Waste Management

Opportunities and Challenges for Sustainable Development

Editors

Gunjan Mukherjee
Sunny Dhiman

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Editors

Gunjan Mukherjee

University Institute of Biotechnology
Chandigarh University
Mohali, Punjab
India

Sunny Dhiman

University Institute of Biotechnology
Chandigarh University
Mohali, Punjab
India

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Preface

Water is the most essential for life and nearly 70% of the Earth's surface is covered with water, where the oceans hold about 96% of all Earth's water, and only about 0.3% will be usable by the mankind. But with rapid urbanization and industrialization across the globe, water has more demand not only in terms quantity but also quality. This underlines the significance of water management, in the perspective of global industrialization. Both the consumption as well as release of water into the environment is increasing eventually due to industrialization. In order to transform the industrial waste water into human consumable form, pre-treatment is most adequate and essential step where various designed processes can be exploited successfully.

This book aims to focus on numerous technologically feasible waste water processing methods in response to the growing global problem of waste water management from both domestic and industrial effluents. The world population is eagerly looking forward to the best possible practices and methods for the management and recycling of limited consumable water resources. The establishment of waste water processing plants with different strategies can be adopted to make the waste water suitable and usable for domestic as well as agriculture fields. Substantial quantities of wastewater have to be targeted to treat extensively to make it human consumable, besides the satisfactory regulatory mandates of environmental laws.

Different types of wastewater results from the numerous industries and diverged operational activities possess distinguishing qualities that demand appropriate wastewater treatment methodology based on the type of pollutants held by waste water resources. These pollutants need to be successfully removed by establishing the appropriate wastewater treatment plants across the world. The biochemical nature of wastewater varies significantly with different geographical localities along with type of industries. Generally, most of the waste water resources will be enriched with numerous biodegradable toxic and nontoxic materials with elevated levels of biochemical oxygen demand (BOD), along with suspended solid material (SSM). The major constituents of several kinds of industrial wastewater are generally very difficult to predict due to non-uniformity in terms of BOD, pH, metals, soluble gases etc. in effluents from different processing industries. Because of increased demand for the implementation of the environmental laws strictly almost in all developed and developing nations, all sorts of industries across the globe are looking for the adoption of innovative and cost-effective methods of wastewater effluent treatment and disposal.

Besides, waste water management, solid waste management also has been considered as one of the challenges to convert them either into non-toxic forms or into value added products. For the past few decades, certain nations around the world have adopted different scientific methods of solid waste management from numerous sources in their major cities. These solid wastes produced by domestic as well as various industries don't have appropriate scientific disposal methods; thus, accumulation of these solids influences not only the environment but also geographical problems. Recently, Environmental Biotechnology research outputs have come out with proper solutions, which can be adopted immediately after proper disposal, along with removal of numerous toxic chemicals and other solid waste from various types of industries like, food, textiles, dyes, pharmaceuticals, etc., as well as municipal solid waste by advanced biological processes in solid waste treatment. As of today, in most of the countries like India, the solid waste is generally disposed by dumping at specified locations, majorly peripheral regions of the cities. On the other hand, urbanization is most rapid in major countries. Thus, the waste solid dump not only requires a large area in the midst of the city but also it will possess numerous toxic substances that are detrimental to the environment. Both of these hurdles can be dealt with the alternative biotechnological methods, for instance, biodegradation and composting by adopting the significant biological efficient research outcomes for solid waste management. In this book, we have also addressed these kinds of problems with best possible biotechnological solutions.

This book provides detailed information on current and emerging technologies for both solid and liquid waste management. Apart from this, the book majorly emphasizes on the best practices in the recovery of most valuable materials/products from the advanced waste management strategies for sustainable development. All the chapters in this book illustrate the numerous innovative ideas of comprehensive biotechnologists, biochemical engineers and environmental scientific community from numerous industries and academic research bodies at their expeditions to improve technological innovations for waste management. This book can also be used as both textbook as well as reference book for graduates of Biological Sciences, Biochemical Engineering and Environmental Science disciplines.

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Solid and Liquid Waste
Current Global Scenario

Larissa Renata Santos Andrade,[1,*] *Ianny Andrade Cruz,*[1]
Ram Naresh Bharagava,[2] *Muhammad Bilal,*[3] *Hafiz M.N. Iqbal,*[4]
Luiz Fernando Romanholo Ferreira[1,5,*] and *Renan Tavares Figueiredo*[1,5,*]

1. Introduction

The increase in industrialization and urbanization rates intensified the massive production of waste, generating harmful effects on the environment. Thus, concern about global warming, health and the depletion of conventional energy resources have become themes widely discussed. Factors such as uncontrolled disposal of by-products can cause drastic effects on health and the environment, such as groundwater contamination, proliferation of harmful animals, spread of diseases and increased animal mortality (Koupaie et al. 2019). These residues have high energy power, nutrients and water, which reinforces the importance of their treatments and adequate disposition. In this sense, initiatives aimed at reducing waste disposal, treatments with low operational costs and expanding the recovery potential of these materials through proper management are well analyzed (Barampouti et al. 2019).

In this context, the complexity of physical, chemical and biological properties is considered of great relevance during the maximization of energy generation and value recovery (Chen et al. 2018). As far as liquid waste is realized, they can be used as energy recovery options (Andrade et al. 2020), as a potential support for agricultural cultivation (Abou-Dahab et al. 2019), in addition to the supply of usable by-products (Wang and Serventi 2019). Moreover, solid waste can be converted into bioenergy (Pour et al. 2018, Barampouti et al. 2019, Souza et al. 2020), fertilizers (Geethamani et al. 2020) and even be used in the manufacture of sustainable building materials (Zhao et al. 2020).

Restrictions imposed by governments during the COVID-19 pandemic have caused the reduction of noise, sea and air pollution (Zambrano-Monserrate et al. 2020, Shakil et al. 2020). On the other hand, the increase in the consumption of food and materials from online purchases has intensified

[1] Graduate Program in Process Engineering, Tiradentes University, Av. Murilo Dantas, 300, Farolândia, 49032-490, Aracaju, SE, Brasil.
[2] Laboratory for Bioremediation and Metagenomics Research (LBMR), Department of Microbiology (DM), Babasaheb Bhimrao Ambedkar University (A Central University), Vidya Vihar, Raebareli Road, Lucknow, 226025, Uttar Pradesh, India.
[3] School of Life Science and Food Engineering, Huaiyin Institute of Technology, Huaian 223003, China.
[4] Tecnologico de Monterrey, School of Engineering and Sciences, Campus Monterrey, Ave. Eugenio Garza Sada 2501, Monterrey, N.L., CP 64849, Mexico.
[5] Institute of Technology and Research. Av. Murilo Dantas, 300, Farolândia, 49032-490, Aracaju, SE, Brasil.
* Corresponding authors: larissa_rsa@hotmail.com; romanholobio@gmail.com; luiz.romanholo@pq.cnpq.br; renan_figueiredo@yahoo.com.br

the production of household waste. Moreover, hospital waste has experienced a significant increase due to the high demand for health service materials (Zambrano-Monserrate et al. 2020, Sharma et al. 2020). Consequently, the concern with the treatment and proper destination of infectious waste has become the target of several researches in the world (Kulkarni and Anantharama 2020, Wang et al. 2020a).

This way, this chapter discusses the classification of hazardous waste and reduces the amount of origin and composition, the impacts caused by the disposal of these materials and their applications, in addition to reinforcing the importance of preventing and treating hazardous waste and reducing the mitigation of environmental impacts. In this chapter, the types of treatment suggested for solid and liquid waste contaminated with the coronavirus will also be described.

2. Classification of residues by origin

2.1 Solid waste

Waste is subject to waste generated in agricultural, industrial, domestic, urban cleaning, commercial and institutional activities, which can be divided into recyclable and non-recyclable (Zhao et al. 2020). The management and treatment processes of these wastes must be evaluated individually, taking into account the impacts on the environment and human health (Sözer and Sözen 2020). Below are some types of solid waste classified according to origin:

2.1.1 Agricultural

Population growth and industrialization drive the increase in agricultural activities, facilitating the expansion of the volume and variety of waste generated in this activity. These agricultural residues are associated with problems such as: emission of methane and leachate during the decomposition of biomass and production of CO_2 and various pollutants during the burning of these heavy residues (Asim et al. 2015). The world production of this waste is 4.5 times greater than urban waste, these numbers being higher in the countries with the largest number of agricultural industries (Kaza et al. 2018).

2.1.2 Industrials

At this time, increasing the growth of waste from industrial processes also has a strong impact on the environment. Economic development and world technology drive the production and diversification of consumer goods, thus increasing the generation of waste in different industrial sectors. These wastes can be classified into common wastes and hazardous wastes, according to risk characteristics caused to the environment and human health. Ordinary waste can be compressed, crushed, decomposed, incinerated, and landfilled (Guan et al. 2018), unlike hazardous waste that uses advanced technologies in terms of treatment.

2.1.3 Urban

As a result of population and economic growth, there is an increase in wastage, and consequently, the generation of domestic, urban, commercial and institutional waste. These can come from residential, commercial, government agencies, warehouses, or practical activities and use of individualized management (Sözer and Sözen 2020). It is common to discharge construction waste into landfills associated with a category of municipal residential waste. This category usually includes medical, hazardous and electronic waste in its composition (Kaza et al. 2018).

2.2 Liquid waste

Liquid residues are rich in organic matter, and may also contain industrial and agricultural compounds, pharmaceutical products, hormones, and pathogenic organisms, which intensify the environmental impact. In this sense, wastewater recovery practices combined with continuous monitoring of the concentration of these substances are of great socio-economic and environmental importance (Chojnacka et al. 2020). Below, some types of waste classified according to the origin will be selected:

2.2.1 Agricultural

The incorporation of technologies in agriculture and livestock has intensified production and, consequently, the generation of waste. Agricultural products are constantly used as a raw material in the industry. For this reason, many of its by-products are called agro-industrial waste. These effluents are varied and can present toxicity due to the presence of organic load, toxic compounds, and pesticides (Garcia et al. 2017, Cruz et al. 2019, Andrade et al. 2020).

2.2.2 Industrial

Industrial wastewater has large volumes, varied composition, and complexity in terms of biodegradability (Liu et al. 2019a). Also, many cases have high phytotoxicity, mainly due to the presence of heavy metals (Chojnacka et al. 2020). Thus, the discharge of these residues in water bodies or on the ground can cause negative effects on the ecosystem. In addition, water scarcity in several countries has made reusing used wastewater one of the most important sustainable solutions, widely used in the agricultural and industrial sectors (Arooj et al. 2020).

2.2.3 Urban

Urban wastewater has a high organic load, in addition to medicinal compounds, which affect the health of humans and animals, altering their metabolism. These problems are caused by the lack of proper treatment of these effluents discharged into aquatic environments (Casierra-Martinez et al. 2020). Hospital activities are also part of this group and are responsible for the generation of these unwanted by-products, including toxic elements, pathogens, and heavy metals (Khan et al. 2020).

3. Classification of solid waste according to composition

Solid waste is generally divided according to its composition into categories such as recyclable and non-recyclable waste. The characterization of the waste must be carried out considering raw material and its origin. According to the World Bank report "What a waste 2.0", food waste (food and green) represents the majority of the world's waste with a share of 44%. Dry recyclables represent 38% (glass 5%, metal 4%, paper and cardboard 17%, plastic 12%), as seen in Figure 1. However, this composition may vary according to local income, in which the percentage of organic matter in

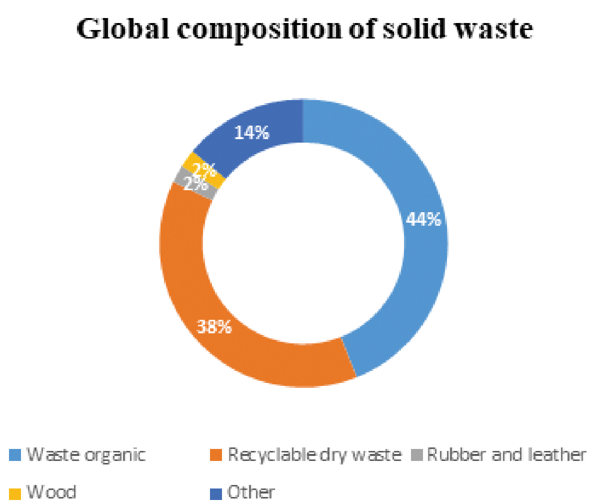

Figure 1. Global composition of solid waste (%). Adapted from Kaza et al. 2018.

the waste is inversely proportional to the increase in income. Advanced countries generate more materials, such as paper and plastic (Kaza et al. 2018).

Dry recyclable waste is that which can be reused after chemical and/or physical treatment. These can be used after transformation into the original form or as a raw material for different products. In this sense, researchers from several countries develop works on the use of recyclable waste in several components (Mwanza and Mbohwa 2017, Ragaert et al. 2017, Saidan 2019, Ferronato et al. 2020, Guo et al. 2020, Yang et al. 2020). Organic waste, highlighted by its expressive production, is composed of biodegradable materials and can be produced in domestic, urban, agricultural, industrial, or basic sanitation activities in treatment plants (Chen et al. 2020). In this sense, recycling the organic fraction of waste has become a topic widely discussed in academic papers (Alvarenga et al. 2017, Corcione et al. 2020, Lang et al. 2020, Qi et al. 2018).

The category of non-recyclable waste includes dry waste (plastics and non-recyclable paper, rubber, leather, etc.) and waste that cannot produce energy or is hazardous (ceramic waste, non-recyclable glass, paints, pesticides, batteries, medicines, etc.) (Yousefloo and Babazadeh 2019).

Hazardous waste needs different technologies in terms of treatment and prevention. Their properties may be responsible for burns and chemicals under normal conditions, corrosion and intoxication (Guan et al. 2018, Saeidi-mobarakeh et al. 2020). The multi-component industries are responsible for the emission of hazardous waste into the environment. On the other hand, most are involved in environmental initiatives, mainly to comply with laws and regulations, as many consider that investment in environmental practices affects the company's financial performance (Fakoya 2020).

4. Some applications

Global waste generation is estimated to exceed population growth by 2050 (Kaza et al. 2018). In this sense, the concept of green chemistry has been discussed in recent years in order to mitigate the various impacts caused by this exacerbated generation. The traditional scenario of waste as pollution is being transformed into the vision of waste as the resource, encouraging the sustainable economic development of several countries (Tang et al. 2020). In this sense, solid and liquid waste management strategies are evaluated over the years in various sectors.

4.1 Solid waste

One way to recover solid waste is recycling, which is introduced in developing countries and reduces the environmental problems generated by landfills (Lawrence et al. 2020). The application of these resources through recycling is diverse, from the production of bioenergy to the production of sustainable building materials. Therefore, this stage presents current and emerging technologies for the management of this waste.

4.1.1 Catalyst production and wastewater treatment

Recycled waste can be used as a substitute for some chemical substances, which is an ecological and economically viable alternative. Waste such as bird eggshells (Farid et al. 2020, Guo et al. 2019), ash (Xu et al. 2019), batteries (Moura et al. 2017, Gallegos et al. 2018), electronic waste (Wang et al. 2020), mollusk shells (Liu et al. 2019b), animal bones (Obadiah et al. 2012), livestock manure (Zhang et al. 2013), and calcium-rich industrial waste (Li et al. 2015) are some examples of residues rich in metals or metal oxides. Due to the development of various technologies and processes, these recycled residues can be converted into catalysts (Wang et al. 2020), used in residues to optimize the production of biomethane (Andrade et al. 2020), in addition to being included in the treatment aimed at the discharge and reuse of effluents (Goswami and Pugazhenthi 2020).

4.1.2 Bioenergy production

Another application for waste is the production of bioenergy through anaerobic digestion. The treatment of anaerobic digestion promotes the conversion of the organic fraction of solid waste into biogas and digested. In this regard, different residues, such as rice straw, wheat straw, animal manure (Samun et al. 2017), organic fraction of solid urban waste (Pour et al. 2018, Cesaro et al. 2020), microalgae biomass (Mishra et al. 2019) can be used as a substrate in this treatment. The production of liquid biofuels also stands out as a solution to mitigate the pollution generated by the burning of fossil fuels. In this context, Barampouti et al. (2019) studied the technologies available for the production of bioethanol and biodiesel from urban waste. Another alternative is the pelletizing of agroforestry residues, with a focus on energy generation. Its consumption contributes to the reduction of the percentage of fossil fuels consumed in power plants. Thus, Souza et al. (2020) evaluated the potential of coffee residues associated with eucalyptus wood in the production of pellets for industrial or non-industrial applications (for example, residential heating).

4.1.3 Fertilizer production

The conversion of organic residues (food residues, vegetables, sewage sludge, etc.) into fertilizers is an efficient way to mitigate the production of greenhouse gases, in addition to improving soil quality. This conversion occurs through biological processes, of which digestion and anaerobic composting stand out (Chen et al. 2020). In this sense, Oliveira et al. (2019) evaluated the recovered and digested phosphorus produced by the anaerobic digestion of the organic fraction of municipal waste as a suitable fertilizer for agriculture. In another aspect, Juan et al. (2020) worked with composting vegetable waste, food scraps, sewage sludge, and municipal waste, evaluating the phytotoxicity of compounds during the process. In this segment, Benlboukht et al. (2016) studied families of compounds generated during the composition of solid waste from a tannery. In another study, the organic fertilizer generated during the rapid composting of institutional waste (dry and wet leaves, vegetable seedlings, grass clippings, tree trimmings) was applied by Geethamani et al. (2020) in the institution's own plants. This application reduced the costs of chemical fertilizers and solved problems with the disposal of waste.

4.1.4 Production of sustainable building materials

Construction and demolition waste, aged pavements, fly ash, low ash, rubber and plastics are some examples of recycled waste used in the production of sustainable building materials (Zhao et al. 2020). The ashes recovered from the incineration of municipal waste can be applied in the lower layers of roads and field structures (Sormunen and Kolisoja 2017). Municipal waste can also be incorporated into geopolymer compounds and can be used in the form of precursors, aggregates, stress fibers or additives (Tang et al. 2020). Another example is waste from non-ferrous metals, which can be converted into building materials. In this context, the geopolymerization of waste from the non-ferrous industry is seen as a promising conversion method for safe disposal and valuable application of these materials (Singh and Singh 2019). Another application was evaluated by Jannat et al. (2020), who discussed in their review the use of agricultural by-products in the production of blocks of land, presenting the results of different tests carried out by various authors over the years.

4.2 Wastewater

The reuse of wastewater has become a widely discussed topic, as its valorisation generates economic and socio-environmental benefits. In this context, below are some ways to apply these treated effluents.

4.2.1 Fertilization and fertigation

The concentration of nutrients and organic matter in the composition of recovered wastewater maintains soil fertility and productivity and is of great importance for agriculture. Thus, fertigation appears as a nutritional source of plants through irrigation. However, it is necessary to use monitoring technologies or insert new tests during recovery, as the effluents may be contaminated with pathogens and chemicals (Chojnacka et al. 2020). From another perspective, Coelho et al. (2020) evaluated the quality of the soil fertigated by the treated effluent, where increased fertility, quality and productivity of planting were observed, stimulating the introduction of sustainable agricultural production. On the other hand, Abou-Dahab et al. (2019) reused the cheese whey in the fertigation of the plantations as a strategy to face the problems caused by the inadequate disposal of the effluent in regions close to cheese factories. In another perspective, Dantas et al. (2017) used cassava wastewater as soil fertilizers for sunflower plantation, observing an increase in seed production and leaf area, improving plantation development. Another option is the application of aquaculture effluent in fertilization. Garcia et al. (2019) observed that these effluents provide ideal nutrients (Nitrogen, Phosphorus, and Calcium) for the development of the *Pelargonium zonale* in a short-term crop, reinforcing the reduction of costs with fertilizers and the environmental impacts.

4.2.2 Bioenergy production

The effluents from cassava processing have a significant amount of organic load and nutrients. In this sense, the application in the production of biogas aroused the interest of several authors (Glanpracha and Annachhatre 2016, Palma et al. 2017, Kuczman et al. 2017). However, due to its rapid acidification and concentration of cyanide species, this effluent needs the use of treatments for optimizing the production of biogas during anaerobic digestion (Andrade et al. 2020). In another aspect of recovery energy, Cruz et al. (2019) monitored the production of biogas from the anaerobic digestion of the milk effluent inoculated with sewage sludge, which is shown to be viable for production. Wastewater and solid residues of tannery are also used as nutritional supply for anaerobic co-digestion, however with little biogas production (Agustini et al. 2019). Another nutritional source for renewable energy production is slaughterhouse wastewater. Eric et al. (2020) evaluated the bioenergy production potential and the performance of the anaerobic treatment of this waste as a way of reducing the environmental problems generated in the study region after its disposal. Vinasse, considered a source of contamination in the ethanol industry from sugarcane, fits as another resource with high energy potential. However, the single effluent is not efficient in generating biogas during anaerobic digestion, requiring a nutritional supplement due to low C/N and macro and micronutrient values (Parsaee et al. 2019).

Another example of biofuel is bio-oil, which can be produced using waste from the olive oil industry (solids and effluents). Jeguirim et al. (2020) performed the recovery of effluent organic compounds through the impregnation of olive pomace. Thus, this method added to pyrolysis proved to be a promising technique for the ecological management of these residues. Another type of resource is the effluent from the soft drink industry, rejected in the quality control or return of trade. Some of these residues can be used in the production of bioethanol by alcoholic fermentation in the presence of yeasts due to their high sugar content (Isla et al. 2013).

4.2.3 Disposal and reuse of treated effluents

The reuse of treated wastewater provides economic and socio-environmental benefits. Thus, the quality of water for consumption, disposal, or reuse must follow environmental standards and regulations. However, some countries do not have a regulatory framework to control and monitor the removal of pharmaceutical drugs from wastewater. When wastewater treatment is ineffective or not carried out, these residues are discarded in water bodies, causing adverse effects to the ecosystem (Miarov et al. 2019). Another highly polluting effluent is the liquid residue from petroleum activities, but its discharge is assessed in terms of volume and composition by the inspection bodies. In this context, aiming pollution mitigation and the rational use of this affluent, Zhou et al. (2020) proposed a linear programming model to guarantee the reduced costs and reuse the maximum amount of water, through reinjection in oil wells. Another example of effluent from significant and highly polluting volumes is produced in the dairy and soy industry. In this way, targeted treatments for using the components present in this wastes are evaluated. Among them is the isolation of protein and oligosaccharides present in soy effluent, for foaming in food and prebiotic source, respectively. From another perspective, dairy wastewater procedures can be used to obtain the disposal standard, its reuse in irrigation, or its use in the cultivation of algae for the production of biofuels (Wang and Serventi 2019).

5. Waste management during the COVID-19 pandemic

Currently, the world is going through a crisis due to the COVID-19 pandemic. The world population had to adopt a new routine that includes protocols for social distance, use of personal protective equipment (PPE), and increased attention to hand and food hygiene. New measures are being adopted in companies and institutions, including the use of technologies intensively to keep them functioning. As a result, there was a reduction in the circulation of people and, consequently, a reduction of noise pollution and beaches (Zambrano-Monserrate et al. 2020). Also, this reduction caused little consumption of fossil fuels, contributing to a lower generation of greenhouse gases (Shakil et al. 2020). However, the same did not happen with the production of solids wastes, due to the high consumption of food and materials purchased through the internet (Zambrano-Monserrate et al. 2020). Hospital waste also presented a significant increase during the pandemic, due to the expansion of the use of PPE. Both residues can contain viruses, and when improperly disposed of, without the use of appropriate individual and collective protections, they put the lives of workers involved in this management at risk (Sharma et al. 2020).

To mitigate the impacts generated by the virus, some management practices are being evaluated. In this sense, the World Health Organization (WHO) advised on the proper handling of materials in contaminated and non-contaminated environments during the disease outbreak. Among them are guidelines for correct hand hygiene, non-sharing of bathrooms in cases of contamination, proper hygiene of toilets using PPE, assessment of plumbing, and ventilation system, among others (WHO 2020). As for the attention focused on increasing the generation of infectious solid waste, options such as the treatment and recycling of these in a decentralized way, storage of waste in temporary locations, heat treatment with energy recovery, and the exploitation of automation emerge with management alternatives (Kulkarni and Anantharama 2020).

Wastewater, such as sanitary sewage, has feces and urine in its composition and, when not properly treated, can present various contaminants, mainly pathogens such as viruses, bacteria and protozoa. Therefore, they are sources of infection, mainly in the cases of domestic and hospital wastewater. In this way, the monitoring of infectious diseases such as COVID-19, through wastewater samples, stands out as a complement in the quantification of infected (Thompson et al. 2020, Ahmed et al. 2020). In this sense, Wang et al. (2020) listed different techniques that can be adopted in the treatment of infected and non-infected effluents from health services. Among them are the use of chemical compounds (sodium hypochlorite, chlorine dioxide, etc.) and disinfection with ozone or ultraviolet light. In his work, solid wastes' disinfection procedures were also discussed, such as physical disinfection, chemicals and incineration, in addition to reinforcing the importance of waste classification for effective disinfection. In this stage, some types of treatments suggested by some authors for the management of residues and waste during the COVID-19 pandemic are discussed.

5.1 Decentralized recycling

A decentralization of recycling is suggested as a way to alleviate the burden on the waste management system. This method consists of the treatment and recycling of waste in the generating vicinity, reducing the collection flow and transport and, consequently, an infection of the personnel involved in this service (Kulkarni and Anantharama 2020).

5.1.1 Temporary storage

Temporary storage locations emerge as another waste management option during disasters. They allow the use of pre-treatments aimed at reducing volume and infection, facilitating the disposal of or recycling the waste (Gabrielli et al. 2018).

5.1.2 Heat treatment

Heat treatment is an option for energy recovery through waste processing. Incineration is an example of this type of treatment, which has the advantage of generating energy. Among the most used technologies are pyrolysis steam incineration, rotary kiln incineration, and plasma incineration (Wang et al. 2020).

5.1.3 Chemical disinfection

Chemical disinfection of solid waste usually occurs after mechanical treatment. Chemicals such as sodium hypochlorite and chlorine dioxide are mixed with waste for disinfection (Chen and Yang 2016). Chlorine is one of the methods widely used in the disinfection of wastewater, being responsible for the destruction of a variety of microorganisms, including viruses and bacteria. However, its storage and transportation carry high risks, and it is not viable for water treatment in populous regions (Wang et al. 2020).

5.1.4 Treatment with ultraviolet light

The cost of treatment with ultraviolet light (UV) is considered low when compared to treatment with chemical compounds. Its UV radiation, mainly the UVC, is considered a renewable and effective method in destroying the DNA and RNA structure of viruses and bacteria (Kuo et al. 2020).

5.1.5 Ozonation

Ozone has a high disinfection power for microorganisms, making it possible to improve the quality of wastewater in shorter intervals. However, due to odor and secondary pollution generated by high doses of ozone, this treatment is not suitable for systems with high volumes of wastewater (Wang et al. 2020).

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Pine Bark as a Low-cost and Ecofriendly Material to be Used in Soil and Water Remediation

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Biobased Approaches Towards Treatment and Recycling of Heavy Metals from Wastewater

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