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RESEARCH ARTICLE

Managing urban wastewater to fight the pandemic of COVID-19 effectively

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Abstract: The paper reveals the role of wastewaters in the spread of Coronavirus in cities and focuses on the need for collection, treatment, and management of wastewaters. While the focus of the fight against COVID-19 is on the production of vaccines, drugs and treatments, this article emphasizes the cleanliness of the environment with wastewater management. This paper is a novel work, since it presents a multi-side research concerning fighting against coronavirus through wastewater collection and treatment. Studies show that coronavirus exists in urban wastewaters and spread the COVID-19 everywhere. Coronavirus is attacking people globally and shrinking the economy. The question addressed by this paper is; will communities overcome the coronavirus without well-collected and treated wastewaters? The methods to achieve the goals are theoretical surveys, case study strategy, mathematical modeling, statistical procedures, forecasting the future, and discussions. A mathematical model will be built to calculate the number of deaths caused by the coronavirus with the help of registered statistics and predict the future trend of the disease pandemic in Iran. Since Coronavirus has been seen in wastewaters, results of this research demonstrate the need for carefully collected and treated wastewaters to overcome the coronavirus. This paper gives suitable techniques to treat wastewater as stabilization ponds, bacterial reactors, and anaerobic ponds. Concluding, this paper suggests indicators to select a wastewater treatment technique in every city, and its outcome will assist the global community in fighting the coronavirus more successfully.

Keywords: COVID-19, wastewater treatment techniques, mathematical model, bacterial reactors, anaerobic ponds

1 Introduction

COVID-19 is an infectious disease caused by a newly discovered coronavirus [1, 2]. Coronavirus is an enveloped positive-sense RNA virus, which is characterized by club-like spikes projecting from its surface. Although coronavirus is commonly associated with acute respiratory infections in humans, its ability to infect multiple host species and various diseases makes it a complex pathogen [3]. Scholars declared COVID-19 as a massive health, humanitarian and development crisis. The pandemic is moving like a wave leaving in deaths and weakening economies globally [4]. Newly, researchers declared that wastewaters include coronaviruses [5, 6]. Scholars have shown that coronavirus exist in Stockholm municipal wastewater [7]. In wastewaters, the amount of coronavirus had become doubled in weeks. It reached the same amount as of May 2020. New findings confirmed that wastewater analyzes could warn concerning future virus outbreaks [7]. The coronavirus attack on the people of the world came as a surprise [8]. The coronavirus emerged when states stopped prioritizing public health care and medical services and had policies of austerity and privatization [9].

The policies with considerable cuts to social expenditures, including medical care and public health services and the privatization of health services, imposed by many governments, considerably weakened the capacity of the response to the coronavirus pandemic in the world. The coronavirus emerged when the world was proud of its scientific and medical advances in recent decades. Humankind controlled some dangerous infectious diseases earlier. People thought that would overcome any epidemic disease easily. However, the COVID-19 has created a huge distraction globally to the health care system and community development. The outbreak has laid bare deficiencies in the public health system [10]. The coronavirus emerged when class and income differences between social groups and individuals in societies approached higher rates than ever before.

As the world struggles to deal with the COVID-19 pandemic, stark inequalities in societies have become evident yet again [11]. Scholars recommended environmental procedures, accelerated action for habitat protection, sustainable and affordable clean energy and reversal of global heating as social equitable policies [12].

Because of the extremely market-oriented and unjust policies, many people lost access to health products (such as masks, alcohol, disinfectant solutions, etc.), medical devices (such as ventilators, refrigerants, oxygen capsules, etc.), and medicines that help the patient [13]. It suggested balancing the supply and demand of disinfectants and alcohol during the crisis. Social inequality has created a densely populated urban neighborhood with running sewage in urban neighborhoods. For this reason, some scholars have recently stressed the need for new standards and dimensions in the architectural design of buildings, passages and urban spaces in the post-COVID-19 era [14].

Worse, local and regional, disputes, conflicts, and wars in some countries took over economic resources and people in the countries have been left defenseless against the COVID-19 essentially [15]. Worst of all, lack of information, statistics and awareness for people in low-income areas has led to the expansion of the disease.

To formulate policies at mitigating the adverse health and economic impacts of the COVID-19, experts need reliable and timely data and estimates of the circumstances faced by individuals and households [16]. Unfortunately, the results of information communication technological advances in the monopoly of tyrannical governments have prevented the spread of information on the casualties of COVID-19 [17]. In the situation, problems such as lack of safe drinking water, unclean living environment, and untreated sewage in the streets and alleys of cities also assist the coronavirus attack on the individual and public health. The emergence of Coronavirus in wastewaters can be used as public health observatories of virus circulation in human communities and for preventive or early warning preparedness and response measures [18].

Another study developed an analytical method to detect SARS-CoV-2 RNA in urban wastewater, to be implemented in a surveillance network in Northern Italy [19]. SARS-CoV-2 RNA concentrations in wastewater correlated with clinically diagnosed new COVID-19 cases, with the trends appearing 4–10 days earlier in wastewater than in clinical data [20]. Scientists detected the coronavirus in wastewaters and used wastewater-based epidemiology to observe community-level trends through analysis of various markers in wastewater to make inferences about the public health [21].

COVID-19 exhibited great challenges and practices on wastewater management [22]. In the fight against the COVID-19, the collection, treatment, and reuse of urban wastewaters are essential. Local administrations, national governments, and international organizations such as WHO and UNDP contribute to supplying sustainable sanitation infrastructures and public health systems [23]. The importance of public health in the prevention of COVID-19 has made the resilience of cities against epidemics on the agenda of engineers and urban planners. A mathematical model has been presented to maximize the profitability of resilient buildings by optimizing investments in the required projects of public health [24].

It has been recognized that there is a bilateral route between Coronavirus and wastewaters. Therefore, built environments require treatment plants to eradicate the virus in the ongoing pandemic of COVID-19 [25], and a need for municipal wastewater management exists to treat COVID-19 by preventing the coronavirus from moving and attacking public health.

The creativity of this research comes precisely from understanding the mutual path of urban wastewater management and the epidemic. Because municipal sewage, as mentioned above, contains the coronavirus and wastewater management is a significant procedure to reduce the demand for clinical treatment of COVID-19.

The addressed question is can we defeat the coronavirus without well-collected and treated municipal and household wastewaters? Another is that in this economic crisis and the urgency of cleaning the environment, which wastewater treatment technique shall we use?

This study shows the municipal and household wastewaters' responsibility in the spread of coronavirus. Therefore, the most appropriate techniques for wastewater collection and treatment will be proposed and analyzed. The method of this research is field studies with mathematical modeling. The model shows the capacity of wastewaters in increasing the number of death tolls due to COVID-19. A statistical technique of the trend line has been applied to predict death tolls from this disease in future months. The findings show that trying to fight the coronavirus cannot overcome the evil virus just in hospitals. Well-collected and treated wastewaters are factors required in achieving the victory as well.

2 Methodology

2.1 Theoretical exploration

Theoretical studies purposed shaping a guideline for case studies. Both theoretical and case studies look for the accuracy of the hypothesis that protecting individual and social health against

COVID-19 requires management of wastewater in the cities. Advanced cities have wastewater collection and treatment plants, clean environment, urban infrastructure, and public healthcare system [26, 27]. In countries with unqualified urban administrations and impoverished people, wastewaters are discharging from households to the sidewalks. The sewage of such cities flows in open streams in the streets and passages. The wastewater is exposed to touch, inhalation, and penetration into humans and living organisms in society.

Experiences of the COVID-19 show that poor people living in neighborhoods polluted with the wastewaters flowing in the streets are more infected or dead than affluent people in clean places [28–30]. Therefore, well-treated sewage can protect health against this disease [31].

Untreated wastewater causes damage to the environment and human health. Wastewaters shall be managed to decrease the spread of diseases and pollution of water resources [32, 33]. Procedures to detect viruses in the water distribution systems had been introduced earlier. The COVID-19 pandemic gives a stimulus to evaluate health in the context of a circular that encompasses humans and the environment. This idea will be simulated to detect the coronavirus and declare as the following: The successful transmission of a coronavirus infection depends on factors such as the excreted volume of the wastewater, the latency of the wastewater on the ground, the persistence of the virus, the multiplication of the virus, spatial infectivity, and susceptibility of the individuals.

Urban wastewater contains a range of organic matter, food, chemicals, human waste, and microorganisms. The sewage contains human body waste (feces, urine, nails, and hair) and water used to wash the toilet [34]. Domestic sewage has several chemicals such as detergents, soaps, fats, and various pesticides from home gardens and pots. Microscopic organisms capable of causing human diseases are also in the wastewaters [35]. An infected person becomes diseased, depending on his or her susceptibility to the COVID-19. It happens through geohelminths, human cestode and trematode worms, leptospirosis, and coronavirus in the wastewaters. Non-treated wastewaters will increase the incidence and prevalence of new cases of COVID-19 in a community that occurs in a specified period and a specified point in time [36]. Figure 1 shows that the trend in the number of daily infected people by the coronavirus is increasing.

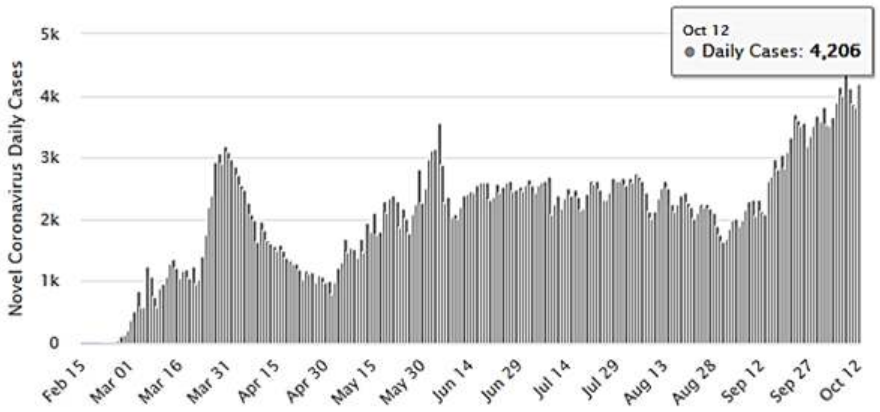

Figure 1 Fluctuations of daily new infected people in Iran due to COVID-19 from 15th February 2019 to 12th October 2020. www.who.int/emergencies/diseases/novel-coronavirus

In the curve, according to official statistics, the number of new patients has been increasing despite the ups and downs. For example, 3186 people were infected daily at the end of March 2019. Unfortunately, this number has reached 4206 infected people on 12th October 2020. An approx. 31% increase in daily patients is the fact of failure in protecting public health. Field observations show that polluted environments and sewage in the cities and villages are also the cause of the spread of COVID-19. Scholars like Barcelo reported similar experiences as well [35]. Wastewaters' collection and treatment are tasks of urban authorities, but they failed to fulfill their work. Planning and design techniques of wastewaters' collecting infrastructure shall be done in the early process of an urban master plan or revising previous master plans [37]. There are the following options to collect and treat wastewater and protect communities' health against COVID-19 and other sicknesses.

(1) Waste Stabilization Ponds;
(2) Anaerobic Ponds;
(3) Facultative Ponds;
(4) Maturation Ponds;

(5) Constructed Wetlands;
(6) Up-flow Anaerobic Sludge Blanket Reactors;
(7) Bio-filtration;
(8) aerated lagoons;
(9) Oxidation ditches.

Wastewaters shall be collected in underground pipes (sewers) and shall not be left in open spaces! The flow in sewers is by gravity, with pumped mains only when unavoidable. From the infrastructure economics viewpoint, such projects are expensive extremely. The infrastructure for a centralized reactor in a whole metropolitan requires many investments. However, there are lower-cost alternatives suitable for use in regions. From a civil engineering view, decentralized wastewater treatment in underdeveloped countries with economic problems is a suitable technique. Various waste stabilization ponds have got anaerobic and photosynthetic technologies that use natural energies [34]. Mara analyzed the technical, chemical, aerobic, organic, and executive characteristics of the systems. Other scholars have worked with wastewater infrastructure collection and treatment technologies [38–40]. It is necessary to say that the choice of one or more techniques requires cognition of the site and the strategic goals of the area. To collect, treat, and even reuse wastewater and to have a healthy and clean environment, the climatic conditions, spatial design, and socioeconomic strategies of every city or region must be carefully analyzed.

2.2 Case studies

Case studies are on wastewater analysis in Iranian cities and their effects on the spread of COVID-19. Iranian cities have a common feature that they do not have wastewater collection and treatment infrastructures. There are certain places for high-ranking officials that look clean. The main street in every city beginning from the airport toward the city administrative center is also better than other parts of the city. Urban spaces are marginal, old, dense, and polluted places. In urban sites, sewage is on the streets. This paper analyzes the origin of wastewater in the cities of Iran and its flow in the streets. It also explores the constituents of wastewater and its effects on public health. It introduces the collection and treatment methods of wastewaters suitable for the economic and climate conditions of cities. Research methods assist in seeing the effects of no-treated wastewater in the communities. For this purpose, this paper presents a mathematical model to show the increasing negative impacts of untreated wastewater through time passing. The model will be simulated in every country/region. A mathematical model measured the COVID-19 disease death tolls in Iran from 29th August 2020 -12th October 2020. The model proved that Iran faced an increasing number of deaths. The losses are related to the unclean environment and particularly untreated wastewater in poor communities. Estimations show that many ordinary people have low incomes [41, 42]. The sewage of Iranian cities, according to field observations, consists of two main parts.

Sewage from hospitals, livestock slaughterhouses, poultry farms, poultry slaughterhouses, car washes, traditional industry workshops, traditional commercial centers, which are dense and crowded markets with open sewage within, such as in Figure 2.

Figure 2 Sewage discharged in the commercial and market center of Iranian cities. Source: Photography by the author.

Traditionally, people used absorption wells to bury sewage in Iranian residential houses. With the passage of time and the congestion of homes in densely populated areas, those wells no longer have the capacity to absorb sewage. Therefore, people leave domestic sewage on the streets. Households pull only one pipe from inside the house to discharge domestic wastewater into the alley, as in Figure 3.

Figure 3 A pipe connects household sewage to a street. Source: Photography by the author.

Domestic sewage is from all residential households, inns, guesthouses, and hotels of Iran's cities. It contains water and all materials added to the water during various uses in the lives. Simultaneously, large amounts of waste and plastic are in this wastewater. The sewage that has entered the side waterways from the households through pipes then requires water canals located on allays and streets. (see in Figure 4)

Figure 4 Sewage enters from homes into the creek in the middle of the alley and streets. Source: Photography by the author.

The wastewaters then run to larger canals. The larger channels originally had a natural origin. In other words, the canals have been the natural water flow channels in Iranian cities, which have become narrower and smaller due to nonstandard constructions in the bed of the seasonal rivers! See, for example, see in Figure 5.

Figure 5 Joining small streams of sewage and pouring them into larger canals. Source: Photography by the author

The canal flow toward the slope of urban lands exists as well. The sewage volume increases due to the joining of more households' sewage. Of course, with the change of temperature in different seasons of the year, sewage changes. Wastewaters in the lowlands with contaminated ponds are the source of traffic problems, bad smells, pests, and diseases. (See in Figure 6)

Figure 6 An example of urban and household wastewaters accumulated in the lowlands of Iranian cities and the formation of polluted ponds. Source: Photography by the author.

Sewage is not eye-catching in appearance and is objectionable. It is not intolerable. It is also dangerous to health. The presence of pathogenic organisms made the wastewater risky. Domestic sewage quickly loses its dissolved oxygen and becomes septic. Septic wastewater has an unbearable odor due to hydrogen sulfide. Iranian cities need wastewater management and treatment for three reasons:

First, wastewater contains microorganisms that transmit diseases to humans in society.

Second, the impact of sewage on society, living things, and plants can cause the spread of diseases from plants and animals to humans.

Third, it pollutes and degrades the environment. It has detrimental effects on the socioeconomic success of the cities.

3 Results

The outcome of this research is a mathematical model that assists us in determining the trend of the COVID-19 pandemic. A model to calculate the sum number of deaths caused by the coronavirus and predict the future of the disease pandemic has been built. The model calculates death tolls during the time with the help of Equation (1).

$$\sum_{DT=1}^{n} f(DT) = \int_{m}^{n} f(DT) \cdot dt \tag{1}$$

The death tolls has been calculated as DT_1 _ DT_{29} in 29 time points according to the following sum

$$\sum_{n=1}^{28} DT_n = \begin{pmatrix} D_1, D_2, D_3, D_4, D_5, D_6, D_7, D_8, D_9, D_{10}, D_{11}, D_{12}, D_{13}, D_{14}, D_{15}, \\ D_{16}, D_{17}, D_{18}, D_{19}, D_{20}, D_{21}, D_{22}, D_{23}, D_{24}, D_{25}, D_{26}, D_{27}, D_{28} \end{pmatrix} \tag{2}$$

Table 1 reports death numbers due to the pandemic in August-October 2020.

Figure 7 exhibits well the rising death tolls from 110 daily deaths in the first point up to 272 deaths on 12^{th} October.

Figure 7 shows a worrying 149% increase in daily mortality from coronavirus. The 149% daily increase in mortality is terrible. What shall be done if the same trend continues in the coming weeks and months? The model uses a statistical linear trend formula based on the following equation to forecast the future of the COVID-19 pandemic.

$$\begin{cases} f\left(DT_n\right) = 4.7857.dt + 107.32 \\ R^2 = 0.8516 \end{cases} \tag{3}$$

Table 1 Daily death toll due to COVID-19 in Iran from Aug. 29 to Oct. 12, 2020

Day (D_n)	Date	Death tolls (DT_n)
1	Aug 29	110
2	Aug 31	109
3	Sep 02	125
4	Sep 03	125
5	Sep 05	139
6	Sep 08	132
7	Sep 10	129
8	Sep 12	116
9	Sep 14	156
10	Sep 16	179
11	Sep 18	144
12	Sep 20	183
13	Sep 22	178
14	Sep 23	184
15	Sep 25	207
16	Sep 26	172
17	Sep 27	195
18	Sep 29	207
19	Sep 30	183
20	Oct 01	211
21	Oct 03	179
22	Oct 04	211
23	Oct 05	235
24	Oct 06	227
25	Oct 08	230
26	Oct 09	210
27	Oct 10	195
28	Oct 11	251
29	Oct 12	272

Reference: WHO, countries, Iran. drive.google.com/drive/folders/17pDRKWFQ35mOBWzZWKqlar2w1HYbSYIq

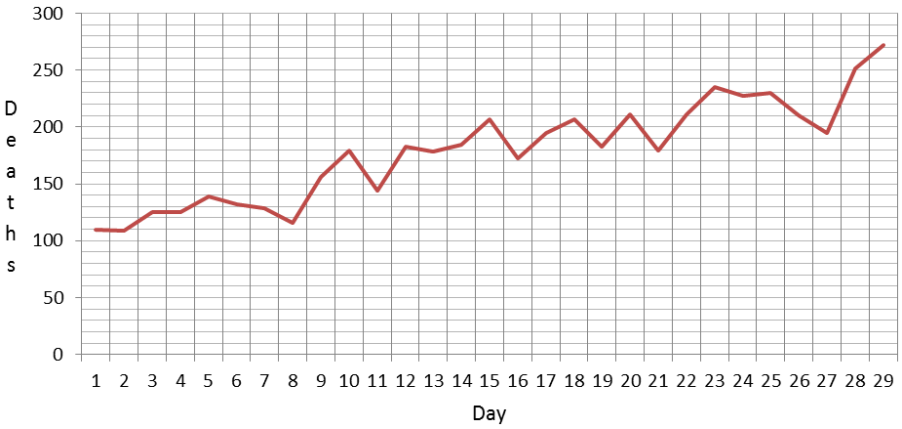

Figure 7 Exhibits the rising death tolls in 29th August-12th October.

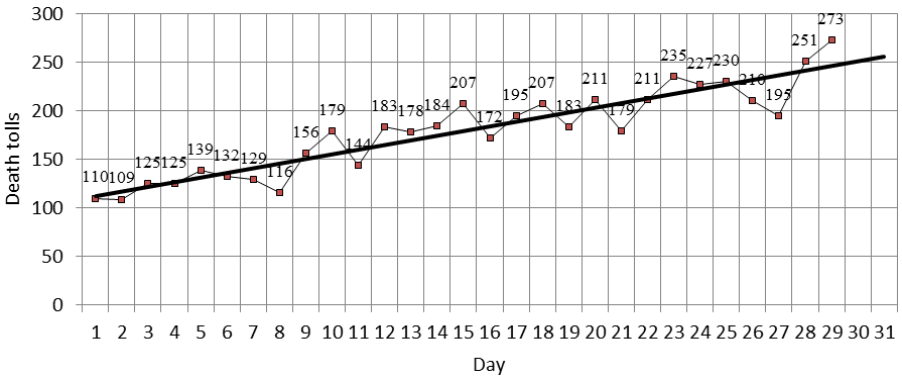

Figure 8 A trend line exhibits the daily death tolls in the future.

In Equation (3), R^2 is the goodness-of-fit measure for our linear regression model. Figure 8 exhibits the trend line geometrically.

As the picture above, the trend line is, unfortunately, increasing with a steep slope, which is a warning sign of a human catastrophe. Therefore, if all variables will be like today, the COVID-19 is increasingly spreading, and a tragedy will happen. As an essential solution way, wastewater in the cities shall be managed, controlled, and treated. In this way, the spread will be prevented with the help of wastewater treatment techniques as soon as possible.

In some cities, the United Nations urban development organization requested modern sewage systems by funding local authorities. However, due to structural corruption in urban management administrations, financial aid has been looted, and projects have been left unfinished. Economic and climate features of cities in every wastewater treatment technique shall be considered.

In cities with hot and dry or temperate climates, domestic wastewater should be injected with oxygen so that the bacteria can consume substances in the wastewater as their food. Equation (4) shows this process. In the process, the combination of oxygen and bacteria with sewage reproduces water as a product.

$$\text{Wastewater} + \text{Oxygen} + \text{Bacteria} \Rightarrow \text{Treatedwastewater} + \text{newbacteria} \quad (4)$$

There are three solutions for injecting oxygen into the wastewater:

1. Oxygen is required for the oxidation of organic wastewater. This method uses oxygen to oxidize the organic part of the wastewater and convert it to carbon dioxide and water. It works according to Equation (5):

$$C_6\,H_{12}\,O_6 + 6O_2 \Rightarrow 6CO_2 + 6\,H_2\,O \quad (5)$$

2. Oxygen is required for the chemical treatment of wastewater. This technique works by oxidizing the wastewater by boiling it with an acidic dichromate solution.

3. Oxygen is necessary for treating wastewater by bacteria. This technique is by bacteria.

From urban physical design views, this paper recommends decentralized wastewater treatment plants for cities in Iran. Factors in designing a wastewater treatment system are the followings:

(1) Percentage of productivity;
(2) Reliability;
(3) Sludge production;
(4) Land requirements;
(5) Environmental effects;
(6) Operating costs;
(7) Construction cost;
(8) Stability;
(9) Ease of operation, maintenance, and care.

Decentralized wastewater treatment plants shall be considered. In urban planning and the physical design of decentralized plants will be the efficient and optimal procedures.

4 Discussions

This paper argued that having a clean environment, including the collected and treated wastewater, is vital to fight the coronavirus and to keep people healthy. The introduced indicators reveal degradation in natural and urban environments in Iran. The indicators exhibit a decrease in the social capital of the government too. Iran experiences structural and institutionalized corruption in governmental institutions. An increase in poverty and social revolts is visible [43, 44]. Economic sanctions and international pressures are also catalysts for now day's problems of Iran. For these reasons and widespread thefts with astronomical figures by governmental bodies, sewage in the cities is uncollected. According to some government officials, a high percentage of Iranians cannot afford masks, disposable gloves, alcohol, and disinfectants, visiting a doctor, and supply medicine. As the field observations have shown, sewage has been dumped in cities, exposing people to diseases, including COVID-19. According to researchers and scientists, coronavirus exists in municipal wastewater. Discharging wastewaters in cities extends the epidemic of this disease. Figure 1 shows that the number of daily new infected people in Iran in October increased compared to the number in February by 31%. More likely, the polluted environment will increase this statistic in the coming months. The mathematical model proved that the number of deaths due to this disease increased. The death tolls on October 12th were 272. Comparing this statistic with other countries respecting the number of population in every country, Iran ranks first in the world in terms of death tolls due to coronavirus. Note that these statistics are official and many researchers have got doubts about their validity. They state

that the death tolls are three to five times higher [45]. There is also concern about increased death numbers caused by the coronavirus in the future. The prediction through the statistical method of the trend line is alarming. The forecast shows that the death statistics are going up. Unfortunately, Iran will experience many more deaths due to this disease in the coming months.

It is necessary to take action to collect, treat, and manage wastewater as soon as possible. Even responsible international organizations shall pay attention to this problem due to the connections of communities.

There are different methods for constructing wastewater treatment reactors with wastewater collection lines and infrastructures that create a centralized system for every city. However, decentralized systems are suitable for Iran and developing countries. This paper recommends decentralized plants on the scale of every urban district. Decentralized models such as wastewater stabilization pools can use natural energies. They are also suitable for the economic and climatic conditions of the cities.

In planning and designing for wastewater collection and treatment systems in cities, indicators of environmental cleanliness, urban landscape, construction and costs, efficiency, and durability shall be included.

5 Conclusions

This article analyzed the presence of coronavirus in urban and domestic wastewaters. It stated that domestic wastewaters and sewage flow in allays, streets, and plazas of slums and poor cities. This article argued that the wastewater in such communities is the source of the spread of COVID-19. The question addressed was how should stop the increasing spread of the disease by collecting, treating, and managing wastewater?

The research methods examined the recent ideas of world scientists. The methods performed are field studies, mathematical modelling, statistical techniques, forecasting the future, and dialectical reasoning.

The findings of this study displayed the interconnectedness of the polluted environment, the uncollected, untreated, and unmanaged wastewater, and the increase in the number of death tolls by COVID-19. The findings similar to global experiences discussed in this paper verified the interconnection among the polluted environment, the uncollected wastewater, and the increasing number of deaths.

This article advised governments and urban managers that the fight against coronavirus should not be limited to hospitals and clinical treatments. Wastewater discharged into the streets and squares of cities must be collected, controlled, managed, and treated as soon as possible. This action would remove one center of the coronavirus' life. The methods applied in this research, its outcomes, and techniques to collect and treat wastewater can be simulated everywhere in the world to fight COVID-19.

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