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The SARS-CoV-2 (COVID-19) pandemic in hospital: An insight into environmental surfaces contamination, disinfectants’ efficiency, and estimation of plastic waste production

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\textbf{ARTICLE INFO}

Keywords:
SARS-CoV-2
COVID-19
VOC lineage B.1.1.7
Plastic residue
Environmental surface contamination

\textbf{ABSTRACT}

The current COVID-19 pandemic that is caused by SARS-CoV-2 has led all the people around the globe to implement preventive measures such as environmental cleaning using alcohol-based materials, and social distancing in order to prevent and minimize viral transmission via fomites. The role of environmental surface contamination in viral transmission in within hospital wards is still debatable, especially considering the spread of new variants of the virus in the world. The present comprehensive study aims to investigate environmental surface contamination in different wards of a hospital as well as the efficacy of two common disinfectants for virus inactivation, and tries to produce an estimate of plastic residue pollution as an environmental side effect of the pandemic. With regard to environmental surface contamination, 76 samples were taken from different wards of the hospital, from which 40 were positive. These samples were taken from contaminated environmental surfaces such as patient bed handles, the nursing station, toilet door handles, cell phones, patient toilet sinks, toilet bowls, and patient’s pillows, which are regularly-touched surfaces and can pose a high risk for transmission of the virus. The number of positive samples also reveals that SARS-CoV-2 can survive on inanimate surfaces after disinfection by ethanol 70 % and sodium hypochlorite (0.001 %). The results correspond to the time that the VOC 202012/01 (lineage B.1.1.7) had emerged in the hospital and this should be considered that this variant could possibly have different traits, characteristics, and level of persistence in the environment. The plastic waste as an environmental side effect of the pandemic was also investigated and it was confirmed that the amount of plastic residue for a single (RT) PCR confirmatory test for COVID-19 diagnosis is 821.778 g of plastic residue/test. As a result, it is recommended that for improving plastic waste management programs, considering challenges such as minimizing plastic waste pollution, optimization of gas control technologies in incinerators, process redesign, reduction of single-use plastics and PPE, etc. Is of utmost importance.

1. Introduction

On December 31, 2019, a novel human coronavirus (CoV) was detected in Wuhan city, Hubei province, China, which causes a respiratory disease that is called severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) by the World Health Organization (WHO). Afterward, COVID-19 was identified in the East of Asia, the Middle East, Europe, North and South of America, Africa and Oceania, spreading in 218 different countries and territories around the world causing a pandemic situation. Although specific precautions quarantine regulations, and preventive measures are taken in different regions, SARS-CoV-2 pandemic is still a very prominent concern due to its rapid spread. According to WHO, until April 23, 2021, SARS-CoV-2 pandemic had led to 144, 358, 956 and 3,066,113 confirmed cases and deaths, respectively. Despite the fact that before the date mentioned above, a total of 899, 936, 102 vaccine doses had been administrated in different regions...
of the world (Kim et al., 2020; Noorimotlagh et al., 2020; Noorimotlagh et al., 2020; Orenes-Pinero et al., 2021), the disease still spreads in all regions and territories of the globe and several new variants of SARS-CoV-2 have been reported with different traits.

There are different mechanisms and routes of transmission for SARS-CoV-2 including the direct route (person-to-person transmission that occurs by having close and prolonged contact with a patient or an infected person) and the indirect routes including airborne transmission by airborne viral infectivity and transmission by contact with contaminated environmental surfaces (Harbizadeh et al., 2019; Coccia, 2020; Kim et al., 2020; Noorimotlagh et al., 2020; Dargahi et al., 2021; Maleki et al., 2021). Based on these routes, WHO and other official agencies suggest that people should use face masks, environmental surface disinfectants and alcohol-based hand gel, and do social distancing to prevent viral transmission (Noorimotlagh, Mirzaee et al. 2020, 2021; Maleki et al., 2021; Marzoli and Bortolami, 2021; Vosoughi et al., 2021).

Among the main routes of COVID-19 transmission, the role of environmental surface transmission is still controversial among scientists due to several factors such as long-term persistence of the virus on different environmental surfaces and its activity’s dependence on temperature and relative humidity, especially in indoor environments (Lee et al., 2020a,b; Noorimotlagh, Jaafarzadeh et al. 2020, 2021; Noorimotlagh et al., 2020; Marzoli and Bortolami, 2021; Moore et al., 2021; Nottmeyer and Sera, 2021). Therefore, detection of SARS-CoV-2 in the hospital environmental surfaces is of utmost importance.

During the few last months, new variants of SARS-CoV-2 have been reported in different regions of the world. One of these important variants is variant of concern (VOC) 202012/01 (lineage B.1.1.7) (designated a variant of concern (VOC-202012/01), also known as B.1.1.7). V1, variant of concern 20DEC-01, or commonly known as the UK variant, British variant, or Kent variant, which first emerged in Kent in South East England in September 2020 (Challen et al., 2021; Davies et al., 2021; Iacobucci, 2021; Mahase, 2021). Based on the early data, Iacobucci (2021) reported that the new UK variant may be linked to the increased death rate (Jacobucci, 2021). Davies et al. (2021) surveyed the transmissibility of SARS-CoV-2 lineage B.1.1.7 in England and reported that this new UK variant shows a similar increase in the rate of transmission (59–74 %) in Denmark, Switzerland, and the United States (Davies et al., 2021).

The current evidence of local officials shows that the new variants of SARS-CoV-2, i.e., variant of concern (VOC) 202012/01 (lineage B.1.1.7), are spread in the world, especially in different cities of Iran. Due to the fact that contaminated environmental surfaces can be indicated as high risk for viral transmission, thus, the role of environmental surface contamination in hospitals is still debatable. On the other hand, knowing the efficiency of the typical disinfectants for inactivating the virus, especially lineage B.1.1.7, is of immense importance. Regarding the spread of the virus, estimation of plastic residue in hospitals is very critical from the environment point of view. Therefore, to achieve these objectives, the present study was conducted to determine the presence of the virus on regularly-touched environmental surfaces, as well as the persistence of the virus to two common types of disinfectants, and finally, to estimate the plastic waste produced by the real-time PCR test and its operators in the hospital.

2. Materials and methods

2.1. Sampling site description and approval of ethics code statement

The present work was accepted by Shoushtar University of Medical Sciences (SUMS) to be performed under ethics code: IR. Shoushtar. REC.1399.049 according to the ethical principles and standards for medical research. Therefore, this study was performed in different wards of Khatam-ol- Anbia Hospital in Shoushtar city, Khuzestan province, located in the Southeast of Iran on April 23, 2021. The hospital was assigned for treatment of patients with confirmed COVID-19. Shoushtar city, with a population of 208,311, was then reported to have 8355 confirmed COVID-19 cases.

2.2. Description of sampling location

According to the objectives of the present study, in order to investigate the distribution of COVID-19 infection in the hospital, the spread of the disease was measured in both the wards with confirmed cases as well as the noninfectious wards. Environmental surface samples were obtained from different wards using pre-moistened sterile swabs to collect nasopharyngeal exudates. Smooth surfaces found in the nursing station as well as the floors, reception desk and patient equipment files, were swabbed using a square pattern (10×10 cm), in an area of 100 cm². All the samples were placed in 2 ml VTM and immediately transported to the laboratory where they were used for SARS-CoV-2 detection.

All the samples were collected in triplicate from identical surfaces. The qPCR procedures and analytical methods were carried out in the same way for the triple samples of each location. Positive or negative results are reported after PCR confirmation.

2.3. Viral genome extraction

Virus genome was purified by utilizing nucleic acid extraction by the Roje Technologies kit (Pishgam, Iran) and was preserved in a deep freezer (−70 °C).

2.4. Virus detection using RT-PCR analysis and quality controls

The real-time reverse transcriptase-polymerase chain reaction (RT-PCR) targeting of viral genomes was used to detect the presence of SARS-CoV-2 in the samples. According to the kit’s instructions (Pishztab Zaman, Iran), 5 μL extracted RNA were added to 15 μL of One-step qRT-PCR master mix supplemented with a mixture of primers and TaqMan probes directed against RdRp and N genes. Amplifications and subsequent analyses were carried out using Applied Biosystems Step One plus RT-PCR System. Thermal cycling conditions included reverse transcription at 50 °C for 20 min, an initial denaturation at 95 °C for 3 min, followed by 45 cycles at 94 °C for 10 s, and 55 °C for 40 s. Samples with cycle threshold (Ct) values < 40 cycles were considered positive. If the Ct values were between 40 and 45 cycles, PCR was repeated. The negative controls were run during each experiment to ensure that contamination is identified if it does occur, while a positive control was applied to each experiment as well to identify possible false negative samples. The current kit of covid qPCR has the Limit of Detection (LOD) of 200 copies/mL. Moreover, the IPI SARS-CoV2 UK Variant Screening kit was used in order to identify the new variant by multiple spike protein mutations (deletion 69–70, deletion 144).

In the present study, due to the shortage of the kit used for identifying the UK variant, only two samples were tested with the new variant’s kit and other tests were performed using the normal SARS-CoV-2 kit. It is worth noting that during the experiments, the variant of concern (VOC) 202012/01 (lineage B.1.1.7) emerged in the hospital and most of the confirmed patients were diagnosed positive for this VOC.

3. Results and discussion

3.1. Detection of SARS-CoV-2 on environmental surfaces

Even though the COVID-19 pandemic has been spreading throughout the world for more than a year, trends of prevalence and mortality of the disease are still high. The inanimate environmental surfaces, especially frequently-touched surfaces, are one of the most important factors for virus transmission. Therefore, environmental surface contamination in different wards of the hospitals should be monitored to achieve hygiene goals and disease control (Noorimotlagh et al., 2020; Moore et al., 2021;
Wan et al., 2021). In this regard, in order to investigate the contaminated frequently-touched environmental surfaces, a total of 76 samples of SARS-CoV-2 were collected from different wards of a hospital designated for COVID-19 patients, while local officials had declared that the new variant of concern (VOC) 202012/01 (lineage B.1.1.7) had spread throughout Iran, especially Shoushtar city. These samples were taken from different wards of the hospital, including the respiratory clinic, neurology, CT scan, kitchen, ICU & ICU2, surgery, emergency triage, laundry, and internal ward, as well as cell phones of the staff.

Specimens were collected from frequently-touched surfaces in these wards. Table 1 summarizes the details of sampling sites and detection of SARS-CoV-2 on frequently-touched environmental surfaces of different hospital wards. In addition, during the sampling period, temperature (°C) and relative humidity (RH %) were recorded in the intended wards of the hospital and they were between 24 and 32 °C and 44–48 %, respectively. Table 2 shows the environmental conditions of the frequently-touched environmental surfaces in different wards of the hospital.

There are various laboratory studies that have confirmed the possibility of existence of viable SARS-CoV-2 on frequently-touched environmental surfaces (from 3 h in aerosols to 8–72 h on dry surfaces, depending on surface material) (Aytoğan et al., 2020; Noorimotlagh et al., 2020; Ong et al., 2020; van Doremalen et al., 2020). In two systematic review studies, Noorimotlagh et al. (2021a,b) (Noorimotlagh et al., 2020) and Marzoli and Bortolami, 2021 (Marzoli and Bortolami, 2021) confirmed that depending on surface material and environmental characteristics, SARS-CoV-2 can survive up to 28 days on environmental surfaces at room temperature, which is longer than other coronaviruses (Noorimotlagh et al., 2020; Marzoli and Bortolami, 2021). It has been reported that compared to SARS-CoV-1 and MERS-CoV, the viability of SARS-CoV-2 is longer (Chan et al., 2011; Van Doremalen, Bushmaker et al., 2013).

In this work, detection of SARS-CoV-2 RNA was performed using 76 samples from environmental surfaces that were obtained from different hospital wards before disinfection and cleaning, from which 40 samples were positive (Table 1). Therefore, due to the high transmissibility of SARS-CoV-2, investigation of fomites and environmental surfaces to determine the fomite transmission risk of COVID-19 infection is of utmost importance. As indicated in Table 1, samples taken from contaminated environmental surfaces in different wards of the hospital such as patient bed handles, the nursing station, reception desk, door handles of doctor’s office, toilet door handles, cell phones, patient toilet sinks, toilet bowls, and patient pillows show that high-touch surfaces can be considered as sources with high risk of virus transmission. Therefore, to prevent and minimize the risk of infection transmission, the above-mentioned high-touch environmental surfaces (Table 1) should be disinfected several times daily. In addition, extra cleaning of the high-risk environmental surfaces in the hospital is recommended due to their important role and contribution in spreading the virus.

Table 3 presents a comparison of the reported results of various literature on environmental surfaces of hospitals regarding the presence of SARS-CoV-2. Bloise et al. (2020), examined a clinical microbiology laboratory for detection of SARS-CoV-2 on high-touch surfaces and concluded that the viral RNA of the virus was detected on the surfaces of commonly-used objects such as keyboards, telephone, and scanners; Therefore, they confirmed that these objects could play an important role as a source of infection for laboratory personnel (Bloise et al., 2020). In a similar study in the Republic of Korea, Lee et al. (2020a,b) indicated that among 80 samples taken from frequently-touched environmental surfaces, only the surface samples of two door handles were positive for SARS-CoV-2 RNA (Lee et al., 2020a,b). In another study, Ding et al. (2021) found that the most contaminated surfaces were the bathroom door handles, bathroom toilet seat covers, and door handles (Ding et al., 2021). Moore et al. (2020) found that samples taken from environmental surfaces such as cell phones, vital signs monitors, toilet door handles, bed rails, bed controls, and nurse call buttons were positive in

| Table 1 | Details of sampling sites and detection of SARS-CoV-2 on frequently-touched environmental surfaces of different hospital wards. |
|---------|----------------------------------------------------------------------------------------------------------------------------------|
| No. | Sampling site | frequently-touched environmental surfaces | Ct- RdRp | Ct-N | resultsa |
| 1 | Respiratory Clinic | Nursing Station | 34.2 | 38.02 | positive |
| | | Reception desk | 30.1 | 34.2 | positive |
| | | Door handles of doctor’s office | 37.1 | 39.4 | positive |
| | | Cell phone | 33 | 34.5 | positive |
| | | Air conditioner | 31.2 | 35.5 | positive |
| | | Clinic floor | 32.9 | 33.6 | positive |
| 2 | Neurology ward | Door handle of toilet | - | - | negative |
| | | Nursing station | 30 | 32 | positive |
| | | Equipment file of patient | 30.6 | 32.5 | positive |
| | | Floor | 33 | 34.9 | positive |
| | | Toilet sink of patient | 35 | 32.6 | positive |
| | | Toilet fluid pedal of patient | - | - | negative |
| | | Toilet bowl | - | - | negative |
| | | Bed handle of patient | - | - | negative |
| | | Socket and switch | 31 | 34.6 | positive |
| | | Console above the patient’s head | 30.2 | 34.8 | positive |
| 3 | CT scan ward | Location of the head | 38.6 | 34.1 | positive |
| | | Location of the body | 36 | 39.08 | positive |
| | | Bed handle | - | - | negative |
| | | Air fan | - | - | negative |
| | | Bed handle | - | - | negative |
| | | Patient chair | - | - | negative |
| | | Food counter | - | - | negative |
| | | Door handle | - | - | negative |
| | | Kitchen entrance | - | - | negative |
| 4 | Hospital kitchen | Refrigerator wall surface | - | - | negative |
| | | Refrigeration cooling system | - | - | negative |
| | | Refrigeration handle | 38 | 39 | Positive |
| | | Refrigerator handle | - | - | negative |
| | | Scales | - | - | negative |
| | | Air conditioner | 31.2 | 35.5 | positive |
| | | Door handle | - | - | negative |
| | | Chest leaders | - | - | negative |
| | | Bed handle of patient | - | - | negative |
| | | Door phone | - | - | negative |
| | | Equipment file of patient | 39 | 32.8 | Positive |
| 5 | ICU1 ward | Door handle of archive | - | - | negative |
| | | Refrigeration system | - | - | negative |
| | | Refrigeration handle | - | - | negative |
| | | Refrigerator handle | 38 | 39 | Positive |
| | | Refrigerator wall surface | - | - | negative |
| | | Air Fan | - | - | negative |
| | | Bed handle | - | - | negative |
| | | Door handle | - | - | negative |
| | | Equipment file of patient | 39 | 32.8 | Positive |
| 6 | ICU2 ward | Nurse station | 35 | 38 | Positive |
| | | Floor | 28 | 30.9 | Positive |
| | | Laundry room | 22 | 26 | Positive |
| | | Ventilation systems | - | - | negative |
| | | The patient’s pillows | - | - | negative |
| | | Door handle | 38 | 39 | Positive |
| | | Entrance door handle | - | - | negative |
| | | Patient bed handle | 26 | 30 | Positive |
| | | Swatches and sockets inside the section | 31 | 36.4 | Positive |
| | | Pre-insulated switches and sockets | - | - | negative |
| | | Cell phone | - | - | negative |
| | | Nursing station | - | - | negative |
| 7 | Surgery ward | - | - | negative |

(continued on next page)
terms of presence of the viral RNA (Moore et al., 2021). Jiang et al. (2020a,b) attempted to detect SARS-CoV-2 RNA on the high-touch environmental surfaces of asymptomatic patients in quarantine rooms and identified the presence of the viral RNA in 36% (eight samples) of the 22 environmental surfaces including pillows, covers, sheets, and duvet covers. Therefore, based on these results, they confirmed that effective cleaning and disinfection procedures are important to minimize the risk of contact transmission of COVID-19. This should be noted that some surface materials may better support the survival, persistence, and transmission of this virus (Jiang et al., 2020a,b). Findings of similar studies that are in agreement with the results of the present study, reveal that among the various contaminated environmental surfaces, hallway floors and door handles are the most infected surfaces regarding the presence of the viral RNA of the SARS-CoV-2 (Mouchtouri et al., 2020; Dargahi et al., 2021). Nevertheless, the role of environmental conditions such as temperature and RH is significant and should be considered.

3.2. Persistence of SARS-CoV-2 after using different disinfectants

In the present study, the efficiency of two disinfectants, namely alcohol-based hand rubs (ethanol 70%) and sodium hypochlorite (0.001%) were examined with regard to inactivation of SARS-CoV-2 on inanimate surfaces (such as the nursing station, reception desk, cell phones, door handles and the floors) of different wards of the hospital at both 5 and 15 min after disinfection. Table 4 summarizes the persistence of SARS-CoV-2 on different inanimate surfaces after using the

### Table 1 (continued)

| No. | Sampling site frequently-touched environmental surfaces | Ct- RdRp | Ct-N gene | results
|-----|-------------------------------------------------------|----------|-----------|---------|
|     | Bed handle of patient                                 |          |           |         |
|     | Console above the patient’s head                      | –        | –         | negative|
|     | air conditioner                                       | –        | –         | negative|
| 8   | Patient bed                                          | 33.2     | 35        | positive|
|     | floor                                                 | 30.8     | 32.8      | positive|
|     | Socket switch                                         | 38       | 32.1      | positive|
|     | Patient’s toilet fluid pedal                          | -        | -         |         |
| 9   | Hospital laundry                                     |          |           |         |
|     | Contaminated clothing table                           |          |           |         |
|     | internal surface                                     | 29.1     | 33        | positive|
|     | washing                                               |          |           |         |
|     | Blankets after disinfection                           |          |           |         |
|     | staff’s Desk surface                                  | –        | –         | negative|
|     | door handle                                           | –        | –         | negative|
|     | wheelchair                                            | –        | –         | negative|
|     | Hall floor                                            | 28       | 35.1      | positive|
|     | socket and switches                                   | –        | –         | negative|
|     | Bed pillow                                            | –        | –         | negative|
|     | Surfaces inside the refrigerator                      | 30.7     | 36        | positive|
| 10  | Internal ward of the hospital                         |          |           |         |
|     | Cell phone of administrative staff                    | –        | –         | negative|
|     | Cell phone of neurology personnel                     | –        | –         | negative|
|     | Cell phone of neurology staff                         | –        | –         | negative|
|     | Cell phone of surgery staff                           | –        | –         | negative|
|     | Cell phone of internal ward staff                     | 38.9     | 31        | positive|
|     | Cell phone of patients                                | –        | –         | negative|
|     | Cell phone in COVID-19 ICU ward                       | 18.9     | 32.1      | positive|
|     | Cell phone in emergency ward                          | 34.1     | 38.9      | positive|

* Positive samples are highlighted with a bold font.

### Table 2

Environmental conditions of frequently-touched environmental surfaces in different wards of the hospital.

| No. | Sampling site frequently-touched environmental surfaces | Ventilation type | T (°C) | RH (%) |
|-----|--------------------------------------------------------|------------------|--------|--------|
| 1   | Respiratory Clinic                                    | natural/mechanical | 25     | 45     |
|     | Nursing Station                                       | natural/mechanical | 25     | 44     |
|     | Reception desk                                        | natural/mechanical | 25     | 44     |
|     | Handles in the doctor’s room                          | natural/mechanical | 26     | 46     |
|     | Cell phone                                             | natural/mechanical | 25     | 44     |
|     | air conditioner                                        | natural/mechanical | 24     | 44     |
|     | Clinic floor                                           | natural/mechanical | 24     | 48     |
| 2   | Neurology ward                                         |                  |        |        |
|     | Door handle of Toilet                                 | natural/mechanical | 25     | 48     |
|     | Nursing station                                        | natural/mechanical | 25     | 48     |
|     | Patient’s equipment file                               | natural/mechanical | 24     | 48     |
|     | Floor                                                  | natural/mechanical | 25     | 45     |
|     | Patient’s toilet sink                                  | natural/mechanical | 25     | 48     |
|     | Patient’s toilet fluid pedal                           | natural/mechanical | 24     | 48     |
|     | Toilet bowl                                            | natural/mechanical | 25     | 47     |
|     | Patient’s bed handle                                   | mechanical        | 25     | 47     |
|     | Socket and switch                                      | natural/mechanical | 25     | 47     |
|     | Console above the patient’s head                       | natural/mechanical | 25     | 48     |
|     | Patient pillows                                        | natural/mechanical | 25     | 48     |
| 3   | CT scan ward                                           |                  |        |        |
|     | Location of the head                                   | natural/mechanical | 25     | 45     |
|     | Location of the body                                   | natural/mechanical | 27     | 45     |
|     | The floor of the hall                                  | natural/mechanical | 27     | 45     |
|     | Door handle                                            | natural/mechanical | 27     | 46     |
|     | wheelchair                                             | natural/mechanical | 27     | 46     |
|     | Patient’s chair                                        | natural/mechanical | 27     | 47     |
| 4   | Hospital kitchen                                       |                  |        |        |
|     | Food counter                                           | natural/mechanical | 25     | 46     |
|     | Kitchen entrance door handle                          | natural/mechanical | 25     | 44     |
|     | Shelf surface and warehouse cartons                   | natural/mechanical | 25     | 45     |
|     | Floor (the front door, next to the shoe rack)          | natural/mechanical | 25     | 45     |
|     | Archive door handle                                    | natural/mechanical | 27     | 44     |
|     | Scales                                                 | natural/mechanical | 20     | 38     |
|     | Refrigerator entrance and exit door handles            | natural/mechanical | 20     | 48     |
|     | Refrigerator cooling system                            | natural/mechanical | 20     | 48     |
|     | Refrigerator wall surface                              | natural/mechanical | 20     | 47     |
|     | Air Fan                                                | natural/mechanical | 25     | 46     |
|     | Socket and switch                                      | natural/mechanical | 25     | 44     |
| 5   | ICU ward                                               |                  |        |        |
|     | Nursing station                                        |                  | 25     | 45     |

(continued on next page)
Table 2 (continued)

| No.  | Sampling site       | frequently-touched environmental surfaces | ventilation type | T (°C) | RH (%) |
|------|---------------------|-------------------------------------------|------------------|--------|--------|
| 6    | ICU2 ward           | Nursing station                           | natural/ mechanical | 28     | 44     |
|      |                     | Floor                                     | natural/ mechanical | 28     | 45     |
|      |                     | Laundry room                              | natural/ mechanical | 30     | 43     |
|      |                     | Ventilation systems (4)                   | natural/ mechanical | 27     | 45     |
|      |                     | Patient pillows                           | natural/ mechanical | 28     | 48     |
|      |                     | Door phone                                | natural/ mechanical | 25     | 47     |
|      |                     | Patient bed handle                        | natural/ mechanical | 26     | 45     |
|      |                     | Switches and sockets inside the section   | natural/ mechanical | 25     | 44     |
|      |                     | Pre-insolated switches and sockets         | natural/ mechanical | 28     | 44     |
|      |                     | Cell phone                                | natural/ mechanical | 25     | 44     |
| 7    | Surgery ward        | Nursing station                           | natural/ mechanical | 30     | 48     |
|      |                     | Patient bed handle                        | natural/ mechanical | 25     | 48     |
|      |                     | Console above the patient’s head          | natural/ mechanical | 25     | 48     |
|      |                     | air conditioner                           | natural/ mechanical | 23     | 45     |
| 8    | Emergency triage    | Patient bed                                | natural/ mechanical | 28     | 44     |
|      |                     | floor                                     | natural/ mechanical | 25     | 44     |
|      |                     | Socket and switch                         | natural/ mechanical | 28     | 46     |
|      |                     | Patient’s toilet fluid pedal              | natural/ mechanical | 25     | 42     |
| 9    | Hospital laundry    | Contaminated clothing table               | natural/ mechanical | 24     | 43     |
|      |                     | Internal surface washing                  | natural/ mechanical | 30     | 48     |
|      |                     | Blankets after disinfection               | natural/ mechanical | 32     | 45     |
|      |                     | Staff’s desk surface                      | natural/ mechanical | 28     | 47     |
| 10   | Internal ward of the hospital | door handle                                                         | natural/ mechanical | 27     | 43     |
|      |                     | wheelchair                                | natural/ mechanical | 24     | 44     |
|      |                     | Floor of the hall socket and switches     | natural/ mechanical | 25     | 45     |
|      |                     | Bed Pillow                                | natural/ mechanical | 27     | 48     |
|      |                     | Surfaces inside the refrigerator           | natural/ mechanical | 25     | 42     |

disinfectants.

As it can be seen in Table 4, SARS-CoV-2 could survive on inanimate surfaces including the nursing station, reception desk, cell phones, door handles, and floors for 5 min after using alcohol-based hand rubs (ethanol 70 %), while in the case of the reception desk, the presence of SARS-CoV-2 was positive after 15 min. With regard to sodium hypochlorite (0.001 %), SARS-CoV-2 could survive on inanimate surfaces including the nursing station, reception desk and the floors at both 5 and 15 min after disinfection, but not on cell phones and door handles. The materials of the inanimate surfaces including the nursing station, reception desk, cell phone, door handle and the floors were medium-density fiberboard (MDF), wood, plastic, stainless steel and ceramic, respectively.

The results demonstrated the capability of SARS-CoV-2 to persist on the tested inanimate surfaces against the two used disinfectants (Bloise et al., 2020; Noorimotlagh et al., 2020; Ong et al., 2020; Marzoli and Bortolami, 2021). On the other hand, it can be argued that the level of viral load of patients or infected people in the hospital was high and perhaps several times the amount of disinfectant should be used, especially on high-touch surfaces, to ensure that presence of SARS-CoV-2 on inanimate surfaces is negative. It can be hypothesized that SARS-CoV-2 can survive on different materials for different durations. As it can be inferred from the results of Table 4, that SARS-CoV-2 has more persistence on surfaces made from MDF, wood, and ceramic. In accordance with these results, Noorimotlagh et al. (2021) and Marzoli and Bortolami, 2021 have shown that the survival of SARS-CoV-2 depends on surface material and environmental conditions. (Noorimotlagh et al., 2020; Marzoli and Bortolami, 2021). Based on the obtained findings, it can be suggested that the interval between disinfection operations should be decreased and the disinfectants could be replaced with more efficient ones.

It should be noted that the previous studies are related to the typical SARS-CoV-2 (COVID-19). However, the results of this study correspond to the time that the variant of concern (VOC) 202012/01 (lineage B.1.1.7) had emerged in the hospital. Therefore, it can be concluded that this variant may have different traits, characteristics, and persistence compared with SARS-CoV-2. The results of this study can be used by other researchers to further investigate and determine the characteristics of this variant.

3.3. Estimation of plastic waste pollution during SARS-CoV-2 pandemic

Nowadays, plastic has an indispensable role in the daily life of human beings. Some studies have predicted that the current trend of production and use of plastics leads to a twofold increase in the amount of plastic debris including micro and nano-sized plastics, by 2030. Because of the increased production of plastic and related environmental challenges, one of the top priorities in the political agendas of Europe and the entire globe should be to reduce plastic leakage and pollution (Patrício Silva, Prata et al., 2020; Patrício Silva, Prata et al., 2021).

The SARS-CoV-2 pandemic has reemphasized the essential role of plastic in our lives, considering the excessive need and consumption of plastic materials including personal protective equipment (PPE) and other single-use medical equipment. Bearing this issue in mind, SARS-CoV-2 pandemic has severely disrupted all the policies concerning the increased level of plastic pollution in the world. Due to the excessive need and consumption of plastic materials during the COVID-19 pandemic, the amount of plastic waste production has been increased significantly and, in addition to the disease, it has intensified the potential negative effects of plastic debris in the aquatic and territorial environments, which impact the health of humans and wildlife (Patrício Silva, Prata et al., 2020; Saadat et al., 2020; Parashar and Hait, 2021; Patrício Silva, Prata et al., 2021). There are a few review studies regarding the increased plastic production and plastic waste management during the COVID-19 pandemic (Patrício Silva, Prata et al., 2020;
ever, they did not consider the PPE used by the operator of the RT-PCR machine, while in essence, that type of plastic residue must be included. Therefore, the total amount of disposable plastic generated by a single RT-PCR confirmatory test can be distinguished in three categories including sample collection, RNA extraction, and (RT) PCR amplification, while the PPE used by the personnel performing the (RT) PCR test should be included as well. According to the results of Table 5, the amounts of plastic waste in a single (RT) PCR confirmatory test in three stages of sample collection, RNA extraction, and (RT) PCR amplification are 31.893, 327.655, and 462.23 g, respectively. In total, it can be concluded that plastic waste for a single (RT) PCR confirmatory test for COVID-19 is 821.778 g of plastic residue/test. (Patrício Silva, Prata et al., 2020; Celis et al., 2021; Patrício Silva, Prata et al., 2021). To the best of the authors’ knowledge, this is the first experimental study that estimates the exact amount of plastic waste produced in a hospital during the confirmatory test (mainly RT-PCR) for COVID-19.

In this pandemic, the RT-PCR test is used as a diagnostic and a confirmatory test for the infected people. Table 5 summarizes a detailed classification of plastic waste in a single (RT) PCR test as a confirmatory test during the pandemic. As it can be seen in Table 5, the plastic waste in a single (RT) PCR confirmatory test can be distinguished in three categories including sample collection, RNA extraction, and (RT) PCR amplification, while the PPE used by the personnel performing the (RT) PCR test should be included as well. According to the results of Table 5, the amounts of plastic waste in a single (RT) PCR confirmatory test in three stages of sample collection, RNA extraction, and (RT) PCR amplification are 31.893, 327.655, and 462.23 g, respectively. In total, it can be concluded that plastic waste for a single (RT) PCR confirmatory test for COVID-19 is 821.778 g of plastic residue/test. It is worth noting that during the (RT) PCR confirmatory test, the operator is required to use PPE and, therefore, the plastic residues of the PPE should be included in the total amount of plastic residue. Recently, Celis et al. (2021) (Celis et al., 2021), investigated the plastic residues produced by the confirmatory tests for SARS-CoV-2 disease and reported that the amount of plastic residue per sample test by RT-PCR is 37.27 g. However, they did not consider the PPE used by the operator of the RT-PCR machine, while in essence, that type of plastic residue must be included.

Therefore, the total amount of disposable plastic generated by a single RT-PCR diagnostic test of SARS-CoV-2 and the PPE used by PCR operators is 821.778 g. Based on these calculations, a great attention should be paid to biomedical plastic waste management. It is reported that about 97 % of the biomedical plastic waste is incinerated, but due to their hazardous nature, toxic by-products such as dioxins and furans could be released into the environment. Therefore, in the plastic waste management programs, there are many challenges to overcome such as minimizing plastic waste, optimization of gas control technologies in incinerators, process redesign, reduction of single-use plastics and PPE, etc. (Patrício Silva, Prata et al., 2020; Celis et al., 2021; Patrício Silva, Prata et al., 2021).

### 4. Limitations

The present study suffers from several limitations. First, in this work, viral culture was not done to demonstrate viability. Second, not enough UK variant kits were available to perform all the diagnostic tests with them. Therefore, only two tests were conducted with the UK variant kit, and the other tests were performed by RT-PCR.

### 5. Conclusions

The present comprehensive study represents an important insight into the detection and persistence of the novel human SARS-CoV-2 (COVID-19) on high-touch environmental surfaces in a hospital. The results of this study are consistent with the findings of other researchers regarding the presence of SARS-CoV-2 on inanimate surfaces. They confirmed that samples taken from the frequently-touched environmental surfaces of different wards of the hospital such as the respiratory clinic, neurology, CT scan, kitchen, ICU1 & ICU2, surgery, emergency triage, laundry, and the internal ward, as well as the cell phones of the staff were positive for SARS-CoV-2. Therefore, understanding the possibility of infection transmission from inanimate surfaces in hospital wards is of utmost importance and it is necessary to determine the nature of the persistence of SARS-CoV-2. In the other section of this study, it was revealed that SARS-CoV-2 can survive on inanimate surfaces including the nursing station, reception desk, cell phones, door handles,

### Table 3

Comparison of the reported results of various literature on environmental surfaces of hospitals regarding the presence of SARS-CoV-2.

| Ref. | test origin | No of sample | T (°C) | RH (%) | No. of Positive (%) | Positive touched surfaces |
|------|-------------|--------------|--------|--------|---------------------|--------------------------|
| Wan et al. (2021) | China | 31 from single site | * | * | 60 (72.7 % of all positive cases) | fingertip of electrocardiogram (ECG) monitoring |
| Chia et al. (2020) | China | 245 | * | * | 125(56.7 %) | floor, bed rail, locker handle, and cardiac table |
| Ding et al. (2021) | China | 107 | * | * | 4(4 %) | ward door handle, bathroom toilet seat cover, and bathroom door handle |
| Moore et al. (2021) | England | 336 | 21-25 | 21-41 | 30(0 %) | Nurse call button, toilet door handle, bed rail, bed control, portable vital signs monitor, and cell phones |
| Jiang et al. (2020a,b) | China | 130 | * | * | 1(0.77 %) | Nursing station (keyboard) of isolation ward |
| Lee et al. (2020a,b) | Republic of Korea | 80 | 25 | * | 2(2.5 %) | door handle |
| Ong et al. (2020) | Singapore | 28 | * | * | 17(61 %) | toilet bowl, sink, and door handle |
| Colaneri et al. (2020) | Italy | 26 | * | * | 2(7.6 %) | plastic covering of the continuous positive airway pressure (CPAP) helmet |
| Dargahi et al. (2021) | Iran | 50 | 19-25 | 33-36 | 9(18 %) | COVID-19 word floor/trolley table, toilet/bed pan, CT scan of the floor, patient bed/room floor, bathroom door handles |

### Table 4

Persistence of SARS-CoV-2 on different inanimate surfaces after using the disinfectants.

| disinfectant type | inanimate surfaces |
|------------------|--------------------|
|                  | Nursing station | Reception desk | Cell phone | Door handle | Floor |
|                  | 5 min | 15 min | 5 min | 15 min | 5 min | 15 min | 5 min | 15 min |
| Alcohol-based hand rubs (ethanol 70 %) | positive | negative | positive | positive | positive | negative | negative | positive |
| Sodium hypochlorite, 0.001 % | positive | positive | positive | negative | negative | positive | negative | positive |

### Table 5

| Virus type | No of Positive (%) | Positive touched surfaces |
|------------|--------------------|--------------------------|
| SARS-CoV-2 | 60 (72.7 % of all positive cases) | fingertip of electrocardiogram (ECG) monitoring |
|            | 125(56.7 %) | floor, bed rail, locker handle, and cardiac table |
|            | 4(4 %) | ward door handle, bathroom toilet seat cover, and bathroom door handle |
|            | 30(0 %) | Nurse call button, toilet door handle, bed rail, bed control, portable vital signs monitor, and cell phones |
|            | 1(0.77 %) | Nursing station (keyboard) of isolation ward |
|            | 2(2.5 %) | door handle |
|            | 17(61 %) | toilet bowl, sink, and door handle |
|            | 2(7.6 %) | plastic covering of the continuous positive airway pressure (CPAP) helmet |
|            | 9(18 %) | COVID-19 word floor/trolley table, toilet/bed pan, CT scan of the floor, patient bed/room floor, bathroom door handles |

### Not reported.
and the floors for 5 min after disinfection by alcohol-based hand rubs (ethanol 70%), and in the case of the reception desk, the presence of SARS-CoV-2 was positive after 15 min. After disinfection by sodium hypochlorite (0.001%), SARS-CoV-2 could survive on inanimate surfaces including the nursing station, reception desk, and floors at both 5- and 15 min after disinfection, but not on cell phones and door handles.

The results of this study correspond to the time that VOC lineage B.1.1.7 was concluded that plastic waste for a single RT-PCR diagnostic test for SARS-CoV-2 variant of concern 202012/1: matched cohort study. BMJ 372, n579.

The present study was financially support by Shoushtar University of Medical Sciences (IR.SHOUSHTAR.REC.1399.049), which is greatly appreciated. We would also like to thank the healthcare personnel of the hospital complex at Shoushtar city, Khuzestan province, Iran.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Table 5

Detailed classification of plastic waste in a single (RT) PCR test as a confirmatory test during COVID-19 pandemic.

| NO. | Experimental step | Materials required | Application description | plastic (g/unit) | Quantity for a sample | Plastic (g/test) for a single test | Plastic type |
|-----|------------------|--------------------|--------------------------|------------------|-----------------------|-----------------------------------|--------------|
| 1   | sample gathering | 10 cm plastic swab | sampling                 | 1.04             | 1                     | 1.04                              | Polyester    |
|     |                  | 5 ml falcon tube   | sample transport         | 3.31             | 1                     | 3.31                              | Polypropylene|
|     |                  | surgical masks     | PPE                      | 3.35             | 1 for 24 samples      | 0.14                              | Polypropylene|
|     |                  | N95 Masks          | PPE                      | 6.23             | 1 for 24 samples      | 0.26                              | Polypropylene|
|     |                  | 15 ml falcon tube  | Laboratory sample transfer| 6.55             | 1                     | 6.55                              | Polypropylene|
|     |                  | Face shield        | PPE                      | 22               | 1 for 48 samples      | 0.458                             | Polycarbonate|
|     |                  | Isolation gowns    | PPE                      | 450              | 1 for 48 samples      | 9.375                             | Polypropylene|
|     |                  | Disposable gloves  | PPE                      | 10.76            | 1                     | 10.76                             | Polypropylene|
| 2   | RNA extraction   | 1000 µl plastic tip| Sample transfer into the falcon tube | 0.9              | 6 for 1 sample        | 7.2                               | Polypropylene|
|     |                  | 100 µl plastic tip | Reagent transfer         | 0.25             | 1                     | 0.25                              | Polypropylene|
|     |                  | 10 µl plastic tip  | sample homogenization    | 0.17             | 1                     | 0.17                              | Polypropylene|
|     |                  | safety box         | Secured container         | 200              | 2                     | 100                               | Polypropylene|
|     |                  | Plastic Eppendorf Tube 1.5 ml | Storing liquid samples | 0.73             | 2 for 1 sample        | 1.46                              | Polypropylene|
|     |                  | Plastic Eppendorf Tube 2 ml | centrifuging liquid samples | 0.82             | 5 for 1 sample        | 4.1                               | Polypropylene|
|     |                  | Face shield        | PPE                      | 100              | 1                     | 100                               | Polycarbonate|
|     |                  | Isolation gowns    | PPE                      | 150              | 1 for 48 samples      | 3.125                             | Polypropylene|
|     |                  | disposable gloves  | PPE                      | 10.76            | 5 pairs for 1 sample  | 107.6                             | Polypropylene|
|     |                  | Buffers’ plastic bottle | buffer container       | 88.7             | 4 for 100 samples     | 3.55                              | Terephalato de polietileno|
| 3   | (RT) PCR amplification | 1000 µl plastic tip | Sample transfer into the falcon tube | 0.9              | 2 for 48 sample       | 0.0375                             | Polypropylene|
|     |                  | RT-qPCR Vials      | Storing reagents of PCR  | 3.5              | 4 for 100 sample      | 0.04                              | Polypropylene|
|     |                  | 100 µl plastic tip | reagent transfer         | 0.25             | 2 for 48 sample       | 0.01                              | Polypropylene|
|     |                  | 10 µl plastic tip  | sample homogenization    | 0.17             | 1                     | 0.17                              | Polypropylene|
|     |                  | Plastic Eppendorf Tube 1.5 ml | storing liquid samples | 0.73             | 2 for 48 sample       | 0.03                               | Polypropylene|
|     |                  | safety box         | secured container         | 200              | 1 for 48 sample       | 4.16                              | Polypropylene|
|     |                  | 0.2 ml PCR tube strips | PCR applications       | 6.7              | 1                     | 6.7                               | Polypropylene|
|     |                  | Disposable gloves  | PPE                      | 10.76            | 2 for 48 sample       | 0.448                             | Polypropylene|
|     |                  | Isolation gowns    | PPE                      | 450              | 1 for 48 sample       | 450                               | Polypropylene|
|     |                  | Face shield        | PPE                      | 22               | 1 for 48 sample       | 0.458                             | Polycarbonate|
|     |                  | Face masks         | PPE                      | 9.58             | 1 for 48 sample       | 0.199                             | Polypropylene|

Credit author statement

Faezeh seif: Methodology, Validation, Writing - review & editing. Mojtaba Kalantar and Nozar Kalantar Fard: Methodology, Validation, Writing - review & editing. Barat Barati and Mahdi Emamian Fard: Methodology, Writing - review & editing. Zahra Noorimotlagh: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Supervision. Seyyed Abbas Mirzaee: Conceptualization, Methodology, Validation, Resources, Writing - original draft, Writing - review & editing, Project administration.

Acknowledgments

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and the floors for 5 min after disinfection by alcohol-based hand rubs (ethanol 70%), and in the case of the reception desk, the presence of SARS-CoV-2 was positive after 15 min. After disinfection by sodium hypochlorite (0.001%), SARS-CoV-2 could survive on inanimate surfaces including the nursing station, reception desk, and floors at both 5 and 15 min after disinfection, but not on cell phones and door handles. The results of this study correspond to the time that VOC lineage B.1.1.7 had emerged in the hospital; therefore, it can be concluded that this variant may have different traits, characteristics and persistence in the environment. The results of this study can be used by other researchers to further investigate and determine the characteristics of this variant. During the COVID-19 pandemic, the RT-PCR test was identified and used as a diagnostic and a confirmatory test for the cases of infected people. However, an increased level in plastic waste was inevitable. It was concluded that plastic waste for a single RT-PCR diagnostic test for COVID-19 is 821.778 g of plastic residue/test. It is worth noting that during the (RT) PCR confirmatory test, the operator is required to use PPE, and therefore, the plastic residue of the PPE should be also included in the total amount of plastic residue. Finally, overcoming certain challenges such as minimizing plastic waste, optimization of gas control technologies in incinerators, process redesign, reduction of single-use plastics and PPE, etc. are of utmost importance for improving plastic waste management programs.

Credit author statement

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