,919 asylum seekers passed from them in 2015, while this number decreased to 91,506 in 2016 and 12,795 in 2017. Most of the asylum seekers originated from Syria, Afghanistan and Iraq, while citizens from other Asian countries (e.g. Pakistan, Iran, Algeria, State of Palestine) and Africa (e.g. Algeria, Morocco, Congo) also stayed in these camps. Nowadays, following the EU – Turkey statement of 18.03.2016, the asylum seekers are kept in these camps until they are registered and processed. Kara Tepe camp accommodates families and vulnerable populations, while Moria is the place mostly for initial asylum seeking phase and single men (Jauhiainen, 2017). Concerning solid waste management, garbage trucks of Lesvos Municipality collect the municipal solid waste daily from both camps and transfer them, via a transfer station, to the central landfill of the island which is located 30 km North West of the city of Mytilene. Regarding sewage management, Kara Tepe camp has been connected via sewerage system with Mytilene's Sewage Treatment Plant (STP), while sewage from Moria camp are transferred there using sewage trucks.

So far, limited information is available regarding the production of solid waste in refugees' camps and this information originates exclusively from the Middle East (Al-Khatib et al., 2010; Saidan et al., 2017) and North Africa (Garfi et al., 2009). Specifically, Al-Khatib et al. (2007, 2010) studied solid waste management in Palestinian districts and reported information for the production of solid waste in refugees' camps of this area. Garfi et al. (2009) collected data from Saharawi refugees' camps in Algeria, where refugees from Western Sahara are mainly hosted, and compared different waste collection and management scenarios. Saidan et al. (2017) conducted municipal solid waste composition analysis in two seasonal campaigns in a Jordan camp hosting Syrian refugees (March and November 2015) and estimated a daily solid waste generation of 13.6 tons in a district serving 16,000 refugees. This is the first study for the generation of municipal solid waste in refugees' camps that have been constructed in Europe. Additionally, to the best of our knowledge, no data is available for the sewage production in refugees' camp worldwide. The existence of such data is important for the assessment of the environmental footprint of refugees' camps as well as for the efficient planning of the needed infrastructures of these settlements.

* Corresponding author.
E-mail address: astas@env.aegean.gr (A.S. Stasinakis).

https://doi.org/10.1016/j.wasman.2019.01.036
0956-053X/

Based on the above, the main objectives of this study were: (a) to estimate the monthly produced amounts of solid waste and sewage in Lesvos refugees' camps, (b) to calculate the daily production of municipal solid waste and sewage per asylum seeker. These values were compared with the corresponding values of the permanent population. For this reason, data was collected for the period May 2016 – April 2017, while 2014 was used as base year for comparison purposes. A preliminary estimation of the cost of waste and sewage management was also conducted, while the emitted greenhouse gases (GHGs) from the produced solid waste and sewage in Lesvos refugees' camps were calculated.

2. Materials and methods

2.1. Study periods

The period between January 2014 to December 2014 was selected as base year for studying the generation of solid waste and sewage in the metropolitan area of Mytilene, due to the very small asylum seekers flows in Lesvos Island and the negligible residence of asylum seekers this year. On the other hand, the period between May 2016 and April 2017 was selected as study period for the environmental footprint of the asylum seekers, because after the EU – Turkey statement of 18.03.2016 the arrivals and the residence time of refugees and migrants to the island were much more normalized comparing to the previous period. This resulted to the existence of more reliable data for the number of overnight stays of the asylum seekers in Moria and Kara Tepe camps. For the same period, data was also collected for the metropolitan area of Mytilene for comparison purposes.

2.2. Collection of data

Population data for the permanent population in the metropolitan area of the city of Mytilene and the number of nights spent by tourists at tourist accommodation establishments of this area was collected in a monthly basis by the Hellenic Statistical Authority (ELSTAT, 2018) and the Greek National Tourism Organization (personal communication), respectively. The daily stays of asylum seekers to Kara Tepe and Moria camps was collected by the Greek Ministry of Digital Policy, Telecommunications and Media (MinDigital, 2018). This data originate from the National Coordination Center on Border Control, Immigration and Asylum (Ministry of Citizen Protection, 2018).

The daily amounts of municipal solid waste produced in the city of Mytilene for 2014 and May 2016 to April 2017 as well as the relevant amounts produced in Moria and Kara Tepe camps (for May 2016 to April 2017) was taken from Lesvos Municipality (Cleanliness and Environment Department). It should be mentioned that the municipality weight and records each garbage truck which transfer solid waste to Lesvos' central landfill, on a daily basis. The total daily sewage flowrates in Mytilene's STP were collected by Lesvos Municipal Water Supply and Sewerage Company. As no data was available for the contribution of the studied camps in this sewage production, annual water consumption data was also collected for Moria and Kara Tepe camps and it was considered that 85% of the used water was converted to sewage (Tchobanoglous et al., 2003). This percentage seems realistic as the use of water for irrigation is limited in these sites.

2.3. Statistical analysis

One-way ANOVA test was used for comparing the per capita generation of solid waste and sewage between different population groups at a significance level of 0.05.

3. Results and discussion

3.1. Population data

Information for the population in the metropolitan area of the city of Mytilene for the studied periods is presented in Table 1. According to the results, the total number of permanent inhabitants and tourists was similar in both periods (almost 38,400 inhabitants). The contribution of tourists on the total population was low, ranging between 0.4% (January 2014) to 2.7% (August 2014). It is worth mentioning that Mytilene's economy is not based on touristic activities (total number of beds at tourist accommodation establishments equal to 1736), and most of the tourists do not overnight in the city but in other areas of the island. Regarding the asylum seekers, their mean monthly number for the studied period was 5025 persons, ranging between 3481 and 6318 persons for the different months (Table 1). On average, an increase of the total population in the area by 13% was calculated for the period of May 2016 to April 2017 due to the residence of the refugees and migrants.

3.2. Municipal solid waste production

The total annual municipal solid waste production in the metropolitan area of Mytilene from the permanent residents and the tourists was 19,936 tons and 19,443 tons for 2014 and May 2016 to April 2017, respectively, while the relevant amounts of solid waste collected by Moria and Kara Tepe camps were 1,464 tons. Information for the variation of the monthly amounts is presented in Fig. 1. Noteworthy that a part of the municipal solid waste in the metropolitan area of Mytilene is collected in separated bins as recyclables (mixture of glass, plastic, paper and aluminium) and it is transferred outside of the island for recycling. For 2014, the collected recyclables were 6.5% of the total collected solid waste (1295 tons), whereas this percentage increased to 16% (3111 tons) for the period of May 2016 to April 2017. On the other hand, no collection of recyclables was conducted in Moria and Kara Tepe camps for the studied period.

Taking into account the population served, the daily per capita values of produced municipal solid waste were calculated for different population groups (Table 2). According to the results, 1.42 (±0.16) kg of municipal solid waste per capita and day were produced on average in Mytilene in 2014, while an almost similar value (1.39 ± 0.07) was calculated for May 2016 to April 2017. Having in mind, the low contribution of tourists to the total population of the city, it can be assumed that the per capita solid waste values reported above, actually show the generation rate of solid waste by the permanent population. It is worth mentioning that these values are slightly higher than the mean value that has been reported for Greece in 2016 and it is equal to 1.36 kg per capita and day (Eurostat, 2018). On the other hand, the application of ANOVA test showed that the municipal solid waste generation by the asylum seekers was significantly lower comparing to the permanent population, reaching 0.88 (±0.50) kg of municipal solid waste per capita and day (Table 2). It is noteworthy that the values obtained in Moria and Kara Tepe camps varied significantly between the different months, indicating that the production of solid waste in such settlements is much more sensitive to differences on the accommodated persons and the offered services. As mentioned in Introduction, this is the first study that estimates the municipal solid waste production in refugees' camps that have been constructed in Europe. Similar solid waste production (0.85 kg per capita and day) has been reported in Zaatari refugees' camp in Jordan (Saidan et al., 2017), while lower values have been reported in refugees' camps located in Palestine (0.40 and 0.62 kg per capita

Table 1
Monthly population in the metropolitan area of Mytilene (Lesvos Island, Greece) for the periods January 2014 to December 2014 and May 2016 to April 2017.

Months	Total population 2014 (permanent + tourists)	Population 2016/2017 (permanent + tourists)	Asylum seekers 2016/2017	Total population 2016/2017 (permanent + tourists + asylum seekers)
January	38,059	38,349	6042	44,391
February	38,104	38,325	5468	43,793
March	38,132	38,378	4945	43,323
April	38,070	38,173	4177	42,350
May	38,417	38,264	4117	42,381
June	38,659	38,497	3501	41,998
July	38,881	38,789	3481	42,270
August	38,944	38,869	4470	43,339
September	38,664	38,616	5635	44,251
October	38,123	38,177	5955	44,132
November	38,123	38,255	6185	44,440
December	38,068	38,280	6318	44,598
Mean	38,354	38,414	5025	43,439

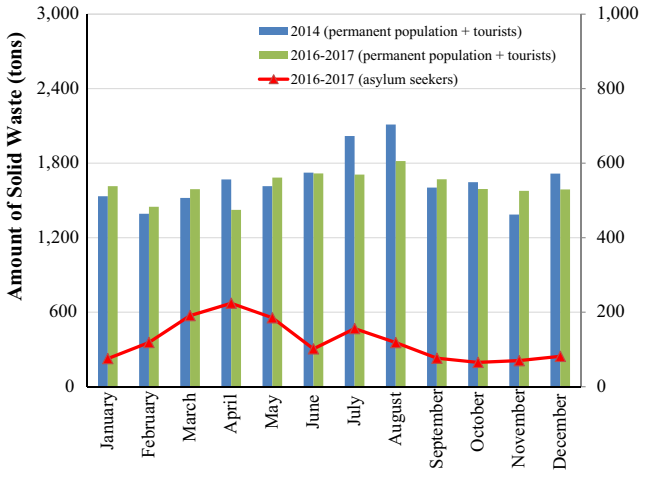

Fig. 1. Monthly amounts (tons) of produced municipal solid waste in the metropolitan area of Mytilene (Lesvos Island, Greece) for the periods January 2014 to December 2014 and May 2016 to April 2017 (left Y-axis: values for the permanent population + tourists, including recyclables; right Y-axis: values for asylum seekers).

Table 2
Daily per capita municipal solid waste production in the metropolitan area of Mytilene (Lesvos Island, Greece) for the periods January 2014 to December 2014 and May 2016 to April 2017.

Months	Per capita solid waste production for 20,141 (kg per day and inhabitant)	Per capita solid waste production for 2016/2017[a] (Kg per day and inhabitant)	Per capita solid waste production for 2016/2017[b] (Kg per day and asylum seeker)
January	1.30	1.36	0.40
February	1.31	1.35	0.78
March	1.29	1.34	1.25
April	1.46	1.24	1.79
May	1.36	1.42	1.45
June	1.49	1.49	0.99
July	1.67	1.42	1.45
August	1.75	1.51	0.88
September	1.38	1.44	0.46
October	1.39	1.35	0.35
November	1.21	1.37	0.38
December	1.45	1.34	0.42
Mean ± Sd	1.42 ± 0.16	1.39 ± 0.07	0.88 ± 0.50

[a] Calculations for the sum of permanent population and tourists.
[b] Calculations for asylum seekers.

and day) (Al-Khatib et al., 2007) and in Lebanon (0.43–0.53 kg per capita and day) (UNDP, 2014). The lower values reported for Palestine and Lebanon could be due to various actual and methodological reasons. In the article published by Al Khatib et al. (2007), the data was collected from poor Palestinian districts in 2005. Several problems are described for solid waste management in the area during those years (no proper handling of residual waste from house to waste containers; disposal in open or semi-covered dumps etc) that could affect the amounts of produced solid waste. In the report of UNDP (2014), there was no direct measurement of the solid wastes produced by the refugees, but these amounts were calculated by the difference between the actual total quantity collected at sorting facilities of Lebanon by the end of 2013 and the projected quantity of solid waste of the permanent population for the same year.

3.3. Sewage production

The total sewage production in the metropolitan area of Mytilene from the permanent residents and the tourists was 2,675,364 m^3 for 2014 and it was increased to 3,019,077 m^3 for the period between May 2016 and April 2017. The estimated annual volume of sewage produced in Moria and Kara Tepe camps for the same period was 95,550 m^3. Information for the variation of the monthly sewage production is presented in Fig. 2.

Calculation of the daily per capita values of produced sewage showed that on average 191 (±26) L were produced in 2014 by the permanent population, while a slightly higher value

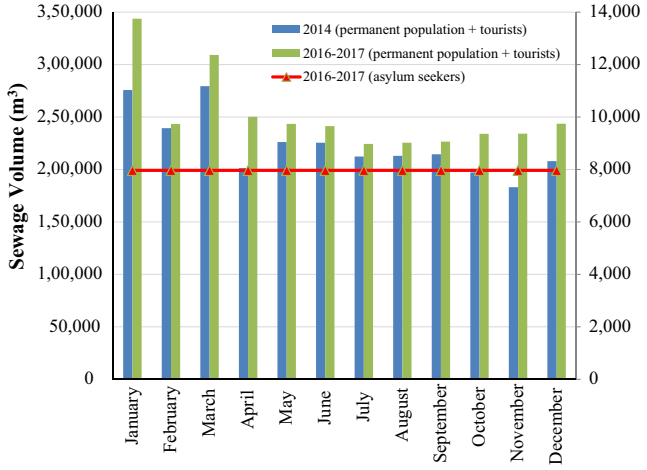

Fig. 2. Monthly volumes (m^3) of produced sewage in the metropolitan area of Mytilene (Lesvos Island, Greece) for the periods January 2014 to December 2014 and May 2016 to April 2017 (left Y-axis: values for permanent population + tourists; right Y-axis: values for asylum seekers).

Table 3
Daily per capita sewage production in the metropolitan area of Mytilene (Lesvos Island, Greece) for the periods January 2014 to December 2014 and May 2016 to April 2017.

Months	Per capita sewage production for 20,141 (L per day and inhabitant)	Per capita sewage production for 2016/2017[a] (L per day and inhabitant)	Per capita sewage production for 2016/2017[b] (L per day and asylum seeker)
January	234	289	43
February	224	205	52
March	236	260	52
April	176	211	64
May	190	205	62
June	195	202	76
July	176	187	74
August	176	187	57
September	184	189	47
October	167	198	43
November	160	197	43
December	176	205	41
Mean ± Sd	191 ± 26	211 ± 31	54 ± 12

[a] Calculations for the sum of permanent population and tourists.
[b] Calculations for asylum seekers.

(211 ± 31) was calculated for the period May 2016 to April 2017 (Table 3). These values are similar to the per capita sewage production that was recently reported for Greece (210 L per day and inhabitant) by Koutsou et al. (2018). Regarding the sewage production in Moria and Kara Tepe camps, the value was significantly lower (54 ± 12 L per day and asylum seeker) (Table 3). To the best of our knowledge, this is the first time that it is estimated the per capita production of sewage in refugees' camps.

3.4. Cost and GHG emissions estimation

According to Lesvos Municipality, the average cost for municipal solid waste management in the metropolitan area of Mytilene is 160 Euros per tonne. This cost includes the costs of collection, transfer and disposal of the solid wastes to the landfill and it excludes the collection and transfer of the recyclables. Having in mind that the collected amounts of municipal solid waste (excluding the recyclables) from the metropolitan area of Mytilene for the period May 2016 to April 2017 were 16,332 tons, while 1464 tons were collected from Kara Tepe and Moria camps, a total annual cost of 2,847,360 Euros is estimated. From this amount, 234,240 Euros are required for the solid waste management of the two camps (8.2% of the total cost). It is worth mentioning that the aforementioned calculations were based on the assumption that the per tonne cost of solid waste management was the same for the city of Mytilene and refugees' camps. This is true for the cost of transfer and disposal of solid waste but possibly not for the collection of waste from different areas. Future research is needed in order to collect more accurate data for the management cost of solid waste produced by permanent residents and asylum seekers.

Regarding the cost of sewage management, a value equal to 1.19 Euros per m^3 of sewage is typically used in Greece for the construction, maintenance and operation works related to sewage collection and treatment (YPEKA, 2017). Based on this, the total cost for sewage management in the metropolitan area of Mytilene for the period May 2016 to April 2017 is estimated to 3,706,406 Euros, where 113,705 Euros (or 3.1%) are due to the sewage production in Kara Tepe and Moria camps. As for the period of study, sewage trucks were used for wastewater transfer from Moria camp to Mytilene's STP, an additional annual cost of 515,000 Euros is estimated for sewage transfer. This cost is expected to be eliminated by the summer of 2019 as the construction of the sewerage system connecting Moria camp and the existing network is planned for the coming months.

In a recent study, it was reported that on average 132.1 g CH_4 are emitted per m^3 of sewage during wastewater treatment in Greek Sewage Treatment Plants (Koutsou et al., 2018). Based on this, the annual GHG emissions from the treatment of sewage in Lesvos refugees' camps are estimated to 12.6 tons CH_4. Concerning the methane emissions from the disposal of the 1464 tons of solid waste generated in refugees' camps, the use of a methane generation potential equal to 170 m^3 CH_4 per ton of municipal solid waste (EPA, 2016) results to a total amount of 166 tons CH_4 (for P = 1 atm, T = 20 °C, d = 0.667 kg/m^3). Summarizing, the total methane emissions from solid waste and sewage production in studied refugees' camps are estimated to 178.6 tons per year or 35.5 kg CH_4 per asylum seeker and year.

4. Conclusions

For the study period, the mean monthly number of asylum seekers in Moria and Kara Tepe camps was 5025 persons, while the annual production of municipal solid waste and sewage was 1464 tons and 95,550 m^3, respectively. The annual solid waste and sewage production in the metropolitan area of Mytilene from the permanent population was estimated to 19,443 tons and 3,019,077 m^3, respectively. Significant differences were observed between the per capita generation rate of solid waste and sewage between the asylum seekers and the permanent population. The total methane emissions from solid waste and sewage production in studied refugees' camps were estimated to 178.6 tons per year. The total annual cost for the collection, transfer and disposal to the landfill of the municipal solid waste generated in the refugees' camps was estimated to 234,240 Euros, while the annual cost for sewage management to 628,705 Euros (including the cost for sewage transfer from Moria camp to Mytilene's STP using sewage trucks).

Taking into account that this was a first study aiming to provide preliminary data for the operation of asylum seekers' reception sites that have been constructed in Europe, further investigation is needed for the composition of the produced municipal solid waste, the amounts of other types of solid wastes generated in these sites (e.g. bed linen, tents, clothes and footwear) and the characteristics of the produced sewage. This will allow the sustainable design and operation of these asylum seeker sites and the adoption of eco-friendly management practices such as the recycling of valuable materials, the composting of biodegradable solid waste and the wastewater reuse.

5. Declarations of interest

None.

References

Al-Khatib, I.A., Arafat, H.A., Basheer, T., Shawahneh, H., Salahat, A., Eid, J., Ali, W., 2007. Trends and problems of solid waste management in developing countries: A case study in seven Palestinian districts. Waste Manage. 27, 1910–1919.

Al-Khatib, I.A., Monou, M., Abu Zahra, A.F., Shaheen, H.Q., Kassinos, D., 2010. Solid waste characterization, quantification and management practices in developing countries. A case study: Nablus district – Palestine. J. Environ. Manage. 91, 1131–1138.

ELSTAT, 2018. Hellenic Statistical Authority. Population census in Greek municipalities (<http://www.statistics.gr/en/>, last access 13.07.2018, in Greek).

EPA, 2016. Emission guidelines and compliance times for municipal solid waste landfills; final rule. 40 CFR, part 60 (<https://www.gpo.gov/fdsys/pkg/FR-2016-08-29/pdf/2016-17700.pdf>, last access 20.07.2018).

EUROSTAT, 2018. Municipal waste statistics (<http://ec.europa.eu/eurostat/statistics-explained/index.php/Municipal_waste_statistics>, last access 16.07.2018).

Garfi, M., Tondelli, S., Bonoli, A., 2009. Multi-criteria decision analysis for waste management in Saharawi refugee camps. Waste Manage. 29, 2729–2739.

Jauhiainen, J.S., 2017. Asulym seekers in Lesvos, Greece, 2016–2017. University of Turku, Report of the project: Urbanization, Mobilities and Immigration (URMI)/ Academy of Finland/The Strategic Research Council/Urbanising Society (2016–2019).

Koutsou, O.P., Gatidou, G., Stasinakis, A.S., 2018. Domestic wastewater management in Greece: greenhouse gas emissions estimation at country scale. J. Clean. Prod. 188, 851–859.

MinDigital, 2018. Greek Ministry of Digital Policy, Telecommunications and Media (<http://mindigital.gr/index.php/%CF%80%CF%81%CE%BF%CF%83%CF%86%CF%85%CE%B3%CE%B9%CE%BA%CF%8C-%CE%B6%CE%AE%CF%84%CE%B7%CE%BC%CE%B1-refugee-crisis>, last access 06.06.2018, in Greek).

Ministry of Citizen Protection, 2018. National Coordination Center for Border Control, Immigration and Asylum. <http://www.mopocp.gov.gr/index.php?option=ozo_content&lang=&perform=view&id=6413&Itemid=640?option=ozo_search&lang=EN>, last access 9.12.2018).

Saidan, M.N., Drais, A.A., Al Manaseer, E., 2017. Solid waste composition analysis and recycling evaluation: Zaatari Syrian refugees camp, Jordan. Waste Manage. 61, 58–66.

Tchobanoglous, G., Barton, F.L., Stensel, D., 2003. Wastewater Engineering: Treatment and Reuse, Metcalf and Eddy. Mc-Graw-Hill.

UNCHR, 2018. Sea arrivals of refugees and migrants in Greece for years 2015 to 2018. (<https://data2.unhcr.org/en/situations/mediterranean/location/5179>, last access: 12.7.2018).

UNDP, 2014. Lebanon environmental assessment of the Syrian conflict & priority interventions. (<http://www.undp.org/content/dam/lebanon/docs/Energy%20and%20Environment/Publications/EASC-WEB.pdf>, last access: 16.7.2018).

YPEKA, 2017. Hellenic Ministry of Environment and Energy. First review of the river basins' management plan for the Aegean islands (<http://wfdver.ypeka.gr/wp-content/uploads/2017/09/EL14_1REV_P18_SMPE_v02.pdf>, last access 20.07.2018, in Greek).