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Global plastic pollution and informal waste pickers

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Overview Review

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Abstract

Increasingly plastic pollution is being recognized as a critical environmental and human health threat of unprecedented scale and complexity. While trends in plastic production and consumption are still on the rise, the negative effects of uncollected, mismanaged, dumped or incinerated plastic waste are causing profound impacts on the environment, oceans, climate and food chains compromising the quality of life for humans and other living beings, with expected cumulative negative effects for the near future. Particularly populations in the Global South, where new markets for plastic consumer goods have rapidly emerged over the past 30 years, while waste management, in general, has remained precarious, underfunded or inexistent, directly experience the burdens of plastic pollution. The emerging environmental problems are particularly visible in these regions and so are also possible solutions and alternatives. Approximately 20 million informal workers already recover plastic waste from the garbage in the Global South, usually working under precarious, risky and poorly paid conditions. The literature claims that they represent a workforce that if recognized, integrated and valued and under decent work conditions and fair remuneration could potentially increase significantly the capturing of plastic waste and reduce the amount of fugitive plastics. This review paper applies an anthropogenic global environmental change theory lens to discuss the key challenges in managing plastic waste and global plastic pollution, uncovering major causes, impacts from dispersion and leakage of plastics into soil, water and air, recognizing the relational and geographic perspectives of plastic waste. A concerted effort is required to coordinating policies and technological solutions in order to strengthening, fund and recognize the waste picker sector as a key protagonist in addressing this waste issue.

Impact statement

The manifold negative impacts of plastics are far-reaching and not yet fully understood or acknowledged. This research points toward the complex environmental and climate effects of plastic waste and plastic pollution and highlights the fact that climate impacts and environmental destruction occur before we even think of it as a problem: at the extraction level, followed by production and transportation. Plastic waste becomes visible only as discard after consumption, when it ends up in garbage or recycling bins and when it becomes fugitive, widely distributed by wind and water or entangled in nature. Worldwide mismanaged and escaped plastics in particular, have created a global plastic problem. Plastic waste ending up in incinerators produces greenhouse gas emissions, making it difficult for cities to reach the goal of net zero carbon emissions. For plastics that are recyclable the collection, separation and transformation of plastic items have to be channeled toward a circular path, where plastics become a resource to produce new plastic items. Waste pickers worldwide are the main protagonists in collecting and redirecting these materials toward the recycling industry. Yet, too many plastic products are not recyclable, contaminating the recycling stream, hindering the work of waste pickers at the triage centers, ending up as burden costing time and money. This alarming situation calls for a global plastic regulation to avoid the production of materials that are toxic and cannot be recycled. The research shows that waste pickers are central figures diverting plastics, educating households on waste separation practices, adding value to recovered materials and also contributing to building community, by integrating vulnerable individuals into their collective workspaces. While these positive effects of inclusive recycling are recognized in the academic literature, unfair remuneration, stigmatization and risk-prone and unhealthy working conditions are still the reality in most parts of the world.

Introduction

Due to the omnipresence, pervasiveness and persistence of plastic as well as the magnitude of environmental consequences, plastic pollution has become one of the hotspots in current debates

concerned with the health of our planet. In particular, the impacts of post-consumer plastics that are mismanaged, littered, and have escaped into the terrestrial and aquatic environment have become of topmost concern. When plastic waste is not correctly disposed of or recycled, it turns into plastic pollution which enters different life systems; affecting food chains and ultimately also humans and animals in a variety of different ways (Thushari and Senevirathna, 2020; see the review article by Cverenkárová et al., 2021). Research is now making headway in uncovering new assessments and theories of possible irreversible consequences of plastic pollution to different life forms (Lebreton and Andrady, 2019; Kosior and Crescenzi, 2020) affecting our planetary boundaries (Nash et al., 2017; Villarrubia-Gómez et al., 2018).

Plastics have not been around for long. In 1950 production was around 1.5 million Mt per year while nowadays this number has escalated to 460 million Mt per year in 2019, of which most are not biodegradable and only a fraction is collected for recycling (OECD, 2022). The current prognosis for annual plastic production is to further grow another four times until 2050 (New Zealand Ministry for the Environment, 2022). When we speak of plastic, we refer to different families of polymers; the key building blocks for plastics, whose chemical formula varies, resulting in different plastic end products (e.g., low-density polyethylene [LDPE], high-density polyethylene [HDPE], polypropylene [PP], polystyrene [PS], polyvinyl chloride [PVC], polyethylene terephthalate [PET], polyurethane resins [PUR], polyamide and acrylic fibers [PP&A] among others less prevalent commercial plastics). Plastics will increasingly become more complex, with the creation of new polymer families (e.g., silicon or carbon fiber-based plastics) now being introduced to the market as new plastic products for which we do not yet have a recycling concept.

Plastics in the environment are not just an issue of introducing different types and scales of nonbiodegradable material into soils, water and food chains. Plastics also account for 3.4% of global greenhouse gas emissions (OECD, 2022). It is estimated that 40% of the global plastic waste is generated by the packaging industry. Those plastics that are not collected most often end up in rivers and are carried into the oceans where they are transported with the ocean currents. Smaller pieces finally settle as microplastics and nano plastics on the ocean floor. According to the OECD, an estimated 30 Mt of plastic waste has already accumulated in oceans and seas and another 109 Mt in rivers, which suggests the continuation of plastic leakage into the oceans for years to come, even if we were to halt plastic leakage now (OECD, 2022).

The challenges produced by plastic waste pollution are compounded in the Global South, due to limited infrastructure and waste collection services, reduced access to human and financial resources, poverty and social exclusion as well as the import of waste from other countries, particularly from the Global North, described by Brooks et al. (2018) for the case of plastic exports to China, but also reported for plastic waste, E-waste and other toxic wastes by Okafor-Yarwoof and Adewuni (2020). Illegal dumping and irregular waste accumulation, which is a global problem, becomes even more accentuated in informal settlements and their surroundings as well as other underserviced neighborhoods and locations in the Global South.

These factors result in high rates of mismanaged and fugitive plastic waste. Nevertheless, it is exactly in this part of the globe that we find between 15 and 20 million mostly informal workers, collecting and diverting plastics, performing an important public and environmental service. This human labor force includes the most impoverished and excluded citizens retrieving recyclables for their survival. This current unprecedented social and environmental challenge to humankind and the planet demands urgent actions.

For this overview article a broad literature search using Academic Web Search Engines has been applied, using focused keywords and prioritizing recent academic productions. I will begin with presenting anthropogenic global environmental change theory to address the worldwide crisis situation and to situate plastic waste and plastic pollution within this scenario. Plastics have not only become a marker for the Anthropocene (Crutzen, 2006), the human-induced global environmental change, but are also contributing to greenhouse gas emissions during production and manufacturing processes as well as when incinerated. The global scale of plastics entering the environment (soil, rivers, lakes and oceans), as well as different life forms (including humans), is another crisis aspect related to plastics and plastic pollution that is described and analyzed within this theoretical framework.

I will take a brief historical approach outlining the advent of the current complex and diverse environmental and social issues, to then review the literature that highlights the scope and extent of the geographies involved in the generation, management and mismanagement of plastic waste. The following section will introduce works on the world of informal waste management with waste pickers and waste workers being key protagonists, outlining the different forms in which their work is performed, as well as the challenges they face on an everyday basis. Finally, the article will discuss a multipronged approach to halting plastic waste pollution with the support of the informal and organized waste picker sector. The described actions are part of the proposed solutions and, undeniably and simultaneously require innovations in design and regulations to constrain and control the chemical aspects involved in the production of plastics in order to improve circularity (Wilson et al., 2009; Sinha, 2018; Calisto Friant et al., 2022).

We have learned that plastic waste pollution is a global problem which involves complex networks of actors (the industry and business sector, different layers and offices in Government, academics, community and grassroots organizations), different power structures in decision-making, as well as diverse social and technological innovations with experiences from the grassroots and the establishment, considering global value chains and trade and management of plastics. Hence, a global approach to waste management, specifically with regards to plastics, is required, where sources of financing will be made available, to integrate and expand the current capacity of the informal waste collection and recycling sector for a strong coproduction in waste management, specifically in the Global South. This section will review the literature on the contribution of waste pickers to resource recovery in different parts of the world, demonstrating the feasibility of expanding their roles in the circular economy, provided that funding will be made available to strengthen this sector and to expand the infrastructures they require. Finally, key steps will be suggested to move toward a worldwide resolution of plastic waste issues with the integration of waste picker organizations.

Plastics: A double-edged sword

Theoretical considerations

Human-induced or anthropogenic environmental change and specifically climate change is the most significant challenge jeopardizing the long-term well-being and survival of humanity and all other life forms (Dryzek and Pickering, 2019; Merchant, 2020). Human activity, specifically since the era of industrialization, has

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caused such far-reaching impacts on the planet that geologists have begun to term the current era Anthropocene (that is the era of humanity) (Crutzen, 2006). Without going into the multiple ways of interpretation that have come along with the term Anthropocene, it is a powerful label that expresses the profound changes humans have created on the Earth. "*It is an epoch where everything on the planet is shaped by humans*" (Porta, 2021), not only the changes in vegetation cover or the diversity of plant and animal species on land and in the oceans, but also the atmospheric chemical content, sea levels and climate change are all dominated by human actions (Steffen et al., 2007).

It has been observed that specifically since World War II, a so-called "great acceleration" in human activity with wide-ranging consequences has taken momentum, affecting the earth's systems (McNeill and Engelke, 2016). This exponential scale of the human footprint increase has been documented for different factors, such as global temperature increase, CO_2 concentration, land use by humans, extinction of living organisms and damming of rivers, plastic production, mass consumption, just to mention some (Merchant, 2020). With the rise of atmospheric gases, called greenhouse gases (GHG), such as carbon dioxide, methane, nitrous oxide, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and others, the critical human impact on the climate has been scientifically proven. Growing levels of GHG result in an increase of the average temperature on earth, which leads to climate change, the rising of the sea level and other negative effects on the environment. There is consensus among the scientific community that this situation demands immediate actions in order to mitigate the negative consequences for life on this planet. Thus, it is critical to reduce CO_2 and other greenhouse gas emissions, through shifting towards renewable energies, but also by reducing the impacts from consumption. Consumption has direct impacts on the environment and climate. The production, use and discard of plastics, as will be discussed further in this article, contribute to GHG emissions and are leaving visible traces of the lasting human footprints on terrestrial and in marine environments around the world (Porta, 2019).

Anthropogenic global environmental change theory provides elements to better understand the current global crises, and stresses the need for rethinking and changing practices, behaviors, principles, worldviews, institutions, social structures and systems in general (Steffen et al., 2015). The theory which supports this article underlines a systems approach and builds on transdisciplinary knowledges, recognizing different scales, historical layers and geographic contexts, applied to various aspects and perspectives of plastics.

A historical lens on plastics

Plastics have become central and seemingly essential in our modern lifestyles. There is little doubt about its attractiveness, convenience, adaptability allowing it to be shaped into endless creative and innovative purposes that facilitate our life. Plastics have been introduced into everyday routines, increasing safety, making material abundance more readily available and raising the standard of living for many people.

Plastics are fossil fuel-based, composed of a wide range of synthetic and semi-synthetic materials that use polymers as main ingredients and as the name reveals, are "*pliable and easily shaped.*" With the discovery of new materials such as nylon during World War II, research into material studies and design was intensified, driving the expansion of the plastics industry, shaping polymers into multiple consumer-uses and purposes and starting the "plastics revolution" (Freinkel, 2011). The scaling up of industrial plastic production has allowed for plastics to become almost infinitely diverse, cheap, globally accessible and desired, permeating almost all our consumer goods and allowing for disposability in everyday realms ranging from construction, transportation, household appliances, toys, electronics, health care, food packaging, the film industry and even outer space activity, just to mention some (Vox et al., 2016). Nowadays, plastics are integral to the global economy, acting as an enabling technology in almost every sector of economic activity.

Despite first observations of plastic debris in the oceans as well as early alarming warnings from scholars such as Rachel Carson (2002) (voiced in her book *Silent Spring* published in 1962), it was only in 1997 with the discovery of the *Great Pacific Garbage Patch* – an extension of 1.6 million km^2 in the ocean covered with plastic waste accumulating between Hawaii and California – that the public started to fathom the scale and extent of plastic in our environment (Lebreton et al., 2018). Plastic has become one of the markers of humans' tragic impacts on the globe, justifying the term Anthropocene (Porta, 2021).

The hidden global environmental and climate impacts of plastic

While we are becoming more aware of the negative impact plastics have on life, due to the visibility and durability of plastic waste and plastic debris in our surroundings, we have not yet grasped the hidden environmental and climate damages of plastics before becoming waste. As with every material before turning into a consumer object, resources have to be extracted from nature, transported to industrial plants where they are transformed into ingredients for manufacturing of the final products, which then are transported to close and far retailers and consumers, generating waste and emissions along the chain (Pollans, 2021). These processes involve aggressions to natural environments (and often also to remote and rural communities (Mihai et al., 2022), disturbance of natural habitats for animal and plant life, contamination of soil, water and air, often with highly toxic residues, as well as the emission of GHG and the use of energy along the progression from extraction to consumption, leaving behind toxic trails and what Josh Lepawsky calls *discardscapes* (Lepawsky, 2022) (see Figure 1).

Oil is the primary ingredient necessary to make plastics. During the extraction stage waste is generated and environmental impacts are caused, for example, with water and air contamination from hydraulic fracturing and drilling. These impacts have to be accounted for when considering plastic's ecological footprint. Waste is created and dispersed during the oil and gas extraction phase, accompanied by GHG emissions. This happens during the volatilization of organic materials contained in the waste, by wind dispersion of particulate matter (dust) and by the liberation of damaging chemical reactions (e.g., the production of hydrogen sulfide from sulfur-bearing wastes) (Finer et al., 2008). Worldwide, these impacts affect the land and off-shore and deep-sea drilling locations. The extraction and processing and refining of oil and gas consumes large volumes of water, produces wastewater and contaminates surface and groundwater resources with benzene, methane, radiation and other chemicals. Long-term pollution and habitat destruction affect wildlife, biodiversity and consequently also reduces ecosystems services (Finer et al., 2008).

The next stage before plastic arrives at the shelf for consumption and before turning into discard refers to the plastic manufacturing, with product-specific impacts, GHG emissions and wastes being generated along the transformation process. Just looking at the

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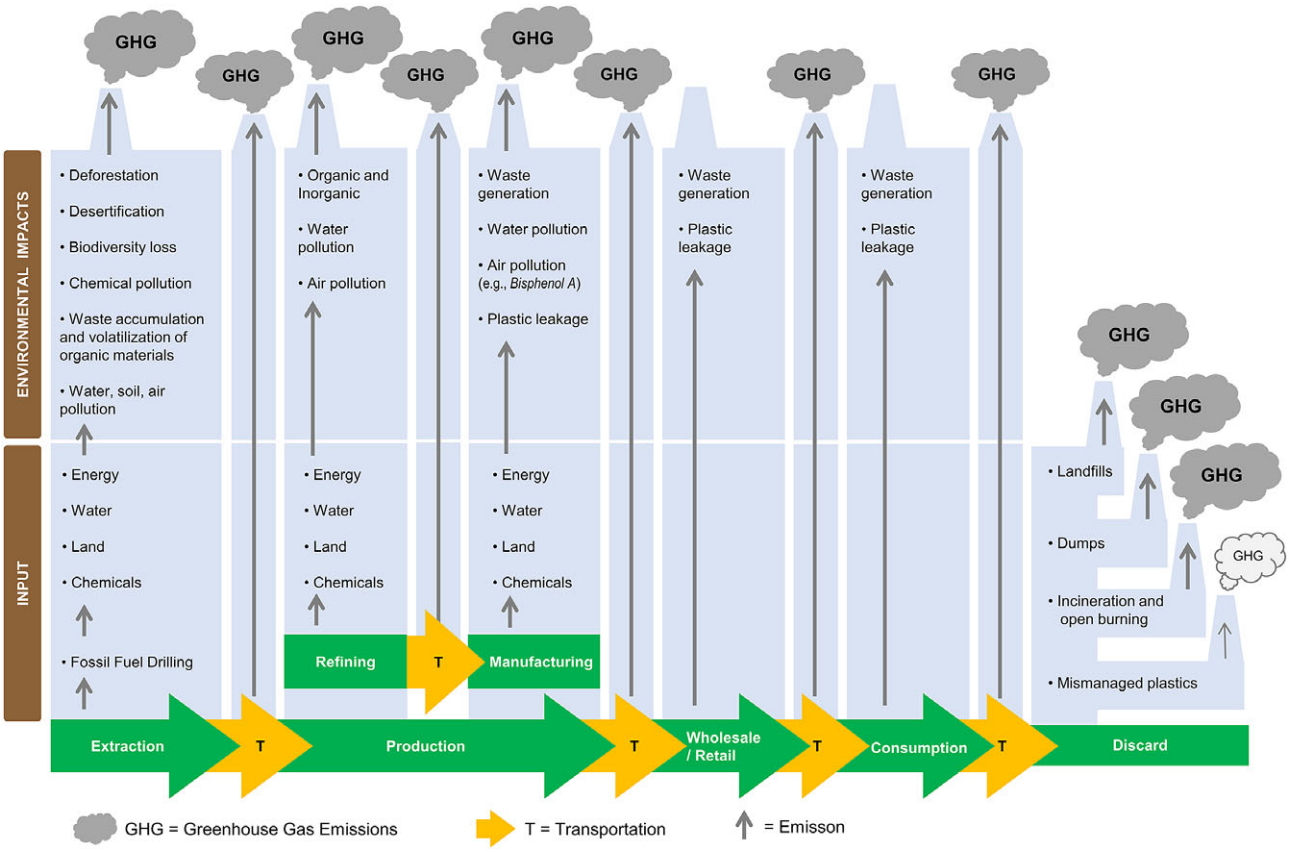

Figure 1. Trail of environmental and climate impacts from the plastic production chain.

example of PVC and plastic manufacturing plants highlights the different wastes that are produced at manufacturing, printing, dye-cleaning and shaping, which creates hazardous waste (Öncel et al., 2017). These environmental and climate impacts and wastes that happen at previous stages even before something becomes plastic also need to be accounted for when analyzing the impacts of plastic. Yet, we are usually not trained or educated to make these connections about the cumulative environmental impacts embedded in any product, including plastics. To us, plastic waste becomes obvious when we do not want or need a product anymore and discard or litter it; then it becomes waste and is visible.

Scientists and activists are now uncovering the all-pervading, powerful global environmental, ecosystems and public health issues related to plastic littering and dispersion in the environment and atmosphere (Nash et al., 2017; Villarrubia-Gómez et al., 2018; Lebreton and Andrady, 2019; Kosior and Crescenzi, 2020). Plastics leak into the air as nanoparticles, into soils as microplastics, into rivers and oceans as plastic debris; affecting marine life in the deepest of our seas. Plastics accumulate in remote terrestrial ecosystems such as mountain tops, remote valleys in the Amazon or polar regions, and ultimately enter food chains and accumulate within different life forms. We have become more aware of the pervasive plastic impacts on marine life, brought into our homes with moving images of dead turtles entangled by plastic bags and plastic debris found in starved sea animals and birds (Mitchell, 2015). We find plastics on almost all our beaches worldwide and plastic is seriously affecting the economic livelihoods of communities that depend on fishing, mariculture and tourism. Plastic has become an undeniable and persistent problem that does not go away without appropriate actions.

While plastics are so widespread and frequently used in almost every sector, the impacts of plastic waste are felt differently amongst people, animals and the environment around the globe. Specifically in regions where formal regular waste collection is not a given, plastic waste accumulation becomes a very visible environmental and human health problem, causing the largest harms. It is often also in those regions that the local population has to rely more heavily on plastic resources for specific packaged goods, such as drinking water packaged in plastic sachets or PET bottles, which becomes a particular challenge in most countries in the African continent. The effects of unwanted plastics in the environment are place based and can affect the local population in many different ways, triggering various responses. A shift away from plastics will depend on the implementation of a comprehensive regular framework as well as changes in producer and consumer behaviours (see Figure 2). As we will see in the following section, there are significant contrasts in terms of plastic use and disposal between different places and regions and between what is considered the Global North and the Global South (for a definition of the concept Global North and Global South see Clarke, 2018).

Scope and extent of plastic pollution

Between 1950 and the present day, more than 8.3 billion MT of plastic has been created, which represents a 230-fold growth during that period. In parallel with population growth and higher

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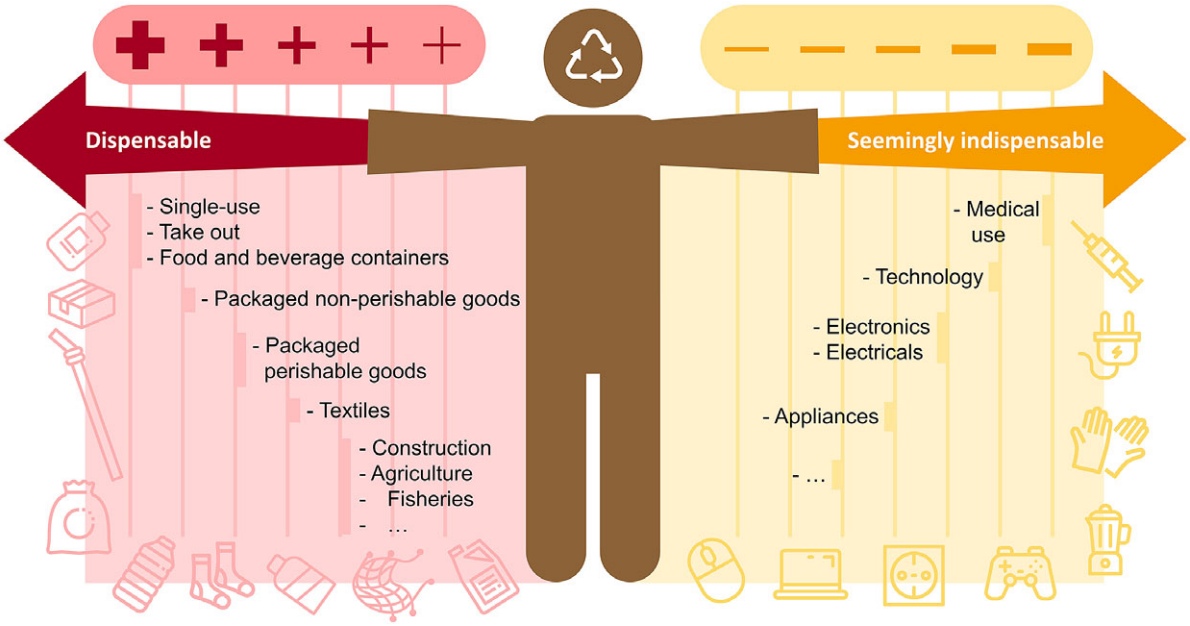

Figure 2. Plastics currently in use and potential shifts in producer/consumer behaviors.

income, plastic production has grown exponentially, spiraling from 234 million MT in the year 2000 to 460 million MT in 2019 (OECD, 2022). This means that plastic waste has also globally doubled within the period of almost 20 years. In 2019, only approximately 9% of the plastic waste was recycled, 19% was incinerated, 50% went to sanitary landfills and the remaining 22% were dumped, burned or escaped into the environment (OECD, 2022). Due to its singular properties of malleability and flexibility no other manufactured material has grown as much as plastic production. The largest market for plastic is packaging, which has further increased with the relatively recent global shift from reusable to single-use (Geyer et al., 2017).

Most of the fugitive plastic (86%) is driven by mismanaged waste and occurs in non-OECD countries (OECD, 2022). It seems likely that several million metric tons of mismanaged plastic wastes enter the oceans from land-based sources every year (Jambeck et al., 2015). Especially concerning is the discharge of plastic wastes into the oceans through major river systems, particularly in low- and middle-income countries (Jambeck et al., 2015). Southeast Asia is one of the top regions of plastic ocean pollution, particularly Indonesia, Malaysia, the Philippines, Thailand and Vietnam (in order of ranking), generate nearly 28% of the land-based marine plastic litter (Lebreton et al., 2017; Borongan and Na Ranong, 2022). At the end, most of the plastics are transported into the ocean. Manila Bay in the Philippines, an area of almost 2,000 km^2 and a coastline of approximately 190 km, is just one of many testimonials in the region making headlines globally in relation to its plastic-contaminated waters and coastline (Borongan and Na Ranong, 2022).

The world's poorest region Sub-Saharan Africa (covering 50 different countries in the south of the Sahara) has been reported as a region where plastic littering and leakage into the environment is fast growing. In Sub-Saharan Africa, the total solid waste generation is likely to triple by 2050 (UNEP, 2018), based on population growth and rural to urban migration rates, which also presupposes an increase in mismanaged waste if no immediate measures are taken (Browning et al., 2021).

There are several reasons for the increase in mismanaged plastic waste in certain parts of the world. One of them is the inefficiency of the public services in waste management. Failed neoliberal approaches to the privatization of public services in cities in the Global South have added to the complete dysfunction of waste management in many cities in the region (Obirih-Opareh and Post, 2002). Urban household waste is highly mismanaged because of inadequate regulatory frameworks, poor infrastructure, weak institutions, lack of continuous environmental education, unreliable data, lack of funding, and low technical capacity (Asase et al., 2009; Guerrero et al., 2013; Oduro-Appiah et al., 2020) (see Figure 3).

In many parts of Africa, the collection of household waste is chronically underfunded and mostly covers central and high-income neighborhoods, while informal settlements, where the majority of the urban population lives, do not have a regular waste collection system. Here, residents have to find their own ways of disposing of their waste (Pew Charitable Trusts and SYSTEMIQ, 2021). Consequently, illegal dumping is a prevalent practice (Chanakya et al., 2015; Shwetmala et al., 2021). Of course, Illegal dumping is not only a predicament in poor nations but also happens in rich countries despite access to regular waste collection and expensive separate household collection for recyclables. The magnitude of illegal dumping, however, is manifold in the Global South, particularly in urban and peri-urban poor areas without regular waste collection and minimal enforcement of any environmental control.

According to UNEP (2018) over 90% of waste generated in Africa finds its way into uncontrolled dumpsites and landfills, often associated with open burning (Velis and Cook, 2021). Furthermore, 19 of the world's largest unregulated and unsanitary dumpsites are located in Sub-Saharan Africa. Plastic waste pollution also challenges rural communities due to illegal dumping (Mihai et al., 2022). This is an obvious issue and the volumes and hotspots of informal dumps often remain unknown, making it difficult to mitigate (Chanakya et al., 2015). In small and isolated communities (including islands and less accessible locations as can be found in the Andean or Amazon region), the geography and distances to recycling markets make plastic diversion particularly challenging in these places.

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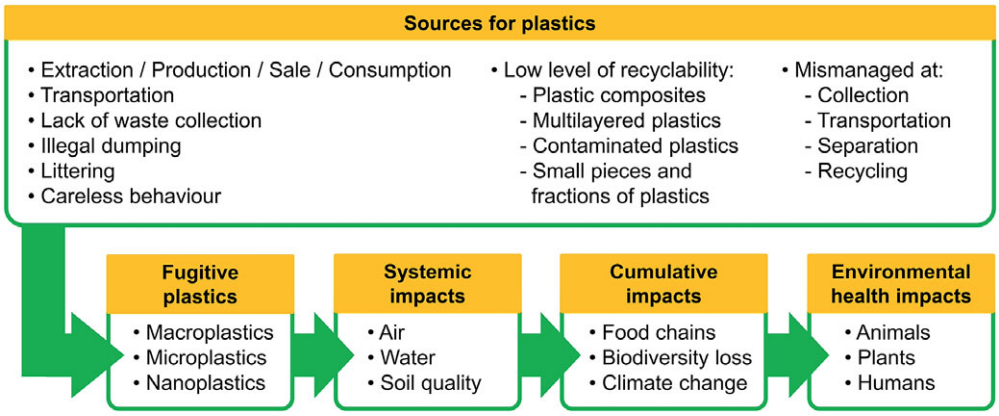

Figure 3. Pathways for global plastic dispersion and potential impacts.

Because of the relatively recent population transition from rural to urban, it is expected that countries in Africa and Asia will continue to undergo most dramatic social and economic transformations with continuous rapid urban growth, which will also bring changes in lifestyle and consumer habits, purchasing of packaged goods, throw away items and items made of plastic. This trend will also lead to further exponential growth in waste generation (UNEP, 2018). City administrations are not prepared for dealing with these demands, putting immense strain on existing waste management services and infrastructure. Around 30% of the waste generated in Tanzania is currently collected, resulting in widespread open burning, burying, and landfilling of the remaining 70% of waste (Palczynski and Scotia, 2002). In addition, insufficient wastewater treatment, littering, illegal dumping and inadequate corporate social responsibility by industry are further cited as factors adding to plastic pollution (Mathis et al., 2022). The lack of access to safe drinking water in Ghana, Nigeria or Tanzania has stimulated the commodification of water in sachets and plastic bottles, contributing to exponential growth of plastic waste (Stoler et al., 2014). Water sachets litter the streets and rivers, leading to many additional environmental hazards, including sewage and drainage obstructions, and air pollution from burning (Dumbili and Henderson, 2020).

Despite the progress made over recent years, approximately 30% of the world's population (2 billion people) still lacks access to regular waste collection and roughly 41% (3 billion) has no access to controlled disposal services for household waste (Wilson and Velis, 2015). Within the next 15–20 years, municipal solid waste is prognosed to double in many cities in Africa and Asia, as a result of growing populations, continued migration from rural to urban areas and due to the increase in waste that accompanies economic development.

The accentuated quantity of mismanaged plastics is also linked to the waste trade from high-income to low-income countries. For example, in 2019, countries in the European Union have exported around 1.5 million MT of plastic waste, almost exclusively to Asian countries (Browning et al., 2021). The authors speak of the emergence of an environmental and human health crisis due to inundating these places with plastic waste that is mostly not recycled and finds ways to leak into the environment. The consequences are further amplified by the already existing systemic social, political, ecological, and economic challenges most countries in the Global South face since colonialism. Besides impacting the local environment, the import of plastic waste from rich countries floods the local market, lowers the material prices and thus affects the livelihoods of local waste pickers, a situation that can be observed in Brazil since the beginning of 2023 (Gasparini, 2023).

Cities are in many ways overwhelmed by rapidly expanding populations and the existing lack of accountability, equity, and capacity in waste governance, generating a public and environmental health crisis that urgently needs our attention. Everything is connected and every action generates a reaction. Plastic litter, for example, can be carried by wind, rainwater and snowmelt from waste and storm-water outlets, small tributaries and streams into rivers and finally into the sea (Sheavly and Register, 2007), which suggests that rivers are a major "vector of transport" for plastics (Lebreton and Andrady, 2019).

Since we can never know the exact quantities of waste that enter the environment, the published estimates vary quite significantly. While Jambeck et al. (2015) refer to 8 million MT of plastic being pushed into the oceans every year, contributing to the total estimated 150 million MT of plastic waste products that are already found in the world's oceans; Van Wijnen et al. (2019) speak of about 1–2.5 million MT of plastic transported by rivers into the oceans every year. Despite the difference in the numbers and scope of the plastic input, the resulting marine pollution is generating detrimental impacts on the life of oceans. Rivers act as major transport pathways for plastics to the oceans which underscores the urgency for actions to hold back this leakage and to address the mismanagement of waste (Ferronato and Torretta, 2019; Verster and Bouwman, 2020).

Scientific data shows that with the "great acceleration" beginning in the mid-1940s, the exponential increase in plastic production has also contributed to aggravating climate change and further promoting global environmental change (McNeill and Engelke, 2016). While poor communities throughout the world contribute little to the production of plastics, they are bombarded with plastic products designed and packaged elsewhere. Plastics have originated in the Global North and have now created a major environmental health crisis in the Global South. Even though the consumer footprint in the South is considerably smaller than in the North, the South bears the burden of having to find solutions to manage the waste, without having the required resources or infrastructure. Environmental justice issues related to plastic pollution are central in the design of more ethical and circular waste management systems. The next section will explore these informal and organized

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initiatives that emerge collecting and diverting waste and recyclables from local waste streams.

Informal sector contributions to waste management and prevailing working conditions

The absence of formal waste management and recycling systems, as well as gaps in resource recovery, have led to the rise of a large and diverse informal waste sector providing collection, disposal and diversion, particularly in those parts of the city where these services are missing or are inadequate (Oduro-Appiah and Afful, 2020). In many parts of the world, these insufficiencies are addressed by the informal sector. The informal economy refers to "*all economic activities by workers and economic units that are – in law or in practice – not covered or insufficiently covered by formal arrangements*" (OECD/ILO, 2019, p. 155). With approximately 2 billion people globally, the informal sector accounts for 61% of all employment and comprises 90% of employment in developing countries (ILO, 2018). Informal recycling is intrinsic to the urban fabric throughout the world, particularly in Africa (Yu et al., 2020), Asia (Sen, 2018) and Latin America (Dias, 2016). Estimates of the International Labour Organization reveal a total number of 15–20 million informal waste pickers (ILO, 2018; WIEGO, 2019). However, the real scope and extent of this sector are unknown, due to the stigma attached (Yousafzai et al., 2020), the invisibility and high volatility of this work. Generally, waste pickers fall into three categories: autonomous (independent), organized (into cooperatives, associations, networks and other collective forms) and contract laborers. Waste pickers collect recyclable materials (paper, cardboard, metals, glass, plastics, etc.) while waste workers collect garbage for disposal.

Country and city-specific studies suggest that at least 0.6–2% of the urban population in Global South cities are engaged in some form of informal or organized waste picking. To provide some examples, a total of 4 million waste pickers are mentioned for China (Chen et al., 2018), up to 800,000 for Brazil, with 398.348 waste pickers officially confirmed (Dagnino and Johansen, 2017) and around 300,000 waste pickers suggested for Colombia (Marello and Helwege, 2014). The Global Alliance of Waste Pickers cites approximately 2 million waste pickers working in Indonesia (Globalrec, n.d.). Furthermore, Mbah et al. (2019) speak of 1 million waste pickers that are currently active in Nigeria and Schenck et al. (2019) cite the number of 60,000 to 90,000 waste pickers involved in informal recycling in South Africa. Kasinja and Tilley reveal 13 million waste pickers in India, reporting that in some cities, almost 80% were women (2018). In Cairo, Egypt up to 70,000 waste-pickers (Zabaleen) handle 1/3 of all city waste and recycle almost 80% of all waste collected (Ramusch and Lange, 2013). The Global Alliance of Waste Pickers further reveals the existence of waste pickers in European cities (e.g., in France with 500 organized waste pickers through a network called *Amelior*, and in Italy with 23 groups organized by the *Rete Nazionale Operatori dell-Usato* – Rete ONU) (Globalrec, n.d.). While these numbers are estimates based on local or national studies or census data, the evidence is clear that we are dealing with an immense human labor force that is actively retrieving plastics among many other materials from local waste streams.

The contribution informal waste pickers make to reduce plastic pollution becomes evident in the case of India, where they recover approximately 50–80% of the plastics produced in the country (Nandy et al., 2015). Waste pickers in many ways fill a gap by providing a service that is not offered by the local governments, particularly in neglected and marginalized parts of town, as described by Sen for the city of Calcutta, India (2018). In other countries, such as Pakistan or the Philippines, the collection rates are nearly 50% (Liang et al., 2021).

Waste pickers are also present in cities in the Global North and have been described by different authors (Scheinberg and Anschtz, 2006; Trembley, 2007; Gutberlet et al., 2009; Scheinberg et al., 2016; Bulla et al., 2021). In Canada, informal waste pickers are called Binners, Diverters, Les Valoristes or Canners depending on the region where they operate and they collect mostly cans, plastic bottles and other plastic or glass returnable containers within provincial refund systems. In doing so they complement or maintain their livelihoods (Tremblay et al., 2010; Sholanke and Gutberlet, 2020; Sholanke and Gutberlet, 2021). Most waste pickers work independently, but some of them are loosely organized as cooperatives (e.g., in Montreal with the Coop *Les Valoristes*) or as association (the *Binners Project* in Vancouver or under the *Diverters Foundation* in Victoria, British Colombia). This work attracts primarily individuals outside formal employment, relying on low-barrier jobs and who may suffer from mental health issues or drug dependency. Impoverished individuals or those interested in doing an environmental service can also be found among these *hunters and gatherers.* They use shopping carts or bicycles with attached carts as tools and usually do not wear any health protective equipment. In the Global North context, these workers operate without support from local governments, are stigmatized and sometimes even harassed. While the demand for social inclusion of this sector has been articulated, waste pickers in the Global North remain mostly unrecognized and absent from official waste management (Gutberlet, 2021).

Not to forget are the direct and indirect health hazards associated with the job of collecting and sorting waste and recyclables. Since the majority works under informal conditions the occupational health risks are multifarious. The literature widely discusses these health implications of informal workers collecting in the street (Gutberlet and Baeder, 2008; Uddin and Gutberlet, 2018; Uddin et al., 2020; Zolnikov et al., 2021), working at dumps and landfills (Cruvinel et al., 2019; Schenck et al., 2019; Made et al., 2020) and working in cooperatives (Gutberlet et al., 2013).

Independent waste workers

As portrayed earlier, the human workforce of waste pickers and independent waste workers in the Global South is huge and they fill the waste collection and recycling service gap that most cities experience in this part of the world (Gutberlet et al., 2017b). Independent waste workers are individuals and small-scale entrepreneurs who collect household waste as, mostly unofficial initiative, in local communities deprived of these services. Households would otherwise burn, bury or discard their waste in nearby dumps, creeks or drainages. Waste workers are remunerated by a small fee households pay voluntarily for the regular disposal. Of course, not everybody can afford this private service or is aware of the advantages of waste collection, which puts waste workers in a financially vulnerable situation and consequently exacerbates local dumping. Waste workers sometimes engage in community clean-ups and educational activities to increase their clientele. They transport the collected household waste to the city's dump or to skips that should be serviced by the city. Some of them, however, discard illegally, avoiding the distance to the landfill or the landfill surcharges (Gutberlet et al., 2016). As a consequence of a general call

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for closure of dumps and unsanitary landfills, waste workers and waste pickers in many parts of the world have been banned from entering these sites with their carts to unload the waste they have collected, as described by the case of the landfill *La Chureca* in Managua, Nicaragua (Zapata Campos et al., 2022). In these situations, the collected waste is dumped illegally.

Independent waste pickers

Different to waste workers, waste pickers usually collect recyclable (and reusable) materials directly from households and other clients, from garbage left in the streets, in or around skips, dumps and on landfills. Waste pickers have different names according to language and local contexts: Cartonero or Reciclador (Argentina), Zabaleen (Egypt), Barbécha (Tunisia), Cachurero (Chile), Reciclador (Colombia), Catador (Brazil), Buzo (Costa Rica, Cuba, Nicaragua) or Kabariwalla (India). Negative naming (e.g., *Ciruja* in Argentina or *Basuriego* in Colombia) reinforces existing social stigma and is used to justify violent oppression and prejudice against these workers, associating them with dirt and stereotypes such as being a beggar, an outlaw, vagabond, slacker or destitute, which further distances these individuals from other citizens within their communities (Kariuki et al., 2019; Yousafzai et al., 2020).

Waste pickers sort recyclable materials into different categories (different plastics, paper and cardboard, metals and glass), often in their own backyards, in the street or in organized recycling centers. They sell the collected materials (classified or not) to middlemen, subject to asymmetric power relations, exploitation, and volatile prices, which make their survival a daily challenge. Middlemen themselves often employ workers to classify the materials, allowing these small-scale businesses to sell to specific recycling industries or to middlemen who can stockpile materials and sell to larger industries. Material values increase along this chain of actors in resource recovery. When waste pickers are organized in cooperatives, associations, networks or other collective forms, they are enabled to bypass middlemen and sell directly to the recycling industry, increasing the value of the materials (Carenzo et al., 2022) (see Figure 4).

Worldwide, between 15 and 20 million informal waste pickers operate in specific local political and geographic contexts with clearly defined hierarchies, based on the location where they perform the work, the tools and infrastructure used, the forms in which they sell their collected and separated materials, the level of connections they have and the networks they engage with as well as the degree of recognition and legal framework that supports them. In some cases, waste picker organizations have developed relationships with governments, business or their communities, which range from supportive to oppressive. These specific contexts will determine how much they can thrive or are exploited and trapped within the waste and value hierarchy (Barford and Ahmad, 2021).

The informal waste and recovery sector is an integral part of municipal solid waste management systems across the world, especially in cities in the Global South, where they are often the only source of waste collection, recycling and reuse (UN-Habitat and NIVA, 2022). They provide different environmental services, increasing the urban quality and liveability of cities worldwide (Gutberlet, 2008, 2016, 2020, 2021). Their work helps prevent urban water logging, flooding and the spread of vector-borne diseases associated with solid waste accumulation (Krystosik et al., 2020). The act of recovering plastics and other recyclable material also contributes to climate change mitigation by reducing GHG emissions and saving energy (Gutberlet and Donoso, 2015; King et al., 2016). With redirecting the recyclable materials into new production cycles, less energy is spent and less GHG emissions are created. In addition, less virgin natural resources are extracted for the production of new goods. These environmental benefits and services are not yet accounted for and hence the waste pickers are not yet remunerated for these climate and environmental benefits they provide (da Silva et al., 2022).

Apart from earning a livelihood through waste collection, the informal sector provides a critical service for cities by adding value and recovering what would otherwise be wasted and they provide

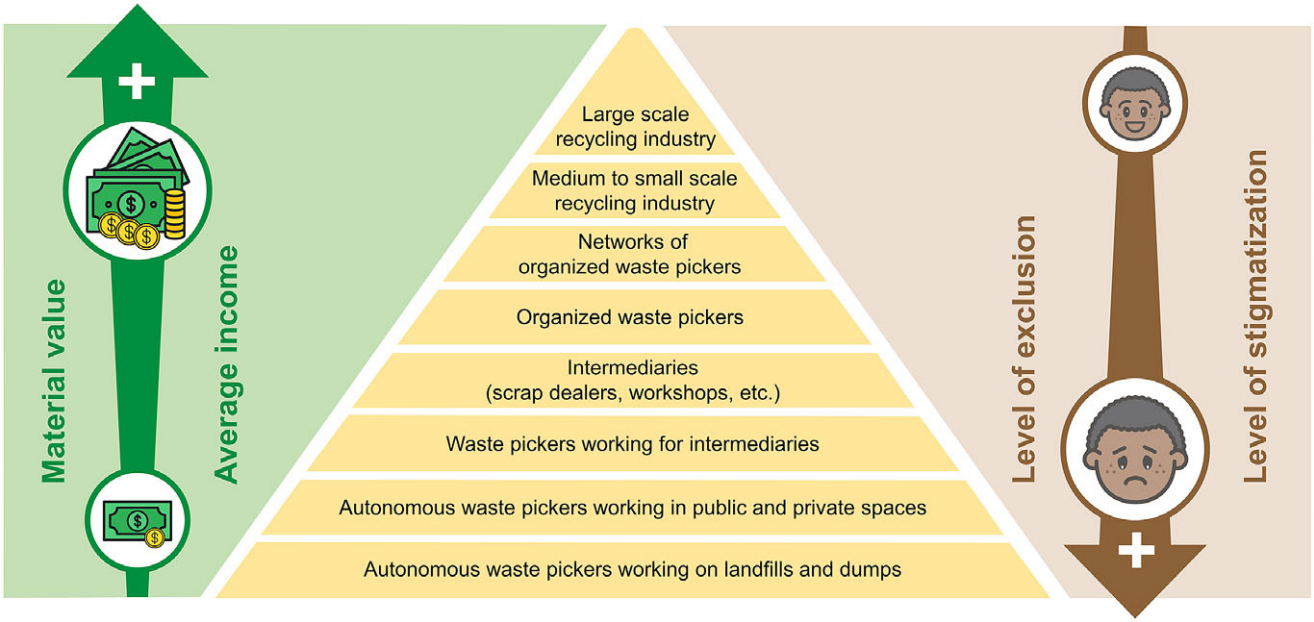

Figure 4. Social and economic standing of waste pickers in the plastic value chain.

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the feedstock for the formal recycling chain. Browning et al. (2021) give us an overview of the local decentralized circular economy, composed of waste pickers, underscoring their presence and potential in the local waste management and recycling system, as they operate in many different countries.

Organized waste picker collectives

Increasingly, waste pickers are organized in many different forms. These include business collectives, micro-enterprises, cooperatives, associations or unions and other forms of community-based organizations such as self-help groups, women or youth groups and extended family groups (Zapata Campos et al., 2020; Buch et al., 2021). Particularly in Latin American countries, waste pickers have recently managed to further build second-level organizations which include networks, federations, trade unions and social movements, which create further leverages in their development toward inclusion and recognition (Marello and Helwege, 2017).

Local authorities at times maintain informal arrangements with waste pickers who complement formal private sector contracts filling small niches in urban waste management, for example by collecting in informal settlements that are not serviced by the city (Carenzo et al., 2022). Exceptionally, local authorities establish contracts with these waste picker organizations or may offer formal recognition to waste pickers, providing identity cards, work clothing, access to health insurance or even remuneration for the service provided (Gunsilius et al., 2011; Dias, 2016; Gutberlet, 2016; Gutberlet et al., 2020). Local authorities often tend to be reluctant to acknowledge the role of waste pickers in the waste system and do not fully support their initiatives. WPOs habitually experience discontinuities or unfulfilled agreements and contracts that had been established with local governments and despite the obvious benefit cities gain from the work of waste pickers, local authorities do not want to pay for this service, which has historically been delivered for free. Hence, with every government change new arrangements have to be renegotiated; which requires time and energy.

The level of organization and labor formality of waste pickers varies, which reflects and influences their ability to earn a living wage. Collective work forms are fundamental to creating platforms that help them improve working conditions, but also increase work efficiency, which promotes greater levels of recognition in waste management (Dias, 2016). Their organizations help them access financial and infrastructure support (access to space, machinery, equipment) or technical advice and professional training (Rutkowski and Rutkowski, 2015). Often waste picker organizations are required to update formal requirements in order to receive government support, a process that can be demanding and costly and sometimes even breaks the organization. Furthermore, it is critical for WPOs to have officially approved and controlled waste transfer points where collected waste and recyclables can be stored. Access to space, infrastructure (water, sanitation, electricity) and amenities are vital for WPOs to operate efficiently and safely, and should be reflected in the urban planning process.

Good relations with local governments and the private sector are important, despite the fact that these can also create dependencies to government or nongovernment actors, challenging the autonomy and self-governance of waste pickers (Tirado-Soto and Zamberlan, 2013; Gutberlet et al., 2023). Particularly in view of reverse logistics schemes, extended producer responsibility (EPR) and sectoral agreements it is necessary for waste picker to expand their entrepreneurial skills in order to not be left behind.

Fair and inclusive plastic waste diversion with waste pickers

Undeniably, waste workers and waste pickers are the key actors in waste reclamation and need to be recognized for their professional experience and everyday contributions. Their local, regional, national and international representatives need to be at the table when the time comes to plan and implement waste management. Their leaders already persistently speak up and demand to be heard. Some examples of participatory waste governance, based on the recognition of their *indigenous* knowledge on waste (and specifically on plastics) as well as on the inclusion of waste picker organizations have been described by several scholars (Nizzetto and Sinha, 2020; Ribeiro Siman et al., 2020; Barford and Ahmad, 2021).

We need accurate data on this sector, which is still regarded informal and invisible. Most studies in the academic literature are city or country specific and given the dynamic within this sector, may become quickly outdated. Wilson and Velis stress *"that waste and resource management data are actively included within wider international action"* which will allow for more targeted actions that can stimulate sustainable development (Velis, 2015), making these key actors visible.

Isolated studies already provide us with ideas about the significance of the informal sector worldwide in contributing specifically to plastic recycling. A case study conducted in Tiruchirappalli City, India, showed that of the material collected by the approximately 200 local waste pickers, 46% was polyethylene and an additional 18% was mixed plastics (Chandramohan et al., 2010). A single waste picker collects, sorts, and transports anywhere between 10 and 15 kg of plastic waste a day in Delhi. Waste pickers with tricycle carts can collect up to 50 kg a day (Sinha, 2018). Another study conducted in New Delhi confirms that between 80,000 and 104,000 people, which roughly represent 1% of the city population and 2.5% of the working population, recycles 60–80% of all plastic waste generated in the city (Gill, 2014). In Tunisia, 8,000 waste pickers (*Barbéchas)* are able to recycle 5 out of 8.40 Mts of PET plastic generated annually in the country (Scheinberg and Savain, 2015). In Blantyre, Malawi, 42 waste pickers regularly remove a substantial quantity of plastics from the waste stream, collecting on average 9 kg of plastic waste per person/day with some waste pickers retrieving up to 20 kg per person/day (Kasinja and Tilley, 2018). Prices for plastic are less rewarding than other materials. A waste picker would earn, for example, only approximately 0.54 USD per day from selling to the plastic industry, compared to 3.40 USD per day from selling metal to the local industry (Kasinja and Tilley, 2018).

The contamination of plastics that have been soiled, particularly on dumpsites, remains a huge challenge. For example, a study reports that by weight, 73% of soft plastics and 30% of hard plastics were contaminated with impurities, demonstrating the problem with materials that are not collected at the source but are rather captured in a mismanaged state (Sasaki et al., 2020). These plastics come with high levels of impurities which often disqualifies these materials from becoming diverted toward the plastic industry. Significant amounts of water are needed to clean the materials. These issues are important, given that with increasing quantities of waste, with growing diversity of plastics and globally rising recycling standards, the differentiating factor in the market for recyclables is quality (OECD, 2018). Another challenge is finding reliable

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buyers, as the plastic product market in many countries still relies almost exclusively on cheaper virgin material (Bening et al., 2022). This translates into higher transportation costs, sometimes shipping the materials abroad.

Waste pickers and the circular economy

Despite their obvious significant role, waste pickers are usually not included in the design of waste management programs, nor in the development of the local and regional Circular Economy (CE). A study conducted by Kirchherr et al. (2017)) analyzed 114 definitions of the CE. There was hardly any mentioning of the impact of the CE on social equity. This limiting understanding of the concept is quite concerning and problematic, considering the highly involved nature of waste pickers within the collection, sorting and selling of recyclable materials, which explicitly embeds them within the circular economy framework. An amended perspective of the CE also includes the social solidarity economy as a frame that combines environmental protection and economic prosperity with social equity (Gutberlet and Carenzo, 2020) (see Figure 5). An ecologically and socially inclusive circular economy can create a variety of new employment not just in collection and classification, but also in sectors of innovation, repair, refurbishment, remanufacturing, and recycling (Horbach et al., 2015). Such lens for circularity sees waste pickers and their empowerment as part of the resource recovery cycle (Nizzetto and Sinha, 2020). Barford and Ahmad call this a "socially restorative circular economy," which includes the emphasis on the very people who enable such circularity to function, from the bottom up (2021).

Regardless the precarious working and living arrangements, waste pickers are a specialized workforce efficient in the reclamation of plastics and other materials (Gutberlet and Carenzo, 2020). Waste picker movements and academics have insisted on the inclusion of perspectives from the Global South in the framing of the CE emphasizing a need to address systemic injustices (Preston et al., 2019). Public policies need to recognize the importance of popular waste management praxis and knowledge, thus ultimately redefining the CE (Gutberlet et al., 2017a; Buch et al., 2021).

Programs such as Morocco's first polyethylene terephthalate (PET) bottle-to-bottle recycling project aims to empower and integrate over 900 informal waste pickers into the system, while diverting plastic waste (Schroeder and Barrie, 2022). Another project is the waste bank system implemented in Indonesian cities, rewarding the collection of plastic waste (Geldin, 2018; Fatmawati et al., 2022).

The data and examples shared in this review confirm the widely supported hypothesis that the workforce of informal recyclers is propping up the recycling industry, specifically in the Global South, a claim which is also in unison with the demand from the international waste picker community for the inclusion of waste pickers in the transition toward a just circular economy, inclusive of grassroots and bottom-up initiatives (Amorim de Oliveira, 2021; Barford and Ahmad, 2021).

Municipalities play a key role in including waste pickers in the local waste management systems, creating jobs and promoting local economic growth (Gall et al., 2020). However, this comes with a certain price, which municipal budgets are often unable or unwilling to pay. The costs involved in setting up an inclusive waste management system, building on the workforce of waste pickers, has to be shifted to the plastic packaging industry, which has created the problem in the first place. Regulatory interventions based on the principle that the polluter should pay for the cost, such as suggested by EPR, are progressive forms that help improve the current system (Massarutto, 2014; Watkins and Gionfra, 2019). Voluntary agreements of packaging and other producers can equally support this model. Taxes, fees, EPR schemes – if applied in a fair and inclusive way – hold producers liable for the collection and recycling of plastic packaging waste (Bening et al., 2022). These systems can stimulate the avoidance of putting materials on the market that are not recyclable, while redirecting financial resources to the waste picker community. In practice, however, EPR systems often exclude waste pickers, increasing unfair competition with small- to large-scale recycling operators and setting up formal hurdles that jeopardize their livelihoods (Talbott et al., 2022).

The work by Gall et al. (2020) showcases that a successful "fair-trade-like business model" was achieved in Nairobi, Kenya, for

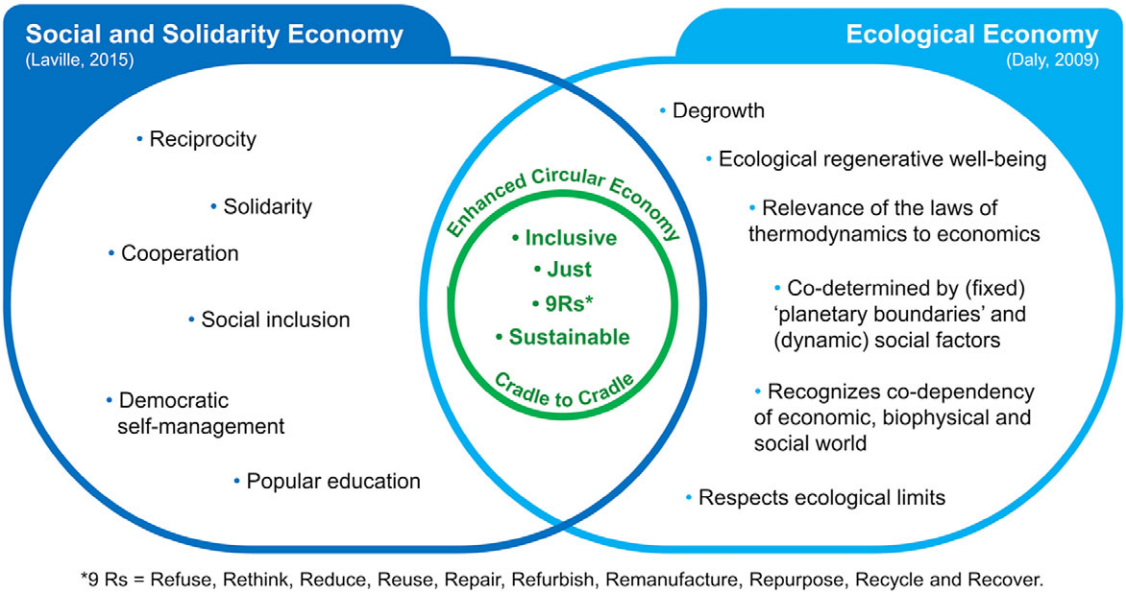

Figure 5. Enhanced socially inclusive circular economy.

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high-quality mechanical recycling, by cooperating with local informal waste pickers who collect post-consumer plastics providing socio-economic benefits to them. This kind of new model for a "*socially restorative circular economy which provides fair pay, safe working conditions, social protection, legal rights, voice, respect, services, and education,*" recognizing the multiple environmental services provided by the informal waste picker sector is envisioned by Barford and Ahmad (2021, p. 761). The need to find "*models for partnering with the informal recycling sector in an effective, scalable, and sustainable manner*" has been articulated (Gall et al., 2020). Examples highlight grassroots innovations to improve waste management and specifically plastic diversion. In these cases, waste picker organizations have demonstrated their contribution to the circular economy, resulting in a potential win–win situation for the industry and the government (Gutberlet et al., 2017a; Gall et al., 2020; Gutberlet and Carenzo, 2020; Ribeiro Siman et al., 2020; Buch et al., 2021). Questions remain whether it is possible to replicate these experiences under different circumstances.

Some authors question to what extent an upscaling of the recycling sector in these countries would result in the integration of waste picker organizations or even the formalization of the sector (Fei et al., 2016; Buch et al., 2021; Bening et al., 2022). There certainly are tensions in wanting to formalize or integrate informal workers, and as it often happens, unequal power relations may disadvantage some of the players. "*Common ground between formal and informal sectors should be built for making new waste management policies in the way that the existing informal recycling system is successfully integrated into the formal recycling system*" (Sasaki and Araki, 2013, p. 57).

Specifically, from a Global South perspective, plastic incineration for fuel and energy generation is problematic, since these schemes rely on plastics as primary feedstock to generate energy, which is incompatible with plastic recycling which retrieves these fossil fuel-based materials. Waste pickers are concerned that once installed, such expensive technology would affect their livelihoods by displacing their work. There is also a fundamental sustainability concern linked to this technology, locking society into a system of continuous resource extraction and destruction. In their policy brief the authors Talbott et al. (2022, p. 21) assert: *"plastic producers' investment in waste-to-energy systems (often using public funds) signals that producers expect to continue producing increasing amounts of nonrecyclable plastics, and are looking for ways to hide the evidence of that waste or to appear solutions-oriented."* Maintaining the linear *production-consumption-discard* status quo, which is currently supported by the plastics industry, also has a climate cost. Producers as well as decision-makers need to be made accountable for the GHG emissions, biodiversity loss, loss of employment, unfair remuneration and other social and environmental consequences attached to the linear resource flow involving plastics.

Finally, environmental education is a key transversal element essential for capturing the relational aspects of waste, transforming policies and behaviors toward the 9-R framework (refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle and recover) (Kirchherr et al., 2017) and to accordingly redesign waste management to address plastic pollution and associated climate and environmental crisis (Korhonen et al., 2018). Key stakeholders such as government and business need to be trained for inclusive and sustainable waste management. Society at large also has to take on new and expanded responsibilities, partnering in the effort of avoiding and reclaiming plastics. Clean sorting at the household level, at work, in schools and in hospitals enlarges the potential to reduce the sorting complexity, increasing the value of the materials. In this context, community engagement and environmental education for improved source separation practice becomes imperative. This learning process can happen in tandem with waste pickers and collectors (Gutberlet et al., 2021). A good example for proactive educational measures comes from Bangkok, Thailand where the Government (e.g., the Ministry of Natural Resources and Environment and the Ministry of Education) has changed the recycling norms by embedding the concept of sustainable waste management in the school curriculum (Vassanadumrongdee and Kittipongvises, 2018). These are innovative proactive measures that on a medium- to long-term time scale promises positive outcomes.

Conclusion

The lens of global environmental and climate change as well as the theoretical concept of the Anthropocene as a marker evidences the undoubtable accelerated influence human activities are having on the planet. This can be illustrated through the example of plastics in our environment. The exponential growth in plastic production, the widespread dissemination and perversive plastic waste generation has affected every corner of the planet and is already starting to accumulate in ecosystems and organisms.

Global plastic waste pollution has made it evident that although not often rated as top priority on national and even international political agendas and budget, solid waste management is a critical service in society and requires adequate infrastructure to contribute to healthy cities and healthy environments. The challenges related to plastic waste need to be framed as a global issue of highest priority in order to not only capture all plastics before they become waste and prevent littering, open burning and mismanagement, but also to avoid producing plastics that cannot be recycled!

> The same properties that make plastics so adaptable in innumerable applications – durability and resistance to degradation – make these materials difficult or impossible for nature to assimilate (Geyer et al., 2017, p. 3).

To stop plastic leakage globally is a daunting and almost impossible task, given the widespread use of plastics, their light weight and easy transportability through wind and water, makes it easy for plastics to find existing gaps in our waste management systems. Furthermore, ways to address plastic pollution that might be appropriate for rich nations are not always effective in the Global South, particularly in low-income and rural communities. Appropriate waste management is a situated and cross-cutting issue of social, economic and environmental significance.

There are real opportunities embedded in waste resources to help reduce rising urban poverty. By implementing strategies to increase the earnings for independent waste workers and waste pickers, several of the sustainable development goals (SDGs) can be addressed, particularly goal number 1; to end poverty. Many voices across society, activists, and social movement leaders, stress the importance to align production, consumption and waste management with sustainability principles to focus on local, grassroots and context-specific solutions; valuing already existing assets and promoting inclusive waste governance models. They pledge for the inclusion of representatives from the informal waste picker sector in local, national and international delegations that work on programs to end plastic pollution and to implement inclusive recycling

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programs. To guarantee their inclusion in these spaces, their participation needs to be facilitated and financed.

Alternative scenarios that seek a fair and sustainable transition, integrating the full social, political, and ecological implications of a circular future, will have to substitute the still dominant technocentric discourses. As highlighted in this article, research already contributes with policy insights and recommendations for governments, practitioners, industry and academics to better understand and implement the shift toward a sustainable and inclusive circular economy. However, we should not delude ourselves; with plastic having the current dominant properties of not being biodegradable, we will not be able to fully recover all plastics, since there will always be some fugitive plastics throughout the process from production through to consumption, waste collection, recycling and refabrication of plastics. Also, due to the laws of entropy, we cannot recycle plastic endlessly, and even recycled or refurbished plastic products 1 day will end up as waste without further options for recycling. Therefore, it is of great importance to move away from our current plastic heavy packaging and plastic-intense lifestyle toward truly biodegradable materials.

Many of the publications on plastic waste prioritize actions in policy coordination and finding technological solutions to improve waste management systems and expanding the circular economy. However, relatively few articles underline the crucial role of the informal sector in the circular economy, creating an inclusive and all-encompassing circular economy framework that encompasses the 9Rs and empowers the worldwide waste picker community. For that to happen, we must create collaborative networks of key waste actors (involving business, government and the grassroots sector) in order to enable the inclusion of waste pickers. Significant efforts should go into empowering and expanding the technical skills and capacity of waste pickers, enabling them to expand into new areas: for example, diverting organic waste, stimulating reuse and refurbishing, adding value to classified materials, informing and educating the community about best waste practices and waste avoidance, among many other ideas.

We can learn important lessons from waste picker cooperatives and enterprises that can be expanded and need to be integrated into the formal economy. For that to happen, of course, we need to share knowledge and make new appropriate technologies and fair markets available to waste pickers so that they can not only collect and classify, but also manufacture and upcycle products. We can find the motivation and inspiration for change in the people that make up this sector. *"I think I give new life to things that are unwanted, that people have thrown away"* articulates a waste picker in Delhi, India, emphasizing the important role waste pickers play in the circular economy (Gidwani, 2013).

After reviewing the literature on the evolution of our current plastic crisis, highlighting the wicked problems that are caused by plastic waste and pollution to our ecosystems and climate, and finding some of the key contributors to plastic leakage into the environment, I turn specifically toward the millions of waste workers and waste pickers operating in the Global South as an important solution to the problem of capturing discarded plastics and fugitive materials; at least as long as we are still producing plastics. This overview article provides the evidence for the needed transition into inclusive waste management, recognizing, valuing and integrating the informal workforce into restorative and renewable production cycles and economies, based on social justice and solidarity as well as ecological principles (Daly, 2009). A just transition is required in order to achieve the crucial changes that can address plastic pollution.

Open peer review. To view the open peer review materials for this article, please visit http://doi.org/10.1017/plc.2023.10.

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