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Post COVID-19 recovery: Challenges and opportunities for solid waste management in Africa

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A B S T R A C T

The current COVID-19 pandemic has significantly altered the quantity and composition of waste generated on the African continent. This new phenomenon, coupled with the indiscriminate disposal of used personal protective equipment (PPEs), poses serious challenges to local authorities, most of whom have limited experience or lack the strategy to handle this occurrence. These PPEs, like the face masks, are made up of polymeric materials that are liquid-resistant and remain for a long time in the environment after discard. They are considered as a significant source of plastic pollution in the environment. Nonetheless, the environmental challenges associated with COVID-19, if Africa is to be ready for the expected growth in waste generation and variation in waste composition in the coming century as predicted by the African waste management outlook report in 2018, she has to have a renewed focus and seize the unique opportunities that COVID-19 presents. The continent has to indulge in introspection of its shortcomings in managing waste and consciously make efforts that would ensure social and technological innovation and investment in services and infrastructure in the waste and secondary resources sector than never before seen in Africa. This approach would help the continent achieve its waste management vision of extending regular and reliable waste collection services to all while valorizing waste generated. This critical review paper reveals the silver lining in the dark cloud of the COVID-19 pandemic by highlighting some of the noticeable environmental challenges in Africa due to the current pandemic and elucidating the rare opportunities that African countries can harness to improve the waste management sector.

1. Introduction

Since the novel coronavirus (COVID-19) disease emerged in Wuhan, Hubei Province of China in December 2019 and its subsequent declaration by the World Health Organization (WHO) as a global health emergency on 30th January 2020 and subsequently a pandemic on 11th March 2020, (Harapan et al., 2020), the US Centers for Disease Control and Prevention, National Centers for Disease Control, WHO, Regional and Local health authorities have announced various protocols to break the COVID-19 virus transmission, which includes frequent handwashing with soap under running water, social distancing, quarantine, and the wearing of face/nose mask. Many governments have equally imposed a complete or partial lockdown on their population and a ban on selected activities (Agence Française de Développement (AFD), 2021). The pandemic as of 14th September 2021 had killed 4652,640 people globally, with America, Europe, and Asia accounting for 47%, 26%, and 23% of the total global deaths, respectively (Worldometer, 2021). Health professionals, especially frontline workers, are encouraged to adhere to the use of Personal Protective Equipment (PPEs) such as surgical masks, disposable gloves, aprons, face shields, and N95 facepiece respirators (World Health Organisation (WHO), 2020b).

Several countries in Africa such as Nigeria, Chad, Ghana, Kenya, Morocco, Egypt, Central African Republic, South Africa, Angola, Ethiopia, Equatorial Guinea, DR Congo, Liberia, Gabon, Burkina Faso, Cameroon, and Rwanda have enacted laws to make the use of medical-grade or cloth face masks in public spaces and the workplace mandatory (Benson et al., 2021). As a result, the volume of medical waste generated has skyrocketed. In China, for instance, it is estimated that approximately 469 tonnes of medical waste linked to COVID-19 were generated every day (Peng et al., 2020). Medical waste refers to wastes derived from diagnosis, curative, palliative, follow-up, and preventive treatment in human and veterinary health sectors. These infectious wastes include waste containing microorganisms that may generate and spread diseases to humans and all materials used in the medical sector (Agence Française de Développement (AFD), 2021). Even before the pandemic, very little was known about the management of medical waste, in Africa. In 2013, it was estimated that, 282,447 tonnes of medical waste was generated each year from an estimated 67,740 health care facilities operating across Africa (Udofoji and Nriagu, 2013).

The use of these PPEs, which are considered emerging pollutants in the post-COVID-19 pandemic, has increased the volumes of household and medical waste (Agence Française de Développement (AFD), 2021; Peng et al., 2020; Sangkham, 2020; Kwak and An, 2021). The volume and composition of waste generated during this pandemic is a new phenomenon, with which local authorities on the African continent most likely have limited experience or waste management strategy, coupled with the fact that the situation keeps evolving causing the WHO to develop waste management protocols for PPE disposal on regional levels (World Health Organisation (WHO), 2020b). For instance, there is a dearth of knowledge regarding how much, what types, and the environ-

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https://doi.org/10.1016/j.envc.2022.100442
Received 28 November 2021; Received in revised form 2 January 2022; Accepted 2 January 2022
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mental effects that this waste will have (Ammendolia et al., 2021). This picture seems ominous for a continent that lacks the requisite structures to monitor efforts and quantify the emerging trend of improperly disposed of PPE debris. But the continent has proven through past crises that it can be resilient in the face of difficulties. The resilience of the continent was demonstrated during the Ebola outbreak and the global financial crisis of 2008/2009. Contrary to initial fears of widespread deaths on street corridors of Africa, current data on the pandemic shows clearly that Africa has well-weathered the storms of COVID-19, accounting for only 4.3% of global deaths (World Health Organisation WHO, 2021), although this does not warrant relaxed vigilance. However, it has been suggested that the low number of cases recorded may be due to the low testing capacity of the continent. Factors such as inadequately trained human capital, lack of infrastructure, cultural beliefs, unavailability of testing kit, and other logistics constraints have been highlighted as reasons for this low testing capacity (Adepoju, 2021; Mulu et al., 2021).

Many studies have highlighted the challenges that the current pandemic presents to the waste management sector (Benson et al., 2021; Ammendolia et al., 2021; Carpenter, 2020; Fadare and Okofo, 2020; Mol and Caldas, 2020; Prata et al., 2020; United Nations Settlements Programme (UN-Habitat), 2020b), with very few studies highlighting some opportunities that the crises present (Sharma et al., 2020; Vanapalli et al., 2021), albeit these opportunities were generic and often applicable to the developed world. However, importing solutions that work in advanced worlds may not necessarily be successful in many developing countries in Africa due to the socio-cultural and economic complexities of the African continent. Thus, there is the need for tailor-made and applicable solutions that are scalable and feasible in Africa. This review sought to highlight some of the challenges that the current COVID-19 pandemic imposes on the African continent and by extension low-income countries and the opportunities that can be harnessed to simulate its readiness and develop effective strategies to build resilient systems for sustainable management of waste during pandemic situations.

2. Materials and methods

2.1. Research approach

This study reviewed how African countries have managed waste generated due to the current COVID-19 pandemic, the challenges that confronted most of these countries, and the opportunities that the current pandemic presents. Data were collected and triangulated from various sources such as scientific journals, articles, and reports. In sourcing information for this study, keywords such as Waste management in Africa, COVID-19 and Waste management, Environmental perspectives of COVID-19, Disposal and Reuse of facemasks in Africa were searched in search engine Google Scholar, PubMed, ResearchGate, UN official sites, and Microsoft Academic.

2.2. Study area

This study focused on the African continent, which is the second largest continent after Asia. The continent covers about 20% (30,365,000 square km) of the total land surface of Earth and is bounded on the west by the Atlantic Ocean, on the north by the Mediterranean Sea, on the east by the Red Sea, and on the south by the Indian Ocean. The number of countries that constitute the African continent are 59, with a total population of 1,378,941,754 (Worldometer 2021).

3. State of municipal solid waste (MSW) generation in Africa before the COVID-19 pandemic

As of 2012, the African continent generated 125 million tonnes of MSW (United Nation Environment Programme (UNEP), 2021). As the population grows, Africa is predicted to undergo a major social and economic transformation over the next century. This transformation could lead to urbanization, change in purchasing power and habit, and a significant growth in waste generation, which would put pressure on the already challenged waste management infrastructure. For instance, by 2025, MSW generation is expected to reach 250 million tonnes (United Nation Environment Programme (UNEP), 2021), with a potential increase in this estimate due to the current pandemic. The top three countries that generate the largest volumes of waste are Nigeria, Egypt, and South Africa (Fig. 1). Despite this significant growth in waste generation in Africa, waste collection services are still a challenge with an average MSW collection rate of only 55% meaning nearly half of all MSW generated in Africa ends up in streets, open fields, gutters, drains and water bodies.

3.1. Composition of municipal solid waste in Africa

Generally, low-income economies and rural areas generate more organic waste, while high-income countries generate more metals and plastics due to differences in consumption patterns and purchasing powers (Lu et al., 2020). The composition of waste generated in Africa is generally made up of 13% of plastic and 57% of organic waste, while glass and metal waste remain the least with 4% each (Fig. 2). Considering this composition of waste generated, it is estimated that 70 – 80% of the MSW generated in Africa is recyclable; yet only 4% is currently recycled (United Nation Environment Programme (UNEP), 2021). The world bank confirmed that in low-income countries, over 90% of waste generated is often disposed of in unregulated dumps, poorly managed land fields, or openly burned (The World Bank, 2019). For instance, about half a million tonnes of plastic waste is estimated to be mismanaged in Nigeria, which is projected to increase to 2.5 million tonnes by 2025, and that of Egypt is predicted to increase from 500,000 to about 1 million tonnes. Regrettably, no country on the continent of Africa is projected to improve on its plastics waste management approach by 2025, but rather may worsen, except for Seychelles, where the situation is likely to remain unchanged (United Nation Environment Programme (UNEP) 2021; Jambek et al., 2015). This is unfortunate as the continent is unable to harness the significant socioeconomic opportunities that these wastes present as bulk (more than 90%) of it is currently dumped at uncontrolled dumps and landfills, often with associated open burning. It has been established that 19 of the world’s 50 biggest dumpsites are in Africa, specifically Sub-Saharan Africa (United Nation Environment Programme (UNEP), 2021). Reasons that have been attributed to this weak system of waste management in Africa include corruption, weak legislation and lack of enforcement, lack of public sensitization, political instability, and lack of political will (Godfrey et al., 2020).

The current COVID-19 pandemic is likely to significantly change the estimates, projections, and composition of waste generated in Africa. Depending on cultural and economic factors, the wearing of face masks (single-use or reusable) has been voluntarily or compulsory adopted by the public. Disposable or single-use masks refer to loose-fitting surgical masks and well-fitted respirators with filtration efficiencies characterized as (FFP = filtering facepiece), FFP1 (80%), FFP2 (94%), and FFP3 (99%) in Europe and (N = non-oil) N95 (95%), N99 (99%), and N100 (100%) in the US (Cizagin and Ronkay, 2020). The pandemic has caused industries producing these PPEs to increase their manufacturing capacity to meet the surge in demand. Although before the pandemic, China was already the world’s largest producer of face masks (1.3 million masks/day), its production has increased about 12 times after the pandemic (Peterson Institute for International Economics (PIIE), 2020; The New York Times, 2020). As of February 2020, the daily production of medical masks stood at about 14.8 million/day. The Japanese Ministry of economy, trade, and industry reported that over 600 million orders for face masks per month were secured as of April 2020 (Fadare and Okofo, 2020). Disposable single-use face masks are produced from polymers such as polypropylene, polyurethane, poly-
acrylonitrile, polystyrene, polycarbonate, high-density polyethylene, or polyester. The mask is composed of 3 layers; an inner layer (soft fibers), a middle layer (melt-blown filter), and an outer layer (water-resistant non-woven fibers). The main filtering process occurs at the melt-blown filter, which is formed when melted polymers are extruded through tiny nozzles, with high-speed blowing gas to produce micro and nanofibers (Fadare and Okoffo, 2020; Zafar et al., 2016). The color and texture of masks could indicate their material composition; nitrile (black or blue), vinyl (translucent), latex (white), and polyethylene (transparent with a larger fit than vinyl) (Ammendolia et al., 2021). Table 1 gives a description of some popularly used masks.

### 3.2. Cost of mismanaged waste in Africa

Before the pandemic, it was evident that the cost of the inactions of many African countries was significant as the mismanagement of waste is having economic, social, health, and environmental impacts, especially in coastal economies where marine plastic litter is on the ascendency (United Nation Environment Programme (UNEP), 2021). The indiscriminate dumping of waste in urban areas is linked to the increased risk of flooding, environmental pollution, and diseases. UNICEF named pneumonia, diarrhea, and malaria as responsible for approximately 29% of global deaths among children under the age of 5 in 2018. In 2019, 274,000 children under five years of age died of malaria, representing 67% of the global malaria deaths; sadly, every two minutes, a child dies of malaria. These infectious diseases are particularly prevalent in sub-Saharan Africa, where weak waste management systems are common (United Nations Children’s Fund UNICEF, 2020). Since about 57% of the waste generated on the continent is organic, when they are disposed of in open landfills, they generate greenhouse gasses which contribute to climate change, and leachate, which can pollute ground and surface water. These unregulated landfills, which are a breeding ground for disease vectors, are open access for scavengers who walk through in search of recyclable materials. Furthermore, these landfills also serve as a "food
bank” for livestock which is later sold on the market, exposing both the livestock and humans to various diseases (Nzediegwu and Chang, 2020).

4. Impact of COVID-19 pandemic on MSW management in Africa

As of 14th September 2021, the continent had recorded a total of 8128,632 COVID-19 cases, with South Africa leading in the number of recorded cases (35%), followed by Morocco (11%) (Worldometer, 2021). There is currently no empirical data on the exact quantity of face masks or medical waste disposed of during the COVID-19 pandemic.

4.1. Estimation of daily PPEs waste generated in Africa

This study used the mathematical model Nzediegwu and Chang (Nzediegwu and Chang, 2020) proposed to estimate the number of face masks used in Africa and, consequently, the amount of face mask waste generated each day using Eq. (1). The mathematical model estimates the quantity of daily face mask usage based on the population of each country and the percentage of the populace in the urban areas.

\[ D_{FM} = P \times U_p \times F_{MAR} \times \frac{F_{MGP}}{10,000} \]  

(1)

Where ‘D_{FM}’ represents daily face mask use (pieces), ‘P’ represents population (persons), ‘U_p’ represents the percentage of the urban population, ‘F_{MAR}’ represents face masks acceptance rate (60%) and ‘F_{MGP}’ represent the average daily facemasks per capita (the assumption is that each person in the general population uses one face mask each day).

Even though there is no current studies on the real quantity of medical waste generated in health facilities in Africa as a result of COVID-19, the WHO estimates that, high-income countries generate on average up to 0.5 kg/bed/day of hazardous waste while low-income countries generate on average 0.2 kg/bed/day, but since low-income countries do not often segregate their medical waste into hazardous or non-hazardous wastes, the real quantity of hazardous waste is much higher (World Health Organisation WHO, 2018). In Egypt, the average amount of medical waste generated is estimated to be between 0.7 and 1.7 kg/bed/day, while that of Nigeria, Mauritius, Libya, Ghana, Kenya, Algeria, Ethiopia, and Sudan are 0.81, 0.11, 1.3, 1.2, 0.92, 0.72, 1.79 and 0.38 to 0.87 kg/bed/day, respectively (Abah and Ohimain, 2011; Ansari et al., 2019; Asante et al., 2014; Azage and Kumie, 2010; Chisholm et al., 2021; Mazru, 2010; Mohee, 2005; Sawalem et al., 2009; Sefouhi et al., 2013). Even though very few African countries have documented their quantity of medical waste generated/bed/day, an average was found for the existing data (0.92 kg/bed/day) since these countries could represent the different cardinal regions of the continent. Since the few existing wastes were generated pre-COVID-19 era, the average data was doubled to make up for the suspected increase due to COVID-19. This was used to estimate the current expected medical waste being generated following Eq. (2). The amount of medical waste generated in health facilities is proportional to the number of infected persons and the average waste generation per bed (Sangkham, 2020).

\[ M_W = N_{IC} \times M_{WGR} \times H_{AR} \times 1,000 \]  

(2)

Where ‘M_{W}’ represents medical waste (tonnes/day), ‘N_{IC}’ represents the number of COVID-19 cases (infected persons), ‘M_{WGR}’ represents medical waste generation rate of 2.14 kg/bed/day and ‘H_{AR}’ represents the hospital admission rate (30%).

From Eq. (1), it can be estimated that the number of face mask waste generated on the continent per day is 352,984,160 and about 10.5 billion per month, which corresponds to about 8% of the global disposable masks usage of 129 billion per month (Prata et al., 2020). Thus, about 131,000 tonnes of face masks could be discarded each month on the African continent (Benson et al., 2021). Specifically, countries that use the most daily face masks are Nigeria (64,315,551.8 pieces), followed by Egypt, DR Congo, South Africa, and Algeria with 26,402,276, 24,718,947, 23,842,093 and 19,206,757 pieces, respectively (Table 2).

Considering the different parts of the continent, Western Africa produced the most masks used per day (121,442,125), followed by Northern Africa, Eastern Africa, Southern Africa, and Central Africa with 77,482,428, 63,863,185, 55,008,787, and 39,024,853, respectively (Fig. 3a).

South Africa generated the most amount of medical waste per day (1578 tonnes), followed by Morocco and Tunisia with 500 tonnes and 379 tonnes, respectively. As a block, Southern and Northern African countries generated the most quantities of medical waste per day while Central African countries generated the least amounts of medical waste of 776 tonnes/day (Fig. 3b). WHO estimates that, for frontline workers to be fully equipped for COVID-19 response, 89 million medical masks are required each month. For examination gloves, that figure goes up to 76 million, while international demand for goggles stands at 1.6 million per month (World Health Organisation WHO, 2020a).

4.2. Environmental pollution induced by extensive use of PPEs

The threat to plastic pollution in Africa due to the COVID-19 pandemic is increasing exponentially (Benson et al., 2021). Compared to the developed world, most African countries are more vulnerable as their solid waste management framework often lacks structures and resources and does not include specific measures for medical waste management. In such low-income countries, most COVID-19 related waste that emanated from households ended up in landfill sites or, worse, discarded in streets, creating environmental and public health problems (Sangkham, 2020; Corburn et al., 2020). These landfills are poorly constructed and managed, which pose great dangers to the health and life of scavengers. More than two-thirds of the over 130 people killed in recent landfill collapses in Africa were women (United Nations Environment Programme (UNEP), 2021). The widespread public use of PPEs and the indiscriminate littering of used products have imposed pressure on municipalities and local authorities to properly collect and dispose of potentially infectious PPEs. An environmental NGO, Ocean Asia in Soko islands concluded from their survey that in Hong Kong a large amount of discarded single-use masks were washed up to a 100-meter stretch of beach (Saadat et al., 2020). These waste in the oceans could be mistakenly taken in as food by animals leading to their death (Hellewell et al., 2020). The face masks are made up of polymeric materials that are liquid resistant and remain for a long time in the environment after discard.

Single-use polymeric materials have been identified as a significant source of plastics and plastic particle pollution in the environment. The used disposable face mask, if not properly discarded, could emerge as a new source of microplastic fibers, as they can degrade into smaller particles of sizes under 5 mm, known as microplastics under environmental conditions. A Fourier-Transform Infrared Spectroscopy (FT-IR) analysis of degrading face masks showed predominant peaks of polypropylene for the outer layer and high-density polyethylene for the inner layer (Fadare and Okofo, 2020).

The use of nose mask as a personal protective equipment against COVID-19 infection, invariably, also protects an individual against exposure (via inhalation) to atmospheric particulate matter (PM) and associated pollutants such as heavy metals and persistent organic pollutants (POPs) that may be attached to the PM. This is because the wearing of nose mask potentially filters out many of such pollutants, which are eventually adsorbed onto the plastic surfaces of the mask through electrostatic interactions and non-covalent forces. Thus, when the used masks are indiscriminately disposed of, there is a risk that the adsorbed pollutants may remobilize and contaminate environmental media such as soil and water and aggregate in biota (Pu et al., 2021; Yu et al., 2019).

Therefore, if urgent measures are not taken to mitigate the flow of waste, especially plastics, into the ocean, coastal economies are bound to suffer. Likewise, the production of face masks impacts the environ-
ment through the release of greenhouse gasses. The production of N95 mask releases 50 gCO₂eq/single-use mask (excluding the transportation process), surgical mask production releases 59 gCO₂eq/single-use mask (includes transportation), while cloth mask production contributes about 60 gCO₂eq/pcs (without consideration of washing stage). Thus, the cloth/reusable PPE could be an effective option with lower energy consumption/environmental footprint when the washing is considered (36 gCO₂eq/usage, assuming that one mask can be used for 183 times) (Klemel et al., 2020).

5. Post-COVID-19 opportunities for MSW management in Africa

If Africa is to be ready for the expected growth in waste generation and change in waste composition in the coming century, the continent has to seize the unique opportunity that the current COVID-19 presents to make an introspection of its shortfalls in the management of waste and consciously make efforts that would ensure social and technological innovation and investment in services and infrastructure in the waste and secondary resources sector than never before seen in Africa. Rightly,
the vision of the African waste management outlook for the continent is “Extending regular and reliable waste collection services to all. Safe disposal of residual waste to sanitary engineered landfills, while maximizing the recovery of secondary resources from these waste streams through social and technological innovations appropriate for Africa”. Moreover, the African Union has set a target that “African cities will be recycling at least 50% of the waste they generate by 2023” (United Nation Environment Programme (UNEP), 2021).

5.1. **Legislate waste management as an essential service**

Since the nature of emergencies evolves overtime, often, what is meant by essential services depends to a large extent on the particular circumstances prevailing in a country, although in the strict sense essential services are defined as services the interruption of which would endanger the life, personal safety or health of the whole or part of the population (International Labour Organisation (ILO), 2006). In the wake of the COVID-19 pandemic, the UNEP is urging global governments to acknowledge waste management, including medical, household, and other hazardous waste, as an urgent and essential public service in order to minimize possible secondary impacts upon health and the environment (United Nation Environment Programme (UNEP), 2020c). Many local governments and authorities have responded, referring to the waste management industry as an essential service, although this title is not reflected officially in state or federal government legislation, accounting for the sector’s continuous exclusion from many strategic government policies and plans. According to the International Labour Organization (ILO), some sectors that could be considered as essential services include the hospital sector, electricity services, water supply services, telephone service, police and the armed forces, fire-fighting services, public or private prison services, provision of food to pupils of school age and the cleaning of schools, and air traffic control. The emergency status of the abovementioned services is formally recognized as such through government actions and plans as their services are considered a priority in strategic planning and is ultimately protected from disruption from outside sources such as natural and man-made disasters, market failure, economic pressures, community complaint and mismanagement (Municipal Waste Advisory Council (MWAC), 2021). However, the ILO indicates that refuse collection services do not constitute an essential service in the strict sense of the term even though refuse collection service might become essential if the strike action of workers in this sector exceeds a certain duration or extent to endanger the life, personal safety or health of the population (International Labour Organisation (ILO), 2006). The current COVID-19 pandemic has, however, underscored that waste management services cannot continue to serve as an ad hoc emergency/essential service. The formal recognition of waste management services as an essential service is long overdue as this could help address some of the challenges of the sector, such as; the lack of consideration of waste management infrastructure and services in planning, inadequate funding of waste management activities, poor maintenance culture, the lack of consideration of waste services in emergency management and contingency planning and the potential impacts of economic crises or market failure on waste services (Municipal Waste Advisory Council (MWAC), 2021). In low-income countries where there exists no ‘essential services legislation’, the current pandemic could serve as a catalyst to enact one which would include waste management services. However, these legislations should not be enacted just to serve as a guide during industrial actions, as such an approach would not address the challenges and concerns of the waste sector. It must be noted that, without commitment from government and local authorities, raising the profile of waste management services at government and community levels alone would not translate into a robust waste management system, with corresponding investments and financial sustainability measures. Additional legislation is also needed to provide guidelines on how healthcare waste generated from non-healthcare facilities, such as households and public places should be handled (United Nation Environment Programme (UNEP), 2020b).

5.2. **Waste segregation at source is no more an option**

If the continent ever needed a reason to be convinced about the significance of waste segregation at source, this current pandemic has provided a shred of indisputable evidence to that effect. In developing continents like Africa, where access to infrastructure is lacking, a significant number of COVID patients are treated at home. Such patients generate infected waste, which is likely discarded together with general domestic waste. A recent study concluded that coronaviruses could remain active on inanimate hard surfaces (such as metal, glass, or plastic) for up to 9 days (Kampf et al., 2020). Doremalen et al. (2020) also corroborated that viable COVID-19 virus could be detected up to 3 h post aerosolization, up to 4 h on copper surfaces, up to 24 h on cardboard, and up to 2, 3 days on plastic and stainless-steel surfaces. These infectious waste generated by the COVID-19 outbreak pose a major environmental and health concern to many countries (Saadat et al., 2020), particularly in developing countries where waste management is already a challenge (Mol and Caldas, 2020) and, if not well managed, may in-

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**Fig. 3.** (a) Face mask usage per day (b) Medical waste generated per day for Western Africa (WA), Eastern Africa (EA), Northern Africa (NA), Central Africa (CA), and Southern Africa (SA).
crease the spread of viral disease in the environment (Nzediegwu and Chang, 2020). Thus, such mixed waste presents serious health risks not only to the waste collectors during transport but also to waste segregators who would be sorting out recyclable materials in various waste sorting centers. If waste sorting at source was an existing practice in African countries, municipal authorities could have capitalized on this practice to sensitize the populace about which marked and identifiable plastic bag or bin to use for disposing of used PPEs. In advanced economies where waste sorting is a conscious practice, municipal authorities leveraged on this practice to sensitize the populace about effective means of disposing of used PPEs (Carpenter, 2020; City of Toronto 2021).

Additionally, local governments could have provided free bins at public places and be assured that such bins would be used only for the designated purpose. Likewise, in low-income and informal settlements, it is recommended to distribute waste bags to households (United Nations Human Settlements Programme (UN-Habitat), 2020a). Such an approach would protect our waste collectors and managers and curb indiscriminate littering of PPEs in streets. Thus, henceforth, there should be strict adherence to waste sorting at home as this is the surest guarantee to optimal recycling of waste generated. However, if the populace is to be sensitized about the need for segregating waste at the source, then sorted waste should not be mixed with other types of waste in the same truck during collection in order not to erode public confidence and zeal. In the long term, developing countries should invest in automated waste segregation to reduce the exposure of waste workers to hazards. The introduction of artificial intelligence-enabled automated segregation systems could improve the efficiency of the process and speed of recycling, reduce risk to humans and enhance the quality and value of recycled products (Chidepatil et al., 2020).

5.3. Phase-out dumpsites

Dumpsites pose serious health risks, both to people who work informally at the dumpsites, as well as the communities around them. The environment is also severely polluted through water pollution, emission of toxic and greenhouse pollutants from the open burning of common waste with hazardous and infectious waste, as well as soil pollution. Air pollution from the open burning of waste and fires at dumpsites aggravates the health condition of the population and makes them more vulnerable to viruses such as the SARS-CoV-2 (United Nation Environment Programme (UNEP), 2020a). During a Forum of Ministers of Environment of Latin America and the Caribbean (LAC), five critical areas of action in relation to waste management were considered by LAC countries to “build back better” during the recovery phase from the COVID-19 pandemic. Key among them was the decision to phase-out dumpsites and replace them with effective management practices and sustainable waste disposal methods. Justifying this resolution, they emphasized that the cost of inaction in terms of health, environmental impact, and development can be up to 5 to 10 times higher than the cost of sound waste management (United Nation Environment Programme (UNEP), 2020a). Even though this action may seem ambitious, the African continent could take inspiration from it and equally put in measures and policies to progressively phase out dumpsites since LAC countries are also composed largely of developing countries. If Africa starts seeing the opportunities waste presents as an untapped secondary resource, it could be possible to phase out dumpsites in Africa considering the composition of waste generated. These resources, if well harnessed, could help grow and strengthen local manufacturing, create safer jobs, improve food security, address unemployment, minimize negative environmental and human health impacts associated with poor waste management practices and build local and regional economies. Value-retention practices such as remanufacturing, refurbishment, repair, and direct reuse could cut industrial waste by between 80 and 99% in some sectors and reduce greenhouse gas emissions by 79–99% (United Nation Environment Programme (UNEP), 2018)). The implementation of circular economy models with emphasis on waste prevention and recycling should be promoted during the post-COVID-19 recovery phase, considering this approach’s practical socioeconomic and environmental benefits. Furthermore, phasing out dumpsites would also enhance the resilience of the waste sector during emergencies.

5.4. Africa is capable of developing her own waste management solution

The quest to protect economies and supply chains from the shock of coronavirus has taught Africa the tough lesson on the importance of self-sufficiency. At the peak of the pandemic, when the demand for disposal face masks was higher than the supply, many populations from low-income economies, due to either economic reasons or the non-availability of imported medical-grade masks, developed an alternative locally made cloth mask with some being incorporated into fashion. Due to the socioeconomic and cultural complexity of the continent, solutions that have been successful on other continents or societies are not guaranteed to be successful or economically viable on the African continent. Additionally, some of the tried and tested large-scale recycling and recovery technology could cost the continent between US$6 billion and US$42 billion in the short term, increasing to between US$17 billion and US$125 billion in 2040 depending on the alternative waste treatment technologies adopted (United Nation Environment Programme (UNEP), 2021). These costly technologies could not be siply adapted due to most countries’ economic challenges, especially in the wake of the current pandemic. There is, therefore, the need to look within and develop local, small-scale, decentralized, community-driven, and cheap social and technological alternatives in waste management. For instance, on a continent where plastic accounts for 13% of the total waste generated, each municipal or district (many of which face huge infrastructural deficit) could be tasked to valorize their plastic waste to solve some of their infrastructural challenges by using the waste as a binder for the constructing houses, schools, hospitals, toilets, and pavement blocks for roads. For instance, a company in Columbia, Conceptos Plásticos (Plastic Concepts), recycles plastics to make bricks (mixing sand and melted plastics) and pillars which are then put together like Lego pieces in a construction system to build houses up to two stories high in only five days (Conceptos Plasticos, 2019). This approach has proven to be effective on the continent as a similar project has been undertaken in Ghana, where an indigenous plastic recycling company, Nelplast, has built a house and pavement using recycled plastics. About 13,000 kg of plastic was recycled into bricks for the house (Nelplast Ghana Ltd, 2020; Embassy of Denmark in Ghana, 2021). Additionally, some indigenous, decentralized, and low-cost solutions like the use of motor tricycles for waste collection in inaccessible areas have proven to be effective. The 57% organic waste produced could equally be valorized to valuable products such as biofuels and fertilizers to reduce the economic burden on product imports. Countries like Ghana are already ahead in valorizing organic waste by hosting the biggest composting plant on the continent. The Kumasi Compost and Recycling Plant (KCARP) is a complete integrated recycling and compost plant designed to recover all manner of waste. It has a capacity of 2400 metric tonnes of waste per day and can produce over 3000 bags (25 kg/bag) of compost/day (Graphic Online, 2021; KCARP, 2021). It is estimated that if waste is diverted away from dumpsites and landfills towards reuse, recycling, and recovery, an additional US$ 8 billion could be injected each year into the African economy and create significant socioeconomic opportunities for the continent (United Nation Environment Programme (UNEP), 2021). Thus, due to the economic benefits of the sector, local authorities could attract public and private sector investors to develop tailor-made, cost-effective, and centralized waste management solutions to compliment efforts being made by central governments.

5.5. Investment in waste management research

The current pandemic has brought to light that local authorities cannot neglect the needs of the waste sector by not investing in research
5.6. Social support for the informal waste sector

The COVID-19 pandemic has negatively impacted several aspects of our economy, including the waste management sector, where waste collectors in the informal sector have lost their livelihoods. This is not surprising because even before the pandemic hit, the price of virgin PET had been declining, and it saw a very sharp drop in 2020. The fall in prices of virgin material has caused some recycling plants to temporarily or permanently stop recycling (United Nations Human Settlements Programme (UN-Habitat), 2020b). This is very disheartening because globally, it is estimated that 20 million people rely on informal waste recycling for their livelihoods (International Labour Organisation (ILO), 2013). This pandemic has underscored the importance of having social support initiatives for informal waste managers, most of whom are women, to cushion them against future economic crises. Thus, if drastic measures are not taken, the current pandemic could exacerbate existing gender inequalities. To limit the risk of informal sector waste management workers’ risk of infection, there should be training and education with well-crafted specific programmes to equip them with the technical knowledge to implement and manage sustainable waste management practices (United Nation Environment Programme (UNEP), 2021).

6. Conclusion

There is no excuse for the continent not to exploit the benefits of recycling 64–76% of its recyclable MSW generated, particularly when most of her countries are low-income countries. Even before the COVID-19 pandemic, the cost of mismanaged solid waste on the economic, social, health, and environment of the continent was evident, which is predicted to get worse post-COVID-19 due to the significant change in the composition and quantity of waste generated. The current pandemic, however, presents a fresh beginning which, if harnessed, can revolutionize waste management on the continent. This can, however, only be possible if member states enact favorable policies and appropriate incentives to promote waste reuse, recycling, and recovery. Such policies should create a favorable environment and be attractive to boost the confidence of the private sector to invest in the waste management sector. Where waste policies and legislation are lacking or have gaps that can be easily exploited, reforms should be made to make new legislation and strengthen weaker ones. By addressing these lapes, the waste sector would be well-positioned to contribute effectively towards the post-COVID-19 recovery phase by reducing the risks of its activities on health and environment, contributing to economic growth through waste valorization, and standing in readiness to respond more appropriately to future pandemics.

Declaration of Competing Interest

None.

Funding source

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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