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Hospital wastewater in Iran: a systematic review and challenges for proper management during coronavirus disease (2019) pandemic

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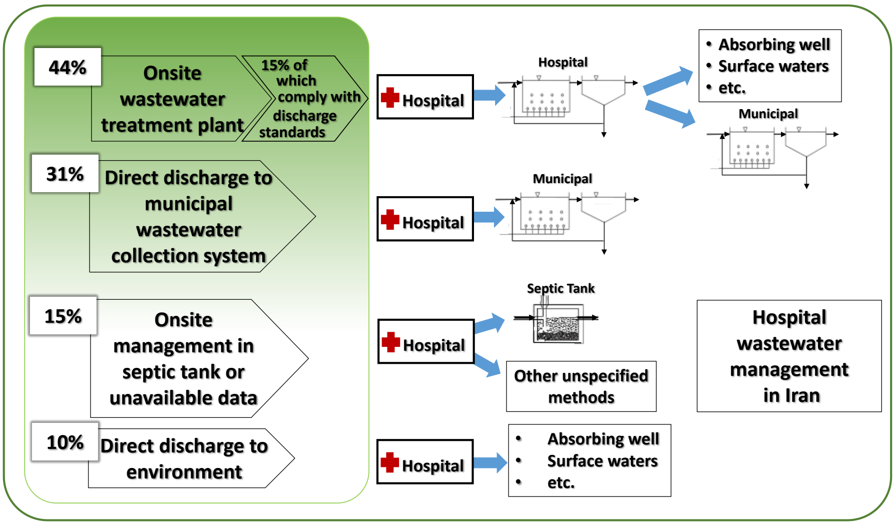
GRAPHICAL ABSTRACT



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ABSTRACT

Healthcare facilities are vital establishments to improve the public health, but with poor waste and wastewater management, may turn into a potential health risk. The fecal-oral transmission potential of SARS-CoV-2 and the role of the wastewater as a potential source of infection, more than ever highlights the importance of proper wastewater management during the COVID-19 pandemic. This systematic review represents a picture of the current state of hospital wastewater (HWW) management in Iran; an upper-middle income country with a paucity of proper data concerning HWW management and further provides suggestions for hospital wastewater management during COVID-19 pandemic in the country. We reviewed 31 papers that published from 2005-2020 evaluated 163 hospitals from 82 cities and 17 provinces. HWW generation in Iran varies from 354 to 1892 liter per bed per day (839±363 L/bed/d). BOD, COD and TSS in the raw HWW were in the range of 119-1270, 205-1611 and 58-464 mg/L, respectively. Total coliforms and/or total fecal coliforms were in the range of 10^5-10^8 (MPN/100 mL). 44.2 % of hospitals had an active WWTP at the time of the study from which, only 15.3 % complied with discharge standards. More than 55 % of the hospitals in Iran use no disinfection, and less than 7 % comply with the discharge requirements. HWW management in Iran is very poor and there has been no improvement in HWW management within the last decade. To best respond to this pandemic, responsible authorities should address wastewater management in hospitals.

1. Introduction

As of May 2021, the number of confirmed deaths of the novel coronavirus has reached to 3.2 million (ISC COVID-19 Visualizer 2021) and is still increasing. While the proper management of wastewater is always vital to ensure the public health, the new concerns are raised during COVID-19 pandemic. Although the main routes of transmission are through direct contact with infected person or respiratory droplets (WHO and UNICEF 2020), the potential health risks of COVID-19 in sanitation systems, especially to wastewater treatment plants workers are likely to be of concern (Zaneti et al. 2021). Based on WHO interim guidance, the risk of the fecal-oral pathway for SARS-CoV-2 appears to be low and there is no report of detecting infectious SARS-CoV-2 in sewage (WHO and UNICEF 2020). Liu et al. 2020 reported a list of the recent publications that could detect SARS-CoV-2 in wastewater in 130 samples from 10 countries. Most of the positive cases are reported in untreated municipal and HWW. However, the evidence of transmission of COVID-19 via infected wastewater is limited and not fully understood. HWW is a complex mixture of various pathogens, pharmaceutical residues, and chemical and organic compounds with

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different potential health risks; Khan et al. 2020). Contaminants of greatest concern are pathogens (Zhang et al. 2020), antibiotics and pharmaceutical residues as their concentration is high in HWWs (up to five times higher than urban wastewaters; Carraro et al. 2016). Antibiotic-resistant bacteria and genes are also a source of risk in HWWs (Verlicchi et al. 2015). While the quality of wastewaters of some hospitals may be similar to domestic wastewater (Carraro et al. 2016; Mesdaghinia et al. 2009), its characteristics can be quite various among different communities and countries (Giannakis et al. 2017b). COD and BOD in HWW may be about 2.5 times higher than municipal wastewater. The plaque-forming unit (PFU) counts for noroviruses and adenoviruses in HWW are also reported to be about 4 logs higher than municipal wastewater (Giannakis et al. 2017b). Several lines of evidence suggest that organic matter and suspended solids present in wastewater may protect and influence the survival of the virus (Mandal et al. 2020). Since the content of suspended solids is also reported to be higher in HWWs (Giannakis et al. 2017b), its proper management is a priority to protect the public health. The wastewater discharge of those hospitals lacking appropriate treatment would increase the infection risk to public health. The pollution load of HWWs found to be 5-15 % higher than other sources and conventional wastewater treatment processes usually are not able to sufficiently remove emerging contaminates (Khan et al. 2021) and pathogens (Carraro et al. 2016). Therefore, the contaminants in HWW can scape wastewater treatment plants and contaminate the environment (Khan et al. 2021).

There is no thorough study or nationally available data on HWW quality and management practices in Iran. To our best knowledge, the research by Verlicchi et al. is the only review that briefly mentioned HWWs in Iran. However, their review is based on three papers and cannot be assumed as representative of the country's situation. Therefore, under COVID-19 pandemic in Iran, it is necessary to reduce the health and environmental risks. This short review systematically summarizes the current state and practices of HWW treatment in Iran according to the published studies and available data, and further focuses on the challenges in Iran as a middle-income country. In addition, the treatment methods with a potential for virus removal are briefly reviewed. This review also provides suggestions for HWW treatment during COVID-19 pandemic, which can be of great importance for other similar middle-income countries to find the appropriate treatment and disposal methods compatible with their conditions.

This study has two main sections. In the first section, we briefly summarized results of the recent works and review papers investigated the effective technologies to remove viruses from wastewater. T he survival and occurrence of coronavirus in wastewater are also presented in this section. The second section is a systematic review to evaluate the wastewater treatment practices within hospitals across the country.

2. Methods

Methodology of the second section of this study is explained in the following paragraphs.

2.1. Search strategy

Both international and national databases namely, Google Scholar, Scopus, Magiran (https://www.magiran.com/), Scientific Information Database and SID (https://www.sid.ir/) were used to find the published works from 2005 to 2020. Most of the publications on HWW treatment in Iran are in Persian, with few studies in English. The reviewed papers are summarized in Table 1. We used the following keywords to find the studies in accordance with the objectives of this research: “hospital wastewater”, “treatment”, “virus removal”, “virus”, “wastewater treatment” and “Iran” alone or in combination with “OR” and/or “AND”.

2.2. Screening process

The abstract and/or conclusion of all the retrieved articles were assessed to identify the pertinent studies, and duplicate papers were removed. Next, the texts were skimmed to select the articles that comply with the inclusion criteria. We considered the following eligibility criteria in this review for investigating the HWW treatment in Iran:

-Published full-text articles in Persian or English that studied the quality of a HWW in Iran.

-The studies that monitored the quality of a HWW by direct sampling and analysis and/or evaluated the wastewater management through questionnaires and surveys.

-Papers that evaluated the performance of a full-scale treatment plant of HWW. Pilot-scale studies were excluded.

-Studies reported at least one of the following wastewater quality parameters: BOD, COD, total coliforms/total fecal coliforms.

-Studies that mentioned the name of the city where the hospital was located. Where the authors did not mention the name of the hospital(s), the article was included if there was enough information (e.g. numbers of beds, type of hospital, etc.) to distinguish between different hospitals studied in the same city.

2.3. Data extraction and analysis

The reviewers extracted data from the final 31 relevant articles. Any water adversely affected in quality during provision of healthcare services (WHO 2018) is considered as HWW. However, for the purpose of this study, we mainly considered wastewater from wards and patients (excluding wastewater produced during cooking and laundry), unless the wastewater from different parts of the hospital is mixed and managed in the same way. The following descriptive information were extracted from the articles: title, author(s), year of publication, name of the hospital (city), number of active beds, per capita wastewater generation, treatment system, disinfection method(s), discharge method (after treatment for hospitals that have a WWTP and direct discharge for others), BOD, COD, total coliforms and fecal coliforms for influent and effluent, compliance with national standards and sludge management. The third reviewer performed the final inspections on the extracted data to distinguish and resolve any conflict. Finally, the studies were analyzed according to the following questions to assess the performance of treatment activities for HWW across the country:

-How much are the volume of wastewater and per capita generation rate in hospitals?

-How much are the organic load and microbial pollution of the wastewater hospitals?

-How many hospitals have a treatment plant and/or any disinfection method for wastewater treatment?

-How many hospitals do not have any treatment plant?

-in hospitals without a treatment plant, where is the wastewater discharged to?

In case of the hospitals assessed in two or more studies, the most recent data was considered and duplicates were removed, unless the former was more complete.

3. Hospital wastewater in the context of coronavirus

3.1. Coronavirus in wastewater, survival and infectivity

SARS-CoV-2 is a spherical particle of about 100 nm diameter (60-140 nm (Gonçalves et al. 2021)) and its positive-sense RNA is embedded in a fragile lipid envelope (Nghiem et al. 2020). The morphology and chemical structure of SARS-CoV-2 are similar to other coronaviruses (including SARS (severe acute respiratory syndrome coronavirus) (WHO and UNICEF 2020). It is implied that coronavirus in wastewater is relatively short-lived. The life span of SARS-Cov-2 in sewage and solid feces is reported to be 3 and 3-4 days, respectively (Nghiem et al. 2020). The genetic similarity between SARS-CoV-2 and SARS-CoV-1 and the reported fecal-oral transmission potential of this virus (Nghiem et al. 2020), puts an emphasis to consider a similar potential transmission pathway for SARS-CoV-2, and the role of the wastewater as a potential source of infection. Wastewater aerosols are previously reported as a highly probable transmission route of SARS (Nghiem et al. 2020). WHO interim guidance cited some reports that RNA fragments of SARS-CoV-2 were detected in untreated sewage and sludge samples around the same time the first positive cases reported, and increased with the number of confirmed cases (WHO and UNICEF 2020). Gonçalves et al. 2021 recently detected the RNA in a HWW in Slovenia using RT-qPCR. They reported that 10 kDA centrifugal filters can be a successful method to concentrate SARS-CoV-2 RNA from wastewaters (Gonçalves et al. 2021). The idea was to use the presence of SARS-CoV-2 RNA as an early warning for COVID-19 infections and a potential indicator for the public health monitoring of a population, known as wastewater-based or sewage epidemiology (WBE). There are publications that reported some correlations between SARS-CoV-2 RNA concentration in wastewater and the COVID-19 positive patients (Randazzo et al. 2020). In one case, researchers reported a correlation between the presence of SARS-CoV-2 viral genome in untreated wastewater samples and the increased number of COVID-19 positive patients in Jaipur, India (Arora et al. 2020). Nevertheless, this potential tool (WBE) seems to be still in preliminary stages and requires more studies. Developing easier and cheaper methods may accelerate the use of WBE. A potential case is briefly reported in china that the broken sewer from the apartment of a patient caused the transmission of the SARS-CoV-2 to other households (Liu et al. 2020). The inhalation of aerosolized fecal matter during management and treatment of wastewater/sludge or in public toilets, is also considered as a possible pathway (Yang et al. 2020). However, to our knowledge, there is not any other published evidence for secondary transmission of SARS-CoV-2 via wastewater. While the virus is detected in fecal of infected patients, it is shown that the load of the virus is not infectious (Gonçalves et al. 2021). In case of SARS-CoV-1, the transmission of virus through wastewater plumping system is previously reported in an apartment complex in Hong Kong. Viral aerosols in building plumbing system were believed to transport through floor drains to the bathrooms and further spread to adjacent buildings by winds (McKinney et al. 2006). The risk of exposure to bio-aerosols generated during wastewater treatment is estimated to be negligible to surrounding habitants for noroviruses. However, as slightly higher noroviruses concentrations are detected inside the WWTPs, the possibility of health risks due to airborne exposure cannot be excluded for WWTP workers (Uhrbrand et al. 2017). Although there is no indication of fecal-oral transmission of the COVID-19 through wastewater, the importance of using personal protective equipment for personnel who handle and are exposed to the untreated waste mater has been emphasized in international guidelines (WHO and UNICEF 2020). A quantitative microbial risk assessment on the potential health risks of the COVID-19 to WWTPs workers revealed that when the SARS-CoV-2 concentration in sewage was more than 2.28×10^{3} $GC.mL^{-1}$ (genome copies per *mL)*, the estimated risks were likely to be above the WHO benchmark value (10^{-3}) (Zaneti et al. 2021). Therefore, it is important for sanitation workers to access to proper training and personal protective equipment (PPE) (WHO and UNICEF 2020).

3.2. Wastewater treatment and disinfection methods for virus removal

The wastewater treatment system of a hospital typically comprises the collection system, treatment and disinfection units. The different treatment and disinfection methods reported or reviewed in different studies are summarized in Table 1. Ozone, ultraviolet irradiation (UV), liquid chlorine, chlorine dioxide, and sodium hypochlorite disinfections are commonly used methods for HWW disinfection (Chen et al. 2014; Lizasoain et al. 2018; Yu et al. 2014). There are several studies on wastewater treatment methods that considered different viruses as a target. For example Giannakis et al. 2017b reviewed the use of light assisted advanced oxidation processes (AOPs) for elimination of viruses in urban and HWWs. While the UV/H_2O_2 or photo-Fenton process are reported to effectively inactivate some viruses (studied on MS2 bacteriophage model virus) (Giannakis et al. 2017a) (Giannakis et al. 2017b), their application is still limited in pilot scale studies. Therefore, the concentration here is mostly on treatment/disinfection methods and technologies that showed successful results at full-scale studies.

Since SARS-CoV-2 is less stable in the environment compared to non-enveloped human enteric viruses with known waterborne transmission (like adenoviruses, norovirus, rotavirus and hepatitis A) (WHO and UNICEF 2020), the treatment technologies that reported to be effective for non-enveloped enteric viruses are assumed to be effective for COVID-19 as well. Conventional secondary treatment methods such as, natural oxidizing lagoons and rotating biological disks are reported to be ineffective for human astroviruses (non-enveloped positive-sense) removal from HWWs that contain a high pathogenic load (Ibrahim et al. 2017). Therefore, a disinfection method is necessary for HWW treatment to comply with discharge requirements.

Mandal et al. 2020 specifically reviewed some disinfection/removal technologies that are reported to be effective in removing SARS-CoV-2. Wang et al. 2020 also reviewed disinfection technologies for HWW and provided a selection diagram based on the scale of the hospital, costs of the method and complexity of the maintenance. Although the small or large hospitals are not defined by the authors, and the efficiency of the methods is not studied in case of SARS-CoV-2, the diagram (Wang et al. 2020) may be used as a primary decision guide. Table 1 summarizes the main results of the two reviews along with some other reported methods.

4. Hospital wastewater in Iran

There are no international data on wastewater collection and sanitation in case of Iran (United Nations, 2017). Reliable national statistics on wastewater treatment in the country are also rare. The only national statistics are based on Iran statistical yearbook (2016) published by the statistical center of Iran (SCI). The most recent version of the report updated in 2016 and the section about HWW treatment may not be published anymore (SCI 2018; SCI 2016). Around 51 % of the population has access to wastewater collection and removal services (2018), and 77.6 % of hospitals reported to have appropriate wastewater management (2016), though “appropriate management” is not defined in the SCI report.

Table 1. Treatment/disinfection technologies for hospital wastewater treatment.

Disinfection/treatment method	Removed virus	Notes	Reference
Chlorine	SARS-CoV, BJ01	40 mg/L of chlorine in 10 min is enough to inactivate SARS-CoV and Escherichia Coli, but cannot completely inactivate bacteriophage f2.	(Mandal et al. 2020)
Chlorine dioxide	Not specifically mentioned, general suggestion for microorganisms including bacteria and viruses.	Double siphon automatic fixed-ratio dosing chlorine system is usually required for disinfection by chlorine dioxide.	(Wang et al. 2020)
Sodium hypochlorite	Not specifically mentioned, general suggestion for microorganisms including bacteria and viruses.	Double siphon automatic fixed-ratio dosing chlorine system is usually required for disinfection by sodium hypochlorite.	(Wang et al. 2020)
Ozone	Not specifically mentioned, general suggestion for microorganisms including bacteria and viruses.	Suitable for smaller scale wastewater treatment systems with high effluent quality. For a 300 beds hospital, it is suggested to use an ozone treatment system with capacity of 18 t/h to 20 t/h wastewater treatment.	(Wang et al. 2020)
Ultraviolet irradiation	Not specifically mentioned, general suggestion for single-celled microorganisms including bacteria and viruses.	The wavelength in range of 200-300 nm is suitable for disinfection (the optimal wavelength is believed to be 253.7 nm).	(Wang et al. 2020)
Membrane bioreactor (MBR), nominal pore size of 0.04 µm	Enteric viruses (HAdV, EV and NoV)	Studied for municipal wastewater. Average removal values for HAdV, EV and NoV GGII of 5.5, 5.1 and 3.9 log units, respectively achieved.	(Simmons et al. 2011)
MBR, nominal pore size of 0.04 µm	Adenovirus, norovirus genogroup II	It is studied for municipal wastewater. MBR can reliably provide more than 4 logs of removal for the mentioned viruses.	(Chaudhry et al. 2015)
On-site disinfection of fecal material with sodium hypochlorite	Not studied, generally suggested based on the authors' experience	Suggested for newly added COVID-19 inpatient wards, or in cases that wastewater system of the infectious wards is not separated from other wastewater systems	(Liu et al. 2020)
Increasing the temperature of wastewater treatment by 5-10 ºC in cold periods as a temporary measure	Not studied, generally suggested based on the authors' experience	Where using other disinfection methods is not possible. Suggested for middle to high latitudes, electrical or steam heating equipment can be used. Precautionary principals regarding the warm vapor and	(Liu et al. 2020)

aerosols should be addressed and wearing personal protective equipment for operators is necessary.

In Iran, the ministry of health and medical education (MOHME) is responsible for HWW management. It seems, when there is a lack of quantitative data and statistics in other vital parts of the healthcare system, wastewater and environmental management in hospitals are not a priority for authorities. MOHME published a guideline for water, wastewater and waste management during COVID-19 pandemic that is a translation of WHO and UNICEF on water, sanitation, hygiene and waste management for COVID-19 technical brief on 3 march 2020. At the time of writing this study, this guideline is the only national document in the field in response to the COVID-19 pandemic. There also exists another national guideline, inclusively for HWW management, that published in 2012 by MOHME. Chlorination (in the form of chlorine gas, calcium hypochlorite and sodium hypochlorite) is the most important disinfection method suggested in this guideline (“A guide to hospital wastewater management” 2012). The performance of WWTPs is usually determined through comparison between physical, chemical and biological parameters of effluent and national discharge standards of the Department of Environment (DOE). DOE standards for each application (landscape irrigation, agriculture, industrial processes, discharge to surface waters and discharge to absorbing wells (soakaway)) define the microbial pollution thresholds based on the number of total coliforms, total fecal coliforms, Escherichia coli, Enterococcus and intestinal parasites including the number of nematode eggs (Ascaris, Trichuris and hookworms). Nonetheless, there is no indicator and threshold for virus contamination in wastewater in Iranian national standards. Moreover, no comprehensive national study has been done on hospital wastewater, its quality, quantity, current treatment, management and discharge methods and the compliance with national standards. The only research carried out in twelve years ago, which studied 70 governmental hospitals in ten provinces of Iran. It revealed that most of the well-known hospitals (52 %) did not have any wastewater treatment system, and the treatment system at other hospitals was not efficient (Majlesi Nasr and Yazdanbakhsh 2008). We did not consider this study in our review since the details of the hospitals are not provided by the authors. There are also some cross-sectional and/or regional studies that investigated the wastewater management in some hospitals. Table 2 shows the 31 papers we reviewed here. It also represents the results of the evaluation of hospital wastewater in 163 hospitals from 82 cities and 17 provinces. Based on the studies reviewed here, 44.2 % of the hospitals had an active WWTP at the time of the study from which, only 15.3 % (6.8 % of the total hospitals) are reported to comply with DOE discharge standards (Table 2). Compliance with the discharge requirements was checked by the reviewers or reported by the authors. In some cases, the authors evaluated the performance of the plant based on limited parameters (BOD, COD, and TSS). While this does not necessarily suggest that the effluent comply with the standards, they are considered as compliance cases. In Iran, 55.8 % of the hospitals did not have any treatment plant however; nearly half of those (55 %) were connected to the municipal wastewater collection system. This is different from the report of Verlicchi et al. at who concluded that discharge into public sewage system and co-treatment with urban wastewaters is the general practice in Iran (Verlicchi et al. 2015). For the hospitals without a treatment plant, 17.6 % (around 10 % of the total hospitals) discharged their wastewater directly to the environment through absorbing wells or to the surface water sources, while the others had a septic tank or the authors did not mention the discharge method. Some hospitals had a WWTP, but it was not active (in some cases from the first day of opening the hospital) due to different reasons, including improper operation and maintenance, insufficient financial resources for wastewater management, lack of skilled operators in hospital treatment facilities, improper design and construction of treatment plants.

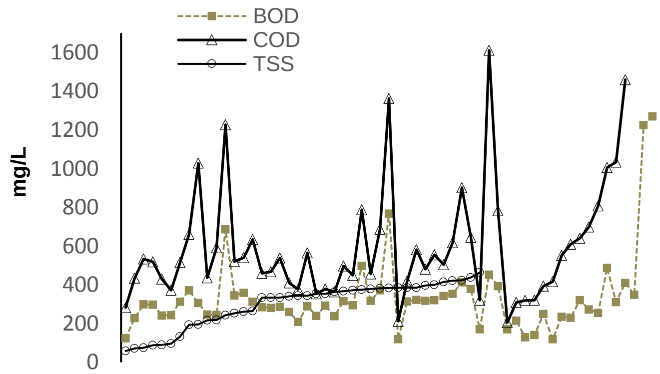
Table 2. The summary of the studies reviewed here.

Reviewed articles	Year of publication	Number of cities (hospital locations)	studied hospitals*	hospitals with active wastewater treatment plant	hospitals comply with discharge standards	Hospitals without treatment plant that are connected to municipal wastewater collection system	Direct discharge to the environment without treatment (absorbing well/surface waters)	Wastewater generation (L/bed/d)
Khorsandi et al.	2005	1	1	1	0	0	0	-
Yousefi and Ghoochani	2005	1	3	3	N.A.	0	0	-
Sarafraz et al.	2006	4	7	1	1	N.A.	N.A.	-
Binavapour et al.	2007	1	1	1	0	0	0	586
Nazemi et al.	2009	1	1	1	0	0	0	-
Mahvi et al.	2009	7	7	7	1	0	0	-
Ghavidel et al.	2009	1	3	2	0	0	1	-
Mesdaghinia et al.	2009	1	4	4	0	0	0	696-1090
Dehghan Kang Zeiton et al.	2010	1	4	4	1	0	0	546-1692
Âmouei et al.	2010	1	4	4	0	0	0	370-716
Ghanadzadeh et al.	2010	10	11	2	1	2	5	-
Teimouri et al.	2010	1	1	1	0	0	0	870
Khalesidoost et al.	2011	1	1	1	1	0	0	1641
Mahmoudkhani et al.	2012	1	13	13	2	0	0	750-1500
Shahryari et al.	2012	1	1	1	0	0	0	-
Taghizadeh et al.	2013	21	31	0	0	18	N.A.	-
Ghafouri Safa et al.	2014	1	3	0	0	3	0	-
Sadat Taghavi et al.	2014	1	1	1	1	0	0	-
Mazlomi et al.	2014	1	7	0	0	7	0	-
Kebriaei et al.	2014	1	1	1	0	0	0	1892
Tashi et al.	2014	1	1	1	0	0	0	618
Fahiminia et al.	2015	1	8	0	0	3	5	360-910
Takdastan et al.	2016	1	1	1	1	0	0	787
Almasi et al.	2016	1	3	3	1	0	0	-
Azizi et al.	2016	19	31	9	N.A.	17	3	-
Mollaie Tavani et al.	2017	1	1	1	0	0	0	550
Alamshah et al.	2017	1	1	1	0	0	0	354
Hashemzadeh et al.	2017	1	1	1	1	0	0	650
Heydari et al.	2019	1	1	1	0	0	0	723
Akya et al.	2020	1	1	1	0	0	0	-
Karimi et al.	2020	7	9	5	N.A.	0	2	688-705

* Duplicate hospitals are removed and other eligibility criteria applied.
N.A.: Data not available.

Typical water consumption in hospitals is estimated to be 200-1200 L/bed/d accompanied by an equal amount of wastewater (Khan et al. 2021). HWW generation in Iran is higher and varies from 354 to 1892 liter per bed per day (839±363 L/bed/d). The average HWW generation in high-income countries is higher than countries with lower income levels and is reported to be 730 L.patient^{-1}.day^{-1} (Majumder et al. 2020).The quantity of HWW production depends on the number of beds, types and number of wards and management policies (Khan et al. 2021). The quality of raw hospital wastewater was very variable in different hospitals over the country. Figure 1 shows the ranges of three parameters in raw HWW for each reported hospital. BOD, COD and TSS were reported to be in the range of 119-1270, 205-1611 and 58-464 mg/L, respectively. These are comparable with the results of Khan et al. that reported the typical range of TSS, BOD and COD in hospital wastewater is 11-900, 80-1530 and 150-2664 mg/L, respectively (Khan et al. 2021).

There exists no national indicator or standard for viral contamination of wastewater. The investigated indicator for microbial pollution of wastewater was total coliforms and/or total fecal coliforms, which were in the range of 10^5-10^8 (MPN/100 mL). It is demonstrated that common bacterial indicators are not reliable for detecting pathogen contamination of hospital wastewaters (Carraro et al. 2016). Other wastewater parameters including suspended solids, organic matter and temperature are also important in the infectious characteristics of the wastewater. It is reported that suspended solids may shield and protect the virus and may need higher doses of disinfectants. However, increasing the dose of disinfectants may lead to formation of disinfection byproducts and ecological risks (Mandal et al. 2020). Hence, it is of great importance to effectively treat the wastewater and decrease the organic load (BOD, COD) and TSS content of the wastewater before the disinfection process.



	BOD	COD	TSS
Range, mg/L	119-1270	205-1611	58-464
Mean, mg/L	336.3±207.3	594.2±297.7	298±118.5

Fig. 1. BOD, COD and TSS in raw hospital wastewaters across 59 hospitals in Iran.

Extended aeration activated sludge was the most common treatment used for hospital wastewater. In few cases, other biological methods are reported. Conventional activated sludge and integrated fixed film activated sludge are other reported methods, and chlorination was the only disinfection method used in the hospital WWTPs. There exists no disinfection in hospitals without a WWTP and few of those that had one. In few cases the researchers reported the free chlorine residual and it was in the range of 0- 1 mg/L (Âmouei et al. 2009; Mollaie Tavani et al. 2017; Sadat Taghavi et al. 2014; Yousefi and Ghoochani, 2005). The problems of chlorination unit and its inefficiency was a common reason for high microbial load of the effluent, even in some hospitals with a proper and efficient treatment plant. In some cases, the researchers did not mention the disinfection method, nevertheless it can be said that more than 55 % of the hospitals in Iran discharge their wastewater into the environment without any disinfection. Previous studies reported no disinfection in 57 % of the hospitals (Majlesi Nasr and Yazdanbakhsh 2008).

Accordingly, there has been no improvement in hospital wastewater management within the last decade, which inevitably would lead to a complicated environmental and public health issue in long-term and requires serious attention, especially during COVID-19 pandemic. A study in some hospitals of Tehran suggested the discharge into municipal wastewater collection system as the best wastewater management method for the hospitals under study (Mesdaghinia et al. 2009). This approach is not applicable to all hospitals, as nearly half of the country's population do not access to the municipal wastewater collection. On the other hand, conventional wastewater treatment plants are not suitable for complete removal of pathogens from hospital wastewaters (Carraro et al. 2016). This approach may be appropriate only for large municipal wastewater systems where hospitals represent a small fraction of the sewage. The best option for HWW management can be different depending on the size of the hospital, the type of healthcare services, available resources, receiving waters and must be defined based on a technical and economical feasibility study (Verlicchi et al. 2015). Currently extended aeration activated sludge is widely used in the hospitals and is a well-known technology in the country. Therefore, with a chlorination unit and a trained operator, it may be the most simple and common approach for hospital wastewater treatment. In those hospitals that installation of a WWTP and connection to the municipal wastewater collection system is not possible, two-chamber septic tank with a lined soakaway is suggested as a minimum approach to wastewater management (WHO 2018). The potential use of MBRs instead of activated sludge is another possible approach that needs more investigations. MBR showed promising results against enteric viruses (Table 1) and is considered as an alternative for conventional activated sludge treatment (Craun and Calderon 2006). Since MBR technology could remove the SARS-CoV-1 about 2 log units, compared to more than 5 log removal of bacteria (Craun and Calderon 2006), installing a disinfecting unit is still required. Segregation and special treatments are recommended for special wastewaters generated in radiology wards, and also wastewaters from laundries, oncological wards and clinical analysis laboratories (Verlicchi et al. 2015). Special care is also required to proper TSS removal from HWW during outbreak of SARS-CoV-2, as viruses may settle on the suspended matters and become highly stable (Majumder et al. 2020).

To choose the best type of a disinfection technology, comprehensive consideration of both economic and feasible factors are necessary. Factors such as the amount of wastewater, safety conditions, the supply of disinfectants, the distance between the wastewater treatment system and the ward as well as the residential area, investment and operation costs and operation management level should be considered (Wang et al. 2020). However, based on the current conditions and considering the technical limitations, chlorination is likely the most applicable method for hospitals of Iran, which is the only disinfection method reported in hospital WWTPs across the country.

5. Conclusions

On average, hospitals in Iran generate higher volume of HWW in comparing to hospitals in high-income countries. As the country is suffering water crisis, hospitals should revise their management strategies accordingly. Hospital wastewater management in Iran is poor and national discharge standards are usually violated by hospitals, posing a threat to the public health and the environment. Less than 7 % of hospitals across the country complied with the discharge requirements. Most of the hospitals in Iran did not have an onsite WWTP and around 10 % of hospitals discharged their wastewater directly to the environment without any treatment. Lack of economic resources and inefficient environmental management are important reasons for this national challenge. WWTPs in some hospitals were not active from the first days of the construction, while in few other cases, the plant was active for some few months/years and then shut down due to several operational problems. The evaluation of those hospital WWTPs that were working properly showed that conventional treatments and a common disinfection method could be enough in most cases as long as there existed proper operation and maintenance in the treatment plant. Some specialized hospitals may need more advanced treatment methods based on their wastewater characteristics. While the current national standards developed based on common bacterial indicators and are not reliable for detecting viruses in the HWWs, comply with them can be considered a minimum acceptable level of management. Obviously, further improvements are expected through upgrading the current hospital WWTPs to remove the emerging contaminants and developing stricter discharge standards. Healthcare facilities are vital establishments to improve the public health, but with poor waste and wastewater management, may turn into a potential health risk. SARS-CoV-2 is detected in HWW in different countries and direct discharge and/or improper treatment of HWW may lead to additional challenges and health risks during COVID-19 pandemic. Proper operation of the hospital WWTP and controlling the TSS, COD and the coliforms along with other parameters below the discharge limits would reduce the health concerns during pandemics.

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Nomenclature

BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
HWW	Hospital wastewater
MBR	Membrane bioreactor
SARS	Severe Acute Respiratory Syndrome
TSS	Total suspended solids
WEAP	Water evaluation and planning system
WWTP	Wastewater treatment plant

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