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Subject review

Analysis of Trends and Challenges of a Worldwide Solid Waste Management with Emphasis on Covid-19 Pandemic - A Review

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Abstract: Low collection coverage, lack of a safe and appropriate destination for all generated waste and pollution caused by inadequate waste disposal procedures are probably one of the most significant threats in the current decade (2021-2030). At the beginning of 2020, a new and unforeseen challenge emerged - the COVID-19 pandemic. This article provides a brief overview of the state of waste management in the world, identifying significant challenges that arose during the pandemic. As the situation changed daily in all regions of the world, many local authorities were obliged to react urgently and adjust the current way of waste management. People's habits have changed and the mandatory wearing of protective masks has increased the daily amount of plastic waste worldwide by approximately 21 000+ tons. This represented an additional burden for already under capacitated waste management systems. Also, waste collected from households in many parts of the world had to be treated as medical waste due to the COVID-19 positive people. There was a drastic increase in the daily amount of generated medical waste due to this, which in some cases was up to 6 times higher than usual.

Keywords: COVID-19 pandemic; management practices; solid waste; sustainability; waste management

1 INTRODUCTION

Accumulation and generation of waste is a direct result of urbanization, economic development of a country and population growth. In today's world, more and more products are becoming available to citizens, which results in the creation of increasing amounts of waste. This is especially true for urban centers, i.e., cities, which are experiencing continuous population growth all around the world. The direct result of this is the increased rate of waste that needs to be disposed of in some way. According to the World Bank, in 2016 a total of 2,01 billion tons of solid waste was generated by cities, which is approximately 0.74 kilograms per person per day [1]. With continuous population growth and urbanization, it is expected that the annual production of waste will increase by 70%, i.e., it will rise from the 2,01 billion tons (2016 level) to 2,59 billion tons in 2030 and to 3.40 billion tons in 2050 [1].

Solid waste management is a universal issue and one of the biggest problems of today's modern society. Governments and communities in all countries all over the world made decisions and regulations that affect health, productivity, and cleanliness of entire communities [2]. In other words, these decisions impact the quality of life. Poor or improper waste management results in a negative impact on the quality of surface water and groundwater, oceans, soil and allows disease transmission among living beings [3]. Improper waste incineration can result in respiratory problems when waste-burning particles (such as dioxins and furans) are emitted into the air, which in sufficiently high concentrations can adversely affect human and animal health [4]. Finally, this can negatively affect the economic development of an environment (for example, reduction in the number of tourists).

During the last decades with the advent of economic growth, there has also been a generation of increasing amounts of municipal solid waste [1]. Improper waste management therefore requires urgent intervention and the involvement of stakeholders at all levels of society. As an environment develops in the range from low to medium and ultimately high income, circumstances related to waste management begin to develop [5]. Urbanization of rural areas leads to population growth which results in higher waste generation per capita. The creation of so-called "population centers" results in difficult collection of all types of waste and reduces the amount of land that can be used for necessary waste processing and disposal [6].

In early 2020 the world was hit by another challenge the COVID-19 pandemic caused by the SARS-CoV-2 virus. A strict "lockdown" has been introduced in many countries and globally, on July 20, 2021, 190,770,507 confirmed COVID-19 cases were recorded by noon, including 4, 095,924 deaths reported by the World Health Organization [7]. To prevent the spread of infection during the pandemic, it was and still is mandatory to wear face masks, medical gloves, prescribed hand disinfection, which resulted in an increased amount of medical, potentially hazardous waste. The reason why this type of waste is hazardous lies in the fact that there is a possibility that such waste contains infectious properties.

The hypothesis for this research lies down in the fact that pandemic requires public authorities and utilities to adapt their waste management systems and procedures in a short period of time, because changes in the waste generation rates and staff shortages are to be expected.

2 GENERAL CHALLENGES FOR THE WASTE SECTOR

Knowing the amount of waste generated with increasing urbanization and population in an environment, as well as the type of waste and income per household, allows local governments to choose adequate methods of planning and waste management for the future and to properly prepare before it is too late [8].

Waste management requires a lot of resources and capacities to be able to carry out adequate planning, management, and supervision of the entire system, which in most cases in the world is the responsibility of local authorities [1]. Complex waste disposal procedures require generous financial resources from the budget, which is why waste disposal is forced to compete with other priorities such as education, health care, drinking water supply or other communal infrastructure. Because of this, majority of low- and middle-income countries in the world are

struggling to address the problem of waste. For example, in some countries waste disposal is carried out without the inclusion of measures affecting the decomposition of waste (so-called "conventional disposal" which still includes other technical measures such as daily waste coverage or collection and management of landfill gas and leachate) [9]. Poor waste management can have a strong impact which affects the population living in poverty, which is often without protection, and is therefore exposed to waste that is improperly disposed of in open areas and near their homes. Proper waste management is key to the development of modern sustainable cities. Despite this fact, it still poses a challenge to many countries and cities which are in development. Establishing an efficient waste management system requires generous allocations and is estimated to account for approximately 20 to 50% of municipal budgets. For a waste management system to be considered efficient, it is necessary to integrate a system that will be efficient, sustainable and, most importantly, accepted by local community [10].

Waste management problems differ significantly between developed and developing countries. For example, the increase in generated organic waste can be considered inherent in highly developed societies, which is why the composition of waste in such countries is completely different [11]. Unlike developed countries, developing countries in most cases have not developed appropriate waste management policies, systems, nor the utility companies that operate in them. Also, their government institutions do not operate efficiently which results in improper management of their own waste. Precisely for these reasons, most such countries do not have any organized means of controlling solid waste. As a result, the waste itself is very rarely collected in some cases and laws are often written inadequately. Regarding laws, the statement means that the laws themselves lag behind today's trends which in some cases allows the incineration of waste or its disposal in open areas. Frequent lack of financial resources prevents municipalities in such countries from establishing an adequate waste management system at all and skilled workers are discouraged by low wages which leads to the employment of unskilled workers, resulting in inefficient management of the system [12].

The result is in many cases that waste in developing countries accumulates in waterways and on land, creating serious health and environmental hazards.This problem with a waste is particularly active in countries with fast-growing urban areas. As poorer nations industrialize and become richer and more consumer-oriented, waste problems tend to worsen which then leads to major environment and public health concerns [12].

2.1 Low Collection Coverage

Uncollected waste in rural communities is one of the fundamental problems in the field of waste management as uncontrolled waste disposal (such as open disposal or incineration) has a direct impact on the components of the environment (air, water, soil) and human health. The primary reason for this is that rural areas are very often neglected by utilities due to several factors, such as being located very far from urban areas (which means additional transport costs) or being in hard-to-reach areas. Other factors which contribute to this are poorer socio-economic conditions, low population density, etc. [13]. According to available data, waste collection rates can vary significantly from country to country and the rates are approximately as follows: around 50% for low-income countries; 50-80% for middle-income countries; more than 90% for high-income countries [14]. Illegally disposed solid waste thus creates many problems not only in underdeveloped countries, but also in developed countries [15, 16] transition economies [17, 18] or developing countries where rural areas are often exposed to environmental threats precisely because of the low representation of waste collection [19].

2.2 Lack of Organized Waste Management System

Globally, almost 40% of waste is currently disposed of in landfills, about 19% is subjected to material recovery by recycling and composting, and approximately 11% is treated by incineration [1]. Governments around the world are increasingly starting to recognize the costs and risks of landfills, together with impact that they are having on environment and human health. Because of that, they are starting to follow more sustainable methods of waste disposal. Current waste management methods vary greatly from country to country, and they depend solely on region and income level. For example, in low-income countries, about 93% of waste is incinerated or disposed of along roads to "open dumping" or waterways, while in high-income countries only 2% of waste is improperly disposed of in the above ways [1]. High- and middle-income countries have the highest percentage of waste dumped in landfills at 54%, reducing this amount to 39% in high-income countries, while approximately 36% of waste goes to recycling and composting, and 22% to incineration [1]. Incineration is predominantly used in countries with high incomes, waste capacities and which are limited in land or territory [20].

2.3 Pollution Caused by Open Dumping and Open Incineration

Open incineration in landfills and open dumps occurs close to the ground, as opposed to incineration in controlled conditions such as incinerators where particles are emitted high into the air through chimneys, allowing pollutants to be dispersed more properly to reduce their health impact [21]. Open incineration in landfills and open landfills usually involves the incineration of large amounts of non-selective waste, which in many developing countries may include hazardous medical and industrial waste that is dumped in open landfills in addition to municipal waste. Large, visible clouds of black smoke accompany these fires in landfills / dumps, and fires generally burn very slowly, last for significant periods of time and allow the accumulation of the amount and concentration of pollutants [22].

2.4 Low Demand for Secondary Raw Materials

According to European Parliament, "secondary raw materials" are recycled materials that can be used in

manufacturing processes instead of, or alongside, primary raw materials. This types of materials can be obtained from production waste or from End-of-Life products, therefore reducing manufacturing costs. Other advantages of using secondary raw materials are increased security of supply (because these types of materials can be traded and shipped just like primary raw materials) and reduced material and energy use which leads to reduced impact on the climate and environment [23].

2.5 Harmful/Hazardous Substances in Materials Composition

Harmful substances in waste materials are one of the reasons why some types of waste cannot be fully recycled and why the priority is to focus on the removal of hazardous and undesirable substances. For example, plastic parts in electrical and electronic waste equipment may contain significant amounts of hazardous substances such as cadmium, mercury, polybrominated flame retardants, lead, or lithium. This means that plastic components from some types of electrical and electronic waste equipment must be treated as hazardous waste.

2.6 Lack of Funding/Minimum Required Sources

Financing the waste management system is a major challenge and is often one of the biggest concerns for municipalities as the construction and establishment of waste management infrastructure is an enormous cost. That's why most often such investments are supported by investments of national governments or various international organizations (donors). In some cities, national and local authorities may fund parts of the waste system, although general government funding and the collection of waste fees are usually not sufficient to deal with waste [1].

3 COVID-19 PANDEMIC AND IMPACT ON WASTE SECTOR

In the city of Wuhan, which was the first source of the infection, medical waste has risen from a normal level (40 tons per day) to approximately 240 tons per day. At that time, the maximum incineration capacity for the city was 49 tons per day [24]. According to Zhaou Qunying, head of the emergency department of the Ministry of Ecology and Environment, the central government in China has deployed 46 mobile medical waste treatment facilities in Wuhan and built a new 30-ton plant in just 15 days [24]. Existing facilities have also been upgraded in such a way that they can process medically hazardous waste, which has enabled the increase of waste treatment capacity to over 263 tons per day. The measures are intended to increase the city's waste treatment capacity from the previous 49 tons to over 263 tons per day [24]. Also, the COVID-19 pandemic caused an increase in the use of plastic material, which led to an increase in this fraction of waste. The reason for the greater use of plastic waste lies in the fact that new regulations related to the use of disposable products have been adopted and due to, for example, closed restaurants, the demand for distribution and collection of food and goods has increased, as well as the demand for plastic for medical purposes [25].

Table 1 Estimated daily facemask use in regions with confirmed COVID-19 cases (table modified from [26])

Region	Population*	COVID-19 cases**	Urban population / % ***	Total daily facemask / pieces ****	Discarded facemask / tons/day *****
Asia	4,641,054,775	60,755,032	50,9	3,779,675,008	11,339
Africa	1,340,598,147	6,556,361	43,8	939,491,181	2,818
Europe	747,636,026	50,870,886	74,5	891,182,143	2,674
North America	368,869,647	41,942,872	82,6	487,498,125	1,462
South America	653,962,331	35,176,671	82,5	863,230,277	2,59
Oceania	42,677,813	98,192	67,8	46,296,892	139

* Data taken from [27]
** Data taken from [28]
*** Data taken from [27]
**** Total daily facemask usage was estimated according to [29]
***** The mass of discarded facemask was calculated based on the assumption (3 g/facemask)

It should be noted that although everyone faced the same crisis and problems, the effectiveness of the taken measures differed drastically in each region of the world. To adapt to the new situation in the shortest possible time, countries and their governments have adopted various restrictive measures, ranging from more lenient proposals (such as limiting the number of people staying in public spaces, shops, etc.) to more restrictive measures (such as strict closures and bans for leaving the household).

The impact of this situation on the waste management system was related to the amount of waste that has increased or decreased in some countries and cities; waste distribution; safety due to increased risk of infection; changes in waste composition; changes in the time of collection and frequency of waste collection. Given the changes in the waste management system caused by the pandemic, local authorities and operators in charge of waste management were obliged to revise waste collection and separation (adjust existing plans due to changes in the amount and composition of waste) and change the existing waste collection system (both the frequency of collection and the route of waste collection that could potentially change according to the demand for waste collection at different places and at different times). The reason for the above changes lies in the fact that the SARS-CoV-2 virus can survive up to 72 hours on plastic and stainless steel, up to 24 hours on cardboard and up to 4 hours on copper, according to a study by the World Health Organization [30]. One of the important items that had to be considered was the protection of workers who collect waste, as well as those who work in waste recycling plants, since recycling waste, for example, could expose workers to the risk of infection.

The United Nations has therefore, as part of its United Nations Human Settlements Program (UN-habitat), adopted a strategy called Strategic Leadership: The Solid Waste Management Response to COVID-19. As part of this strategy, 10 points are prescribed for efficient waste management under the circumstances of the COVID-19 pandemic [32] to prevent further spread of the virus, and thus to keep sustainable waste management systems under control:

1. Map sources of waste generation so that the changes in amounts and flows of waste can be identified which will in return increase the efficiency of used resources
2. Separate infectious waste in households
3. Maintain and expand waste collection service
4. Ensure that waste is treated and disposed safely
5. Protect waste workers, formal and informal
6. Regularly communicate with citizens and stakeholders
7. Engage with stakeholders
8. Accelerate procurement procedures
9. Apply the international and national guidelines related to medical waste and public health care
10. Design scenarios and contingency plans

At the same time, the International Network of Cities and Regions (Association of Cities and Regions for Sustainable Resource Management - ACR +) also launched a study in 2020 on the impact of COVID-19 on municipal waste management systems. The study was aimed at local authorities and waste management organizations which operate in their area. The purpose of this study was to provide insight and assess the impact that the SARS-CoV-2 virus had on waste management systems in their area (especially in terms of quantities collected, the way waste was collected, how they were communicating with their users and what safety and health measures were taken) [32].

The study led to the identification of following key trends:

- Municipal waste production has been reduced in most cities, with a significant reduction in waste generated by commercial activities.
- Changes to the waste generation rates and shortage of staff were to be expected, that is why local authorities had to prioritize waste services so they could adapt to new situation. Civic amenity sites were closed, and "on-demand" collection of waste was interrupted in some regions
- Measures for the collection of potentially contaminated waste varied considerably from city to city and changed almost daily (depending on the situation). Some of the cities have set up special routes to facilitate the collection of waste from households with sick people, while some of the cities have introduced only precautionary measures.
- Organizations that provide selective waste collection services in their communities have experienced a significant decrease [32].

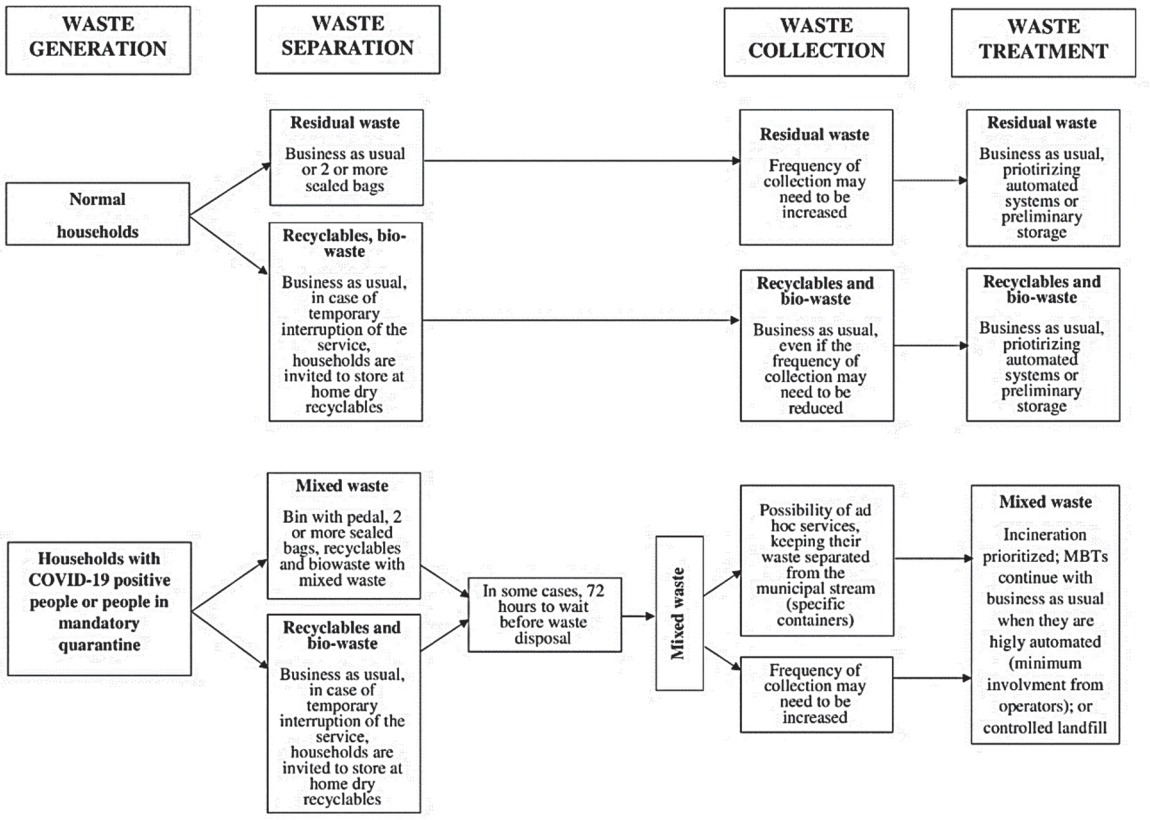

Figure 1 Solid waste management trends and practices during COVID-19 pandemic (modified from [32])

International Solid Waste Association (ISWA) considered three overall priorities for waste management during the period of the pandemic of COVID-19:

Ensure the continuity of the services. This segment does not only mean the removal of municipal waste in front of the doorstep, but also hazardous industrial and medical waste. ISWA stated that maintaining a continuous

recycling process is very important not only during the crisis, but also after it, due to the fact that mass non-separation will lead to rapid fulfilment of available capacities. As a result, the system will be loaded with 30 to 50% more material, which will lead to the collapse of the system itself. At the same time, if the collection of waste going for recycling would be interrupted, it could send the negative message to citizens that recycling is not as important as they thought it were. It is also necessary to take additional measures for waste collection workers to protect them from any virus infection, whether they handle the equipment or waste itself [33].

Adjusting recycling services. ISWA sought to focus on making the recommendations it makes useful to cities and regions and to make it easier for them to communicate with their citizens. The aim of the given measures was to prevent a negative impact on the existing guidelines related to waste management. In order to reduce the impact of the pandemic and preserve the health of waste collection workers, collection should only take place providing that waste management authorities in a given area can ensure waste collection after the waste storage fractions have been stored for at least 72 hours. Depending on their established waste management system, local authorities may require that citizens who are infected with the SARS-CoV-2 virus or who are in mandatory quarantine to hand over all collected waste as mixed municipal waste and thus be temporarily excluded from the separate waste system collection. It is important to note that ISWA stipulates that any hazardous type of household waste or electrical waste is not subject to this method of collection. Also, it may be required that the waste of infected persons or those in quarantine to be stored separately until incineration (or any other means of disposal in controlled landfills) [33].

Ensure safe collection, disposal, and treatment of healthcare waste. It is necessary to ensure that at the global level all medical waste is collected, treated, and disposed of in a safe manner, and it is necessary to take additional measures in case the current local capacities are not sufficient. Disposal and treatment of all waste as hazardous due to the possible presence of pathogens can lead to a very rapid fulfillment of all available capacities. This problem is especially relevant for hospitals and their waste because all waste which is generated as a result of care for patients with SARS-CoV-2 virus should be treated as infectious, and therefore hazardous. It is also important to take into account the fact that many developing countries still do not have adequate infrastructure for the treatment of infectious and hazardous waste. In such a case, waste generated in healthcare facilities should be sent to storage or landfills where it can be covered on a daily basis and isolated from non-hazardous waste [33].

4 CONCLUSION

The COVID-19 pandemic has significantly changed the way we live our daily lives and has certainly left its mark on us. In addition, several industries have suffered a significant blow. What they all have in common is that waste management systems, as well as waste treatment systems, are designed to handle waste under normal conditions. Such an unplanned pandemic caused drastic changes in people's habits which resulted in the change of type of waste circulating in established waste management systems and waste treatment facilities. A significant role in this segment is played by engineers who must make decisions in a very short time that will not lead to the collapse of the entire system.

Waste management is one of the services that is critical for the community, and the non-existence of it would cause a big problem. It has been proven that workers and companies operating in this area (despite all the challenges they faced every day) could not stop serving the city because otherwise that would lead to the collapse of already established waste management systems and habits acquired by the local communities, thus, putting human health and the environment at even greater risk.

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