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Estimation of COVID-19 generated medical waste in the Kingdom of Bahrain

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1. Introduction

During the pandemic period, the demand for medical equipment, more specifically personal protective equipment’s (PPEs), drastically increased. This increase could be an inevitable consequence of disease...
Waste generated during the COVID-19 pandemic is specifically called COVID-19 medical waste (CMW). A huge volume of waste has been produced and is still growing due to the prevailing pandemic situation with unique characteristics, such as lower density than regular medical waste, requiring special attention to be treated before disposal (Purnomo et al., 2021; Chen et al., 2021). The CMW includes PPEs, such as face shields, face masks, gloves, goggles, coverall suits, in addition to other related waste such as disinfectant containers and hand sanitizer (Vanapalli et al., 2021). There is an obligation to use standard PPEs by the health workers (nurses, doctors, and caregivers), patients and healthy people who have close contact with the infected patients. Presently, all the citizens in most countries worldwide are obliged to wear face masks during all outdoor activities (Siddique et al., 2021; Dzekashu et al., 2017). As an inevitable outcome, many disposable PPEs are made available and used, leading to a massive increase in potentially infectious waste, posing further health and environmental threats. It was found that on surfaces of the material, including plastic, steel and glass, the COVID-19 virus can last for several days (Wang et al., 2020; Hantoko et al., 2021). The risks of these threats are increasing in developing countries with an inadequate medical waste management system, which is a threat to humanity (Kampf et al., 2020). Since its inception, the waste is increasing every day by introducing new activities like vaccination, and it needs to be handled properly. Before it is dealt with or processed, quantification is of utmost required for efficient and effective planning. Various statistical models, such as STIRPAT (environmental pressure model) and Autoregressive Integrated Moving Average (ARIMA) model (time series model) have been applied to estimate trend in medical waste which seems to be promising (Wei et al., 2021).

Most countries in the world, including Gulf Cooperation Council, GCC states (Bahrain being a member state) have performed a very mature role in the prevailing pandemic situation; thus, a huge amount of waste (in addition to normal MW) has been generated and is expected to be generated till the pandemic comes to its end, which needs proper attention to be brought in the notice of the authorities for adequate treatment. A comprehensive literature survey reveals that no reports have been presented on CMW in GCC member states, particularly in Bahrain. Here, we have estimated the amount of waste generated during the pandemic period in the Kingdom of Bahrain. The medical waste resulting from the COVID-19 pandemic is estimated by calculating activities like healthcare facilities, diagnostic tests, and vaccination. The environmental impact of so far generated and future waste is also discussed.

2. Data collection and calculations of total waste

Besides the pandemic, the waste being generated is of great concern for environmental scientists. Several groups researched the high risk of a pandemic in various parts of the world. The Asian Development Bank (ADB, 2020) proposed an equation (shown below, Eq. (1)) to associate CMW with the number of infected persons. This equation has already been applied in some studies to estimate the CMW in Asian countries (Purnomo et al., 2021). Eq. (1) seems promising in predicting the waste generated or to be generated in the future until the end of the current pandemic.

\[
\text{Amount of CMW (kg/d)} = \text{Number of infected persons} \times 3.4
\] (1)

The same equation will be applied to estimate CMW in Bahrain since the pandemic started, i.e., February 24, 2020, until May 31, 2021; the same calculations will be extended until the pandemic’s possible end. Data of newly infected persons per day in Bahrain from the first case that appeared on February 24, 2020, to April 4, 2021, was collected from the website “Our World in Data” (OWID, 2021). Trend line referred to a best-fit line, and it’s used to characterize a set of data’s behaviors to determine a particular pattern. Moreover, the trend line is an analytical tool employed often in conjunction with a two-dimensional graph of ordered pairs. The trend line can predict future data points (Study.com, 2021). Trend line analysis was used to predict the number of newly infected people and the amount of CMW. The mass of all PPEs used in five health care centers was determined for representative samples using an analytical balance. Posteriorly the daily weight of PPEs in each center was calculated by Eq. (2):

\[
\text{Daily PPE's weight (kg/d) per center} = \text{average PPE's weight per worker} \times \text{total number of workers}
\] (2)

Online/Call interviews were conducted with several staff members working in dedicated five health care centers during COVID-19. Information about the quantity of each PPE they are using during their duties was collected. The selected healthcare facilities are the Exhibition center, Bahrain International Hospital (BIH), Kanoo center, 5th and 6th floors (6 wards on each floor) in Salmanya Medical Complex (SMC) and Hereditary Blood Disorder Center (HBDC). The following equation (Eq. (3)) has currently been proposed to estimate the quantity of daily face masks (Nzediegwu and Chang, 2020):

\[
\text{Total daily facemasks} = \text{population} \times \text{urban population} \times \text{facemask acceptance rate} \times \text{average daily facemasks per capita/10,000}
\] (3)

The data of population size and urban population percentage were collected, taking most of the help from the website world meters (Worldometer, 2021a, 2021b). Following the literature and the Government of Bahrain’s strict implementation of facemask policies, it assumes that the face mask acceptance rate is 80%. Based on the literature (Wu et al., 2020), the assumption that everyone in the general population uses one face mask daily was also considered. The estimated data about face masks being used by the general population of the Kingdom at an 80% acceptance rate were calculated and summarized in Table 1.

The vaccination sets, including syringe, glass vial and alcohol swab, have been weighted to estimate the waste generated from vaccination. Data on the number of COVID-19 vaccines in Bahrain was collected from the website https://ourworldindata.org/grapher/cumulative-covid-

| Table 1: Important statistics of GCC member states, by 2020, taken from the website world meter. |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Bahrain | Oman | Kuwait | Qatar | Saudi Arabia |
| Total population | 1,701,575 | 5,106,626 | 4,270,571 | 2,881,053 | 34,813,871 |
| Urban population, % | 89 | 87 | 100 | 96 | 84 |
| Total land, Km² | 760 | 309,500 | 17,820 | 11,610 | 2,149,690 |
| Population density (persons/Km²) | 2239 | 16 | 240 | 248 | 16 |
| Yearly change in population in % | 3.68 | 2.65 | 1.51 | 1.73 | 1.59 |
| Median Age, in years | 32 | 31 | 37 | 32 | 32 |
vaccinations?country=BHR (Data, 2021a) and (MOH, 2021b). The total waste’s weight generated from all the vaccinated people was calculated using the formula.

Total waste’s weight of vaccination in kg
= weight of vaccine set × number of vaccinated people

Lastly, to estimate the weight of waste generating from COVID-19 tests, the items of the test kit comprising nasopharyngeal swab and bottle of a chemical preservative have been weighted. Data on the number of covid-19 tests performed in Bahrain was collected from the website https://ourworldindata.org/grapher/full-list-total-tests-for-covid-19?country=BHR (Data, 2021b). The total waste’s weight generated from all the COVID-19 tests performed was determined using the formula.

Total waste’s weight of COVID−19 tests in kg
= weight of test kit × total number of tests performed

3. Results and discussion

Bahrain is a member of GCC states with a total population of 1,701,575 and a total area of 760 km². Its 89% population is urban (comparison with other GCC member states is provided in Table 1). The Kingdom was selected for this study based on its highest population density among GCC member states. The control and handling of COVID-19 in Bahrain are much difficult and sensitive. The Kingdom provides the best health facility to all citizens; several health centers were designated to treat COVID-19 related patients during the pandemic. As stated above, the data were collected from the website and were validated for Bahrain.

3.1. Estimation of CMW

The number of newly confirmed cases since the first case in Bahrain from February 24, 2020, till May 31, 2021, are plotted using Microsoft Excel (Fig. 1). It can be seen that the curve is affected by two components of the time series analysis: the cyclic and irregular components. In time series analysis, the cyclic component is defined as the periodic changes or regular fluctuations around the trend, forming a series of expansion and contraction phases (OECD, 2007). The countries in the world have been hit by the coronavirus waves (Vahabi et al., 2021) and the Kingdom of Bahrain is one of them; it is highly affected by the corona various waves, which formalized a cyclic pattern of high and low slopes in the curve. The other component that causes the variation and irregular movements in the curve of the confirmed cases is the irregular component, and its sudden changes occur in a time series that are unlikely to be repeated (OECD, 2007). Here leading factors for the irregular component are vaccination of publics and lockdown imposed to curb the spread.

Their best-fit line was found using the derived polynomial functions (3rd order) with a coefficient of determination R² equals 0.8549; this indicates a good fit-line and reliable model for a future forecast. R² measures the “goodness of fit” and represents a value between 0.0 and 1.0 (Investopedia, 2020; Wei et al., 2021). The cubic equation used to estimate the number of newly infected cases is found as: 

$$y = 0.0001x^3 − 19.417x^2 + 856018x − 1E + 10$$

Where y refers to the number of newly infected cases and x refers to the date (number of days).

It is worth mentioning that this study assumes the exact current situation, for instance, without any more advanced precautionary measures. Therefore, the best-fit line reveals that the expected number of newly infected cases is to increase after May 2021; by the middle of July 2021 number of newly infected cases would reach around 3700. However, this could not happen due to the two abovementioned factors (cyclic and irregular components); for instance, a new wave of the deadly COVID-19 could hit the country. Vaccination is a vital factor, where the daily rate of COVID-19 vaccines increased in Bahrain, especially in May 2021 (TRACKERS, 2021). Up to May 28, 2021, the number of COVID-19 vaccine doses administered are 1.67 million (Data, 2021a). Another critical factor is the precautionary measure, i.e., imposition of lockdown. As found in the literature, the lockdown has a significant impact in decreasing the number of infected persons in the Kingdom of Bahrain. It was reported that implementing the lockdown, closing stores and businesses and restricting social gatherings in April 2020, led to a drastic drop in the infected people by 64% (AlSayegh and Iqbalbc, 2021). The Government of Bahrain imposed a lockdown on May 27, 2021, to limit the spread of the coronavirus (MOH, 2021a), which could affect the estimated number of cases.

Consequently, it is expected that the CMW has to increase as well. Therefore, the graph for CMW was drawn to figure out the anticipated quantity of CMW using the same method as shown in Fig. 2. The calculated amounts of CMW (using Eq. (1)) are plotted using Microsoft Excel, as depicted in Fig. 2. Their best-fit line was found using the derived polynomial functions (3rd order) with R² equals 0.8582; means it is a good fit-line and reliable model for a future forecast (Investopedia, 2020; Wei et al., 2021). The amount of CMW is expected to increase up to 13,000

![Fig. 1. The number of new daily infected persons of COVID-19 in the Kingdom of Bahrain and forecast of new cases.](image-url)
kg/day by the middle of July 2021. The cubic equation used to estimate the amount of CMW was found as:

\[ y = 0.0005x^3 - 65.939x^2 + 3E - 4E + 10 \]

where \( y \) refers to the amount of CMW and \( x \) refers to the date (number of days).

### 3.2. Estimation of the daily protective disposable face mask of the general population

The rapid spread of the COVID-19 virus has prompted people to wear masks daily as a precautionary measure. In this regard, the government of Bahrain has adopted even strict measures to make it compulsory during outdoor activities. A disposable medical mask (surgical mask) is primarily designed and used to protect healthcare workers from hazards during medical activities. However, most citizens wore the medical face mask extensively during the outbreak of infectious diseases, for instance, SARS in 2003, PDM H1N1 in 2009, and current COVID-19, as recommended by the authorities (Elachola et al., 2020). It is believed that the face mask could reduce the risk of disease transmission, resulting in the prevention of disease to a healthy person and the protection of asymptomatic transmission.

WHO has stated that, in response to the current COVID-19 virus, the global requirement for face masks is approximately 89 million per month (WHO, 2021). As of February 2020, the daily production capacity in China has been raised to about 15 million pieces of face masks (Xinhuaneet al., 2020). The global market for face masks (including respiratory and surgical) was expected to increase from about 14.6 billion in 2019 to 33.4 billion in 2023, with an annual increase of about 23% (Research, 2020). The weight of the surgical mask was measured to be 2.85 g, the calculated total number of facemasks used by the general population of Bahrain @80% acceptance during the pandemic is 12,449 per day. Therefore, the total weight of the face mask used by the general population in Bahrain in one day is 2.85 × 12,449, which is equal to 35,479.65 g = 35.480 kg.

### 3.3. The number of PPEs used for each staff per day

The SARS-CoV-2 is still novel, and most probably, it spreads by direct contact and droplets. For ensuring routine droplet barrier precautions, generally proper infection prevention practice, environmental hygiene and to minimize the risk of infection when treating COVID-19 patients, the Health Workers are required to use protective gears such as masks, goggles, PPE suits, face shields, shoe covers, etc. after their use, decontamination and discarding should be safe (Adams and Walls, 2020). These protective gears are essential as they play a vital and influential role in controlling transmission.

Most PPEs are mainly organic polymeric material; sustainable plastic and its waste pose risks to biota and environmental segments. Mismanaging the waste threatens human beings and puts a greater burden on the environment, which is already inundated by the current amount of plastic waste generated daily from non-medical sources (Purnomo et al., 2021). The respiratory mask N95 is polypropylene (PP), the surgical mask is PP, and the textile and Fabric mask is cotton. The main components of face shields are polystyrene terephthalate (PET), polycarbonate (PC), and polyvinylchloride (PVC). Goggles are made of PC, and the protective gown contains PP, polyester (PES), or polyethylene (PE). The coveralls (white and blue suits) comprise mainly of high-density polyethylene (HDPE), while the main component of Latex gloves is natural rubber, vinyl gloves is PVC, Nitrile gloves are acrylonitrile and butadiene, neoprene gloves is carbon, chlorine, sulfur, and hydrogen-containing material. See Tables 2 and 3 for details.

In Table 2, the COVID-19 centers are arranged by nature of patients, i.e., case severity. Exhibition center receives all suspected persons, Bahrain International Hospital (BIH) receives the mild cases, Kanoo center, 5th and 6th floors (6 wards on each floor) in SMC receive the severe cases, and HBDC receives critical cases (Intensive Care Unit – ICU). The data in Table 2 were used to calculate the total weights of PPEs in kg per day for each center, as has been summarized in Table 3. Table 3 reveals that the total amount of medical waste is 1849 kg/day. SMC (1243 kg/day) generated the highest amount of PPE waste among the five selected centers. The lowest amount of waste is being caused by Kanoo center (51 kg/day). The variation in the amount of waste generated in these five centers is due to the difference in the number of patients attending the center and the difference in the number of health workers in it.

### 3.4. Waste generated from COVID-19 vaccination

The vaccination drive against COVID-19 has been started since the beginning of 2021 around the globe and is continuing. The vaccine production has been increased to achieve the general population’s desired immunization levels against COVID-19 and meet global needs. Governments worldwide are trying to vaccinate as many people as possible frantically to eliminate the coronavirus pandemic. However, that could lead to some negative consequences on the environment (POLITICO, 2021). The vaccination campaign could cause another concern in raising the waste, which is added to the waste produced by single-use PPE to protect medical staff and general people from the virus. With the
acceleration of vaccine development among the current pandemic and
the immunization campaigns growth, a substantial surge in the quantity
of plastic, rubber, and glass resulting from vaccine bottles is anticipated
(Phadke et al., 2021). It is noted that this resulted burden will be enor-
mous, especially on the poor, low-income areas, which do not have sig-
nificant waste management resources, with adverse environmental and
financial impacts in the short and long term (UCLA, 2014)

In the Kingdom of Bahrain, the Ministry of Health has provided vari-
ous vaccinations and urged people to take them, as the national cam-
paign for vaccination against COVID–19 continues to preserve the
health and safety of citizens and residents by raising and strengthening
immunity through vaccinations to provide the highest levels of health
security in Bahrain (MOH, 2021c). Indeed, there is a high turnout of cit-
izens and residents to take the Coronavirus vaccination, and the intake
is in rapid increase, as demonstrated in Fig. 3. By April 14, 2021, the
number of vaccination doses administered reached 1,008,746.

The vaccination drive is at its best, and by May 11, 2021, the number
of vaccinated individuals who took two doses was 602,390, and 813,728
vaccinated individuals with the first dose (MOH, 2021b). The time inter-
val between 1st and 2nd dose is 3 weeks (21 days); it is estimated that
the given number of an individual will take their 2nd mandatory dose
within the stipulated time (This number is also included in calculations
as given below). Table 4 shows all the necessary items and required dur-
during an individual’s vaccination for a single dose. The data depicted in
the table can be used to calculate the total weight of the waste produced
during vaccination for far. The total weight of waste generated from
the vaccine until May 11, 2021, is 16,632.505 g and would reach
23,337.62 kg/day (Table 5).

3.5. Number of COVID–19 tests performed

In March of 2020, the Global Emergency Committee and the World
Health Organization called for early exposure to prevent the virus
from spreading among people (Catrin Sohrabi et al., 2020). To detect
the coronavirus, a swab is used to take a sample from the mouth, nose
or lungs, which is kept in chemical preservatives in a plastic tube.
Then, the sample is analyzed and extracted by polymerase chain reac-
tion (PCR), precisely, Real-Time PCR (RT-PCR). This procedure uses

| PPE name          | Exhibition center | Bahrain International Hospital (BIH) | Kanoon center | S5th and S6th floors in SMC | Hereditary Blood Disorder Center-HBDC | The average weight of the item (g) |
|-------------------|-------------------|-------------------------------------|---------------|-----------------------------|--------------------------------------|-----------------------------------|
| Surgical face mask| 2                 | 4                                   | 4             | 5                           | 5                                    | 2.85                              |
| Face mask N-95    | 1                 | 1                                   | 1             | 1                           | 1                                    | 10.46                             |
| Face shield       | 1                 | 1                                   | 1             | 1                           | 1                                    | 33.56                             |
| White suit        | 1                 | 1                                   | 1             | 1                           | 1                                    | 36.0                              |
| Gown              | 2                 | 10                                  | 15            | 25                          | 25                                   | 60.8                              |
| Goggle glass      | 1                 | 1                                   | 1             | 1                           | 1                                    | 34.35                             |
| Gloves (pairs)    | 40                | 25                                  | 25            | 30                          | 30                                   | 20.06                             |
| Shoes cover       | 2                 | 10                                  | 25            | 30                          | 30                                   | 27.7                              |

Table 2

Table 3

| Number of staff engaged/day | PPE kg/d per center | Total kg/day (Exhibition center) | Total kg/day (Bahrain International Hospital (BIH)) | Total kg/day (Kanoon center) | Total kg/day (S5th and S6th floors in SMC) | Total kg/day (Hereditary Blood Disorder Center-HBDC) |
|-----------------------------|---------------------|---------------------------------|-----------------------------------------------------|-----------------------------|-------------------------------------------|-------------------------------------------------------|
| 240                         | 341.6328            | 1.516                           | 1.516                                               | 1.516                       | 1.516                                     | 1.516                                                  |
| 42                          | 77.12334            | 0.388                           | 0.388                                               | 0.388                       | 0.388                                     | 0.388                                                  |
| 20                          | 51.115              | 0.259                           | 0.259                                               | 0.259                       | 0.259                                     | 0.259                                                  |
| 365                         | 1242.9783           | 6.214                           | 6.214                                               | 6.214                       | 6.214                                     | 6.214                                                  |
| 40                          | 136.2168            | 0.720                           | 0.720                                               | 0.720                       | 0.720                                     | 0.720                                                  |

Therefore, it equals 12.53 × 4,273,842 = 53,551,240.26 g =
53,551,240 kg generated so far (to the date May 12, 2021). Lastly, all
the solid waste generated during the COVID–19, mainly from March
2020 to March 2021, is summarized in Table 7.
3.6. Efficient management and treatment of CMW

Medical waste management is a serious threat, particularly in developing countries, 45% of workers on average are trained, and still, many countries need to increase this number to deal with the waste. Segregation of 38.9% of normal medical wastes for proper management has been achieved, and still, a lot is needed to be done. Due to a lack of training and experience, workers get serious injuries during waste management. A major portion of the COVID-19 related medical waste is plastic, which needs to be processed for sustainable resource recovery and recycling. The prevailing pandemic situation invites all the countries to use collective wisdom and adopt environmentally sustainable waste management during and after the pandemic (Singh et al., 2021). There are concerns with CMW to be treated before disposal, particularly in developing countries, to curb the spread. For reusable non-medical material, it is proposed to be treated in accordance with set guidelines by using a 70% alcoholic solution for disinfection (Nzediegwu and Chang, 2020). The virus is novel, and much scientific informations are yet unexplored. Like other associated issues with the virus, the CMW is a serious threat to the environment and the scientific community. There are several techniques already in the field to cope

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Table 4
The weight of waste items during one dose of vaccination.

| Tool            | Weight (g) |
|-----------------|------------|
| Syringe         | 5.82       |
| Glass vial      | 1.59       |
| Alcohol swab    | 0.83       |
| Total           | 8.24       |

Table 5
Total calculated waste generated by vaccination till May 11, 2021.

| Number of vaccinated (a) | Does (b) | Weight (g) = 8.24 |
|--------------------------|----------|-------------------|
| 602,390                  | 2        | 9,927,387.2 g     |
| 813,728                  | 1        | 6,705,118.72 g    |
| 813,728                  | 2        | 6,705,118.72 g    |
| 813,728                  | 2        | 6,705,118.72 g    |
| Total weight in g        |          | 23,337,624.64 g   |

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Fig. 3. Total COVID-19 vaccinated individuals in Bahrain; available vaccines are AstraZeneca, Pfizer, Sinopharm and Sputnik.

Fig. 4. The total Covid-19 test performed in Bahrain till May 12, 2021.
but it emits CO2 and other unwanted gases; in contrast, gasification, polystyrene, polyethylene terephthalate and nylon (Dharmaraj et al., 2021) which are convertible into useful products. The processes require elevated temperatures ranging from 300 to 581 °C to afford liquid, requires the least land, and lesser environmental impact. Insufficient operating temperature limits carbonization for processing the CMW, which must be ensured during the process (Purnomo et al., 2021). The CMW is a challenge for the scientific community; it needs to be disinfected before processing any secondary products.

Policies need to be revised or approved to cope with CMW and any possible pandemic situation in future. The waste poses a risk not only to human health but also its leakage adversely affects the environment. Efficient treatment is required to be plasticized and the community shall be ready to deal with any untoward situation in the future (Ilyas et al., 2020). Positive features of pyrolysis are that waste is completely decomposed, and enough energy is produced, but high investment cost and temperature demand are still to be intelligently answered. Before the CMW is subjected to any treatment, certain steps have to be taken to decline the adverse effects (Zand and Heir, 2021; Vanapalli et al., 2021). The current COVID-19 pandemic is a lesson for scientific community and policymakers which calls for speedy and precise decisions and enhancing the capacity building for medical waste management in future abnormal situations. Some steps are necessary to be taken during/before processing the CMW, for instance, risk of infection and transmission to sanitation workers shall be reduced by scientific sanitization of CMW and use of sealed bags for safe disposal. Transition towards environmentally friendly material such as bioplastic must be worked out extensively for normal use and fighting any possible pandemics in future. Behavioral, social and institutional changes must be developed to reduce plastic waste and manage it efficiently. Circular and sustainable practices, public-private investments in research, suitable infrastructure and marketing can bring this dream true. Collective efforts of individuals, corporate and government policies to keep the world transitioning from one disaster to another (COVID-19 to plastic pollution).

4. Conclusion

The solid waste generated in the Kingdom of Bahrain has been calculated from various COVID-19 related activities. The waste estimated in a smaller country with around 2 million population is considerably high to invite the attention of scientists towards sustainable treatment. Daily use of facemasks, test kits and the number of infected cases is an open-end topic. It is a big kick to the economy of many countries of the world. Now it is time to divert the threat into an opportunity by converting the waste into useful material. The Kingdom is facing solid waste in Face masks 12,950.108 kg/year, PPEs relate waste 1849 kg, vaccination-related 23,337.625 kg, and tests related 53,551 kg. The major portion of the waste is plastic, and it needs serious attention. Small and developing countries like Bahrain may establish a sustainable treatment program as recommended.

Table 6

| Tool                      | Weight (g) |
|---------------------------|------------|
| Nasopharyngeal swab       | 1.23       |
| Bottle of chemical preservative | 11.30     |
| Total weight for one test | 12.53      |

Table 7

| Total waste generated from COVID-19 related activities in Bahrain | Weight         |
|-----------------------------------------------------------------|----------------|
| Predicted CMW by July 13, 2021                                  | 13,000 kg/day  |
| Face masks used by the general population                      | 35,480 kg/day  |
| PPEs used by medical staff in 5 centers                         | 1849 kg/day    |
| Number of vaccinations, by May 11, 2021                         | 23,337.62 kg   |
| COVID-19 tests, by May 31, 2021                                 | 53,551.240 kg  |

The solid waste generated in the Kingdom of Bahrain has been calculated from various COVID-19 related activities. The waste estimated in a smaller country with around 2 million population is considerably high to invite the attention of scientists towards sustainable treatment. Daily use of facemasks, test kits and the number of infected cases is an open-end topic. It is a big kick to the economy of many countries of the world. Now it is time to divert the threat into an opportunity by converting the waste into useful material. The Kingdom is facing solid waste in Face masks 12,950.108 kg/year, PPEs relate waste 1849 kg, vaccination-related 23,337.625 kg, and tests related 53,551 kg. The major portion of the waste is plastic, and it needs serious attention. Small and developing countries like Bahrain may establish a sustainable treatment program as recommended.
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References

Adams, J.G., Walls, R.M., 2020. Supporting the Health Care Workforce During the COVID-19 Global Epidemic. 60611, pp. 2–3. https://doi.org/10.1016/j.jama.2020.3972.

ADB, 2020. Managing Infectious Medical Waste during the COVID-19 Pandemic. 2. https://www.adb.org/publications/managing-medical-waste-covid19.

AlSayegh, M., Iqbalbc, A., 2021. 28.https://www.tandfonline.com/doi/full/10.1080/25769229.2021.1903143.

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. Sci. Total Environ. 760, 144167. https://doi.org/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. Sci. Total Environ. 147522.

Czégény, T., Ronkay, F., 2020. Editorial corner - a personal view the coronavirus and plastics. Express Polym Lett 14 (6), 510–511. https://doi.org/10.3144/expresspolymlett.2020.41.

Data, O.W., 2021a. COVID-19 vaccine doses administered. https://ourworldindata.org/grapher/cumulative-covid-vaccinations?country=~BHR.

Data, O.W., 2021b. Total COVID-19 tests.https://ourworldindata.org/grapher/full-list-tests-for-covid-19?country=~BHR.

Dharmaraj, S., Ashokkumar, V., Pandiyan, R., Munawaroh, S.H., Chew, K.W., Chen, W., O.W., 2021b. Total COVID-19 tests.https://ourworldindata.org/grapher/cumulative-covid-vaccinations?country=~BHR.

Dzekashu, L.G., Akoachere, J.F., Mbacham, W.F., 2017. Medical waste management and disposal practices of health facilities in Kumbo East and Kumbo West health districts. Int. J. Med. Med. Sci. (1), 1–11.

Eikenberry, S.E., Mancuso, M., Iboi, E., Phan, T., Eikenberry, K., Kwang, Y., Kostelich, E., Gumel, A.B., 2020. Modeling or not to mask: modeling the potential for face mask use by the general public to curtail the COVID-19 pandemic. Infect. Dis. Modell. 5, 293–308. https://doi.org/10.1016/j.idm.2020.04.001.

Elacholu, H., Ebrahim, S.H., Gozzer, E., 2020. COVID-19: face mask use prevalence in international airports in Asia, Europe and the Americas, march 2020. Travel Med. Infect. Dis. 35 (March), 101637. https://doi.org/10.1016/j.tmaid.2020.101637.

Hantoko, D., Li, X., Pariatamby, A., Yoshikawa, K., Horttanainen, M., Yan, M., 2021. Challenges and practices on waste management and disposal during COVID-19 pandemic. J. Environ. Manag. 286, 112140.

Ilyas, S., Srivastava, R.K., Kim, H., 2020. Disinfection technology and strategies for COVID-19 epidemic. Sci. Total Environ., 147522.

Kampf, G., Scheithauer, S., Lemmen, S., Salou, P., Suchomel, M., 2020. COVID-19-associated shortage of alcohol-based hand rubs, face masks, medical gloves, and gowns: proposal for a risk-adapted approach to ensure patient and healthcare worker safety. J. Hosp. Infect. 105 (3), 424–427. https://doi.org/10.1016/j.jhin.2020.04.041.

Kumar, H., Azad, A., Gupta, A., Sharma, J., Bhawaihi, H., Labhsetwar, N.K, Kumar, R., 2021. COVID-19 creating another problem? Sustainable solution for PPE disposal through LCA approach. Environ. Dev. Sustain. 23, 9418–9432. https://doi.org/10.1007/s10668-020-01033-0.

MOH, 2021a. Approved measures aimed at mitigating the spread of COVID-19 by closing non-essential sectors and activities. https://healthalerts.gov.bh/en/article/the-national-medical-task-force-for-fighting-the-coronavirus-covid-19-26-05-2021.

MOH, 2021b. Daily COVID-19 Report. https://healthalert.gov.bh/en/.

MOH, 2021c. Health Ministry calls on people wishing to take Sputnik vaccine to register electronically. https://www.moh.gov.bh/COVID19/Details/4630.