
Arab Journal of Basic and Applied Sciences

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tabs20

# Medical waste generation during COVID-19 pandemic in selected member countries of Arabian Gulf region; Google trend analysis

**Khadija Al-Omran, Ezzat Khan & Simone Perna**

**To cite this article:** Khadija Al-Omran, Ezzat Khan & Simone Perna (2023) Medical waste generation during COVID-19 pandemic in selected member countries of Arabian Gulf region; Google trend analysis, Arab Journal of Basic and Applied Sciences, 30:1, 79-91, DOI: 10.1080/25765299.2023.2180884

**To link to this article:** https://doi.org/10.1080/25765299.2023.2180884

ARAB JOURNAL OF BASIC AND APPLIED SCIENCES
2023, VOL. 30, NO. 1, 79–91
https://doi.org/10.1080/25765299.2023.2180884

University of Bahrain
Taylor & Francis
Taylor & Francis Group

ORIGINAL ARTICLE



# Medical waste generation during COVID-19 pandemic in selected member countries of Arabian Gulf region; Google trend analysis

Khadija Al-Omran[a,b], Ezzat Khan[c] and Simone Perna[d]

[a]Environment and Sustainable Development, College of Science, University of Bahrain, Sakhir, Kingdom of Bahrain; [b]School of Logistics and Maritime Studies, Faculty of Business and Logistics, Bahrain Polytechnic, Isa Town, Kingdom of Bahrain; [c]Department of Chemistry, College of Science, University of Bahrain, Sakhir, Kingdom of Bahrain; [d]Department of Biology, College of Science, University of Bahrain, Sakhir, Kingdom of Bahrain

**ABSTRACT**

The variant SARS-CoV-2 (COVID-19) has affected the entire globe; it has caused acute respiratory illnesses and has led to massive environmental problems associated with extra medical waste and single-use plastics. Herein the total quantity of waste generated in the selected GCC countries from different sources has been calculated. The popularity of the medical waste issue through using relative search volume was investigated to associate it with the quantities of Waste. Data was collected from the first COVID-19 case in the respective country until March 26, 2022, from the public domains, "Worldmeter", "Our World in Data" and "Google Trends". Autoregressive Integrated Moving Average (ARIMA) was used to predict the amount of CMW. The calculated values are 1107.980 kg/day from the facemask used by the public, 2,554,812 kg from vaccination, 2,595,772 kg from PCR tests, also the predicted daily total amount of COVID-19 related Medical Waste (CMW) by the end of 2022 (December 31, 2022) to be 3667.25 kg/day. The trend in the generation of CMW has been identified in selected countries. Generally, the waste is expected to get minimized, but it is a lesson for future planning. Especially With extensive vaccination, the cases are drastically decreased, and life is resuming in the regions.

**ARTICLE HISTORY**
Received 5 November 2022
Revised 8 January 2023
Accepted 11 February 2023

**KEYWORDS**
Forecasting analysis; Google trend analysis; medical waste; plastic personal protective equipment; sustainable management; waste generation in Gulf countries

## 1. Introduction

In early 2020, the infection rate of Coronavirus (COVID-19) had risen to the level of a global pandemic, with more than 675 million confirmed cases worldwide and more than 6 million deaths reported by the World Health Organization (WHO) till December 18, 2022 (Worldmeter, 2022). The COVID-19 pandemic has affected many aspects of life, such as social activities, consumption, production and travel patterns and also has a significant effect on pollution expulsion and environmental quality (Klemeš, Fan, Tan, & Jiang, 2020). The pandemic has led to a substantial increase in medical waste. For instance, the pandemic has caused a surge in personal protective equipment (PPE) waste and decreased recycling activities and waste diversion due to the unknown nature of the virus (Ikiz, Maclaren, Alfred, & Sivanesan, 2021). In Wuhan, China, where the first case of COVID-19 was observed, the average of medical waste produced before the COVID-19 pandemic was 45 t/d (Yu, Sun, Solvang, & Zhao, 2020), which has been taken to an immense amount of 110–150 t/d with an increase in COVID-19 cases in mid-February. During the peak period of the pandemic, by March 2020, the amount raised nearly six-fold, reaching an average of 247 t/d (Singh, Tang, Zhang, & Zheng, 2020). In addition, with the number of COVID-19 cases increasing, related to protective items have also increased dramatically, such as gloves, masks, linens, disposable plates, and glasses used by COVID-19 medical staff and patients. Thus, today a surprising and unusual increase in the amount of medical waste being created is observed. In China, until January 20, 2020, the national medical waste disposal level was 1164.0 t/d, and it reached 6066.8 t/d on March 21, 2020 (Ma et al., 2020). With the COVID-19 pandemic, the unexpected increase in medical waste production has created a serious environmental threat. It can significantly affect health in China and the entire world (Sangkham, 2020). The unsafe and insufficient medical waste management pollutes the environment and poses a serious threat to the spread of infectious diseases. It's still uncertain, but it has been observed that the virus could stay up to 9 days on different inanimate surfaces, and the surface

CONTACT Ezzat Khan ezkhan@uob.edu.bh Department of Chemistry, College of Science, University of Bahrain, Sakhir 32038, Kingdom of Bahrain.

thus remains infectious (Kampf, Todt, Pfaender, & Steinmann, 2020). Therefore, the COVID-19 pandemic today, with the rapidly increasing medical waste, must be handled safely to ensure that it does not lead to infection risk.

Interest in public health and environmental themes is vital. Public awareness, engagement, and endorsement are necessary to support environmental management plans and strategies, particularly in the long term (Ficetola, 2013). The internet plays a progressively vital role in popular science and science communication. Thus, Google search patterns could be considered a source of information about general interests (McCallum & Bury, 2013; Wilde & Pope, 2013; Yang, Huang, Peng, & Tsai, 2010). Currently, search patterns can be measured by Google using the tool "Google Trends". This tool measures how repeatedly a term is searched in Google compared to the total number of searches performed on Google.

In this regard, the potential of the internet was used by most countries as well as the WHO to enhance awareness and educational programs on COVID-19, which consequently affects the COVID-19 medical waste (CMW) generation rate. Also, surveying the relative internet search volumes (RSV) has been considered a method to gain information about public interests. Google Trends is one of the most commonly used tools for this purpose (Arora, McKee, & Stuckler, 2019; Effenberger et al., 2020). However, it should be noted that Google Trends is a measure of relative search patterns (Ficetola, 2013).

Google Trends was applied in many studies on public health and the environment, specifically on waste issues (Haider, 2016; Lacitignola & Saccomandi, 2021).

The Gulf Cooperation Council (GCC) countries have played a prominent role in addressing the prevailing pandemic; by performing many necessary actions and activities, which led to the generation of massive medical waste. The waste generation will continue until the end of the pandemic. This matter calls for attention to be paid to the authorities towards adequate and efficient waste treatment.

In GCC countries, during the outbreak, the combined actions of media-driven awareness programs and restrictive government measures have played a vital role in softening the severity of the epidemic, which affects the generation of CMW. Indeed, if mandatory restrictive measures such as lockdowns have minimized disease transmission as a consequence of the dramatic change in the daily behaviours of individuals (Buonomo & Della Marca, 2020), media-driven programs have contributed significantly to maintaining responsible and respectful behaviour over time through ongoing awareness action.

In order to effectively manage this type of hazardous waste, it is essential to accurately estimate the amount of medical waste so that appropriate disposal methods can be determined to address the negative impact on the environment (Sangkham, 2020). However, the studies on the CMW in GCC countries are limited; where only one study was found in literature in the Kingdom of Bahrain that estimated the medical waste produced during COVID-19 (Al-Omran, Khan, Ali, & Bilal, 2021). Herein, this study aims to estimate the amount of medical waste generated during the COVID-19 pandemic from different sources in selected GCC countries, such as facemasks worn by the public and front liners, healthcare facilities, diagnostic testing (PCR) and vaccination, in addition to the general generated CMW. Moreover, this is the first study that figures out the google search volume about the medical waste and related terms, and compare them with the quantities of generated medical waste in the five selected countries.

## 2. Methods and calculations

Different formulae are already in practice to estimate the general medical waste generated during COVID-19, the amount of waste produced by the surgical facemasks worn by the general public and frontline workers, and the significant quantity of waste generated by the vaccination programs and conduct diagnostic tests. The collected data in this study was from the beginning of the pandemic. Specifically, January 29, 2020, in Emirates, February 24, 2020, in Bahrain, Kuwait and Oman, March 2, 2020, in Saudi Arabia, until March 26, 2022.

It is worth mentioning that, on March 28, 2022, wearing a facemask became optional in both indoor and outdoor areas in accordance with precautionary measures in most of the selected countries (MOH, 2022).

### 2.1. Estimation of daily facemasks

The estimated quantity of daily facemasks in GCC countries is calculated by using the following equation (Equation 1) proposed by (Nzediegwu & Chang, 2020):

$$DFM = \frac{P \times UP \times FA \times AFM}{10,000} \tag{1}$$

where *DFM* is the total daily facemasks, *P* is the country's population, *UP* is the rate of the urban population, *FA* facemask acceptance in percentage, and *AFM* is the average daily facemasks per capita.

Data from the public domain, the website "world meters" (Worldmeter, 2021), were collected for the population size and the rate of urban population for

Table 1. Estimated daily facemasks usage in the GCC countries @ 80% acceptance rate.

| Country Name | Population | Urban population (% of total population) | Total daily facemask use (pieces) | Total facemask for 365 days |
|---|---|---|---|---|
| Saudi Arabia | 35,193,520 | 84.065 | 236683.4607 | 86,389,463.16 |
| United Arab Emirates | 9,974,219 | 86.4 | 68941.80173 | 25,163,757.63 |
| Oman | 5,197,118 | 87 | 36171.94128 | 13,202,758.57 |
| Kuwait | 4,314,813 | 100 | 34518.504 | 12,599,253.96 |
| Bahrain | 1,742,586 | 89.3 | 12449.03438 | 4,543,897.55 |
| GRAND TOTAL | 59,337,355 | – | 411199.344 | 150,087,760.6 |

the selected GCC countries. It is worth mentioning that the term 'urban population' refers to the number of people living in an area that is considered an urban area by the national statistical offices. This calculation is based on the urbanization ratios from the United Nations World Urbanization Prospects as well as world bank population estimates from the World Bank (T. W. Bank, 2022).

Following the literature (Nzediegwu & Chang, 2020), 80% is assumed as the rate of facemask acceptance for the GCC countries. Furthermore, based on the research (Wu, Huang, Zhang, He, & Ming, 2020), it was considered that the person in the general population of the country uses one facemask per day; the calculated data are summarized in Table 1.

The weights of daily facemasks in each of the selected countries were calculated *(weight of a single surgical facemask × DFM), where* the weight of a single surgical facemask is 2.85 g, as reported in the literature (Al-Omran et al., 2021).

## 2.2. Estimation of waste generated from vaccines and PCR-Tests

It was determined that the weight of the vaccine set required for one individual per dose is 8.24 g (glass vial = 1.59 g, syringe = 5.82 g, and alcohol swab = 0.83 g) (Al-Omran et al., 2021). This weight value (8.24 g) was utilized to calculate the total weight of vaccination wastes in the GCC countries. Besides, data on the number of given vaccines in the GCC countries up to March 26, 2022, was collected from the website "Our world in data" (Data, 2022a). Therefore, the total weight of vaccine-related waste is determined using the following formula:

$$\begin{aligned}&\text{Total weight of vaccine waste (kg)}\\&= \text{total number of vaccinations}\\&\quad \times \text{weight of items in a single kit}\end{aligned}$$

The total weight of waste resulting from diagnostic tests for COVID-19 was also calculated. The weight of the test kit's items used per individual of the PCR test was determined as 12.52 g (a plastic bottle of a chemical preservative = 11.30 g, nasopharyngeal swab = 1.23 g) (Al-Omran et al., 2021). Also, the total number of tests performed in GCC countries was collected from the website "Our world in data" (Data, 2021). The total weight of COVID-19 tests performed in each country was calculated using the following formula:

$$\begin{aligned}&\text{Total weight of COVID} - 19 \text{ test waste (kg)}\\&= \text{total number of tests performed}\\&\quad \times \text{test kit's weight}\end{aligned}$$

## 2.3. Estimation of medical waste

The pandemic has generated an abnormal amount of waste, which is of greater concern for environmentalists and respective government departments. During the high risk of the spread of the COVID-19 pandemic, several groups in different parts of the world have conducted studies on medical waste generated. For example, the Asian Development Bank (A. D. Bank, 2020) reported that the quantity of medical waste caused by COVID-19 increases with an increase in the number of infected people at a constant rate; for instance, the CMW increases by 3.4 kg/day with each infected person, as shown in Eq. 2.

$$\begin{aligned}&\textit{Amount of CMW } (kg/day)\\&= \textit{Number of infected persons} \times 3.4 \qquad (2)\end{aligned}$$

Different studies have applied this equation to estimate the CMW in Asian countries (Purnomo, Kurniawan, & Aziz, 2021). This equation is used in the current study to estimate the amount of CMW in GCC countries. Where the number of infected persons in the selected countries was collected from the website "Our World in Data" (OurWorldinData, 2021).

We employed advanced time series forecasting techniques to forecast the amount of CMW, the Autoregressive Integrated Moving Average (ARIMA) model that has been used widely in COVID-19 epidemic analysis (Cihan, 2021; Maheshwari, Yadav, Chandra, & Rai, 2020). IBM SPSS Statistics Version 23 software was used for the data analysis.

## 2.4. Google trend

Google Trends is a tool that Google introduced to the public in May 2006 to support studying trends

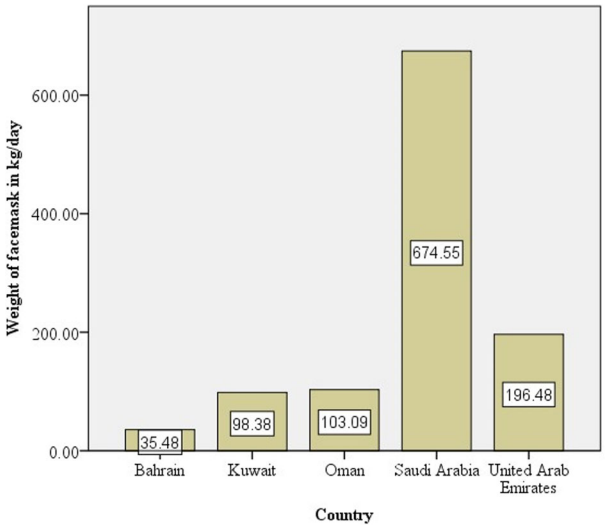


Figure 1. Weights of daily facemasks usage in kg in GCC countries.

founded on searches to Google Search (Rech, 2007). Google Trends provides search volumes that reveal the relative popularity of a search term within a designated region and time (any time between 2004 and the present) (Google, 2022). This analysis allows the relative popularity of specific search terms in a particular category, place, and time range, providing how the terms are popular at a particular time point. The relative popularity is known as a Relative Search Volume (RSV), producing an index with a scale of 0–100 (100 representing the highest relative popularity) (Havelka, Mallen, & Shepherd, 2020; Peng, Li, Rong, Chen, & Chen, 2020).

Google Trends has been used for environmental and health research (Effenberger et al., 2020; Havelka et al., 2020; Jarić et al., 2020; Lacitignola & Saccomandi, 2021; Peng et al., 2020). The trends and patterns of Google search queries can be investigated through Google Trends (Arora et al., 2019). In this study, the Google Trends tool (www.google.com/trends) was used to access data on internet user search activities in the search queries for the search terms "medical waste," "Facemask," "COVID-19 vaccine" and "COVID-19 testing." The retrieved data on internet search queries were on a weekly basis, and it was from the first week that the pandemic started in each selected country until the week of 20–26 March 2022.

## 3 Results and discussion

### 3.1. Estimation of daily protective disposable facemask

The coronavirus spread has led the GCC countries to take strict measures towards facemasks to be worn in public places and during outdoor activities as a precaution. The GCC governments have issued laws to impose penalties and fines on violators for not wearing a facemask (Bahrain, 2021; EUTERS, 2020; GulfInsider, 2020; Jazette, 2020; Observer, 2021; UAE, 2021), which prompted people to wear facemasks daily during all outdoor activities. Though surgical facemasks (disposable facemasks) were mainly designed for the protection of the healthcare staff, in the current situation, they are commonly used in society. The public has extensively used facemasks during infectious diseases like the SARS epidemic in 2003, pdm H1N1 in 2009, and the existing COVID-19 pandemic (Elachola, Ebrahim, & Gozzer, 2020).

It is pertinent to mention that the facemask decreases the transmission risk of the COVID-19 virus from an infected person to a healthy one (Eikenberry et al., 2020). Furthermore, it has been estimated that the international monthly requirement for facemasks is about 89 million in response to the current pandemic (WHO, 2021). Various countries' production capacity has also increased, considering the current demand. For example, China's daily production capacity was raised to ca. 15 million in February 2020 (Xinhuanet, 2020). Therefore, the global market for facemasks comprising surgical and respirator masks is expected to increase by around 23%. Precisely, an increase from approximately 14.6 billion in 2019 to 33.4 billion in 2023 is expected to be achieved (MedicalResearch, 2020). Accordingly, the use of facemasks is increasing day by day in GCC countries in the prevailing situation. Since the consumption of facemasks is directly related to a country's population, it is therefore important to know the total population of these countries. Basic information (arranged based on the countries' population size) about the selected countries is presented in Table 1.

The calculated total facemasks on a daily and yearly basis for the selected countries, and as expected, increased with the increased population. Table 1 indicates that among the selected countries, the most significant number of facemasks used by the general public is found in Saudi Arabia, with more than 86 million per year. This is because Saudi Arabia has the highest population size of more than 35 million, followed by the UAE, Oman, Kuwait, and Bahrain, with annual quantities of facemasks around 25, 13, 12, 8 and 4 million per year, respectively. The total calculated weights of facemasks in kg/day in each country is graphically represented in Figure 1. It can be noted that the facemask's weight in Saudi Arabia is the highest where it reaches 674.548 kg/day, followed by United Arab Emirates (196.484 kg/day), Oman (103.090 kg/day), Kuwait (98.378 kg/day), and Bahrain (35.480 kg/day).

### 3.2. Estimation of wastes generated from COVID-19 vaccination

At the beginning of 2021, the COVID-19 vaccination campaign was started worldwide and is still ongoing.

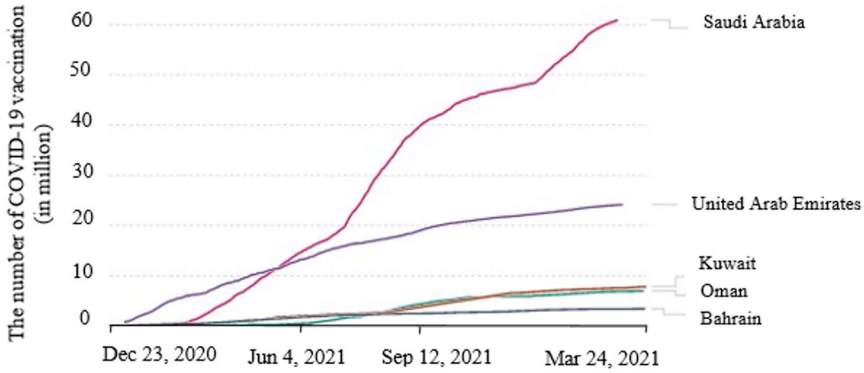


Figure 2. The COVID-19 vaccine doses administered in GCC countries, including boosters. Source: (Data, 2022a).

Thus, efforts have been intensified to increase vaccine production to reach the desired level of immunization of all people against COVID-19 and to satisfy the global demand for vaccines. All countries worldwide seek to vaccinate as many people as possible to eliminate the COVID-19 pandemic. On the other hand, that could generate a large amount of waste that may negatively impact the environment (POLITICO, 2021). Hence, vaccination activities could cause another environmental anxiety by raising medical waste. With the acceleration in vaccination development and immunization campaigns, a significant increase in glass, rubber, and plastic quantities is anticipated (Phadke et al., 2021). It was reported that the predicted burden would be massive, particularly in low-income and developing countries that don't have proper resources for waste management and would harm the environment and financial sector in the short and long term (UCLA, 2014).

Large national campaigns for COVID-19 vaccination have begun, and they continue to preserve the people's health by raising their immunity to afford the highest levels of health security in these countries (MOH, 2021; Online, 2021). In the GCC countries, governments have provided various types of vaccines and have encouraged people to get vaccinated. Until March 26, 2022, the number of fully vaccinated people, including the booster, is continuously increasing in the GCC countries, as displayed in Figure 2.

It was mentioned earlier that the total weight of necessary items for an individual's vaccination for one dose is 8.24 g (0.00824 kg). Based on that and the accumulated number of vaccinated people, the total weights of the generated waste from vaccination in the selected countries are calculated as detailed in Table 2.

The total number of given vaccines with two doses and booster was 103.35 million, generating 2,554,812 kg (2,554.812 tons) of waste in the selected GCC countries until March 26, 2022 (regardless of the latest data availability date). It can be noticed that Saudi Arabia produces the highest accumulated amount of waste concerning vaccination which reached 1,506,684 kg.

### 3.3. Estimation of wastes generated from COVID-19 diagnostic tests

In March 2020, the WHO and the Global Emergency Committee called for the early testing of coronavirus to prevent the virus's spread (Sohrabi et al., 2020). Polymerase chain reaction (PCR), precisely Real-Time PCR (RT-PCR), is used to detect the presence of coronavirus in tested individuals. A swab is needed to collect a sample from the individual's nose or mouth (nasopharyngeal swab) or lungs; the sample is put in a plastic tube with chemical preservatives. The PCR test is applied by collecting a quick sample from the throat or nasopharynx using a long cotton swab into the throat or nostril (Times, 2021). Single-use plastic is used for this process which is 100% disposable (Tang, Schmitz, Persing, & Stratton, 2020). The COVID-19 diagnostic tests produce enormous quantities of plastic waste; environmental scientists are concerned about the adverse environmental impacts of the current pandemic. It was reported that the estimated PCR test generates about 37.27 g of plastic per test (Celis et al., 2021). As of August 2020, an estimated amount of 15,439.59 tons of plastic waste was generated globally only from the COVID-19 tests by PCR. Most plastic residues from COVID-19 diagnostic tests (around 97%) are disposed of through incineration due to their hazardous nature to humans (Celis et al., 2021).

The GCC countries are keen to use the latest technologies to diagnose and treat the coronavirus to limit its spread, facilitate examination methods, and make them available to everyone. Therefore, the GCC governments provide different COVID-19 test facilities at several points in the country and make them accessible to all citizens and residents in all regions through random campaigns and centers (Arabia, 2021; Netherlands, 2021). These centers mostly use PCR tests for coronavirus detection, which is the most popular and reliable test globally. However, as long as the tests continue to be run until the complete eradication of the virus is achieved, there will be an increase in medical plastic waste, leading to adverse environmental effects.

**Table 2.** The calculated waste generated from COVID-19 vaccination for two doses, including boosters.

| Country Name | Vaccinated individuals (million)* | Total vaccine waste (kg) |
|---|---|---|
| Saudi Arabia | 60.95 (Febrauary 28, 2022) | 1,506,684 |
| United Arab Emirates | 24.18 (March 4, 2022) | 597,729.6 |
| Oman | 6.99 (March 22, 2022) | 172,792.8 |
| Kuwait | 7.81 (March 24,2022) | 193,063.2 |
| Bahrain | 3.42 (March 23, 2022) | 84,542.4 |
| GRAND TOTAL | 103.35 | 2,554,812 |

Total vaccine weight (kg) = 3 × vaccinated individuals × 0.00824 kg.
*Data retrieved on March 26, 2022, from: https://ourworldindata.org/grapher/cumulative-covid-vaccinations?country=BHR~SAU~OMN~KWT~ARE

**Table 3.** Weights of waste generated by COVID-19 test in GCC countries, till March 26, 2022.

| Country Name | Total number of COVID-19 tests performed (million)* | Total weight of PCR tests' waste (kg) |
|---|---|---|
| United Arab Emirates | 146.60 | 1,835,432 |
| Saudi Arabia | 41.48 | 519,329.6 |
| Oman | 1.99 (March 12, 2022) | 24,914.8 |
| Bahrain | 9.5 (March 25, 2022) | 118,940 |
| Kuwait | 7.76 (March 12, 2022) | 97,155.2 |
| GRAND TOTAL | 207.33 | 2,595,772 |

Total weight of COVID-19 tests = number of COVID-19 tests performed x 0.01252.
*Data retrieved on March 26, 2022, from: https://ourworldindata.org/grapher/full-list-total-tests-for-covid-19?time=earliest.latest&country=BHR~SAU~KWT~ARE

As mentioned previously, the weight of the test kit used per individual equals 12.52 g (0.01252 kg). Consequently, the total weights of waste generated from COVID-19 tests in the selected country are calculated in Table 3. The table reveals that the diagnostic tests performed in GCC countries until March 26, 2022 (regardless of the latest data availability dates) are 207.33 million, generating around 2,595,772 kg (2,595.772 tons) of waste. The highest quantity of this type of waste is generated in UAE (1,835,432 kg = 1,835.432 tons).

### 3.4. Estimation of medical waste

The numbers of newly confirmed cases and the corresponding calculated amount of CMW in kg/day in GCC countries are visualized in Figure 3. The series of new daily COVID-19 cases and CMW in the graph fluctuate; peaks and valleys are continuously seen, where the values are going up and down. The number of daily cases in the GCC countries declined to 1064, contributing to around 3,618 kg on March 26, 2022 (Figure 3). The ARIMA analysis for the quantities of CMW is presented in Figure 4. It reveals that the predicted daily amount of CMW by the end of 2022, on December 31, 2022, could reach 1,179.52 kg, 240.55 kg, 1,953.13 kg, 0 kg, 294.05 kg for UAE, Saudi Arabia, Bahrain, Kuwait and Oman, respectively. The worst cases also were predicted to be 14,309.09 kg, 30,618.30 kg, 26,441.61 kg, 21,869.06 kg, and 11,630.05 for UAE, Saudi Arabia, Bahrain, Kuwait and Oman, with a 95% confidence interval (C.I).

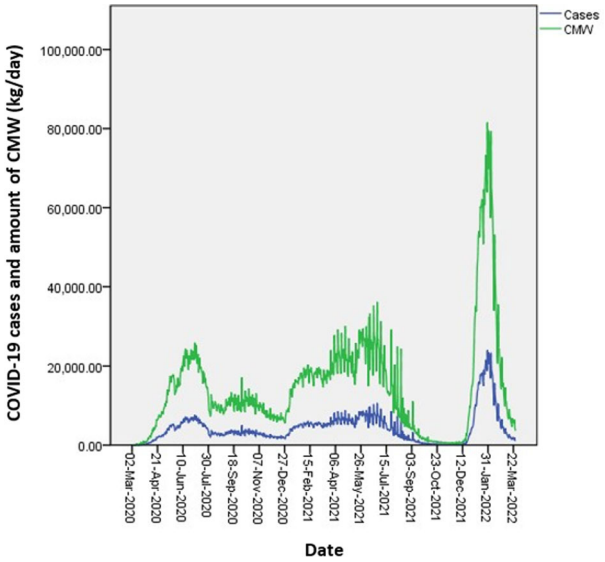


**Figure 3.** Graphical representation of the number of daily COVID-19 cases and calculated CMW amount in kg/day in GCC countries until March 26, 2022.

Generally, in all countries, the amount of CMW is decreased. But in Oman, the amount of CMW fluctuates, and it changes dramatically on a daily basis. Generally, it's clear that there is strict implementation of policies to curb the virus spread in GCC countries, such as travel restrictions and lockdowns within the specific country. As a consequence of these policies, there were significant reductions in the number of COVID-19 cases and the amount of CMW. Moreover, the number of cases is inversely associated with the number of individuals being vaccinated. As can be noticed, vaccination plays a vital role in reducing the cases and, in turn, reducing the amount of medical waste that is generated by the virus. Several studies investigated the effect of vaccination on the spread of coronavirus and indicated that vaccination could substantially impact mitigating COVID-19 outbreaks (Moghadas et al., 2021; Scobie et al., 2021). As shown in Figure 5, the vaccination covers most of the population; it is evident that several of these countries have been declared "green" to resume normal activities in a stepwise/-gradual manner.

All the calculated solid medical waste produced during COVID-19 in the GCC countries until March 26, 2022, is summarized in Table 4. The weight of used surgical facemasks is 1,107.980 kg per day. The weights of waste produced by vaccination and PCR tests were around 2,554,812 kg and 2,598,902 kg, respectively.

## 4. Relative search volume interest in medical waste

The gulf countries have witnessed vast and varying amounts of medical waste during the pandemic since

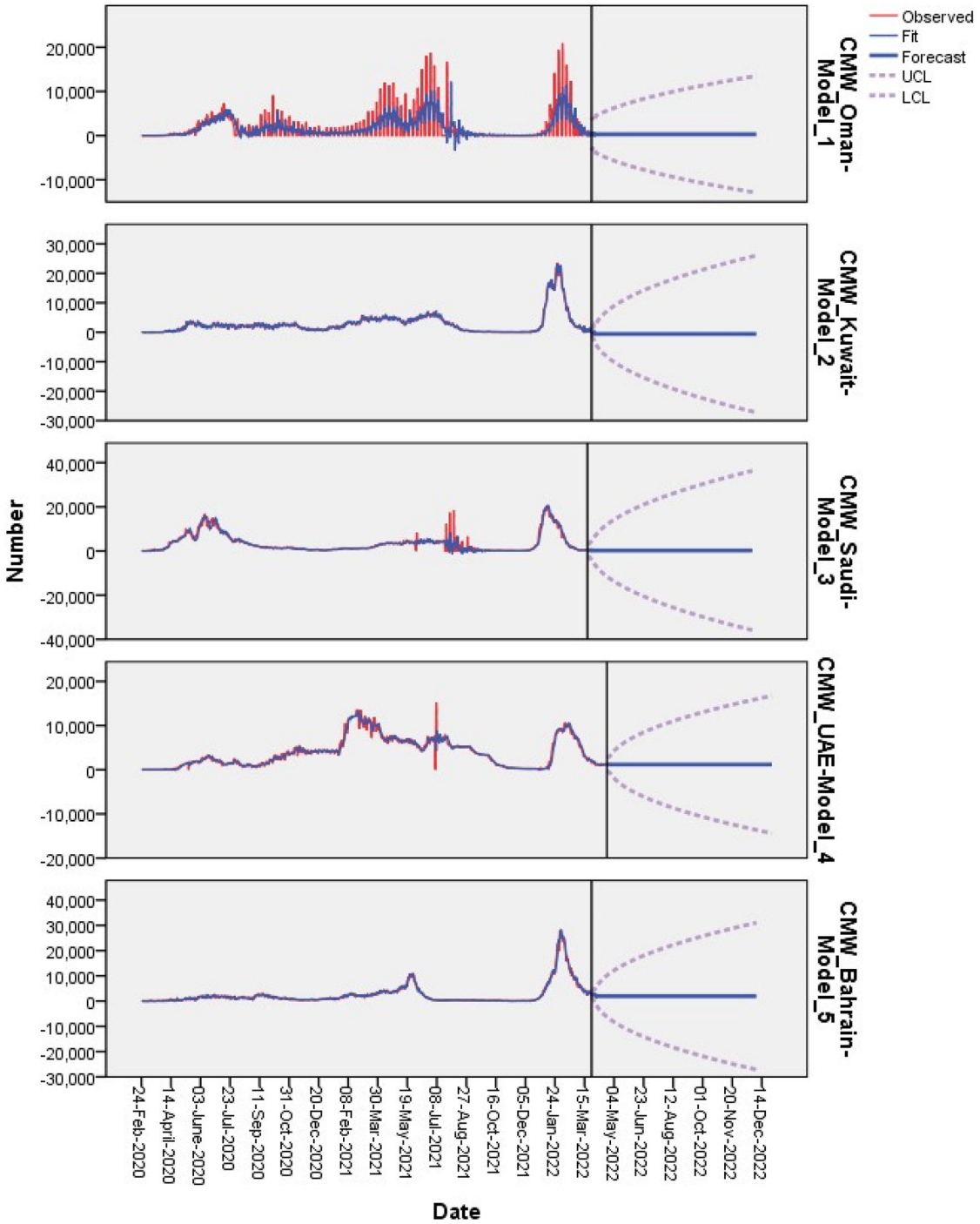


**Figure 4.** Observed and forecasted amount of CMW in kg/day with 95% C.I, until December 31, 2022.

February 2020. This study demonstrates that in some conditions, awareness and public interest in the issue of medical waste can be associated with the generated CMW quantities. The study performs a Google Trends analysis using the terms ("Medical waste" + "Facemask"+ "COVID-19 Vaccine"+ "COVID-19 testing") as a search query and compares it with the trend of the calculated weekly average CMW. The trends and patterns of Google search queries could be investigated through the Google Trends data (Arora et al., 2019). Therefore, data from the start of the pandemic in each selected country until March 26, 2022, has been obtained and analyzed.

The trend of the weekly RSV for the mentioned four search query terms over the last two years in Saudi Arabia is shown in Figure 6A. In the first week of the pandemic in Saudi Arabia, the public interest in the medical waste issue was moderate, with a popularity of 42% on 8–14 March 2020. After four weeks, the popularity decreased to 17% on 12–18 April 2020. Afterwards, the interest rapidly increased and reached the highest peak with a popularity of 100% between May 31 - June 6 in 2020. After that, the interest level dropped and remained low until the end of 2020. The RSV trend reveals that, from early 2021, there was a slight oscillation, but mostly,

low popularity was observed till the end of this study period, where it reached 9% on 20–26 March 2022.

The google trend in UAE does not differ significantly from that of Saudi Arabia. In the early stages of the pandemic in UAE, the public interest in medical waste was nearly moderate, with RSV of 42% on 2–8 Feb 2020 (Figure 6B). However, after two weeks, the interest level dropped to 22% on 16–22 Feb. After that, and within the next five weeks, a rapid growth in interest level could be seen, where RSV peaked at 100% from March 29 to April 4. Then the trend gradually declined until the last week of this study, where RSV reached 13% on 20–26 March 2022. In Bahrain (Figure 6C), the google trend is also substantially similar to Saudi Arabia and UAE trends. It can be seen that the first sign of popularity is noticeable in the highest peak, which appears on 5–11 April 2020, with RSV of 100%. A continuous reduction follows this in interest level until the beginning of 2021; On 7–13 Feb 2021, there was a slight rise in interest level with RSV of 59%. But again, the interest level fell and remained low until the end of the last week of the study period on 20–26 March 2022. Based on the google trend in Kuwait (Figure 6D), it can be observed that when the pandemic started in the country, the interest level was low, with RSV at 13% in the first week of March 2020. Then the trend of popularity goes almost parallel with the average weekly CMW for more than one year. This is followed up by growth in RSV, reaching 63% in the first peak for the two weeks from June 20 to July 3 in 2021; after four weeks, the interest level rose to the highest peak (100%) in the last week of July 2021. However, afterwards, the interest level fell sharply and remained low till the end of the year 2021. Finally, at the beginning of 2022, it increased slightly to 22%, but it did last long as it immediately dropped again and remained low till lately, with the RSV of 5% on 20–26 March 2022. In Oman (Figure 6E), the first sign of popularity is detected in the small peak of the RSV trend, which is visible between March 29–April 4 in 2020, with RSV of 64%. After six weeks, on 17–23 May 2020, the interest level rapidly increased until it reached the maximum with RSV of 100%. After that, it remained fluctuated between up and down, and the trend of the interest took the shape of an open upwards curve with a slight oscillation for almost one year, i.e. until 20–26 June in 2021, with RSV of 84%. Nevertheless, a drop in the interest level was observed with lots of turmoil until it reached 18% on 20–26 March in 2022.

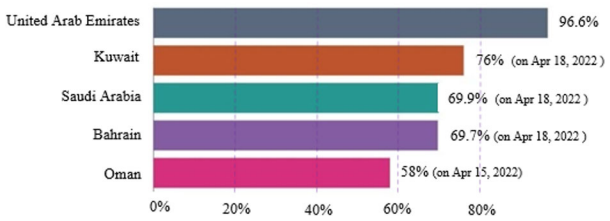


**Figure 5.** Share of the population fully vaccinated against COVID-19 until March 26, 2022, Source: (Data, 2022b).

It can be concluded that, at the beginning of the pandemic, there was a high interest in the issue of medical waste in Saudi Arabia, Bahrain, and the UAE. However, afterwards, there was a change; the interest decreased significantly and remained low until the last week of the study period. The reason behind this change in interest could probably be because, in the beginning, the pandemic was a new emerging situation, and most people were searching for information about the medical waste generated from COVID-19. But later on, people may have learned how to live and deal with the situation and its effects due to the prolonged nature of the emergency. While in Kuwait, the medical waste issue's popularity appeared lately, it appeared with the first significant increase in the weekly average CMW when it reached 6,096.686 kg on 20–26 June 2021. Also, it can be observed that, despite the decrease in the amount of CMW, the interest was growing up until a certain point, but after that point, the interest started to fall again. In contrast, the popularity in Oman was somewhat higher than in other countries but continuously fluctuated during the pandemic.

It was found that awareness plays a significant role in influencing an individual's behaviour and ability to make decisions (Casali et al., 2013). For instance, there is a significant correlation between the awareness generated by the environmental crisis and the behaviour of individuals when it comes to the separation of medical waste (Chen et al., 2021).

Knowing the extent of people's interest and whether there is a movement regarding the problem of increasing medical waste generation in the

**Table 4.** Summary of generated weights of medical waste during COVID-19 in GCC countries by March 26, 2022, in kg.

| Country Name | Facemask/day | Predicted CMW (till December 31, 2022) | Vaccination | PCR tests |
|---|---|---|---|---|
| Saudi Arabia | 674.548 | 240.55 | 1,506,684.00 (Febrauary 28, 2022) | 519329.6 |
| UAE | 196.484 | 1179.52 | 597,729.60 (March 4, 2022) | 1,835,432 |
| Oman | 103.090 | 294.05 | 172792.80 (March 22, 2022) | 24,914.8 (March 12, 2022) |
| Kuwait | 98.378 | 0 | 193063.20 (March 24, 2022) | 97,155.20 (March 12, 2022) |
| Bahrain | 35.480 | 1953.13 | 84542.40 (March 23, 2022) | 118,940 (March 25, 2022) |
| **TOTAL** | **1107.980** | **3667.25** | **2554812.0** | **2,595,772** |

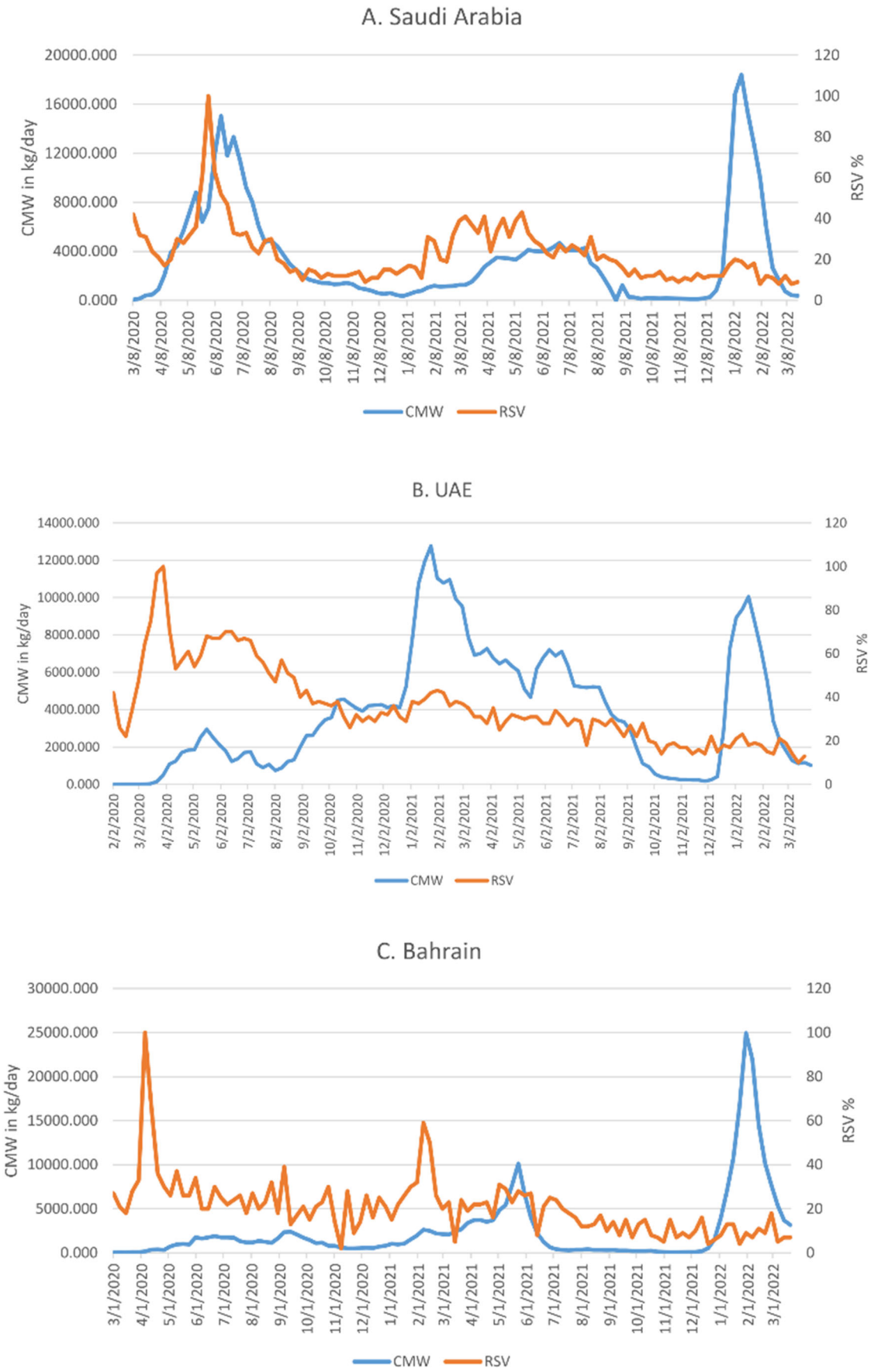


**Figure 6.** Trend of the weekly RSV for the search query "Medical waste", "Facemask", "COVID-19 Vaccine,", "COVID-19 testing" and the calculated COVID-19 medical waste in kg per day since the pandemic started in the respective country till March 26, 2022.

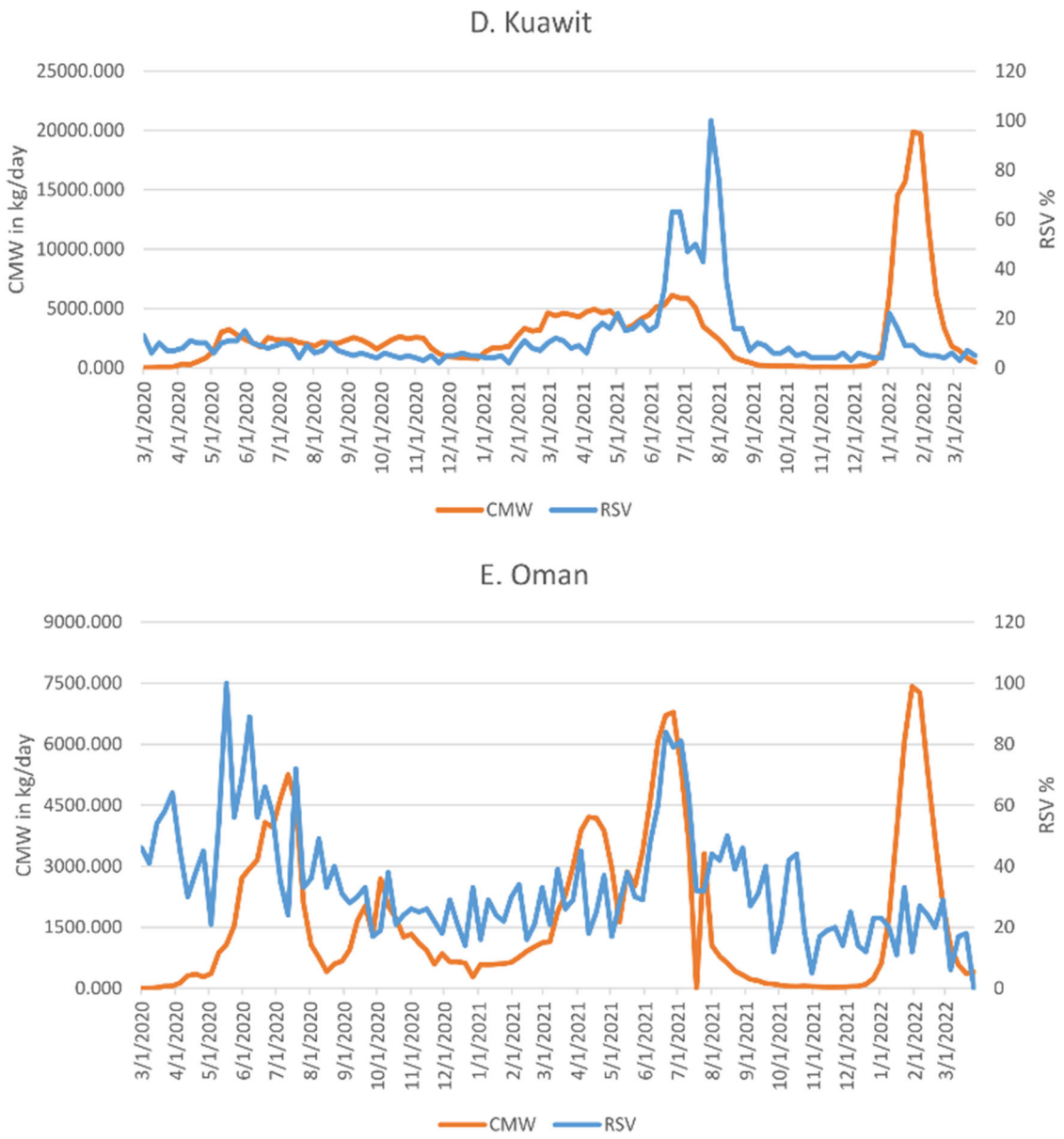


**Figure 6.** Continued.

current abnormal situation is a key step. This is to draw people's attention to this problem, especially the decision-makers, to keep all the dealing hands vigilant to cope with the situation. This work provides a platform for dealing with such an abnormal generation of waste during a pandemic.

## 5. Challenges to the study

The study analyzed Google searches only in the English language; therefore, the study's results have limited generalizability. Moreover, the study was unable to include any specific search volume data about gender, age or occupation in the analysis because Google Trends does not offer information on user demographics. The study could not focus on investigating the interest for managerial positions in environmental agencies like policy-makers. The study is focused on only four terms related to medical waste during COVID-19 being calculated herein. Still, there could be many other related terms that could be included in the search volume in Google Trends to measure the interest in the issue of medical waste quantities. Additionally, the search volumes and amounts of medical waste could be affected by confounding factors (e.g. precautions measures taken in the selected countries and public attention to the medical waste due to media coverage). But this study did not consider these factors because the tool used does not cover these factors. Furthermore, Searching on the internet for information related to medical waste terms through Google could be a measure of interest in the issue of medical waste quantities, or it may be for another purpose, such as for consuming PPE.

## 6. Conclusion

The COVID-19 pandemic generates enormous quantities of medical waste. Therefore, this study calculated

the amount of solid medical waste generated from different sources til March 26, 2022. For instance, the waste generated from the facemask used by the public in the selected GCC countries is 1,107.980 kg/day, the vaccination is 2,554,812 kg, and from PCR test is 2,595,772 kg. Besides, the study predicted daily CMW till the beginning of next year (December 31, 2022) to be 3,667.25 kg/day. Moreover, it investigated the public interest in medical waste using the tool Google Trend. The purpose of this tool was to measure how frequently the medical waste term and relative terms are searched by Google, compared to the total number of searches conducted on Google. It was found that there was a high interest in medical waste issues in Saudi Arabia, Bahrain, and UAE when the pandemic had just started. But after that, the public interest decreased significantly and stayed low until the last week of the study period. While in Kuwait, the medical waste issue's popularity appeared at the end of the study period. However, in Oman, the public interest was slightly higher than in other countries, but it has continuously fluctuated over the pandemic. Knowing the quantities of medical waste generated in a pandemic could be helpful for the planning and designing of future facilities and medical waste management. In the event of any pandemic, it would be critical for all involved to remain vigilant in order to cope with the situation, which could lead to the creation of a platform to deal with the abnormal generation of medical waste during such events. Therefore, it's imperative to investigate the public interest in medical waste matters, especially during the abnormal situation, and this work could draw peoples's attention to the problem.

## Acknowledgement

The authors are grateful to acknowledge the fruitful discussion and valuable suggestions from Mr Jalal Almajed regarding Google trends.

## Author's contributions

**Khadija Al-Omran, Ezzat Khan,** Conceptualization; Formal analysis; Investigation; Methodology; Software; Validation; Visualization; Writing - original draft, **Ezzat Khan, Simone Perna,** Project administration; Resources; Supervision; Validation; Visualization; Writing - review & editing.

## Ethics approval

Not applicable

## Disclosure statement

There is no conflict of interest to be declared.

## ORCID

Ezzat Khan http://orcid.org/0000-0001-7849-6083

## References

Al-Omran, K., Khan, E., Ali, N., & Bilal, M. (2021). Estimation of COVID-19 generated medical waste in the Kingdom of Bahrain. *The Science of the Total Environment*, *801*, 149642.

Arabia, G. o S. (2021). Testing for COVID-19. Retrieved from https://www.my.gov.sa/wps/portal/snp/servicesDirectory/servicedetails/s9142

Arora, V. S., McKee, M., & Stuckler, D. (2019). Google trends: Opportunities and limitations in health and health policy research. *Health Policy*, *123*(3), 338–341. doi:10.1016/j.healthpol.2019.01.001

Bahrain, U. S. E. i. (2021). COVID-19 Information. https://bh.usembassy.gov/covid-19-information., Accessed August 16, 2021.

Bank, A. D. (2020). Managing infectious medical waste during the COVID-19 pandemic. Retrieved from https://www.adb.org/publications/managing-medical-waste-covid19

Bank, T. W. (2022). Data bank-metadata glossary. Retrieved from https://databank.worldbank.org/metadataglossary/world-development-indicators/series/SP.URB.TOTL.IN.ZS

Buonomo, B., & Della Marca, R. (2020). Effects of information-induced behavioural changes during the COVID-19 lockdowns: The case of Italy. *Royal Society Open Science*, *7*(10), 201635. doi:10.1098/rsos.201635

Casali, A. G., Gosseries, O., Rosanova, M., Boly, M., Sarasso, S., Casali, K. R., … Tononi, G. (2013). A theoretically based index of consciousness independent of sensory processing and behavior. *Science Translational Medicine*, *5*(198), 198ra105.

Celis, J. E., Espejo, W., Paredes-Osses, E., Contreras, S. A., Chiang, G., & Bahamonde, P. (2021). Plastic residues produced with confirmatory testing for COVID-19: Classification, quantification, fate, and impacts on human health. *The Science of the Total Environment*, *760*, 144167. doi:10.1016/j.scitotenv.2020.144167

Chen, F., Lou, J., Hu, J., Chen, H., Long, R., & Li, W. (2021). Study on the relationship between crisis awareness and medical waste separation behavior shown by residents during the COVID-19 epidemic. *Science of the Total Environment*, *787*, 147522.

Cihan, P. (2021). Forecasting fully vaccinated people against COVID-19 and examining future vaccination rate for herd immunity in the US, Asia, Europe, Africa, South America, and the World. *Applied Soft Computing*, *111*, 107708. doi:10.1016/j.asoc.2021.107708

Data, O. W. i. (2021). Total COVID-19 tests. Retrieved from https://ourworldindata.org/grapher/full-list-total-tests-for-covid-19?time=earliest.latest&country=BHR~SAU~KWT~QAT~ARE

Data, O. W. i. (2022a). COVID-19 vaccine doses administered. Retrieved from https://ourworldindata.org/grapher/cumulative-covid-vaccinations?country=BHR~SAU~OMN~KWT~ARE(26/3/2022)

Data, O. W. i. (2022b). Share of the population fully vaccinated against COVID-19. https://ourworldindata.org/grapher/share-people-fully-vaccinated-covid?time=2022-03-24&country=SAU~KWT~OMN~BHR~ARE

Effenberger, M., Kronbichler, A., Shin, J. I., Mayer, G., Tilg, H., & Perco, P. (2020). Association of the COVID-19 pandemic with internet search volumes: A google trendsTM analysis. *International Journal of Infectious Diseases: IJID:*

*Official Publication of the International Society for Infectious Diseases*, *95*, . 92–197. doi:10.1016/j.ijid.2020.04.033.

Eikenberry, S. E., Mancuso, M., Iboi, E., Phan, T., Eikenberry, K., Kuang, Y., … Gumel, A. B. (2020). To mask or not to mask: Modeling the potential for face mask use by the general public to curtail the COVID-19 pandemic. *Infectious Disease Modelling*, *5*, 293–308. doi:10.1016/j.idm.2020.04.001

Elachola, H., Ebrahim, S. H., & Gozzer, E. (2020). COVID-19: Facemask use prevalence in international airports in Asia, Europe and the Americas, March 2020. *Travel Medicine and Infectious Disease*, *35*, 101637. doi:10.1016/j.tmaid.2020.101637

EUTERS. (2020). Qatar makes wearing masks outside mandatory with violators fined up to $50,000. Retrieved from https://www.reuters.com/article/us-health-coronavirus-qatar-idUSKBN22Q3IS

Ficetola, G. F. (2013). Is interest toward the environment really declining? The complexity of analysing trends using internet search data. *Biodiversity and Conservation*, *22*(12), 2983–2988. doi:10.1007/s10531-013-0552-y

Google. (2022). About Google Trends. Retrieved from https://support.google.com/trends#topic=6248052

GulfInsider. (2020). Kuwait to impose fine on face mask violators. Retrieved from https://www.gulf-insider.com/kuwait-to-impose-fine-on-face-mask-violators

Haider, J. (2016). The structuring of information through search: Sorting waste with Google. *Aslib Journal of Information Management*, *68*, 390–406.

Havelka, E. M., Mallen, C. D., & Shepherd, T. A. (2020). Using Google Trends to assess the impact of global public health days on online health information seeking behaviour in Central and South America. *Journal of Global Health*, *10*(1), 010403.

Ikiz, E., Maclaren, V. W., Alfred, E., & Sivanesan, S. (2021). Impact of COVID-19 on household waste flows, diversion and reuse: The case of multi-residential buildings in Toronto, Canada. *Resources, Conservation and Recycling*, *164*, 105111. doi:10.1016/j.resconrec.2020.105111

Jarić, I., Correia, R. A., Brook, B. W., Buettel, J. C., Courchamp, F., Di Minin, E., … Roll, U. (2020). iEcology: Harnessing large online resources to generate ecological insights. *Trends in Ecology & Evolution*, *35*(7). 30–639. doi:10.1016/j.tree.2020.03.003.

Jazette, S. (2020). Saudi Arabia reiterates warning of SR1,000 fine for violating coronavirus measures. Retrieved from https://saudigazette.com.sa/article/599479

Kampf, G., Todt, D., Pfaender, S., & Steinmann, E. (2020). Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents. *Journal of Hospital Infection*, *104*(3), 246–251. doi:10.1016/j.jhin.2020.01.022

Klemeš, J. J., Fan, Y. V., Tan, R. R., & Jiang, P. (2020). Minimising the present and future plastic waste, energy and environmental footprints related to COVID-19. *Renewable and Sustainable Energy Reviews*, *127*, 109883. doi:10.1016/j.rser.2020.109883

Lacitignola, D., & Saccomandi, G. (2021). Managing awareness can avoid hysteresis in disease spread: An application to coronavirus Covid-19. *Chaos, Solitons, and Fractals*, *144*, 110739. doi:10.1016/j.chaos.2021.110739

Ma, Y., Lin, X., Wu, A., Huang, Q., Li, X., & Yan, J. (2020). Suggested guidelines for emergency treatment of medical waste during COVID-19: Chinese experience. *Waste Disposal & Sustainable Energy*, *2*(2), 81–84. doi:10.1007/s42768-020-00039-8

Maheshwari, H., Yadav, D., Chandra, U., & Rai, D. (2020). Forecasting epidemic spread of COVID-19 in India using arima model and effectiveness of lockdown. *Advances in Mathematics: Scientific Journal*, *9*(6), 3417–3430.

McCallum, M. L., & Bury, G. W. (2013). Google search patterns suggest declining interest in the environment. *Biodiversity and Conservation*, *22*(6), 1355–1367. doi:10.1007/s10531-013-0476-6

MedicalResearch. (2020). The Global Respiratory Masks Market Is Projected to Grow 22.9% by 2023. Retrieved from https://blog.marketresearch.com/the-global-respiratory-masks-market-projected-to-grow-22.9

Moghadas, S. M., Vilches, T. N., Zhang, K., Wells, C. R., Shoukat, A., Singer, B. H., … Fitzpatrick, M. C. (2021). The impact of vaccination on coronavirus disease 2019 (COVID-19) outbreaks in the United States. *Clinical Infectious Diseases*, *73*(12), 2257–2264.

MOH. (2021). COVID-19 vaccination. Retrieved from https://healthalert.gov.bh/en/category/vaccine

MOH. (2022). The Kingdom's COVID-19 alert level traffic light system to be suspended until further notice: March 28. Retrieved from https://healthalert.gov.bh/en/article/News-468750

Netherlands, G. o t. (2021). Where can I get a NAAT(PCR) or rapid test outside the Netherlands? https://www.netherlandsworldwide.nl/documents/publications/2021/02/01/kuwait--pcr-test-locations., Accessed October 28, 2021.

Nzediegwu, C., & Chang, S. X. (2020). Improper solid waste management increases potential for COVID-19 spread in developing countries. *Resources, Conservation, and Recycling*, *161*, 104947. doi:10.1016/j.resconrec.2020.104947

Observer. (2021). Fine, jail for not wearing mask. Retrieved from https://www.omanobserver.om/article/2935/Local/fine-jail-for-not-wearing-mask

Online, K. G. (2021). List of vaccines. Retrieved from https://e.gov.kw/sites/kgoenglish/Pages/eServices/MOH/VaccinationHistory.aspx.

OurWorldinData. (2021). Data on COVID-19 (coronavirus) by our world in data. Retrieved from https://github.com/owid/covid-19-data/tree/master/public/data

Peng, Y., Li, C., Rong, Y., Chen, X., & Chen, H. (2020). Retrospective analysis of the accuracy of predicting the alert level of COVID-19 in 202 countries using Google Trends and machine learning. *Journal of Global Health*, *10*(2), 020511.

Phadke, R., Dos Santos Costa, A. C., Dapke, K., Ghosh, S., Ahmad, S., Tsagkaris, C., … Ahmad, S. (2021). Eco-friendly vaccination: Tackling an unforeseen adverse effect. *The Journal of Climate Change and Health*, *1*, 100005. doi:10.1016/j.joclim.2021.100005

POLITICO. (2021). The environmental impact of mass coronavirus vaccinations. Retrieved from https://www.politico.eu/article/mass-coronavirus-vaccinations-environmental-impact-climate-change

Purnomo, C. W., Kurniawan, W., & Aziz, M. (2021). Technological review on thermochemical conversion of COVID-19-related medical wastes. *Resources, Conservation, and Recycling*, *167*, 105429. doi:10.1016/j.resconrec.2021.105429

Rech, J. (2007). Discovering trends in software engineering with google trend. *ACM SIGSOFT Software Engineering Notes*, *32*(2), 1–2.

Sangkham, S. (2020). Face mask and medical waste disposal during the novel COVID-19 pandemic in Asia. *Case Studies in Chemical and Environmental Engineering*, *2*, 100052.

Scobie, H. M., Johnson, A. G., Suthar, A. B., Severson, R., Alden, N. B., Balter, S., … Cadwell, B. (2021). Monitoring incidence of COVID-19 cases, hospitalizations, and deaths, by vaccination status—13 US jurisdictions, April 4–July 17, 2021. *Morbidity and Mortality Weekly Report*, *70*(37), 1284.

Singh, N., Tang, Y., Zhang, Z., & Zheng, C. (2020). COVID-19 waste management: Effective and successful measures in Wuhan, China. *Resources, Conservation, and Recycling*, *163*, 105071. doi:10.1016/j.resconrec.2020.105071

Sohrabi, C., Alsafi, Z., O'Neill, N., Khan, M., Kerwan, A., Al-Jabir, A., … Agha, R. (2020). World Health Organization declares global emergency: A review of the 2019 novel coronavirus (COVID-19). *International Journal of Surgery*, *76*, 71–76. doi:10.1016/j.ijsu.2020.02.034

Tang, Y.-W., Schmitz, J. E., Persing, D. H., & Stratton, C. W. (2020). Laboratory diagnosis of COVID-19: Current issues and challenges. *Journal of Clinical Microbiology*, *58*(6), e00512–00520.

Times, K. (2021). Additional PCR tests: New Covid safety rules for flying to Bahrain. Retrieved from https://www.khaleejtimes.com/region/mena/additional-pcr-tests-new-covid-safety-rules-for-flying-to-bahrain

UAE. (2021). Dubai Police issues 443 fines for not wearing mask. Retrieved from https://gulfnews.com/uae/government/dubai-police-issues-443-fines-for-not-wearing-mask-1.76796873

UCLA. (2014). Addressing vaccine waste. Retrieved from https://ph.ucla.edu/news/magazine/2014/spring/article/addressing-vaccine-waste.

WHO. (2021). Shortage of personal protective equipment endangering health workers worldwide. Retrieved from https://www.who.int/news/item/03-03-2020-shortage-of-personal-protective-equipment-endangering-health-workers-worldwide

Wilde, G. R., & Pope, K. L. (2013). Worldwide trends in fishing interest indicated by internet search volume. *Fisheries Management and Ecology*, *20*(2-3), 211–222. doi:10.1111/fme.12009

Worldmeter. (2021). Population: Asia. Retrieved from https://www.worldometers.info/population/asia/

Worldmeter (2022). COVID-19 Coronavirus pandemic. Retrieved from https://www.worldometers.info/coronavirus/#countries

Wu, H-L., Huang, J., Zhang, C. J. P., He, Z., & Ming, W.-K. (2020). Facemask shortage and the novel coronavirus disease (COVID-19) outbreak: Reflections on public health measures. *EClinicalMedicine*, 21, 100329. doi:10.1016/j.eclinm.2020.100329

Xinhuanet. (2020). China focus: Mask makers go all out in fight against novel coronavirus. Retrieved from http://www.xinhuanet.com/english/2020-02/06/c_138760527.htm#:~:text=China

Yang, A. C., Huang, N. E., Peng, C.-K., & Tsai, S.-J. (2010). Do seasons have an influence on the incidence of depression? The use of an internet search engine query data as a proxy of human affect. *PLoS One*. *5*(10), e13728.

Yu, H., Sun, X., Solvang, W. D., & Zhao, X. (2020). Reverse logistics network design for effective management of medical waste in epidemic outbreaks: Insights from the coronavirus disease 2019 (COVID-19) outbreak in Wuhan (China). *International Journal of Environmental Research and Public Health*, *17*(5), 1770.