



The impact of COVID-19 pandemic in medical waste amounts: a case study from a high-populated city of Turkey

Asude Hanedar¹ · Deniz İzlen Çifçi¹ · Nur Zafer¹ · Erdem Görgün²

Received: 11 January 2022 / Accepted: 26 April 2022 / Published online: 23 May 2022
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Abstract

In this study, the amount of medical waste generated in a high-populated city in Turkey between January 2018 and August 2021 was evaluated, and the effect of the COVID-19 pandemic on waste amounts and waste production rate was investigated. While a total of 79,027 kg/month of medical waste was produced in the city before COVID-19, this value reached 116,714 kg/month after COVID-19. The increase in the amount of medical waste due to the COVID-19 pandemic in the province was calculated as 48% on average. It was determined that 75% of this waste amount originates from public hospitals in the city. While the production of medical waste was 0.86 kg/bed day in the pre-COVID-19 period, this value increased to 0.96 kg/bed day in 2020 and to 1.34 kg/bed day in 2021 with the COVID-19 pandemic. According to the results obtained, the amount of medical waste reached in the province due to COVID-19 is the amount of medical waste expected to be generated in the 2040s under normal conditions. It is a very important issue in terms of public health that the capacity of waste disposal in medical waste management in cities is flexible to respond to severe epidemic conditions. Based on the information obtained within the scope of the study, changes in the amount of medical waste in a city with a dense population under pandemic conditions can be obtained based on real data and projections regarding disposal capacity can be made more realistically.

Keywords COVID-19 · Medical waste · Waste amounts · Pandemic

Introduction

The new coronavirus (COVID-19) has spread severely in many countries of the world, with its first outbreak in Wuhan, China, in December 2019 [1, 2]. Various guidelines from the World Health Organization (WHO) have been frequently stated to reduce risks of COVID-19 and take precautions, such as hygiene and social distance, with declaring this disease as a global epidemic on 11 March 2020 [3, 4]. With the notification of the first case seen on 11 March 2020 by the Ministry of Health, schools and universities closed, quarantine applied, flights to some countries banned, and even some cities were restricted in Turkey [5]. However, this

disease spread rapidly in Turkey as well as in many countries, and the number of COVID-19 cases was 6,039,857 and 52,860 people died due to COVID-19 until 09 September 2021 [6].

In addition to the health effects of the COVID-19 pandemic, the increase in the amount of medical waste has been one of the most important concerns about environmental health. Tons of COVID-19 contaminated waste are produced worldwide every day, and the strict management of this waste has become a global challenge [7, 8]. The amount of medical waste produced during the COVID-19 pandemic is above the current capacity of disposal and the risk of infection is higher than medical wastes which is generated pre-pandemic [8–10]. Strategies related to the management and disinfection of medical wastes generated during the COVID-19 period have been specified in literature [11–13]. On the other hand, the amount of medical waste generated during the COVID-19 period has been tried to be estimated with various methods in many countries [3, 14–17]. However, studies the actual amount of medical wastes produces during the COVID-19 pandemic and the effects of this pandemic on the medical waste amounts are very limited [4,

✉ Deniz İzlen Çifçi
dicifci@nku.edu.tr

¹ Department of Environmental Engineering, Çorlu Engineering Faculty, Tekirdağ Namık Kemal University, Çorlu, Tekirdağ, Turkey

² Department of Environmental Engineering, Civil Engineering Faculty, Istanbul Technical University, Maslak, Istanbul, Turkey

18]. According to Kang et al. (2021), disposal capacity of medical waste in China enhanced by 23.9% compared to the pre-epidemic period [18]. Annual medical waste growth in India is estimated up to 775.5 tons per day by 2022 [14]. In addition, there is no study so far on the amount of medical waste produced in Turkey during the COVID-19 period and the impact of the pandemic on the medical waste amounts.

When the first COVID-19 case was seen in Turkey, the Ministry of Health started to take measures regarding this disease according to the directives of the WHO. Along with these precautions, the Ministry of Health has made it mandatory to use masks in all areas, and has provided information on the necessity of giving importance to hygiene with gloves, soap or hand disinfectants. As a result of this, medical wastes, such as face masks, gloves, hand disinfectants, test kits, syringes, etc. showed an incredible increase in Turkey as well as worldwide [17]. The “Circular on COVID-19 Measures in the Management of Personal Hygiene Material Wastes such as Disposable Masks and Gloves” was published by the Ministry of Environment and Urbanization on April 7, 2020, and the management of these wastes was determined within the scope of medical wastes. According to the circular, the generated wastes in the quarantine departments/units and other medical place of institutions should be managed these waste as “medical waste”. Therefore, the amount and management of medical waste generated in Turkey during the COVID-19 pandemic period has gained great importance.

It is a fact that the amount of medical waste has increased during the COVID-19 epidemic. Although there are many estimations in the literature based on the calculations of increasing medical waste values during pandemic, there are a limited number of studies that reveal the change before and during the pandemic with real medical waste data. The aim of this study is to determine the changes in the unit time, per capita and per bed values of the amount of medical waste according to its sources before and during the COVID-19

pandemic in one of the metropolitan cities of Turkey. Based on the data obtained, it was aimed to determine the change of medical waste amounts during the pandemic period and to obtain real data that can be used in medical waste management in future. Obtained data are of importance in terms of revealing the real values obtained in the long term (January 2018–August 2021) and determining COVID-19's impact on the amount and generation rate of medical waste.

Materials and methods

The study area is the province of Tekirdağ, which is located in the west of Turkey. There are 11 districts in the province. According to the data of 2021, the population is 1,107,491 in the city [19]. The industry is a highly developed region, as the province is close to Europe, and has sea and rail transportation opportunities. There are approximately 3,000 industrial facilities within the provincial borders.

The management of medical waste in Turkey is the responsibility of the municipalities. Municipalities are obliged to ensure the sterilization and/or disposal of medical wastes falling within the provincial borders and to establish a medical waste processing facility for this purpose. Municipalities that do not set up the sterilization plant under their own can have a private firm establish a sterilization facility [20]. The data used in this study are real data obtained from the sterilization facility in Tekirdağ province.

Within the scope of the study, the daily amount of medical waste was collected from all medical waste producers and sent to the medical waste sterilization facility in the March 2018–August 2021 period within the provincial borders was evaluated in Tekirdağ. The medical waste producers and their numbers in the province are given in Table 1. As can be seen, there are 12 public hospitals in the city and 3 of them with 475–550 beds, one of them with 245 beds and 8 of them with 50–100 beds. There

Table 1 The medical waste producers and their numbers in the city

Medical waste producer	Number	Description
Factories/workplaces	369	It is obligatory to establish "health rooms" in workplaces with 50 or more employees and to evaluate the wastes produced from these health rooms as medical waste*
Health institution	206	Dispensary, dialysis center, morgues and autopsy centers, laboratories and research centers, blood banks, emergency aid centers, rehabilitation centers, physical-therapy centers, animal hospitals, laboratories and veterinary clinics, acupuncture and esthetic centers
Hospitals		
Public hospitals	12	Public hospitals/public hospitals provide patients with free medical care at government reimbursement, covering costs and fees
Private hospitals	8	Funding in private hospitals (not owned by the government), is by patients themselves, by insurers, or by foreign embassies
Family health centers	90	Organizations where family medicine services are provided

*Official Gazette, 2017 [20]

are 8 private hospitals in the province, 4 of them with 140–180 beds, 2 with 78–80 beds and 2 with 10–50 beds.

In Turkey, “Medical Waste Control Regulation” was published in accordance with the European Union Environmental Directives and the regulation determined the principles for collection, transportation, temporary storage in the healthcare facilities, and removal of medical wastes [20]. According to the regulation, wastes are classified into 3 different groups as infectious wastes, sharp wastes and pathological wastes. In addition, wastes other than medical wastes (hazardous wastes, non-hazardous wastes, packaging wastes, etc.) in health institutions are disposed of in accordance with the "Waste Management Regulation" published in the [21]. The waste codes used for medical wastes within the scope of these two regulations are given in Table S1.

Results

Medical waste amounts

Annual total, monthly and daily average medical waste values calculated based on the amount of waste collected and treated daily in the city in the period of January 2018–August 2021 are given in the Table 2. As can be seen from the table, the annual average medical waste amount, which was 79,027 kg/month before pandemic, reached 116,714 kg/month during the pandemic period and increased by approximately 48%.

The monthly total medical waste values during the whole period are also given in Fig. 1. After detection of the first active COVID-19 case on March 11, 2020, the total number of active cases was 13,532 in March 2020, and this number increased to 106,673 in April 2020 in

Table 2 Medical waste amounts before and during COVID-19

Medical waste producers (kg Medical Waste/year)	Pre-COVID-19		During COVID-19	
	2018	2019	2020	2021*
Hospitals	927,392	910,324	1,237,043	987,331
Health institution	6,234	8,431	12,602	12,514
Family health centers	6,783	8,020	7,982	6,330
Factories/workplaces	18,302	11,154	14,851	12,922
Total (kg medical waste/year)	958,711	937,929	1,272,478	1,019,097
Monthly average (kg medical waste/month)	79,893	78,161	106,040	127,387
	79,027		116,714	
Daily average (kg medical waste/day)	2,627	2,570	3,486	4,194
	2,598		3,840	

*Values for the first 8 months, including August 2021

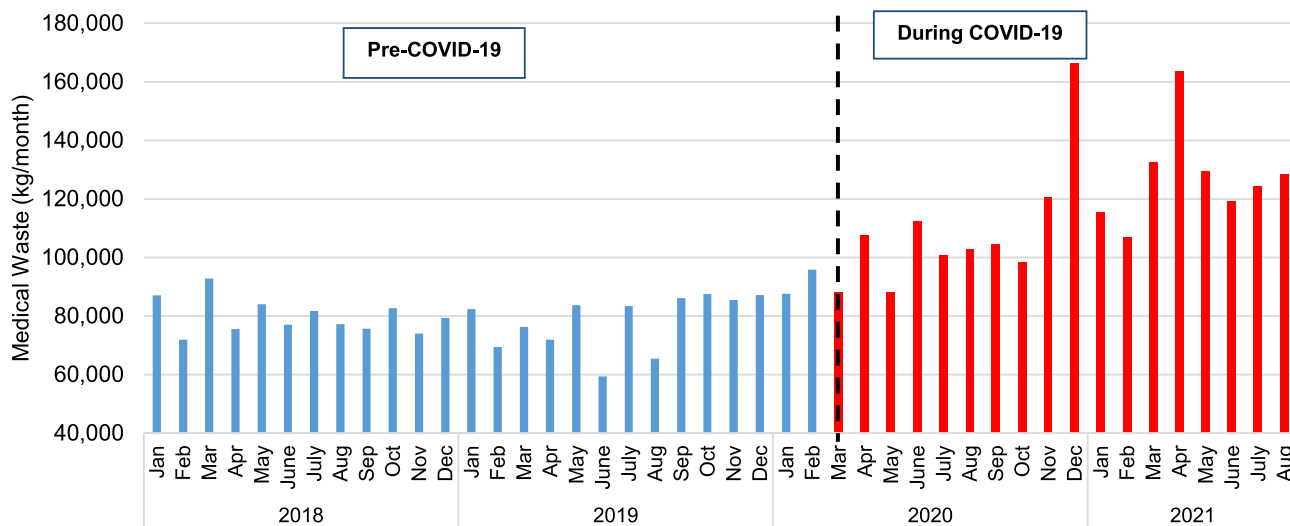


Fig. 1 Monthly total medical waste amounts in the city

Turkey. This increase caused the amount of medical waste from 87,959 kg/month to 107,613 kg/month in the city. Due to the decrease in the number of active cases with the measures and quarantines taken, there was no significant increase in the production of medical waste in the following months.

With the opening of schools on September 21, 2020 and the occurrence of COVID-19 mutations, a second peak was observed in Turkey with the number of 263,480 and 777,004 active cases in November and December 2020 respectively. With the effect of this peak, the amount of medical waste in the city increased to 120,554 and 166,272 kg/month in November and December 2020 respectively and reached the maximum value in December 2020.

Although COVID-19 active cases decreased in January 2021 and February 2021, it started to increase again in March 2021 and active cases reached a maximum of 1,503,409 people in Turkey in April 2021, while the production of medical waste in the city was observed as 163,441 kg/month on April 2021.

Considering sources of the collected medical wastes, it can be seen that the amount of medical waste originating from public hospitals before COVID-19 was 54,360 kg of medical waste/month, and this value constitutes 71% of the total medical waste (Fig. 2). In the COVID-19 period, it is observed that the amount of medical waste originating from public hospitals is 87,567 kg/month and this value has increased by 61% compared to before COVID-19. At the same time, 77% of the medical waste collected from hospitals during the COVID-19 period was produced from public hospitals. Medical wastes produced in hospitals during the COVID-19 constitute 75% of the medical wastes produced from all units, such as hospitals, health centers, family health care and factories/workplaces.

The amount of medical waste originating from private hospitals reached 25,685 kg/month during the COVID-19 period from 22,212 kg/month before COVID-19, with an increase of 15.6%. When the COVID-19 pandemic started, public hospitals were accepted as pandemic hospitals in Turkey and the tests and treatments of COVID-19 patients were carried out only in these hospitals. However, during the peak periods of pandemic, the capacity of public hospitals was insufficient and some of the private hospitals were converted into pandemic hospitals. Therefore, the amount of medical waste originating from private hospitals did not increase significantly during the normal period of the pandemic, but increased during the peak periods of the pandemic. Because of the fact that, the values of the total amount of medical waste before and during COVID-19 in private hospitals were close to each other, but sudden increases were observed during the peak periods of the disease, such as December 2020 and April 2021 (Fig. 2).

During the COVID-19 pandemic period, the patient density in family health centers decreased as people postponed their health needs except for emergencies. In addition, the Ministry of Health in Turkey has implemented some practices to reduce the density in family health centers and hospitals. For example, the reporting periods have been extended so that patients with regular drug use can obtain drugs more easily. For these reasons, a decrease was observed in the amount of medical waste originating from the family health center during the pandemic period (Table 2).

Medical waste amounts per bed

The medical waste values generated per bed per day, calculated using annual and monthly average values, are given in Table 3. As seen in the table, while medical waste was

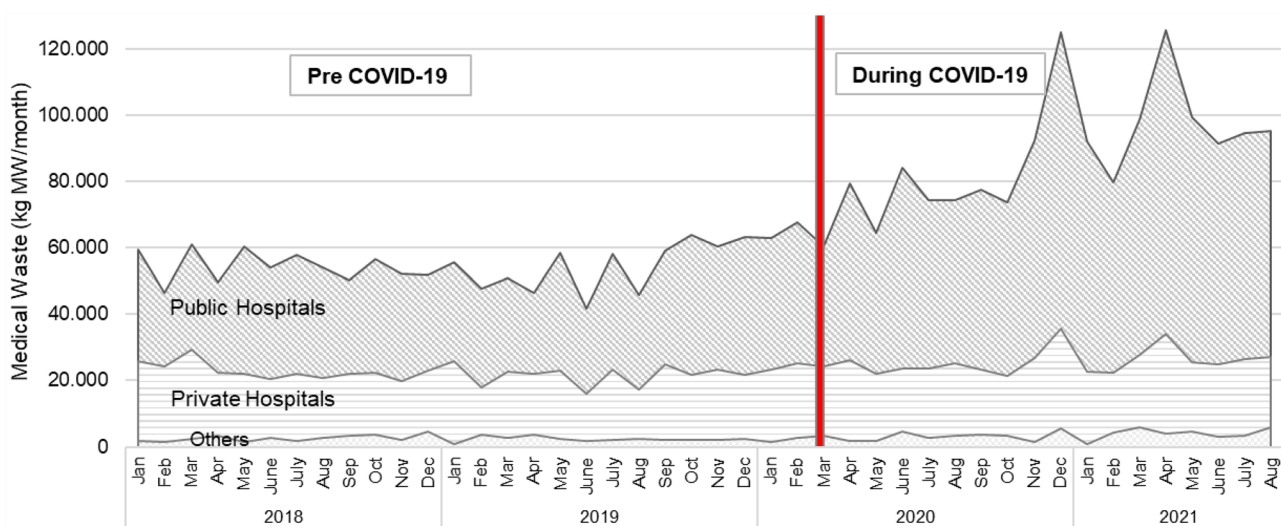


Fig. 2 Monthly amount of medical waste produced in public and private hospitals

Table 3 Medical waste amounts per capita and per bed

	Pre-COVID-19		During COVID-19	
	2018	2019	2020	2021
Population of the city*	977,169	1,055,412	1,081,065	1,107,491
Medical waste amounts				
kg/person-year	0.98	0.89	1.18	1.38
kg/bed day**	0.87	0.85	0.96	1.34

*TUIK, 2021

** The annual change in the number of beds has been taken into account. 100% occupancy rate is accepted

0.86 kg/bed day before COVID-19, it increased to 0.96 kg/bed day in 2020 and 1.34 kg/bed day in 2021 during the COVID-19 period. Although there are not many studies in which medical waste amount values are calculated for Tekirdağ, this value was calculated as 0.82 kg/bed-day for the province in 2004 [22]. For Istanbul, Turkey's most populous city, this value is calculated as 0.63 kg/bed day by Birpınar et al. [23] and 2.11 kg/bed day by Eker and Bilgili [24].

Comparison with literature values

The comparison of the increase in the amount of medical waste due to COVID-19 with the literature study is given in the Table 4. When comparing the amount of medical waste generation with the data in various countries of the world, inconsistent results may be encountered due to the different definitions of medical waste and the incomplete separation of medical waste, especially in low-income countries [31]. According to WHO, high-income and low-income countries produce on average up to 0.5 kg/bed day and 0.2 kg/bed day of medical waste [31]. The amount of medical waste

generated in the city is higher than these values even in the pre-COVID-19 period. However, as can be seen, the results obtained in the study especially for 2021 values are approximately 2.5 times the value recommended by WHO. A study by Winfeld and Brooks (2015) [32], evaluated the amount of medical waste in different countries. In the study, medical waste was defined as “the subset of waste produced in health facilities that are not suitable for municipal solid waste disposal” and it was stated that the amount of waste generation varied in a wide range between 0.08 kg/bed day (Tanzania) and 2.79 kg/bed day (USA).

As can be seen from Table 4, medical waste amount increased from 500–600 kg/day to 1000 kg/day in the first lockdown of COVID-19 in Ahmedabad (India) [25]. In a study conducted with five hospitals in Iran, it was determined that the production of medical waste in these five hospitals increased by 44.2–328.5% with the COVID-19 pandemic [26]. In the other study, the production of hospital wastes increased by 17.6–61.8% due to the COVID-19 outbreak in Tehran, Iran [27]. It was stated that in the city of Wuhan, China, medical waste increased from 40 tons/day to about 240 tons/day with the COVID-19 pandemic, the production of medical waste increased by approximately 26–30% during the April to August 2020 periods [28]. Besides, the medical waste disposal capacity in China increased by 23% [16, 28]. Clinical waste has increased by 27% with the COVID-19 pandemic in Malaysia [33]. It can be said that the values obtained within this study are generally compatible with the results obtained from the literature.

When the amount of waste generated per bed is compared, it was stated that the medical waste production of five hospitals in Iran increased from 0.95 to 3.51 kg/bed/day during the COVID-19 pandemic [26]. Medical waste production in Indonesia increased 1.43 times from 1.10 kg/bed/day to 1.58 kg/bed/day during the COVID-19 outbreak

Table 4 Changes in the amount of medical waste in literature studies

Country	Medical Waste Amount		Increasing rate	Data Source	References
	Pre-COVID	During COVID			
Medical waste amount (kg/day)					
Tekirdağ (Turkey)	79,027	116,714	48%	Real data	In this study
Ahmedabad (India)	550–600	1000	67–82%	Real data	[25]
5 hospitals in Iran	35–267	130–500	44–329%	Real data	[26]
Tehran (Iran)	52,000–74,000	80,000–100,000	17–62%	Real data	[27]
Wuhan (China)	40,000	240,000	26–30%	Real data	[28]
Medical waste amount (kg/bed day)					
Tekirdağ (Turkey)	0.86	0.96		Real data	In this study
Iran	0.95	3.51		5 hospitals	[26]
Indonesia	1.1	1.58		Estimation according to 14 days data	[29]
India	1.93	7.76		1 hospital	[30]

(Sari et al., 2021). Biomedical waste in India has increased from 1.93 kg/bed/day to 7.76 kg/COVID bed/day with the COVID-19 pandemic [34]. According to Agamuthu and Barasarathi (2021) [33], the amount of medical waste in Malaysia was 0.4–1.0 kg/bed/day during the COVID-19 pandemic, while there was a 27% increase in the production of medical waste, respectively, during COVID-19. The fact that the amounts per bed vary in a wide range and are not compatible with this study may be due to the inconsistency of the definition made and the calculations discussed.

Medical waste amounts per capita

The value of waste generation per capita obtained by dividing the population of a settlement by the amount of medical waste generated in the settlement is one of the values frequently used in determining the disposal capacity of wastes originating from health services [35, 36]. Within the scope of the study, the change and projection of the annual amount of medical waste per capita in Tekirdağ were evaluated. As can be seen from Table 3, the medical waste production value in the province, which was 0.98 kg/per capita.year in 2018, decreased to 0.89 kg/per capita.year in 2019. The reason for this decrease in the province, which has continuous population increase, is thought to be the increasing awareness of the correct separation of waste at the source.

In Fig. 3, medical waste amount values were given 2018, 2019, 2020, 2021 and 2022–2025 years. In the figure, 2018 and 2019 years are real data. The actual values in the conditions of COVID-19 for the years 2020 and 2021 are given. At the same time, the amount of medical waste that would

have occurred if COVID-19 did not occur was calculated using an average value of 0.98 kg/per capita.year in 2020 and 2021. The graph also presents the amount of medical waste calculated with the city's population projection values obtained from the official statistical results for the 2022–2025 period [19]. With a simple calculation, it can be thought that the waste amount load caused by COVID-19 in the province will only be reached in the 2040s.

Conclusion

Tekirdağ is a city with a high population density, where medical services and medical waste management are implemented according to certain rules. There are 316 large and small health institutions in the province and the total bed capacity of the existing hospitals is approximately 3,200. Medical wastes are collected separately in health institutions in accordance with the regulations and made ready for disposal in the medical waste sterilization facility. Within the scope of the study, the change in the amount of medical waste before and after the COVID-19 pandemic was evaluated using the daily waste amounts in the province between January 2018 and August 2021. According to the results the annual average medical waste amount, which was 79,027 kg/month before pandemic, reached 116,714 kg/month during the pandemic period and increased by approximately 48%. The amount of medical waste collected during the pandemic period has changed significantly with the course of the pandemic. The amount of medical waste generated per bed during the pandemic period also increased significantly, and the

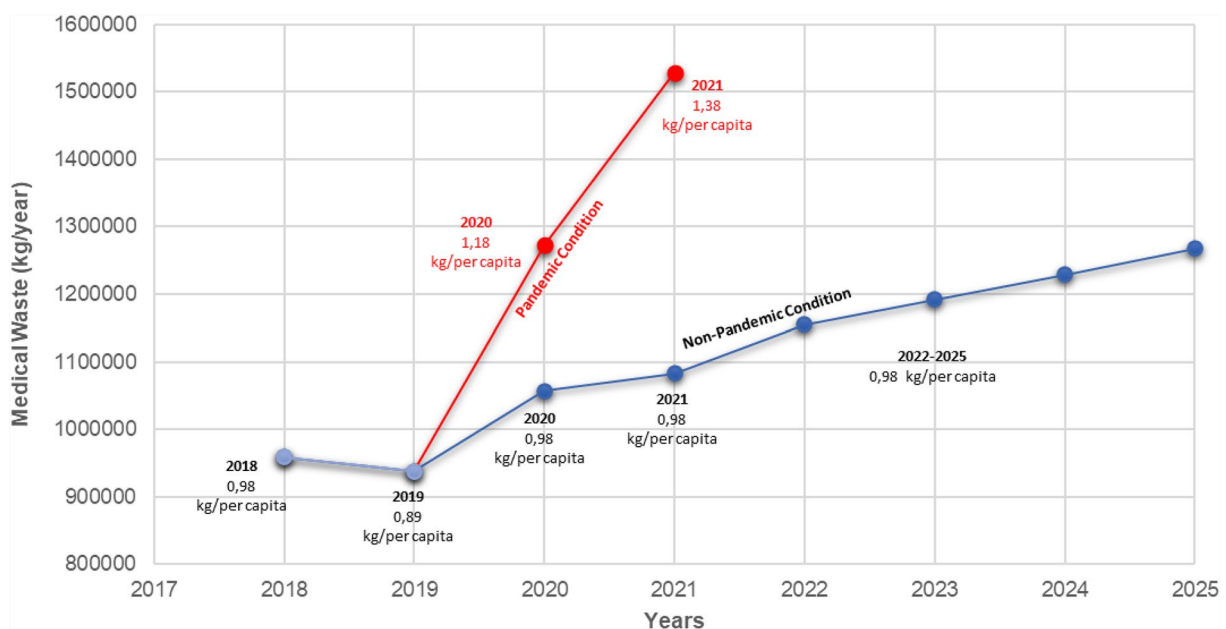


Fig. 3 Medical waste generation and its projections

value of 0.86 kg/bed day before COVID-19 reached 0.96 and 1.34 kg/bed day in 2020 and 2021 years, respectively. When evaluated the amount of medical waste per capita, It was determined that the expected amount of waste in the 2040s with the future years calculations made based on the population projection was reached in the only two years when the pandemic period was experienced.

Discussion

In the conditions of the COVID-19 pandemic, the production of medical waste has increased drastically. Proper disposal of medical waste is essential to minimize the spread of the virus. Under these conditions, it is necessary to review the medical waste management in cities in the conditions of COVID-19. Within the scope of the study, it was observed that there was an increase of approximately 48% in the amount of medical waste during the COVID-19 period compared to the past. Moreover, these values only include medical waste collected from health centers, and personal protective equipment such as masks, etc. used in daily life is not included.

Accurate inventory of medical waste data provides information to guide medical waste management. Establishing a medical waste system that can provide capacity and resistance in future and in case of need in medical waste management can only be possible with the right inventory and tracking system. Medical waste disposal systems should have the capacity to respond to quantity increases due to population growth and epidemics, etc., and it should be flexible enough to meet the needs in extreme conditions. The ability to provide respond to conditions depends on the projection studies to be made in this regard and the reliability of the predictions.

Considering the practices in Turkey, it has been observed that there are parallel practices with the instructions and directives of both WHO and other countries. It can be said that there are no problems with the proper sterilization and disposal of medical wastes, but there are some problems related to the capacities of medical waste sterilization facilities in the country.

The pandemic has shown that medical waste management in a city is not completed only with the disposal of the currently produced medical waste. Medical waste management should be flexible to respond to unexpected increases. In this process, on-site sterilization systems to be established especially in large hospitals and mobile sterilization facilities that can be moved to needed areas are important solutions both to reduce the risk of contamination that may arise from wastes and to increase the flexibility of sterilization capacity.

According to the results of the study, it is revealed that the capacity of the medical waste sterilization facility in a city

should be increased by at least half (50%) when necessary. While projecting the amount of medical waste in developing cities such as Tekirdağ, it should be ensured that the sterilization/disposal capacity is flexible enough to respond to extreme situations besides expected population increases.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s10163-022-01428-3>.

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