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Review

An Imported Environmental Crisis: Plastic Mismanagement in Africa

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Abstract: Plastic waste pollution is currently one of the main items on international agendas. It leads to more and more leakages and constitutes a dangerous threat to living beings and the ecosystem (toxic substances). Globally, only 9% of plastic waste is recycled, while 22% of it is mismanaged. A large part of this waste ends up legally or illegally in Africa. This article uses the available data on plastic waste to shed light on the situation in Africa. Particular attention is paid to imports of plastics and the recycling sector, as well as ways to combat improper dumping and to prevent/reduce marine pollution (microplastics). The roles and responsibilities of actors and institutions in Africa will be discussed. It is urgent for the international community, in cooperation with the local plastic/textile industries, to establish an effective and well-structured collection system for plastic and textile waste. This will help maximize the collection rate and minimize landfills through recycling. It is also necessary to encourage both the plastic and textile industries to opt for product designs that use easily recyclable materials (eco-design), and this option is crucial.

Keywords: plastic footprint; plastic/textile waste; plastic recycling; toxic substances; microplastic; Corporate Social Responsibility (CSR)

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1. Introduction

Africa hardly creates any of its plastics and uses them sparingly for essentials, e.g., storing water. But, Africa has become a dumping ground for the Northern Hemisphere's (i.e., Europe and the USA) plastic waste in the form of so-called "recycled" clothing and plastic feedstock. Global plastic production, estimated at 390.7 million tonnes in 2021 [1,2], has increased rapidly in recent decades [3] and will reach 1800 million tonnes by 2050 [4,5]. Landfill disposal is also increasing, leading to the widespread dispersal of plastic parts into marine environments [6]. The life cycle of plastics is estimated to be several hundreds of years [7]. Since 2015, it has been reported that 12% of plastic waste has been incinerated, with 79% ending up in landfill or leaking into the environment [8,9]. Single-use plastic packaging is the largest segment of plastics produced worldwide [10].

After Asia, the African continent is the place where the mismanagement of plastic waste is most widespread and visible [11]. From data resulting from more than 10 years of research, 33 African countries imported about 126 million tonnes (Mt) of polymers in primary form and 46 Mt of plastic products between 1990 and 2017 [12], which means all these countries imported around 172 million tonnes of plastic materials and polymers during this period [13], with an estimated value of USD 285 billion [14,15]. The import of unprocessed and/or processed plastics, finished products, or packaging made of plastics as well as plastic waste is constantly increasing. Adding to local production, mostly of single-use plastic packaging, the huge import of second-hand clothes (SHCs) with short lifespans in many African countries makes the situation worse. A sustainable solution must be found to this environmental problem.

Several sources and databases such as International Scientific Publications, reports from organizations, web pages, and policy documents were consulted to assess relevant

information for this work. Over 300 articles were reviewed, using keywords such as "plastic production in Africa", "Africa plastic import", "second-hand clothes trade", "second-hand clothes waste in Africa", "plastic waste management in Africa", "plastic recycling in Africa", "plastic plants in the world", "micro-fibres in African wastewater", "microplastic in African aquatic environment", etc. We used the relevant literature and structured this article as follows: statement of the problem, waste management in Africa compared to Europe (EU-27+3), special problem areas, and solution approach initiatives.

This paper focuses on African countries that have received little attention to date and takes an approach to assessing the impact of plastic production and waste management in Africa. The situation is critical [16] and needs to be addressed. This study attempts to gather the existing literature and to empirically underpin the underlying issue of sustainability in Africa to generate results that redefine policy and industry on this topic.

2. Statement of the Problem

2.1. Plastic Production in the World and by Region

Africa produces 5% and consumes 4% of the world's plastic [17,18]. Plastics are used daily for various purposes, e.g., for packaging goods, beverages, and food for easier transport; shoes; clothing; telecommunications; transport; etc. [15]. In 2021 [1], the regions with the lowest yearly plastic production were the Middle East, Japan, and the Commonwealth of Independent States (CIS), with an average of 11,721 kilotonnes (kt), followed by Latin America and Africa, with 15,628 and 19,535 kt; the EU-27+3 (current EU, Norway, Switzerland, and the United Kingdom), with 58,605 kt; the rest of Asia, with 66,419 kt; North America (the USA and Canada), with 70,326 kt; and China, with 125,024 kt, as the largest producer, as shown in Figure 1. In 2017, the share of plastic production in Africa and the Middle East was 7% and increased to 8% (5% for Africa) by 2021 [1]. According to the same source, it decreased by 4% in the EU-27+3 and by 1% in Japan, while it increased by 3% in China and by 1% in the Commonwealth of Independent States (CIS), and stagnated in all other countries during this period.

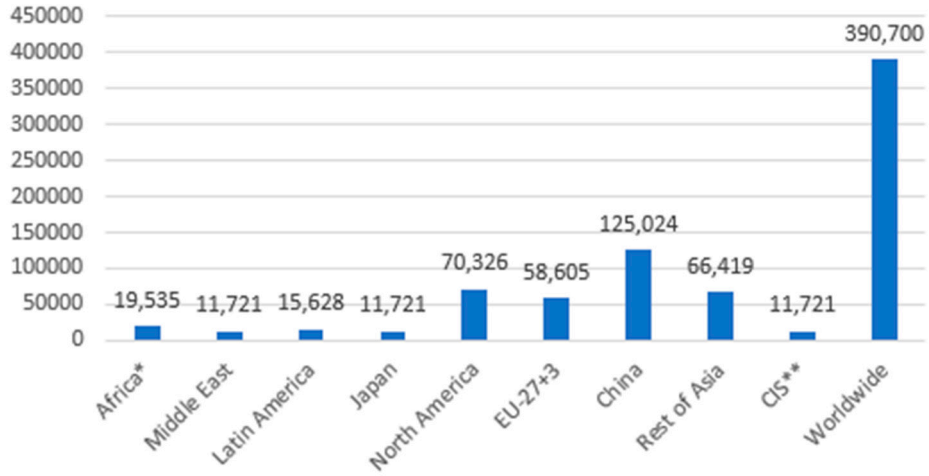

Figure 1. Annual plastic production worldwide and by region in kilotonnes (kt) in 2021 [1]; * Africa and the Middle East together produced 8% (the portion for Africa is estimated at 5%); ** Commonwealth of Independent States: Azerbaijan, Armenia, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Uzbekistan, and Ukraine.

2.2. Plastic Production in Africa

Figure 2 presents some of the plastic producers in Africa. The choice of African countries mentioned in this review is guided alone by the data availability (even if some are old) and confirms the data scarcity [19]. In 2020 [19], Egypt (2329 kt), South Africa (1410 kt), and Nigeria (513 kt) were among the biggest African plastic producers. Ethiopia's estimated production in 2022 was 386 kt [20], Ghana's was 205 kt in 2019 [21], and Kenya's

was 130 kt in 2018 [22]. In 2018, Kenya produced around 30% [23] of the country's 433 kt of primary plastic material.

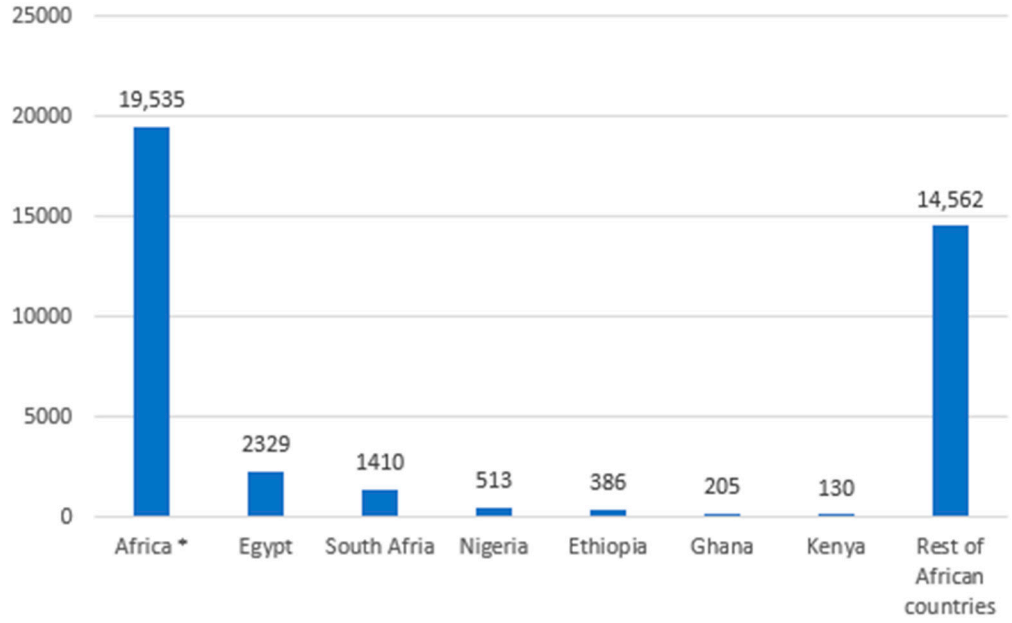

Figure 2. Plastic production in some African countries in kt per year [1,19–22]. * Africa and the Middle East together produced 8% (the portion for Africa is estimated at 5%).

Egypt is one of the largest polymer markets in Africa, accounting for over 20% of demand in 2017 and the country's polymer consumption is estimated at 2 million tonnes, with a per capita consumption of 21.8 kg/capita (investments in the plastics industry in Egypt amounted to USD 7.8 billion in 2016) [24]. In Rabat (Morocco's capital), the plastics manufacturer "Erum" completed an expansion of its plant in Tangier and inaugurated a new facility on 11 May 2023 [25]. The new plant (with a production capacity of 202 million product units) specializes in manufacturing plastic products for the clothing sector, such as plastic hangers [25]. The countries mentioned in this section are the most relevant African plastic producers and for which data are available. Countries from North, South, East, and West Africa are represented.

2.3. Imports of Unprocessed and Processed Plastics for Products

Imports of plastic raw materials from some African countries have increased significantly in recent years. It is not easy to find information concerning all African countries for the same year, so we used different references for different years. For example, from 2007 to 2020, imports for Algeria increased from 304 to 931 kt (+108%), Morocco from 374 to 659 kt (+76%), Tunisia from 209 to 326 kt (+56%), Nigeria from 513 to 848 kt (65%), and Ethiopia from 54 to 224 kt (+315%) [26]. Egypt and South Africa imported 896 kt and 539 kt of plastic raw material in 2020 [26]. In these 27 years (from 1990 to 2017), Africa imported 230 million tonnes (Mt) of plastic product components. The largest share of plastic components went to Egypt (43 Mt, 18.7%), Nigeria (39 Mt, 17.0%), South Africa (27 Mt, 11.7%), Algeria (26 Mt, 11.3%), Morocco (22 Mt, 9.6%), and Tunisia (16 Mt, 7.0%) [14]. Adding the 46 million tonnes of imported plastic products mentioned in Section 1, we can conclude that ((230,000 + 46,000)/27 = 10,222) kilotonnes of plastic products have been imported by the 33 countries on average per year in this period. Assuming that the percentage of countries mentioned above will roughly stay the same, the import quantity of each of these countries can be calculated. According to our references, with data from 2018 for Kenya; 2020 for Ethiopia; 2018 and 2020 for South Africa; 2019 and annual estimations for Ghana; 2020 and the average value across 27 years for Nigeria, Egypt, Algeria, Morocco, and Tunisia. South Africa, Algeria, Nigeria, and Egypt imported the most unprocessed plastics,

while Ethiopia, Ghana, Algeria, Egypt, and Nigeria imported the most processed plastics. Figure 3 presents the yearly average imports of unprocessed and processed (products) plastics of some African countries in kt.

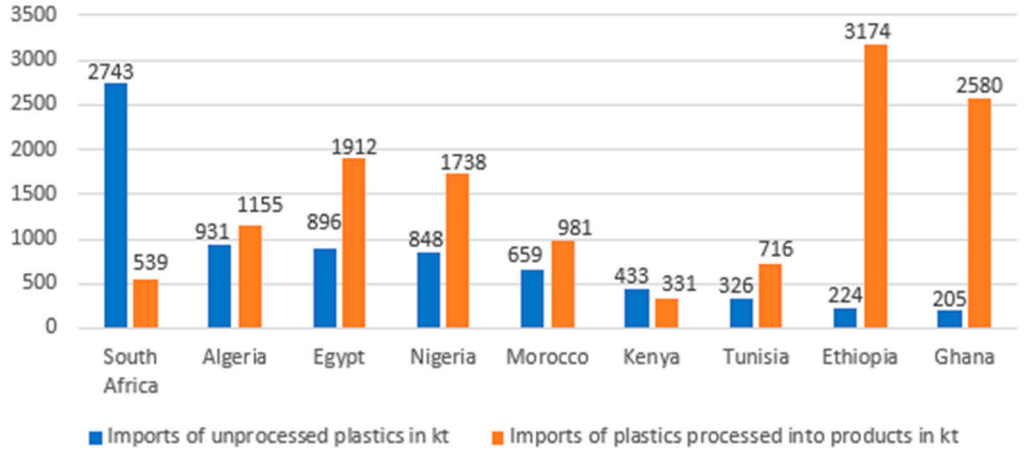

Figure 3. Average African imports of unprocessed plastics and processed plastics for products in kt per year [14,22,27–29].

2.4. Import of Finished Products or Packaging Made from Plastics

Many developing countries, including important producers of plastic, are net importers of plastic packaging. Africa's dependence on imports widely varies, ranging from 70% of plastic consumed in primary form as a product in Egypt and Nigeria to only 27% of primary plastics in South Africa [30]. Globally, according to the same source, 14 Mt of commercialized plastic packaging is significantly smaller than, for example, 196 million tonnes of primary plastic but has a high value in terms of exports, estimated at USD 53 billion in 2018. In addition, packaging products are typically single-use [30] or have a very short "in-use" lifespan (6 months typically or less) [9]. Lightweight, elasticity, and cheapness are properties that make plastic more attractive in the design of useful products. Most of the packaging used in Africa is poor single-use plastic bags (those intended to be used only once before being discarded) [31] for fresh vegetables and short-lived products for daily purchases. Egypt, Nigeria, and South Africa are the largest producers and importers of plastic polymers and products (including imported packaging). In addition, Ethiopia, Ghana, Kenya, and Mozambique are seeing growing production and imports of plastic goods [11]. The increase in imports of plastic products and packaging into African countries is a fact (many countries have formal retail outlets) [11]. According to a WWF [11] report, the COVID-19 pandemic enhanced e-commerce in various African countries and led to a rising consumption of plastic packaging, which is higher in comparison to the packaging consumed in physical stores. Data about the import of finished products or packaging made from plastic for individual African countries were rare, but the increasing tendency of its quantity has been documented.

2.5. Import of Plastic Waste or "Pseudo-Products" That Are De Facto Wastes

In general, waste management remains a major concern for many African countries [32,33]. The number of inhabitants, income of the population, and urbanization also have an impact on people's consumption patterns and the amount of waste produced, such as plastic waste, which continues to increase. In 2018, South Africa and Kenya imported, respectively, 18 kt [26] and 3 kt [29] of plastic waste. In 2018, the ban on plastic waste import in China showed serious consequences for exporters of plastic waste from developed countries, including the USA, the EU, and some other European countries, who were then forced to find new legal or illegal export possibilities in developing countries, mainly in Southeast Asia and African countries such as Ethiopia and Senegal [11]. The USA exported more than 1 million tonnes of plastic waste to Senegal in 2019 [34].

Plastic is also contained in electrical and electronic products. Moyen Massa and Archodoulaki [35] reported that Ghana and Nigeria in Africa are among the biggest recipients of e-waste from developed countries. According to them, approximately 400,000 used computers are imported every month, of which only about 50% are still working. Europe and the USA are among the largest exporters of electronic and electrical equipment to Africa. The authors mentioned that about 300 containers of used and/or discarded electrical and electronic equipment arrive at the ports of Tema in Ghana every month. An average of 75–80% of this imported equipment is already at the end of its life.

Every African consumes 5 kg of textiles per year [36], and due to the increasing exports of used clothing from industrialised countries to developing countries, clothing waste in Africa is on the rise. In general, a considerable amount of used clothing shipped in Africa is already unusable. Greenpeace [37] reported that 30–40% of imported SHCs in Kenya are of such poor quality that they can no longer be sold.

3. Waste Management in Africa Compared to Europe (EU-27+3)

3.1. Recycling Rate

In terms of increasing waste generation, a direct correlation exists between the volume of generated plastic waste, the population growth [13], and the Gross Domestic Product (GDP) [14]. Plastic is not inherently bad and contributes multiple benefits to society, and it has become an essential element of modern life and plays a key role in global progress toward sustainability [11]. Plastic products are helpful in daily human life and only need to become sustainable. The approach of a circular plastic economy (CPE) will be the best in this context. This approach is a system applying the principles of circular economy to the plastic value chain, including the design, manufacture, use, and end-of-life phases. A CPE will promote innovative design, encourage recycling, and incentivize the reuse of materials. The intention is to foster a move toward more sustainable interventions for the plastic challenge through innovation [38]. Due to lax regulations and improvements to its economy, Africa is also contributing to the rise in plastic pollution [39]. Poor management of plastic waste can be observed in almost all African countries: in most sub-Saharan African countries, it is over 80% [40], except South Africa (54%). In Mauritania, the rate is 82%; in Egypt, 67%; in Morocco, 66%; in Tunisia, 60%; in Algeria, 58%; and in Libya, the lowest, at 23% [24]. In general, short-life products (plastic packaging) and medium/long-life products (agriculture, electronics, automotive, construction, and others) generate more than 80% and less than 35% of waste, respectively (with a product consumption of 100% in both cases) [41]. According to Embrandiri A. et al. [42], 49.2% of plastic waste in Africa has plastic packaging as a source. In 2015, Africa generated 19 million tonnes of plastic waste, of which 17 million tonnes were mismanaged [11,43], compared to 60–99 million tonnes (15.8–26.1%) of globally mismanaged plastic waste in the same year. In addition, more than 380 million tonnes of such waste were generated worldwide (including in Africa), and it is projected to triple by 2060 [31]. Figure 4 presents the plastic waste data for some African countries (in kt). This figure shows that Egypt, Nigeria, South Africa, Algeria, the Republic Democratic of Congo (DR Congo), and Tanzania are the largest producers of plastic waste in Africa, with an average of more than 1000 kt. Ghana, Kenya, Angola, Cameroon, Côte d'Ivoire, Morocco, and Uganda generate over 500 kt on average, while Mozambique, Ethiopia, and Zambia over 300 kt.

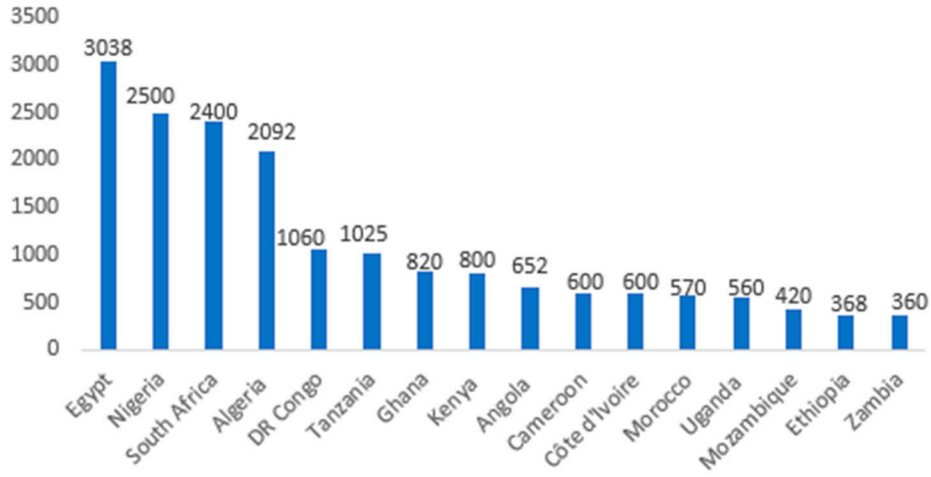

Figure 4. Average data on plastic waste for some African countries per annum in kt [9,44].

In 2019, Klynveld Peat Marwick Goerdeler (KPMG) International [45] forecasted an estimated 12.3 Mt of plastic waste to be sent to recycling facilities in Europe in 2020, while in Africa, small-scale plastic recycling plants existed only in some countries, namely [46] Tunisia with a processing capacity of 30,000 tonnes/year, South Africa 19,200 tonnes/year, Morocco 15,200 tonnes/year, Algeria 7200 tonnes/year, Zimbabwe 4380 tonnes/year, Côte d'Ivoire 1800 tonnes/year, and Ghana 1200 tonnes/year. In the EU-27+3, there are recycling plants with a capacity of over ten million tonnes per year, whereas in the African countries mentioned above, there are only 78,980 tonnes per year. These data confirm the lack of recycling plants with sufficient capacity on the continent. Table 1 compares the recycling rate in the EU-27+3 (current EU-27, Norway, Switzerland, and the United Kingdom combined) with data from some African countries. The average "correct" recycling rate including energy recovery in the EU-27+3 (77%) is higher than the African countries (<46%). Most African countries still have a low average recycling rate (<20%), as shown in Table 2.

Table 1. Post-consumer plastic waste treatment in Kenya, South Africa, and Ghana compared to EU-27+3 [1,26,29,47].

Process	EU-27+3 (%)	South Africa (%)	Kenya (%)	Ghana (%)
Recycling/Incineration (energy recovery)	77	45.7 *	36 *	25 *
Landfill	23	44.3	8	58
Open burning	Ban	10	56	17

* Recycling, all properly disposed processes and/or energy recovery.

The incineration of plastic waste produces tonnes of toxic air pollutants if it is not carried out properly. In addition, the post-treatment of incinerators requires a large amount of land and funding [48]. Open-field incineration of plastic waste, as practiced in many African countries, is one of the main sources of pollution [49]. Municipal solid waste (MSW) contains about 12% plastics, which can release toxic gases into the atmosphere when incinerated [49]. Although the incineration of solid plastic waste results in a 90–99% volume reduction [50] (i.e., a reliable reduction in landfill), it is often carried out in an open field in most African countries, with all the associated negative environmental impacts (e.g., CO_2 emissions and some infectious diseases). Therefore, this is not a suitable solution [51], although the associated energy would be useful in the cement industry for example (a "clean" incinerator with suitable filters) or using suitable filters for plastic waste burning in a vacuum chamber in anaerobic conditions to produce steam which will help to generate electrical energy effectively because such power plants produce on average more CO_2 than the gas-fired equivalents. The presence of toxic substances in recycled plastic waste

has been confirmed [52,53]. Some concentrations of PAHs and polychlorinated biphenyls (PCBs) have been detected in sediment cores of the Lagos (Nigeria) lagoonal system, which may pose a significant ecotoxicological risk to estuarine organisms [54]. Table 2 shows the toxic substances associated with plastic waste.

Table 2. Associated toxic substances in plastic waste [55].

Toxic Substances		
Polycyclic Aromatic Hydrocarbons (PAHs)	**Persistent Organic Pollutants (POPs)**	
	Legacy POPS	**New POPs**
Benzo(c)fluorene, Dibenzo[a,l]pyrene, 5-Methylchrysene, Cyclopenta(cd)Pyrene, Dibenzo[a,e]pyrene, Benzo(j)fluoranthene, Dibenzo[a,i]pyrene, Dibenzo[a,h]pyrene, Benzo(a)pyrene, Acanaphlene, Acanaphthylene, Anthracene, Benz(a)anthracene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(ghi)perylene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno[1,2,3,cd]pyrene, Naphthalene, Phenanthrene, Pyrene	Pesticide Aldrin, Chordane, DDT, Dieldrin, Endrin, Haptachlor, Hexachlorobenzene (HCB), Mirex, Toxaphene, Dioxin-like POPs, Polychlorinated biphenyls (PCBs), Polychlorinated dioxins (PCDDs), Polychlorinated furans (PCDFs)	BFRs: Hexabromocyclododecane (HBCD), Tetra and pentabromodiphenyl, ethers (TeBDE, PeBDE), Hexa and heptabromodiphenyl ethers (HxBDE, HpBDE), Decabromodiphenyl ether (deca-BDE). Others: Alpha-hexachlorocyclohexane, (a-HCH), Beta-HCH, Chlordecone, Dicofol, Hexabromobiphenyl (HBB), Pentachlorobenzene (PCBz), Lindane, Pentachlorophenol (PCPh), Pentafluorooctane sulfonic acid (PFOS), Perfluooctanoic acid (PFOAS), Poplychlorinated Naphtalenes (PCNs), Short-chain chlorinated paraffins (SCPPs), Endosulfan, Hexachlorobutadiene (HCB)

3.2. Energy Recovery in Large Plants and on a Small Scale (Use of Used Textiles as Substitute Fuel in the Domestic Sector)

In 2017, the first conversion of plastic waste into synthetic fuel oil was developed in Kenya and a waste-to-energy plant was commissioned in Ethiopia [42]. The recycling rate for the EU-27+3 in 2021 (42% [1]), shown in Table 1, provides accurate data on energy recovery through plastic incineration plants and confirms that this process is more developed in Western countries. The incineration of plastics purely for volume reduction is not sustainable and is contrary to the goal of the circular economy, which includes the reduction, reuse, and recycling of plastic waste. Material or energy recovery is the best approach as it offers the best environmental outcome [56]. Bassay et al. [56] propose incineration, conventional pyrolysis, conventional gasification, and catalytic gasification as recycling methods for the thermal treatment of plastic waste in Africa. In 2017, Nunes, L.J.R. et al. [57] presented a study on the use of waste from the textile industry (more specifically, cotton waste) as a renewable resource for the production of thermal energy (production of cotton briquettes in Portugal). The construction of large and small plants to convert textile waste into energy for the domestic sector may be more attractive for African countries. Studies on the conversion of used textiles into fuels in Africa were not found in this survey.

3.3. Orderly and Irregular Landfilling

South Africa is the 32nd largest producer of plastics globally, and the plastic industry plays a significant role in the country's economy [58]. In 2018, South Africa properly disposed of 44% [26] of its plastic waste. In most developing countries (including in the African continent), plastic waste is not properly landfilled [9]. There exist more open dumpsites of mixed waste (irregular landfilling), like in Figure 5. Plastic waste is often openly incinerated in such landfills.

Figure 5. Unofficial mixed landfill waste near Mokolo coal market (Yaounde—Cameroon).

In South Africa, 10% of plastic waste is openly incinerated, 17% in Ghana, and 56% in Kenya (Table 1), with all the negative consequences for the environment and living creatures. The biggest problem in landfilling waste is its degradation without any appropriate expert control (negative impacts on human health and the environment). Plastic waste is even more hazardous due to its long lifetime [49], as it can undergo several negative transformations during this time due to the presence of toxic substances and/or additives and become a source of pollution for groundwater. Landfilling, as shown in Figure 5, is not a long-term solution [51] as it contributes to water crises in the affected countries, especially in African drought areas [59]. Table 3 shows the share of textile waste in the waste stream, the estimated recycling rate, and the disposal methods in some sub-Saharan African countries. In all countries listed in the table, the recycling rate is below 20% and even below the EU-27+3 average (77% including incineration with energy recovery). In South Africa, open dumping, burying, burning, incineration, and landfilling are the disposal methods [9]. Dumping, burying, and burning are used in Ghana, Kenya, and most African countries [9].

Table 3. Textiles waste, estimated recycling rate, and disposal methods in some sub-Saharan African countries [9].

	Nigeria	Ethiopia	Dem. Rep. of Congo	Cameroon	Côte d'Ivoire	Mozambique	Rwanda	Tanzania	Uganda	Zambia
Textiles waste in waste stream (%)	5	N.S.	N.S.	N.S.	2.8	N.S.	N.S.	2	1	N.S.
Estimated recycling rate (%)	<10	5	<15	<20	<20	1	10	4	N.A.	1–3
Available disposal methods	Open dumping, burying, burning, incineration, and landfilling	Dumping, burying, and burning	Open dumping, burying, and burning	Open dumping, burying, and burning	Open dumping, burying, and burning	Dumping, burying, and burning	Dumping, burying, and burning	Dumping, burying, and burning	Dumping, burying, and burning	Dumping, burying, and burning

N.S., Not Specified; N.A., Not Available.

4. Examples of Africa's Own and Imported Plastic Waste

4.1. Bags for Drinking Water Supplies

Water scarcity is a big problem in Africa, where 325 million people lack access to safe water [60]. In Ghana, 150,000 bags are produced daily by larger companies and 45,000 bags by small companies for sachet water (85% of the plastic waste generated in Ghana [14]). In addition, over 60 million sachets are consumed daily, with about 1500 sachet water factories alone in Lagos (Nigeria) [14]. In many African countries, low-density polyethylene (LDPE) and high-density polyethylene (HDPE) are polymers used to produce bags for drinking water. Figure 6 presents an example of a 500 mL sachet water.

Figure 6. Example of sachet water (English translation of Non-English character: MINERAL WATER, *to maintain its quality, EAU GOLDEN is regularly checked by an approved laboratory, kept away from sunlight).*

4.2. Imported Used Clothing

The fast fashion business model, which drives the second-hand trade, leads to a colonial relationship between the Global North (GN) and the Global South (GS), with the GN exporting unwanted old clothes to mainly African countries [61]. That said, the GN does not want to dump these clothes locally to distort their environment further but rather exports them legally or illegally to Africa and other places in the world. A huge part of imported unwanted second-hand clothes (SHCs) comes from the US (export volume of around 500,000 tonnes per annum) and the UK (around 319,998 tonnes per annum) land in Africa. [62]. Kenya was Africa's leading importer of second-hand clothing (184,000 tonnes) in 2021 [63]. Ghana, Benin, Tanzania, Kenya, and Uganda received between 2% and 4% of the world's exported SHCs [64]. Current data on the import of SHC into African countries are difficult to find, as they are also traded illegally in this sector. Figure 7 shows the import of SHC to some African countries.

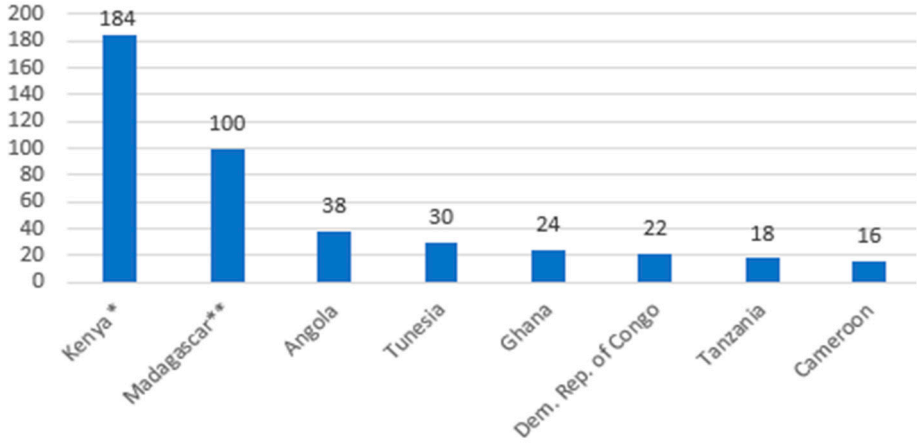

Figure 7. Average imports of SHCs for some African countries per annum from 2015 to 2019 in kt, Kenya (in 2021 *) and Madagascar (estimated annual imports **) [63,65,66].

4.3. Plastic Leakage and Marine Pollution

Mismanaged waste from African shipping and maritime activities such as aquaculture and fishing also ends up in the oceans. Imported, abandoned, lost, or otherwise discarded fishing gear contributes to an estimated 640,000 tonnes of additional marine litter worldwide (including Africa) [67]. In South Africa, it is estimated that 29% of household waste is disposed of by "self-help" [58]. The gaps in the country's waste collection pose some challenges, such as the fact that the local waste recycling economy is largely driven by the informal waste sector and there is still a significant amount of post-consumer materials (599 kt/a according to a 2019 in-country plastic recycling survey) that are not or cannot be recycled, some of which is disposed of in compliant landfills, but which also leads to illegal dumping [58].

Around 80% of all plastic waste in Ghana (similar to most African countries) has land-based sources, whilst 20% has ocean-based sources [68]. Fred-Ahmadu H. O. et al. [69] used the ATR-FTIR method to attest the presence of microplastics such as polystyrene (PE), polypropylene (PP), polyvinyl chloride (PVC), polyamide (PA), polystyrene (PS), polyurethane (PU), ethylene vinyl acetate (EVA), acrylonitrile butadiene styrene (ABS), polyethylene terephthalate (PET), and a mixture of PE and PP in epipsammic sediments in Nigeria. The same source reported the presence of microplastics in Ghanaian coastal la-goon sediments. Kan R. F. et al. [70] confirmed the presence of microplastics in the Nile River (Egypt). Microplastics have been found also in the sediment of the complex la-goon-channel of Bizerte (Northern Tunisia) [71]. According to the WWF [11], four big African rivers—namely, Congo, Niger, Nile, and Zambezi—are among the 14 major rivers around the world to have been identified as plastic leakage hotspots from land-based sources, close to urban centres with high waste generation but poor waste management systems. It is possible that microplastics and other contaminants have synergic effects on the health of organisms or can serve as transport vectors for other contaminants [72–74]. When plastic waste enters the environment in Africa, it begins to decompose and fragment in combination with solar radiation, cold, heat, drought, and rain, resulting in so-called "secondary microplastic", as opposed to microscopic material manufactured for use in various products, such as microbeads in beauty products (used also in Africa) and/or residues from the local plastic industry (primary microplastic) [75–77]; both of these land in the African marine ecosystem and become microplastic (MP) pollution. Due to the small debris that they are or have become, these MPs subsequently become a serious threat to marine fauna and flora on the one hand, and the presence of toxic substances in them has dangerous consequences on the human food chain on the other hand. Many studies reported MP presence in (i) fish [78–85] (fibres are the most common MPs from a morphological view, with 57.6–86.5% of observed particles) [78]); (ii) salt [78–82,84,86,87] (the presence of microplastics in salt samples has been reported, namely, 8–102 particles/kg

in lake salt and 9–16 particles/kg in rock salt [78]); (iii) drinking water [78–90] (which ensures adequate hydration for health, maintains the dietary nutrient-to-calorie ratio, and helps bodily functions [78]), with a worldwide investigation of both bottled and tap water confirming microplastic contamination [78]; and (iv) rice [78,91] (which is the staple food for around 50% of the world population and provides more than 20% of global dietary energy in the human diet [78]), among others. In 2016, an American Chemistry Council (Trucost) study [92] estimated the damage caused by plastic waste (including macroplastics, microplastics, and nanoplastics) to oceans at USD 5 billion and to human health and ecosystems at USD 63 billion in the case of the business as usual policy. Not many articles have been published on marine pollution in Africa; only 59 plastic studies have been conducted on African aquatic environments and were published from 1987 to September 2020 [33]. Worldwide (including Africa), 22 million tonnes of macro- and microplastics on average leaked to the environment in 2019 [93].

5. Initiatives to Solve the Problem

To fight against plastic waste leakage, some African countries including Senegal, Côte d'Ivoire, Mali, Ghana, Kenya, Ethiopia, Malawi, Mauritius, Tanzania, Uganda, Eritrea, and Congo [9,94] have banned single-use plastic bags, but the enforcement and execution of this measure are quite challenging [9].

In South Africa, the preferred waste management method is recycling. Due to collection difficulties, as mentioned above (mostly driven by the informal sector), only 40.3% of short-lived plastics and 17.7% of all converted plastic are taken from recycled-content landfills and recycled at recycling plants [58].

In Rwanda, the combination of a strict legal regime, enforcement, and arguably successful policy has been implemented to substantially reduce plastic pollution [19]. After a study conducted by the Rwanda Environment Management Authority (REMA) in 2003 [95], which provided some evidence of local discussions for anti-plastic action, the Rwandan government responded by initiating nationwide campaigns to increase awareness about the issues in 2004. In 2005 [95], Rwanda banned the import and use of plastics that are less than 100 microns thick. In 2008 [95], Rwanda's anti-plastic bag legislation, which banned the importation and use of non-biodegradable packaging bags, became one of the strictest laws. However, a person who intends to manufacture, import, export, or use plastic carry bags and single-use plastic items for exceptional reasons can apply for authorization [96]. A competent authority establishes the guidelines for the procedures and conditions for the issue of exceptional authorization. Imported products packaged in plastic material or single-use items are subject to an environmental levy following relevant laws [96]. In addition, every manufacturer, wholesaler, or retailer of those products must put in place mechanisms to collect and segregate used plastic carry bags and single-use plastic items and hand them to the recycling plants [96]. Every person/entity recycling this waste must do it in a way that protects the environment. Any person/stakeholder who violates the legislation pays up to a FRW 10,000,000 administrative fine, depending on the law that was violated (USD 1 = FRW 1237). A lack of monitoring and data management systems limits the government's ability to quantitatively measure and assess the impacts and effectiveness of plastics policies needed to design, improve, and implement plastics policies for the effective management of plastic waste [97]. According to the same source, Rwanda needs to invest in establishing data collection and management systems for plastics and plastic waste. However, some qualitative improvements have been achieved through this legislation in Rwanda.

6. Discussion

In 2015, plastic consumption in Africa was 16 kg (24 kg/year in South Africa [14]) per person, which is the lowest compared to the global average of 45 kg and 136 kg in Western Europe [11], but it is steadily increasing. A study estimated that plastic waste will increase to 165 million tonnes in Africa by 2030 [98]. Consumption patterns and

demographics in Africa are constantly changing over time, putting considerable pressure on the waste management system (especially in large cities that attract more unemployed young people) [99].

In 2021, we surveyed Cameroon with 305 participants (40% women and 60% men); 220 valuable responses (72%) were received, mainly from the country's two major cities, Douala and Yaounde. Of the 220 respondents, all admitted to coming into contact with plastics (particularly single-use plastic packaging) daily, but only 64 people (29.1%) are aware of the problem of plastic waste, sort it out, and then pass it on either to third parties or to NGOs for "appropriate" treatment (to avoid it ending up in an open landfill). Sixteen people (7.3%) throw their plastic waste in the rubbish without thinking about what happens to it but are aware of the environmental problems associated with it. These people consider themselves powerless to do anything about it, as they see it as a matter for the municipalities and the state. One hundred forty people (63.6%) stated that they have other concerns, such as the problem of economic survival and worrying about what will happen to the plastic waste afterward (question about the priority of life). Based on our survey, we can assume that each African consumer receives on average 3–4 pieces of single-use packaging (depending on purchasing power) per day as packaging for products bought in markets and/or shops. Consequently, plastic waste will continue to increase in Africa if nothing is done to introduce a recycling process to change this paradigm. This compels the consideration that a recycling strategy needs to be planned and implemented. Figure 8 presents a schematic illustration of plastic waste recycling in Africa.

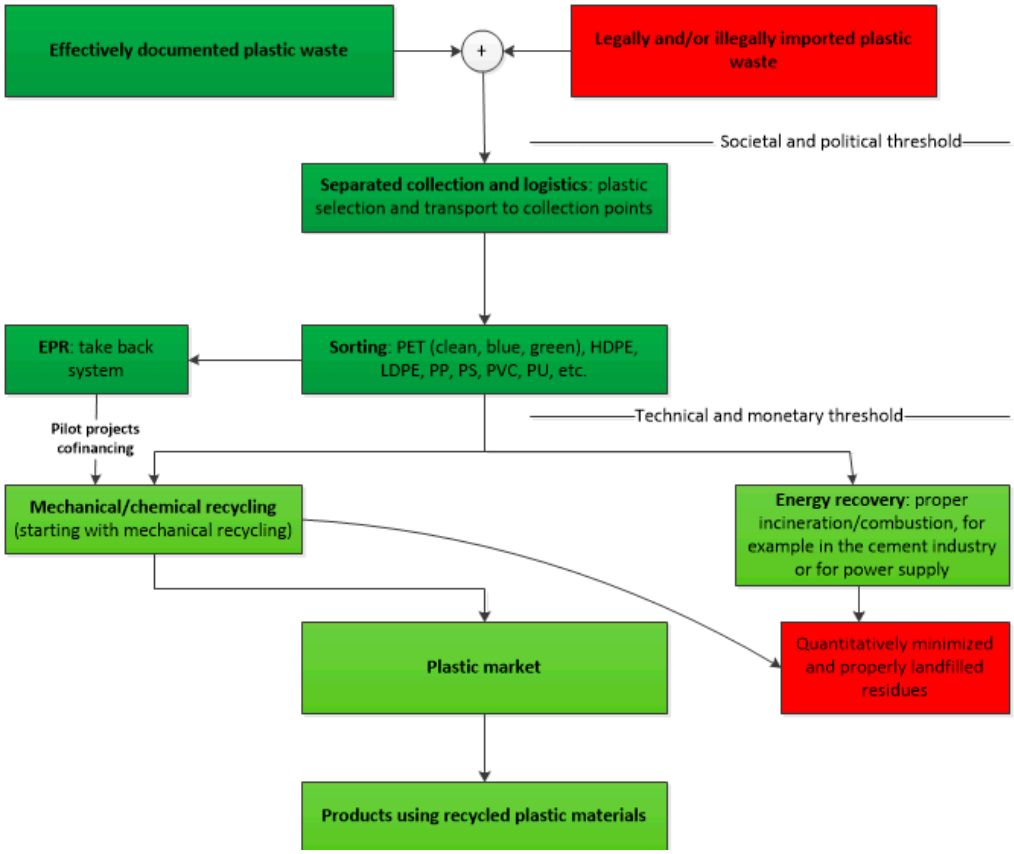

Figure 8. Schematic illustration of plastic waste recycling.

Another solution for the plastic waste problem in Africa is to enter into agreements with the plastics industry (Extended Producer Responsibility, abbreviation EPR), allowing producers to take back product waste and/or to finance the recycling of product waste at the end of their life (investment in innovative and clean technology for suitable product designs). In 2021 [100], South Africa introduced mandatory Extended Producer Responsi-

bility (EPR) and implemented initiatives such as Deposit Refund Schemes (DRSs), which are source segregation programs that are expected to reduce the amount of plastic waste entering the environment by improving collection. The roles and responsibilities of actors and institutions involved in plastic waste in Africa are meaningful. Nevertheless, it is important for the international community, in cooperation with the plastics industry, to establish an effective and well-structured collection system for plastic waste. This will help to maximize the collection rate and to truly minimize landfills through clean recycling. Incentivizing the plastic and textile industries to opt for product design that uses easily recyclable materials (eco-design) is also crucial.

Recycling second-hand clothes can reduce greenhouse gas emissions by 53%, pollution associated with chemical processing by 45%, and water eutrophication levels by 95% [101], and could contribute to the sustainable management of resources and well-being of the population in Africa. Every phase of the life cycle of textile waste recycling (i.e., collection, sorting, transport, and recycling) creates employment and gives opportunities for small and/or family businesses. African countries need to consider the vast amounts of textile waste generated by the second-hand trade (legal and/or illegal) as a possible source of income by introducing a new recycling policy on this issue. The results of a study [57] on the conversion of textile waste into energy show that cotton briquettes made from textile waste have a calorific value of 16.80 MJ/kg and a cost of 0.006 EUR/kWh when used as fuel. This means an annual reduction in fuel costs of 80% and 75% compared to heating oil and wood pellets, respectively. According to the same source, for the domestic sector, it is possible to produce briquettes from a blend of 90% cotton and 10% polyester [57] in small-scale and/or large-scale plants. Furthermore, imports of SHC in Africa have a negative financial impact on the local garment production market due to their low prices.

The link between climate change and plastic pollution is that plastics are mainly made from fossil fuels such as fuel oil, gas, and coal. Global (including Africa) life cycle GHG emissions from conventional plastics were 1.7 gigatonnes (Gt) of CO_2 equivalent (CO_{2e}) in 2015 and are projected to increase to 6.5 Gt CO_{2e} (26% growth) by 2050 at current consumption patterns [102], which will exacerbate the climate change problem. This means that if nothing is done, the contribution of plastics to greenhouse gas emissions will also increase in Africa. CO_2 emissions from the production of polyester are 2–3 times [39] higher than cotton. However, cotton production consumes large amounts of water and accounts for 11% of global pesticide consumption [103], making it an environmental problem for Africa.

The increasing plastic pollution in Africa is due to years of accumulation of waste without any treatment measures. Most studies mention that Africa is a net importer of plastics. Comparing the amount of plastic production in Africa (19,535 kt in 2021) and the annual average of plastic imports over 27 years ((230,000 + 172,000)/27 = 14,889 kt) for 33 African countries, it can be said that the contribution of plastic imports is equivalent to 76% of African plastic production in 2021 and is therefore significant. Knowing that the data for 33 countries are based on estimates, and if we also take into account the data from the other 21 African countries (Africa consists of 54 countries) that are not included in this statistic and the amount of (legally and/or illegally) imported plastic/textile waste, we can probably be sure that plastic pollution in Africa is an imported environmental crisis. We need more studies on this in the future.

Planned regulations should mandate companies to manufacture sustainable and repairable products, exerting a significant influence on their product design. Producers, importers, and consumers should address a hierarchy of measures and essential considerations:

- Evaluate the necessity of using the material;
- Implement strategies to minimize the quantity of used material;
- Opt for materials with easy recyclability;
- Design products for straightforward dismantling at the end of their life cycle.

7. Conclusions

Most African countries import a large amount of plastic products and "pseudo-products that are de facto wastes" every year, but there is not enough up-to-date statistical data and concrete information on the production and import of plastics across the continent. A lack of data leads to underestimation of the problem and deliberate ignoring. The growing population in Africa and the improvement in living standards go hand in hand with increasing plastic consumption. Therefore, without a sound environmental policy, Africa's own and imported plastic waste will lead to a dramatic situation and require a global approach. Banning the illegal/legal trade of unwanted second-hand clothing from industrialized countries to Africa and between African countries themselves is part of the solution. The best option to reduce textile waste is to slow down the production of new clothing and to increase the quality and lifespan of these new products, as proposed in the European Commission's waste hierarchy (2018) [69]. In production, textile companies need to choose and/or develop knitting techniques that reduce fibre loss [104]. The construction of large-scale plants with high exhaust gas purification capacities to utilize used textiles as a substitute fuel for the household sector is the best option for African countries.

In Africa, it is essential to improve plastic waste management strategies through a better collection system, a ban on improper landfilling, the reuse of plastic products, and the improvement of plastic recycling by the local plastics industry. We believe that awareness campaigns for better individual consumption behaviour of plastic products are very important.

Considering the aforementioned disparities and problems that surround the current plastic waste management strategies (including microplastics and nanoplastics), the following can be recommended: (1) Plastic waste should be monitored in the environment globally, with a requirement for all countries to establish a database on their collection and treatment. As a global problem, plastic waste needs the approach to this global solution to be more efficient. (2) Plastic monitoring systems need to be harmonized in terms of regular reporting, monitoring, and assessment of sources, pathways, flows, and balances of waste in the environment to support waste management policies and regulations [105]. (3) Stakeholders need to get involved early in the development of plastic waste prevention measures, which is linked to the psychological importance of taking responsibility for measures, to increase their commitment to the implementation of measures when they are finally adopted (Corporate Social Responsibility, abbreviated as CSR: multinational corporations/companies need to contribute to improvements in worldwide social and environmental standards) [105]. (4) Sustainability awareness should be promoted among the population by recommending well-designed programs that help people see links between their daily activities and plastic waste generation/management [105].

The limitations of this study are the lack of updated data and the low number of studies on plastic exports and imports in Africa, which are the consequence of less transparency among all stakeholders.

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