sustainability

Review

Heavy Metal, Waste, COVID-19, and Rapid Industrialization in This Modern Era—Fit for Sustainable Future

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Abstract: Heavy metal contamination, waste, and COVID-19 are hazardous to all living things in the environment. This review examined the effects of heavy metals, waste, and COVID-19 on the ecosystem. Scientists and researchers are currently working on ways to extract valuable metals from waste and wastewater. We prefer Tessier sequential extraction for future use for heavy metal pollution in soil. Results indicated that population growth is another source of pollution in the environment. Heavy metal pollution wreaks havoc on soil and groundwater, especially in China. COVID-19 has pros and cons. The COVID-19 epidemic has reduced air pollution in China and caused a significant reduction in CO_2 releases globally due to the lockdown but has a harmful effect on human health and the economy. Moreover, COVID-19 brings a huge amount of biomedical waste. COVID-19's biomedical waste appears to be causing different health issues. On the other hand, it was discovered that recycling has become a new source of pollution in south China. Furthermore, heavy metal contamination is the most severe ecological effect. Likewise, every problem has a remedy to create new waste management and pollution monitoring policy. The construction of a modern recycling refinery is an important aspect of national waste disposal.

Keywords: heavy metals; COVID-19; waste; biotoxicity; SARS-CoV-2; CO_2; circular economy

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1. Introduction

One of humankind's greatest issues in the twenty-first century is heavy metal pollution. In recent decades, fast development, which has happened in the majority of places all over the world, has increased concern about and attention to soil quality [1]. In China, heavy metal poisoning of farming soil has been a major problem [2]. Heavy metal bioaccumulation can harm humans through various routes, such as food intake, particle inhalation, particle ingestion, and skin absorption [3]. More than 10 million polluted sites are known to exist worldwide, with heavy metal(loid) contamination found in >50% of sites [4]. By the end of 2000, China had 3.2 million hectares of wasteland, and this number is growing at a rate of 46,700 hectares each year [5]. In China, HMs pollute around 20 million acres of cropland and 12 million tons of grain every year [6,7]. Toxic heavy metals such as lead (Pb), cadmium (Cd), chromium (Cr), and arsenic (As) are found in about 82 percent of polluted agricultural soils in China [8]. Between 2005 to 2013, 1.50 percent of soil samples in China were polluted with Pb, according to the first National Soil Pollution Investigation [9]. Around 80 million hectares of soil are contaminated by heavy metals in China [10].

Heavy metals are mainly obtained from natural and anthropogenic origins. Volcanic emissions, continental dust movement, and the weathering of metal-enriched rocks are all examples of natural sources [11]. Heavy metals originating from mining operations are one of the most hazardous contaminants in surrounding areas [12]. This is especially true when soils are utilized for the discharge of inadequately treated liquid effluents, solid waste disposal, and deposition of exhaust gas from enterprises [13]. One of the biggest causes of heavy metals pollution is atmospheric pollution, notably, dust from zinc and lead industrial processes. Heavy metals from atmospheric deposition could be accumulated in topsoil by sedimentation, impaction, and interception [14]. Toxic metals penetrate the environment via nonferrous metal mining and smelting, through enduring and draining sewage sludge, discharge of contaminated water, or atmospheric particles from smelter piles [15].

Energy scarcity, pollution, and climate change, all linked to population expansion and the combustion of fossil fuels, have become key problems that humanity must address in the twenty-first century [16]. The rapid growth of the world's population, coupled with urban growth and technological advancement, has increased the production of complicated waste materials [17]. China has an important role in almost every aspect of the world economy. China is the most populous country on the planet. Urbanization and advancements in current technology, which contain the innovation of electrical and electronic tools, have a significant impact on a country's economy. It is common knowledge that all electronic tools include a variety of toxic metals, such as Pb, Cd, As, mercury (Hg), zinc (Zn), cadmium (Cd), copper (Cu), and aluminum (Al), which instantly affect public health and the environment [18].

Apart from heavy metals, landfilling modifications have a considerable impact on the biota of the ecosystem. China is a developing country, and while the industry is the main cause of hazardous waste in developing nations, the threats posed by industrial hazardous waste sources are greater. E-waste recycling utilizing rudimentary technologies is being removed quite vigorously in limited sites in south China, driven by profitability. It is rapidly becoming a significant novel source of contamination in these areas [19]. China has become the world's leading distributor and recycler of e-waste, accepting more than one million tons of e-waste each year from the United States and Europe [20]. Hazardous waste management is given priority because of its poisonous nature. This ensures that such wastes are controlled to avoid contaminating the environment, which could negatively affect human, plant, and animal health and biodiversity. In 2015, 191 million tons of municipal solid waste (MSW) were gathered, with almost 94.1% of it being preserved in sterile condition, 63.7% of MSW was disposed of in sterile landfills, 34.3% was handled in furnaces, and 2.0% was preserved through biological procedures [21]. Direct landfilling of uncooked food wastes has been prohibited in Korea since 1 January 2005, to address a lack of landfill space, preserve groundwater and soil from pollution, and encourage food waste recycling as a viable resource [22].

Heavy metal pollution's toxicity may lead to diseases [23]. The coronavirus disease, also known as COVID-19, was announced as a worldwide virus outbreak by the World Health Organization (WHO) on 11 March 2020 [24]. Due to poor respiratory functioning, chronic inflammation, and decreased resistance to diseases, environmental contamination has been deemed one of the threat issues for COVID-19 intensity and death rates, with indirect data from China and Northern Italy supporting this theory [25]. The collapse of numerous organelles, a weakened immune system, impairment to the central nervous system, kidney involvement, fracture, and a decrease in children's IQ are all effects of heavy metal exposure [26]. Soil risk factors are challenging to decompose and can emigrate to plants and humans via food chains and water supply systems, posing a direct or indirect threat to food security and human health [27,28].

This review aimed to highlight the impact of heavy metal and waste on environmental pollution. While providing a comparative valuation of the COVID-19 pandemic and its effect on the atmosphere, humans, and economy. Furthermore, a comprehensive review was conducted on how waste recycling, waste, and biomedical waste management will not only help in fighting against diseases but will also achieve a more circular economy.

2. Heavy Metal Extraction in Soil

There are a variety of forms used for soil analysis, and it depends on the goal of the investigation. In the geochemical investigation and environmental geochemistry, sequential extraction of components from soil and sediment is commonly used [29]. Sequential extraction procedures (SEPs) have grown in popularity rapidly since their inception in the late 1970s [30]. Identifying the primary binding locations, the potency of the bind among metal and soil mixtures, and the step connections of trace elements in soils can all be obtained using SEPs [31]. Several studies have employed the sequential extraction approach with selective chemical agents to partition solid-phase metals in river sediments [32,33]. SEPs, established on the sensible usage of a sequence of additional or particular small reagents selected to solubilize the various mineralogical particles for maintaining the more considerable part of metals sequentially, are the most popular and easiest method to determine the states in which metals are discovered in soils [34]. SEPs have been used to analyze the physicochemical states of metals and offer a more useful interpretation of the mechanisms determining their availability and assessing the efficacy of soil remediation systems and identifying underlying mechanisms [35]. Sequential extraction has recently become popular for evaluating the environmental impact of human activities such as mining [30] and smelting. It is critical to distinguish the accessible and inaccessible states of metals in soil contaminated by metals to assure that the soil is managed to avoid the inaccessible states becoming accessible [34]. The problem of the partial selectivity of chemicals used in sequential extraction schemes (SESs) to dissolve one stage emerges in the assault on other stages, and they may be ineffective in entirely dissolving the stage; modifications to the experimental conditions, including the extraction period, the extractant sample fraction, the chemical content, the extraction temperature, the usage of consecutive extractions with similar chemicals, and so on, can all help to avoid these issues [36]. Although time intensive, sequential extractions provide precise information regarding the source, method of occurrence, biological and physicochemical availability, mobilization, and transportation of trace metals [37].

Several SEPs are available, but some are intended to function within exact factors. In contrast, others are intended for a broader application, such as the Tessier [33], Community Bureau of Reference (BCR) [38], Short [39], Galán [40], and Geological Society of Canada (GCS) approaches [41]. Similarly, several researchers have proposed a modified version of this and applied it to the soil, sediment, and sewage. All sequential extraction procedures (SEPs) facilitate fractionation [42]. Exchangeable, carbonate bound, Fe and Mn oxide bound, organic matter bound, and residual were the names given to these fractions by [33,42]. Fractionation patterns have not been consistent, and the consequences of various methods are not consistently similar due to the deficiency of consistency in the test situations (i.e., the number of extractions, chemicals, shaking period) [43]. Even though various protocols have been described, the Tessier and BCR schemes remain the most commonly adopted [30]. Table 1 shows the operating parameters, including Tessier and BCR schemes [37]. Sequential extraction studies have proven to be useful for determining the metals linked with the main cumulative stages in sedimentary depositions [37]. XRD is also effective for determining silicate clay reactivity during the extraction process [42]. Understanding the chemical and physical features of heavy metals in soil requires identifying the chemical states (speciation) and dispersal of heavy metals released, trapped, or adsorbed on soil particles [44]. To evaluate heavy metal redistribution (Pb, Cd, Zn, and Cu), SEPs were used by the European Union Bureau of Reference Procedure (EUBCR) [45]. According to [30], sequential extraction has a bright future in the twenty-first century, but its sustained utility necessitates researchers' awareness of its limitations, particularly for environmental monitoring. The SEPs future is not as bright as initially assumed, but it is still useful [42]. It is crucial to realize that the Tessier and BCR processes will not always produce the same outcomes. For example, Mn is extracted from agricultural soils primarily by the reducible fraction of the BCR technique but mostly through the residual fraction of the Tessier procedure [30]. Tessier's approach is the most efficient when there is a high soil metal content [46]. Still, no extraction procedure is 100% effective, but we have recommended the Tessier sequential extraction method as a suitable method for estimating high metal(loid) concentrations in soils. Critical problems need critical solutions. In conclusion, the invention of a suitable extraction method is predicted to revolutionize the field of soil contamination research in the future.

Table 1. Original Tessier and BCR SESs. (Reprinted from ref [37], with permission of the publisher).

		Tessier Scheme [a]	
Stage	**Operationally-Defined Phase**	**Reagent**	**Operating Conditions**
1	Exchangeable	8 mL of $MgCl_2$ 1 mol L^{-1} (pH = 7)	1 h at 25 °C
2	Acid soluble	25 mL of NaOAc 1 mol L^{-1} (pH = 5)	5 h at 25 °C
3	Reducible	20 mL $NH_2OH \cdot HCl$ 0.04 mol L^{-1} in HOAc 25% w/w	6 h at 96 °C
4	Oxidizable	3 mL HNO_3 0.02 mol L^{-1} + 5 mL H_2O_2 30% w/v	2 h at 85 °C
		3 mL H_2O_2 30% w/v +	3 h at 85 °C
		5 mL NH_4OAc 3.2 mol L^{-1}	30 min at 25 °C
		BCR Scheme [a]	
1	Acid soluble	40 mL HOAc 0.11 mol L^{-1}	16 h at 25 °C
2	Reducible	40 mL $NH_2OH \cdot HCl$ 0.1 mol L^{-1} (pH = 2)	16 h at 25 °C
3	Oxidizable	10 mL H_2O_2 30% w/v (evaporation)	1 h at 25 °C
		10 mL H_2O_2 30% w/v (evaporation)	1 h at 85 °C
		50 mL NH_4OAc 1 mol L^{-1}	16 h at 25 °C

[a] 1 g sample mass is employed for sequential extraction.

3. Pollution Levels in Various Environmental Compartments

3.1. Soil

Toxic heavy metals are deposited in soils from natural and human activities [47]. As a consequence of environmental and health issues, soil heavy metal pollution has a huge interest [35]. The A horizon is called “topsoil”, in this layer, minerals are present which are generated from the parent material with the organic matter accumulating. The B horizon is called “subsoil” or “zone of accumulation”, the mineral seeps down from the A or E horizons and accumulates in this layer. However, the variation of the elemental concentrations is higher in the A and B horizons. The B horizon, or the third layer of soil, contains the majority of heavy metals [48]. This layer comprises components that were dissolved in the higher layer (the A horizon) and subsequently moved down or sidelong into the inferior layer, where they were dumped, and heavy metals are drawn to the B horizon because it has a high content of iron oxyhydroxides and clay, both of which can absorb cationic aspects [48]. Microorganisms cannot degrade heavy metals in the soil; therefore, they accumulate, influence the soil’s properties, and are assimilated and enhanced in biomass [49]. Cadmium (Cd) pollution is a major problem in China’s agriculture [23]. Pb, Cd, polybrominated biphenyls (PBBs), polybrominated diphenyl ethers (PBDEs), and polychlorinated biphenyls (PCBs) have appeared in high quantities in rice and organic contaminants have been found in vegetables growing surrounding unmanaged e-waste recycling locations [19]. E-waste soil samples frequently contain persistent organic pollutants (POPs), including polycyclic aromatic hydrocarbons (PAHs) and PBDEs. In 2011 (0.59 mg/kg) and 2016 (0.40 mg/kg), researchers found high molecular weight polycyclic aromatic hydrocarbons (PAHs) in paddy soils close to e-waste recycling areas in Taizhou, China [50]. The principal pollutants of concern in e-waste-affected soil are Pb and Cd [50]. According to [19], the maximum Pb (629–7720 mg kg^{-1}) and Cd

(3.05–46.8 mg kg^{-1}) contents found in soils around e-waste combustion operations far surpassed Chinese farming soil requirements (Pb: 250 mg kg^{-1}; Cd: 0.3 mg kg^{-1}). Metal concentrations were highest in historic e-waste incineration locations, with an average of 17.1 mg kg^{-1} of Cd, 11,140 mg kg^{-1} of Cu, 4500 mg kg^{-1} of Pb, and 3690 mg kg^{-1} of Zn. Metals in high amounts could seep out of the locations and contaminate pond water and sediment [19].

3.2. Water

Apart from soil pollution, which can contribute to water quality degradation and various negative environmental effects, heavy metal replication across the food supply chain has serious health impacts [51]. The global demand for freshwater is steadily increasing. Because arsenic (As) pollution affects such a broad population, the toxicity resulting from As enrichment in sedimentary aquifers beyond prescribed limits, which causes drinking water contamination, is a global concern [52]. Because As species are proven carcinogens, their presence in the environment is a primary public concern and is linked to severe health hazards [53]. The possible polluting roots from agriculture, including fertilizer, urban (such as wastewater), and industrial (including spills and leaks), and groundwater contact with surface water sources including rivers and lakes, are depicted in Figure 1 [54]. This refers to the spread of new infections due to pesticides, and it is a threat to human health [55].

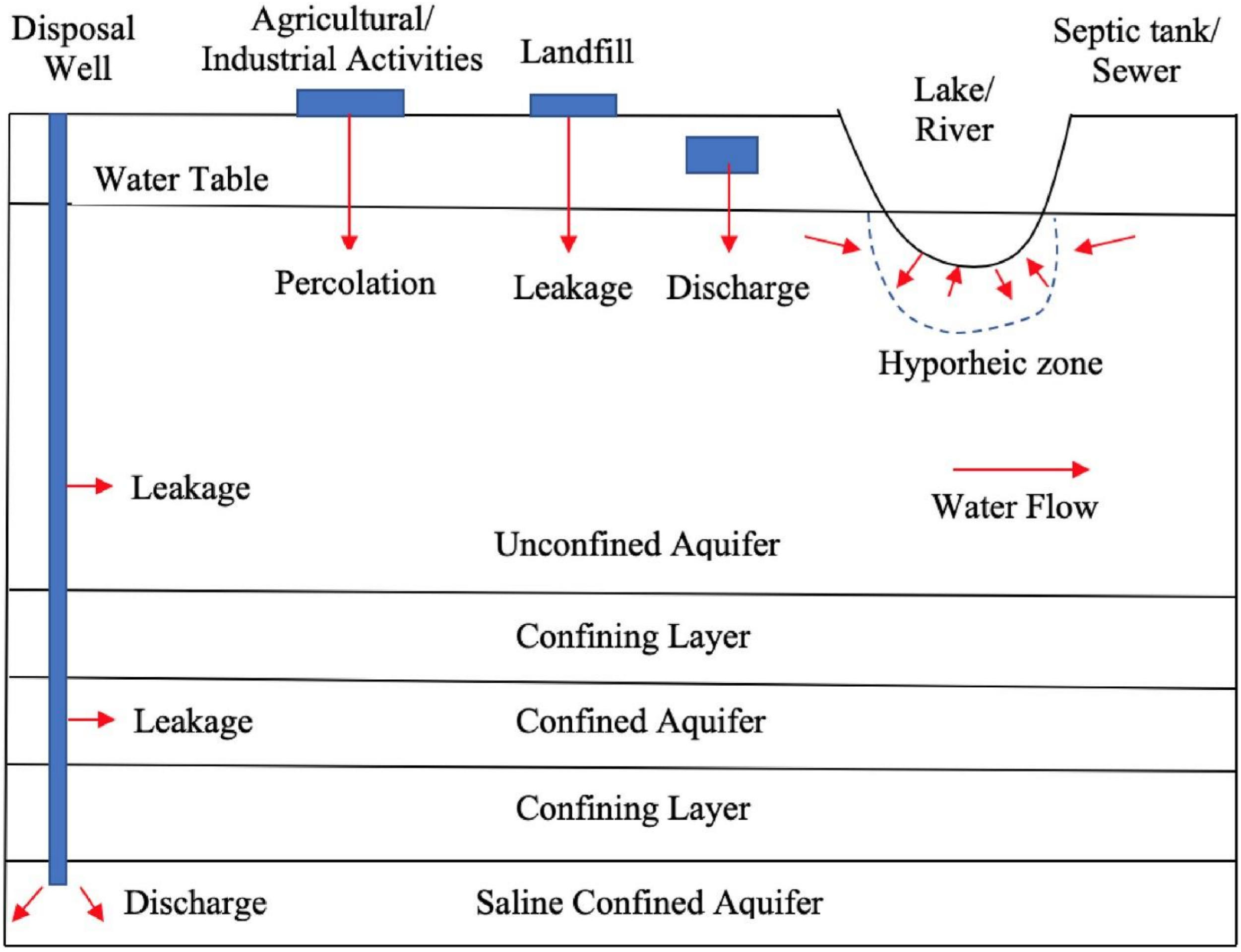

Figure 1. Groundwater interactions with contaminant pathways. (Reprinted from ref [54], with permission of the publisher).

Chronic exposure to harmful contaminants in groundwater has negative health consequences and leads to serious diseases such as cancer, neurological disorders, reproductive system damage, congenital malformations, and, more recently, diabetes mellitus [55]. Enormous amounts of wastewater are released during the liquid and solid separation [56]. Pollutants can enter the groundwater system through karstic soils [55]. Karst covers around 30% of China's land surface, and karst aquifers provide a quarter of the country's groundwater supplies (200 billion m^3 per year) [57]. Many karst locations worldwide have experienced rocky desertification, particularly in southwest China's karst area, known as the world's biggest karst area with constant carbonate rock outcrops [58]. Contamination in the atmosphere in the karst area is difficult to dissipate before precipitating again due to its unique geomorphological properties, as the environmental fragility of the karst aquifer in southwestern China is widely recognized [57]. According to [59], currently, no research has been done on the impact of karst water with various chemical properties on dissolved organic matter (DOM) leaching into karst soils. According to the various contaminants, heavy metals are numerous important and dangerous contaminants for groundwater [60]. The Lianjiang River was found to be polluted by As, Cr, molybdenum (Mo), selenium (Se), lithium (Li), and antimony (Sb), whereas the Nanyang River had higher levels of Ni, Zn, Cu, Pb, cobalt (Co), and silver (Ag) [50]. Toxic heavy metals have been found in wastewater discharged from tailing ponds: Pb, Zn, Cu, Cr, Ni, and As at average concentrations of 4.33, 269.90, 2.40, 1.69, 1.04, 11.40, and 24.62 g/L, respectively [61].

In China, 28% of groundwater examinations surpassed the WHO limit contamination level (10 mg N L^{-1}) between 2000 and 2012. Up to 36% of the river sectors and 40% of the main lakes in China did not fulfill the quality standards to be used as drinking water sources in 2010 [62]. Rainwater, surface runoff, and groundwater in karst environments frequently have high Ca^{2+} levels [59]. Surface waters (from springs and streams to rivers and lakes) can transport heavy metals across long distances, and their chemical structure varies depending on the geological characteristics through which they travel [48]. Furthermore, surplus nutrients in rivers are transferred to seas, resulting in nearly 500 instances of hazardous algae blooms in China's shore waters between 2006 and 2012, posing a threat to human health and shore ecosystems [62]. For a sustainable future, technologies that improve the efficiency of agriculture irrigation are required to grow more food or biomass with less water [63]. Because of socioeconomic and climate changes, this scenario is predicted to deteriorate in the future [62]. The hydrological cycle can forecast several climate change consequences [64]. In e-waste operations, there is still a severe lack of evidence about the origins and characteristics of heavy metal pollution. Groundwater is quickly depleting due to global climate change, and this process is threatening to overrun the entire water cycle. Because the rain cycle follows a four-step procedure in which groundwater is used in the evaporation and condensation process, the aquifer is an important aspect of the rain cycle. Unfortunately, global warming has disrupted the entire cycle.

4. COVID-19

COVID-19 has wreaked havoc on the worldwide economy and health system, resulting in >5 million lives lost [65] and enormous economic and social upheaval. Similarly, an Ebola epidemic began in middle Africa in 2013 and expanded to neighboring nations in Western Africa, resulting in 28,652 human infections and 11,325 lives lost between 2013 and 2016 [66]. COVID-19 is a disease transmitted by the recently identified acute respiratory syndrome coronavirus 2 (SARS-CoV-2) with various clinical symptoms ranging from mild flu-like symptoms to pneumonia and acute respiratory syndrome [67]. COVID-19 is the most troubling challenge humanity has ever encountered. This is owing to the fact that its consequences are both profound and worldwide. Over a couple of years after the financial crisis, the globe is dealing with the health and economic consequences of the latest crisis brought by the COVID-19 epidemic [68]. China has already faced viral outbreaks, such as the SARS outbreak in 2003. The main distinction between COVID-19 and SARS is the intricacy of the distribution networks in which China is now enmeshed [69].

If heavy metals are found to be a source of COVID-19 vulnerability, we will have a valuable tool for identifying who is at risk and a technique for proactively reducing risk [70]. According to the previous research, Cd and Pb are accountable for the COVID-19 mutation of the influenza virus, whereas As and Hg are responsible for the emergence of the COVID Beta variation [71]. Compared to other heavy metals, As has a dual role in viral infections [25]. According to [70], this revelation could save the world economy tens of trillions of dollars, in addition to saving precious human lives. For example, Zn/ZnO nanoparticles (NPs) are also employed as disinfectants and integrated into commercial items, such as food packaging. Furthermore, because the virus can stay active on plastic and stainless-steel surfaces, using nano-Zn as a disinfection agent could help to limit SARS-CoV-2 transmission by generating selfsterilizing coatings [65].

COVID-19 susceptibility and severity have been linked to various medical, lifestyle, and environmental variables (Figure 2) [25]. The novel coronavirus, SARS-CoV-2, has been recognized in wastewater [72]. The advancement of wastewater-based epidemiology (WBE) techniques is described as a harmonizing way of tracking the SARS-CoV-2/COVID-19 surveillance system [73]. According to the WHO, viruses such as SARS-CoV-2 mutate over time and will continue to alter as they circulate. There is also a lack of evidence about COVID-19 variants. Thus, continuous monitoring of SARS-CoV-2 could have a big effect on efforts to figure out how the variants change.

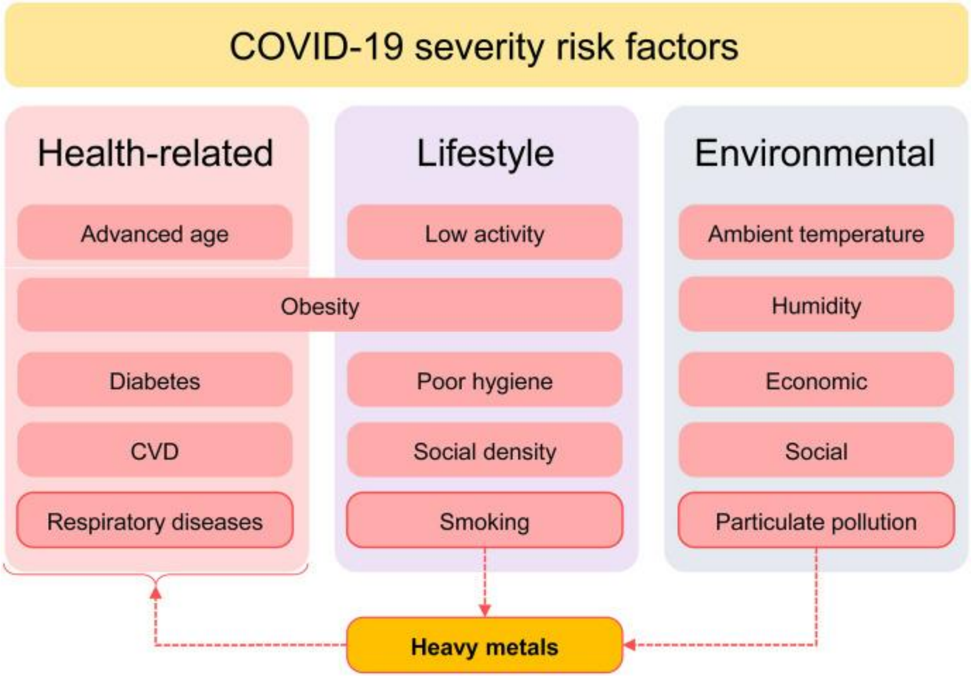

Figure 2. The proposed role of heavy metals as a link between risk factors for COVID-19 severity. Both particulate (PM2.5) pollution and smoking are associated with heavy metal exposure that at least partially mediate adverse effects of these factors on the respiratory system. In addition, heavy metal exposure was shown to be associated with higher incidence of obesity, diabetes, and cardiovascular diseases (Reprinted from ref [25], with permission of the publisher).

Our greatest concern with COVID-19 is to address the public health implications, but it is also critical to maintain our economic recovery. According to COVID-19 vaccinations, the recent findings show that the safety measurement of mRNA COVID-19 vaccinations stands out as the most thorough of any vaccine in United States record [74]. Such effectiveness suggests that the vaccines offer significant protection against infection. Further research should be focused on vaccine safety monitoring. Rapid changes in COVID-19 variants and future vaccinations will need political commitment, financial support, resource management, and multisectoral partnership. Furthermore, lack of sufficient funding is a key obstacle to success for developing countries.

CO_2 Emission

In the global carbon cycle, soil is both an origin and a sink [59]. The fundamental cause of global climate change is carbon dioxide emissions. Carbon dioxide or CO_2 originates from the burning of fossil fuels and the manufacture of cement and solid, liquid, gas, and gas flaring. Transportation, factories, refineries, and agricultural activities contribute to air pollution [60]. Globally, 6 billion tons of CO_2 was emitted in 1950. China is the world's leading emitter; it emits almost 10 billion tons of CO_2 annually [75], accounting for more than a quarter of worldwide emissions. The worldwide COVID-19 lockdown reveals a direct link between air pollution levels [60,76]. COVID-19 is expected to positively influence natural resources and cause a significant reduction in CO_2 emissions globally. The safety measures, which included a travel embargo and the suspension of most commercial and industrial operations, produced an economic downturn and lowered CO_2 and other pollution emissions while also assisting in controlling the pandemic in China [77]. Warmer winter temperatures in 2020 contributed to some of the reduction in China's power sector discharges [78]. In 337 cities across China, hazardous gas and other pollution emissions decreased by 25% at the start of 2020, and air quality improved by 11.4% compared to the start of the previous year; this modification is believed to have saved 50,000 lives in China [79]. Figure 3 depicts global and regional changes in daily CO_2 discharges. The numbers for other countries in the first half of 2020: global (−1550.5 Mt CO_2 −8.8%), the United States (−338.3 Mt CO_2, −13.3%), followed by the EU27 and the United Kingdom (−205.7 Mt CO_2, −12.7%), India (−205.2 Mt CO_2, −15.4%), China (−187.2 Mt CO_2, −3.7%), and Germany (−54.0 Mt CO_2, −15.1%), with significant but gradual drops in Japan (−43.1 Mt CO_2, −7.5%), Russia (−40.5 Mt CO_2, −5.3%), Brazil (−25.9 Mt CO_2, −12.0%), Spain (−23.1 Mt CO_2, −18.8%), Italy (−22.9 Mt CO_2, −13.7%), and France (−21.5 Mt CO_2, −14.2%) [78]. NASA (National Aeronautics and Space Administration) and ESA (European Space Agency) used the Ozone Monitoring Instrument (OMI) to track the sudden drop in nitrogen dioxide (NO_2) content during COVID-19's initial phase in China [79]. During the global shutdown, carbon monoxide (CO), NO_2, and "particulate matter with a diameter smaller than or equal to 10 µm" (PM10) all declined dramatically, but ozone (O_3) increased significantly due to the NO_2 decrease [76]. The reduction in NO_2 concentrations started in China and spread around the world [79]. The pandemic decreased pollution levels in the United States, but to a lesser extent than in China [78].

According to [80], the observed global temperature is rising faster than the simulated temperature when natural variables are taken into account alone, with human activity accounting for the entire difference; the average worldwide surface temperature has risen by 1.07 °C since 1850, with each of the last four decades being warmer than the one before it. Because soil microorganisms and the activities they facilitate are heat sensitive, global factors such as heating are instantly affecting microbial soil respiration rates. The function of increased temperature in microbial metabolism has recently received considerable attention [81]. For example, global warming has already resulted in extensive glacier and Arctic ice retreat, a 0.2 m rise in sea level, and more frequent and severe heavy precipitation occasions as well as hot extremes [80]. Since the beginning of industrialization, the world's environment has been affected, but it is the path to real development. The same scenario has occurred in south China as it also affects the middle riparian zone and the two waters are from the Yangtze River, and Yellow River. Henan Province has many rivers, the terrain is generally higher in the west and lower in the east, and the majority of the region is low plains, putting most cities in the province at high risk of flooding [82]. In central China's Henan province, the city of Zhengzhou received more than 200 mm of rain in a single hour on 20 July 2021 (denoted as "Zhengzhou flood"). More than three million people were affected by the Zhengzhou flood, which claimed the lives of 302 people and left 50 persons missing [83]. The Central Meteorological Observatory of China issued yellow rainfall signals the next morning (06:00 on 19 July), warning of severe heavy rain in areas of Henan Province, including Zhengzhou (24 h of precipitation from 08:00 on 19 July to 08:00 on 20 July, with 100–160 mm) [84]. Scientists are predicting that the rapid climatic change has had a negative impact on the environment, and these changes will affect the water resources worldwide because this can be held accountable for drought and flood in the same year.

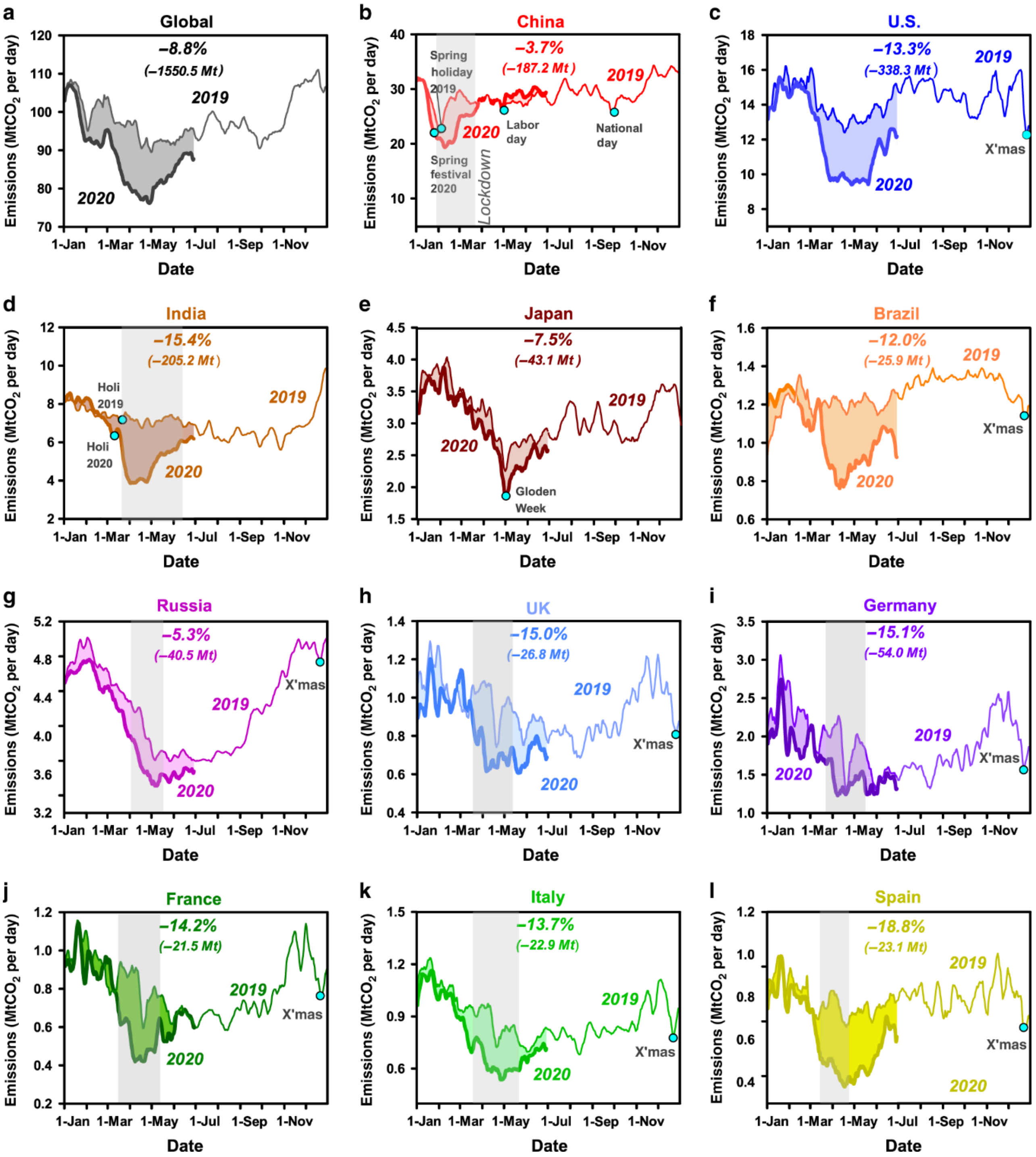

Figure 3. Daily CO_2 emissions for countries. Effects of the COVID-19 pandemic on daily CO_2 emissions globally and in each of 11 regions are reflected by the shaded differences between 1 January and 30 June of 2019 and 2020. (Reprinted from ref [78], with permission of the publisher).

Among the most controversial topics in the global research community working on waste disposal is the provision of appropriate practical resolutions to developing and growing countries [85]. Under each region's waste management standards, medical waste and plastics were usually disposed of before the COVID-19 epidemic [60]. As the epidemic advanced, changes occurred, providing challenges for healthcare facilities, with the amount of waste generated being the most difficult to control. The constant growth in the volume of medical waste following the advent of COVID-19 produced severe issues in managing plastic garbage and even immobilized the waste dumping infrastructure in several nations [60]. COVID-19 has had a terrible worldwide economic impact, with many individuals losing their employment and employers finding themselves unable to maintain their staff as their businesses decline [86]. Climate change is putting the world's food security at risk. Climate change is expected to considerably impact agriculture, affecting crops, soils, livestock, and pests directly and indirectly [87].

Furthermore, the pandemic's potential effect on food production in major food-producing nations (including China, the EU, and the United States) might have considerable impacts on global food availability and costs [88]. The COVID-19 pandemic has added tens of thousands of tons of extra medical waste to the health care waste management systems around the globe, posing a significant hazard to the environment and human health and emphasizing the urgent need to improve waste management approaches according to WHO. The current pandemic has a good effect on environmental pollution reduction, but the COVID-19 biomedical waste is a challenging issue for the world. Such waste could be infected with the virus. Medical waste disposal has become a serious global issue. Medical waste incinerators, both new and old, must adhere to increasingly stringent emission standards for a range of contaminants. There are two types of medical waste: special waste and general waste. All waste items that are not classified as toxic are included in general waste, even the potentially hazardous, and do not require special management and disposal. Special wastes require special management, treatment, and disposal, normally restricted by specialized laws and regulations. Such waste may be hazardous to one's health, safety, or the environment, or it may simply be inappropriate for dumping [89]. The climatic change affects the comparative quantity of soil community components in their physiology, temperature sensitivity, development rates, and function of the soil community [81]. The most important step in dealing with climate change is to minimize the use of fossil fuels on a daily basis.

5. Challenges Associated with Waste

5.1. Waste Management Strategy

Waste management is among the most pressing environmental issues in today's society. Waste management has become a big concern in China, as careless disposal of hazardous materials poses serious damage to the environment. The term "sustainable development" has gotten much interest in many areas, including scientific debates, daily life activities, foreign relations, local and national policies, and commercial [90]. The historic sustainable development summit in 2015 approved the 2030 Agenda, which included 17 sustainable development goals (SDGs) that would guide countries' efforts to build a sustainable world by 2030, and Goal 6 aims to guarantee that everyone has access to clean water and sanitation [91]. Heavy metal pollution and waste require a strong policy, constant monitoring, remediation, the media, and the determination to overcome with public support. As the world is working towards better wastewater treatment, it is improving; what will happen if the water sources decrease due to global climate change? Due to the closure of the manufacturing industries, the quality of the water bodies improved during the COVID-19 lockdown.

5.2. Waste Avoidance and Waste Minimization at Source

China has the world's leading electronics consumer and producer [92]. E-waste has become a severe concern in China and other Asian emerging countries since it is one of the leading causes of heavy metals and organic contaminants in municipal waste and is the most rapidly increasing waste stream [93]. The establishment of China's e-waste recycling system was founded in the early 1990s; transnational flows of e-waste from industrialized to poor nations have gotten a lot of attention because of the substantial contamination related to these recycling activities in some locations in early 2000 [92]. Electronics manufacturing, a main economic driver in China and one of the most rapidly increasing industries since the 1980s, is the third source contributing to the massive volume of e-waste [93]. E-waste is the most rapidly increasing waste source in the industrialized world, expanding at over 4% per year. The Chinese government has tightened its e-waste rules, resulting in a large amount of e-waste being held in Hong Kong's New Territories [94].

In recent years, China has created a standard e-waste recycling strategy with 109 accredited recycling manufacturers armed with the finest functional recycling machinery and supervised by highly stringent environmental safety requirements [92]. Figure 4 shows the predicted e-waste production, reported proportions of dismantled units by licensed e-waste recyclers, and the dismantling capacity of authorized recycling factories in provinces of China in 2004 [92].

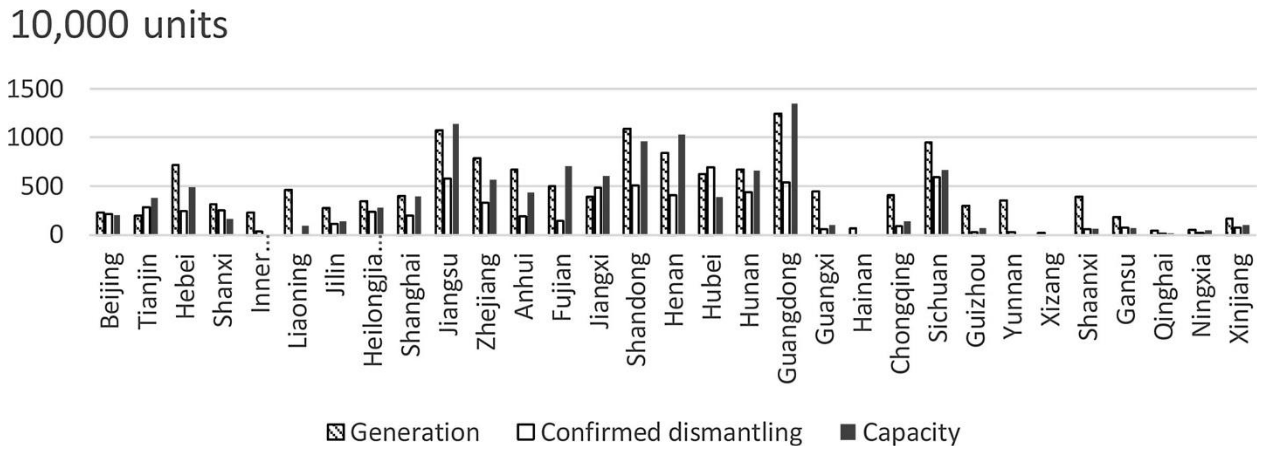

Figure 4. The generation, confirmed dismantled units, and formal recycling capacity of e-waste in each province in China in 2014. (Reprinted from ref [92], with permission of the publisher).

5.3. Reuse, Recovery, and Recycling of Hazardous Waste

According to a report by Toxics Link, 70% of the e-waste accumulated at recycling units in New Delhi, India, was shipped or dumped by industrialized nations [95]. At the same time, roughly 50–80% of the e-waste accumulated for recycling in the western United States is shipped to Asia, with approximately 90% of it going to China for recycling. For about 25 years, the Taizhou area in Zhejiang province, East China, has been e-waste recycling. It is one of China's most well-known e-waste processing facilities [96]. E-waste recycling plants utilizing rudimentary technologies are being removed quite intensively in a few sites in south China, driven by commercial motives, and in these areas, it is quickly emerging as a significant new source of pollution [19]. For example, in Tianjin, Taicang, Ningbo, Linyi, Liaozhong, Taizhou, and Zhangzhou, special resource recovery industrial gardens have been constructed to facilitate effective and ecologically friendly recycling of original and imported metal trash. Such operations are particularly common in the suburbs of major recycling cities, including Guiyu in the Guangdong region and Taizhou in the Zhejiang region, because of a lack of efficient enforcement and oversight [97]. Nonrecyclable waste is burnt or dumped directly on the ground. On a national basis, the partitioning between incineration and landfill is decided for each waste category [98]. In addition, recycling contributes to the decrease of pollutants and landfills.

Modern waste management has two basic goals: to preserve the environment and human health and to conserve resources, including materials, energy, and space [98]. E-waste recycling can provide for at least a portion of the world metal demand, particularly in areas where resources are scarce. Reuse has been encouraged to extend the life of used electrical and electronic devices [99]. Although e-waste accounts for just around 5% of global municipal waste, it is a substantial source of employment in the recycling industries of various low- and middle-income nations, including China, Pakistan, India, Malaysia, Vietnam, Thailand, the Philippines, Ghana, and Nigeria. For example, around 100,000 individuals are engaged as e-waste recyclers in Guiyu, China, likely the world's biggest e-waste recycling center [100]. During the 75th United Nations General Assembly, China declared that it would reduce carbon dioxide emissions to zero by 2030 and attain carbon neutrality by 2060. China stipulated producers' obligations in 2019, demanding them to be in charge of the logistics activities implicated in recycling and reusing lithium-ion batteries [101].

Time monitoring and applying remediation technology can also be sustainable solutions for pollution reduction. As a result, monitoring is critical for addressing current pollution most effectively. Furthermore, the world community must take a holistic strategy to address the waste management problem properly. Creating, on a national level, a pollution-control mechanism. First and foremost, establishing a new strategy based on the current COVID-19 biomedical waste is critical for environmental pollution; otherwise, it links with serious problems.

5.4. Lessons Learned from Waste Disposal

The main cause of COVID-19 is earlier waste management strategies that were ineffective. Insightful research on COVID-19 biomedical waste problems is needed for a new approach to waste management. Climate policies and action programs need to be modified from time to time, concentrating on the most contemporary situation and present necessities and demands. There must be a safe trash disposal system set in place by each government agency to preserve our natural resources and protect against potential health risks [102]. Additionally, wastewater is polluted with COVID-19, which has led to a need to establish a wastewater surveillance system to monitor COVID-19 in wastewater [103]. Such types of waste should be thrown away after being disinfected, according to the WHO recommendations [104]. Healthcare waste can contain hazardous microorganisms that can spread easily to other patients, healthcare professionals, or the general public if it is not properly handled or thrown away [105].

6. The Role of Circular Economy (CE)

Both academics and practitioners are interested in the circular economy notion because it is seen as an effective implementation for firms to apply the much-debated notion of sustainable development [106]. This energy flow paradigm of industrial operations was dubbed "extract-produce-use-dump," "take-make-waste," or "take-make-dispose" by experts [107]. Climate change, sustainable growth, nationwide legislation and policy, patron knowledge and activism, and business continuity appear to be the five guiding principles of the circular economy [108]. These three preceding domains, ecological economics, environmental economics, and industrial ecology, all played a role in developing circular economy [109]. The "Circular Economy Promotion Law," "Solid Waste Pollution Control Law," and "Clean Production Promotion Law" are three key legislations on e-waste management. These rules do not contain specific provisions, but they offer a legal foundation for handling e-waste [97]. In recent decades, recycling, production, and pollution management have received more attention because of the expanding global population and improvement in people's living standards. The 'Circular Economy Promotion Law of the People's Republic of China,' which was signed on 29 August 2008 and went into effect on 1 January 2009, is the most significant contribution to the Chinese legal system to date [110]. As a result of the COVID-19 pandemic, the world economy has been devastated, though the online market has risen significantly. Fortunately, the negative impact has diminished, and the global economy has recovered due to the efforts of developed countries around the world. Since the COVID-19 outbreak has shut down multiple mines, industries, and borders, the supply of cobalt and lithium has been interrupted.

Metal recovery from wastewater and its revaluation as precious metals brings the waste material back into the manufacturing stream, facilitating the transition from a linear to a circular economy. Invest in what we know, China provides nearly 60% of global production and works for modern, clean technologies that are the mainstay of a cleaner ecosystem. Economic development and population growth are linked. The most important aspect of this population growth is the rise of industrialization and urbanization. Then, to produce more opportunities to eliminate poverty and pollution, we must preserve our environmental sustainability. To the best of our knowledge, it is a very complex and challenging environment that requires more than a business as usual solution.

7. Conclusions

This review investigated the impacts of heavy metals, waste, and COVID-19 on the environment. Similarly, population growth is a primary source of contamination in the environment, and China is the most populous country on the planet. For the study of heavy metal pollution in soil, the Tessier sequential extraction method has a bright future. The outbreak of COVID-19 resulted in the close of industries. As a result, there was a drastic decrease in CO_2 emissions. It had a major impact on human lives as well. Millions of people have been affected, with the majority of people losing their employment, and the world continues to be plagued by this deadly virus. Because of the long-term lockdown, the global economy is currently in a perilous scenario. However, COVID-19 biomedical waste is becoming the most serious side effect. As a result of this ignorance and poor waste management practices, environmental and health disasters occur. So far, acid deposition has become a worldwide problem and has become a major issue in agriculture and forestry production, and water resource utilization. Future studies should concentrate on new policies for waste management and pollution monitoring as well as waste recycling. If the issue cannot be countered soon, then the world could face a serious crisis in the near future. At the same time, China's environmental management is still relatively weak. There is a need to conduct a specific investigation on the various factors to gain insight into the future development direction of the industry, the evolution trend of the industry competition pattern, and evaluate the degree of benefit and effect. Under the background of global climate change, the study of heavy metal pollution ecology may go beyond the category of heavy metals and pollution and conduct research in combination with other adversities. Scholars from various fields should be encouraged to collaborate on developing a new treatment approach for the COVID-19 biomedical waste.

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Abbreviations

WHO "World Health Organization" IQ "Intelligence Quotient" SEPs "Sequential Extraction Procedures" SESs "Sequential Extraction Schemes" BCR "Community Bureau of Reference" GCS "Geological Society of Canada" XRD "X-ray Power Diffraction" EUBCR "European Union Bureau of Reference Procedure" PBDEs "Polybrominated diphenyl ethers" PBBs "Polybrominated biphenyls" PCBs "Polychlorinated biphenyls" POPs "Persistent Organic Pollutants" PAHs "Polycyclic aromatic hydrocarbons" DOM "Dissolved Organic Matter" NPs "nanoparticles" CO_2 "Carbon dioxide" NASA "National Aeronautics and Space Administration" ESA "European Space Agency" Mt "Metric Ton" EU27 "European Union '27 Countries'" SARS "Severe Acute Respiratory Syndrome" SARS CoV-

2 “Severe Acute Respiratory Syndrome Coronavirus 2” OMI “Ozone Monitoring Instrument” O_3 “Ozone” CO “Carbon monoxide” NO_2 “Nitrogen dioxide” PM10 “Particulate Matter 10” mRNA “Messenger Ribonucleic acid” Ca^{2+} “Calcium ion” Ni “Nickel” Cr “Chromium” Cd “Cadmium” Pb “Lead” Cu “Copper” Zn “Zinc” As “Arsenic” Hg “Mercury” Mn “Manganese” Mo “Molybdenum” Se “Selenium” Li “Lithium” Sb “Antimony” Co “Cobalt” Ag “Silver”.

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