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Enabling the informal recycling sector to prevent plastic pollution and deliver an inclusive circular economy

Costas A. Velis [a], Britta Denise Hardesty [b,c,*], Joshua W. Cottom [a], Chris Wilcox [b,c,d]

[a] School of Civil Engineering, University of Leeds, Leeds LS2 9JT, United Kingdom
[b] CSIRO Oceans and Atmosphere, GPO Box 1538, Hobart, Tasmania 7001, Australia
[c] Minderoo Foundation, Perth, Western Australia
[d] Centre for Marine Socioecology, University of Tasmania, Hobart, Tasmania Australia

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ABSTRACT

Recycling by the informal sector provides a rapid, inexpensive solution to plastic pollution, whilst supporting the livelihoods via their inclusion and empowerment. This solution will have the greatest benefit to the environment if supporting interventions are targeted at types of plastic pollution that are the most damaging from an ecological and wider risk perspective. Interventions should target three aspects of the pollution: reducing barriers to collection, improving the revenue from the materials and wider informal recycler remuneration, and increasing the quality of the materials. Done well, these interventions will increase the collection rate, reduce pollution from plastics, and help millions of people escape poverty. They present a scalable international solution to a global challenge; and are likely the only viable solution to the widespread lack of solid waste services and infrastructure across low- and middle-income countries.

1. Introduction

Plastic is everywhere. We talk on it, we drive in it, and we make heart valves and artificial joints with it. Despite the many improvements plastic has made to our modern lives, its global mismanagement has led to its widespread release into the environment ('plastic pollution'), with disastrous environmental consequences. Fortunately, a pool of 11 million plus waste pickers, who are in fact plastics recycling experts (Velis, 2017), may be our best hope for preventing this global failure. We propose using the environmental and wider risk posed by this pollution to target interventions to support these recyclers and benefit the environment.

Plastic pollution has ubiquitous impacts on human and natural systems. For instance, more than 700 marine species have been demonstrably affected by this pollution, with the number growing rapidly as more species are studied (Gall and Thompson, 2015). Additionally, there is much discussion about the potential impacts to human health, via toxicological effects through the food system (Rochman, 2015). Its economic costs are also significant, with marine plastic alone estimated to cost between 6 and 19 billion US dollars globally in 2018, accounting for its impact on tourism, fisheries, aquaculture and clean-up activities (Viool et al., 2019). However, the negative effects of plastic pollution differs across items, species and contexts, with disproportionate impacts resulting from particular items (Wilcox et al., 2016) (e.g., plastic straps, plastic bags and fishing gear) due to their propensity to entangle animals or obstruct the gut if ingested. The damage from this pollution is thus a product of the impact of a particular item and its rate of loss into the environment (Fig. 1).

World leaders are now taking full notice of the 'plastic pollution crisis', as reflected in the UNEA-5.2 resolution to work towards a global legally binding treaty to ending plastic pollution (UNEP/EA.5/L.23/Rev.1), putting waste management failures in the spotlight (Silva Filho and Velis, 2022). In the meantime, China stopped accepting imports of certain recyclable waste in 2018, disrupting global plastic recycling markets and making the world acutely aware of the potential mismanagement of globally traded secondary resources; a sustainability crisis we could have anticipated (Velis, 2014, 2015). With the present focus by the United Nations on Sustainable Development Goals (SDGs) to reduce land-sourced pollution in oceans (SDG Target 14.1), improve livelihoods for the World's poor (SDG 1), and improve life in cities by sound waste collection and disposal (SDG Indicator 11.6.1) (UN Environment, 2018), there is an immediate, imperative opportunity for synergistic strategies that achieve multiple goals simultaneously.

* Corresponding author at: CSIRO Oceans and Atmosphere, GPO Box 1538, Hobart, Tasmania 7001, Australia.
E-mail address: denise.hardesty@csiro.au (B.D. Hardesty).

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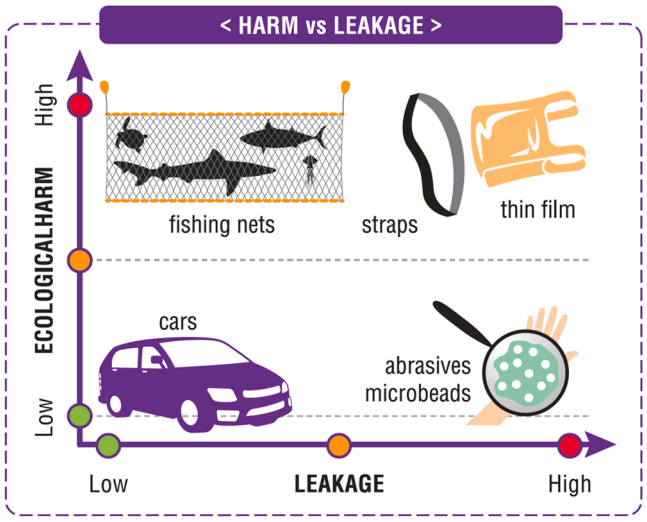

Fig. 1. How we target interventions can take into account the relationship between leakage and harm. Some items such as thin film and packing straps have disproportionately high harmful impacts on ecosystems and are frequently lost to the environment. Other items (e.g., microbeads) are lost to the environment readily, but their resultant ecological harm, whilst still uncertain, is thought to be low (and bans have been implemented). Identifying where items fall on leakage and harm spectrum can maximize environmental benefits and support the informal sector. Although this figure expresses harm in terms of ecological harm, there are many other forms harm can take such as harm to human health, infrastructure (e.g. blocking of storm drains leading to flooding), or economic harm (damage to tourism or clean-up costs).

2. Informal recycling – A rapid solution to plastic pollution

The key to stopping plastics pollution is to target the primary source; that of uncollected waste (Velis et al., 2017b; Williams et al., 2019). Around 3 billion people worldwide lack access to regular municipal solid waste (MSW) collection and/or controlled disposal services (Wilson and Velis, 2015). Therefore, without implementing waste collection services for recycling, or at least collection for controlled disposal (engineered landfill), the tap on plastics pollution cannot be turned off (Velis et al., 2017b). In a recent study, a business as usual scenario projected more than 1.36 billion metric tonnes of plastic will accumulate on land or in aquatic environments from 2016 to 2040 if we do not act (Lau et al., 2020).

The global size of the informal waste and recycling sector has been recently conservatively estimated at 11.4 million waste pickers (Lau et al., 2020) and previously at between 12.5 and 56 million (Ellen MacArthur Foundation, 2016). These individuals are already delivering efficient, viable plastics recovery. This is particularly relevant in the lowest income countries, where most of the solid waste is at risk of 'leaking' into the environment due to insufficient formal solid waste management services and infrastructure. When using the estimate of 11.4 million waste pickers, calculations reveal as much as 27.4 million tonnes of plastic is currently being collected globally by waste pickers (Lau et al., 2020), plastic which otherwise may have entered the environment. Waste pickers and their wider supply chains are therefore already an important part of the solution to plastic pollution.

Despite this contribution the informal recycling sector (IRS) currently make, global plastic recycling is still modest in comparison to other recyclables such as paper, estimated by weight at just 9 % (OECD, 2022). Intergovernmental bodies, such as the G20 countries, are working to coordinate responses to plastic pollution and build the groundwork for both effective waste management and the development of a circular economy. A G20 statement on marine litter contains seven sections, two of which focus exclusively on infrastructure development, operational establishment, and funding of the formal waste management sector. However, the role of the informal sector in addressing waste received scant attention. For instance, the only mention of the informal sector in the G20 Action Plan on Marine Litter (G20, 2017) is, "Where needed, integrate informal waste workers into modernized waste management systems in order to improve their working conditions and livelihoods". This does not suggest including and integrating the IRS broadly as part of the system, and in direct contrast to the statements about the formal sector, it does not support targeting funding on capacity and infrastructure development to enable their efforts. The mentioning of the informal actors in the UNEP/EA.5/L.23/Rev.1 Resolution ("*Recognizing* the significant contribution made by workers under informal and cooperative settings to collecting, sorting and recycling plastics in many countries") could serve as a basis for a more just transition to ending plastic pollution.

We acknowledge the critical role that innovation in materials, durability, and consumption patterns will play in reaching a sustainable circular economy. However, if waste is not collected, the inherent value of its constituent materials cannot be delivered back into the economy. Definitions of circular economy propose that after first-use, materials are best maintained at their highest point of 'value' for multiple cycles (Ellen MacArthur Foundation, 2016). Generally, plastics currently follow a linear approach (make, use, dispose) rather than a circular economy approach (design for use, recover, redesign). For instance, a PET bottle increases in value as it moves from the raw material through to its final point of sale and use (Fig. 2). However, after use the bottle's value is frequently degraded through secondary uses, mixing with other waste, and finally being lost into the environment (Fig. 2). These processes reduce the economic value of the item, by reducing its quality or increasing the effort required to recover it.

While circular economy and its supporting recycling system is a laudable long-term goal, it will require significant investment and multi-year to decadal development times. For instance, extending formal waste management across India via public private partnerships (PPP) would require US$5 billion every year, if it is even possible to implement on the ground (EY and ASSOCHAM, 2019). In contrast, the informal sector requires relatively little infrastructure, is highly responsive to economic signals, and is very flexible in its operations (Scheinberg et al., 2010). By targeting our interventions around enabling the informal sector to collect and recycle after-use plastics, we can immediately begin to tackle plastic pollution.

3. How should we target interventions?

Waste pickers customarily separate materials, components, and products of sufficient value to support their livelihood. However, not all waste items leak into the environment in the same quantities, nor do all items cause similar harm once they become pollutants (Wilcox et al., 2016). Therefore, focusing interventions and providing additional incentives on items such as plastic films, bags and packing straps that are frequently lost into the environment and result in high harm (Fig. 1) is key to maximizing the environmental benefits of investments and supporting the informal sector.

The informal sector faces three key issues that affect the value of waste items: search times, material price, and material quality. These issues are prominent for the currently uncollected items, which are often widely dispersed and mixed with other waste. If we can develop strategies to shift these factors for the informal sector, they will respond rapidly, delivering reduced environmental damage, while increasing economic returns and potentially better human health outcomes.

We contend that organizing, legitimizing, and expanding waste picking activities, as part of a "just transition" (Schröder, 2020), focused on door-to-door collection rather than from dumpsites, is a fast, affordable and implementable strategy for preventing plastics pollution in the short to medium term. To do this, three critical solutions/ levers are suggested (Fig. 2):

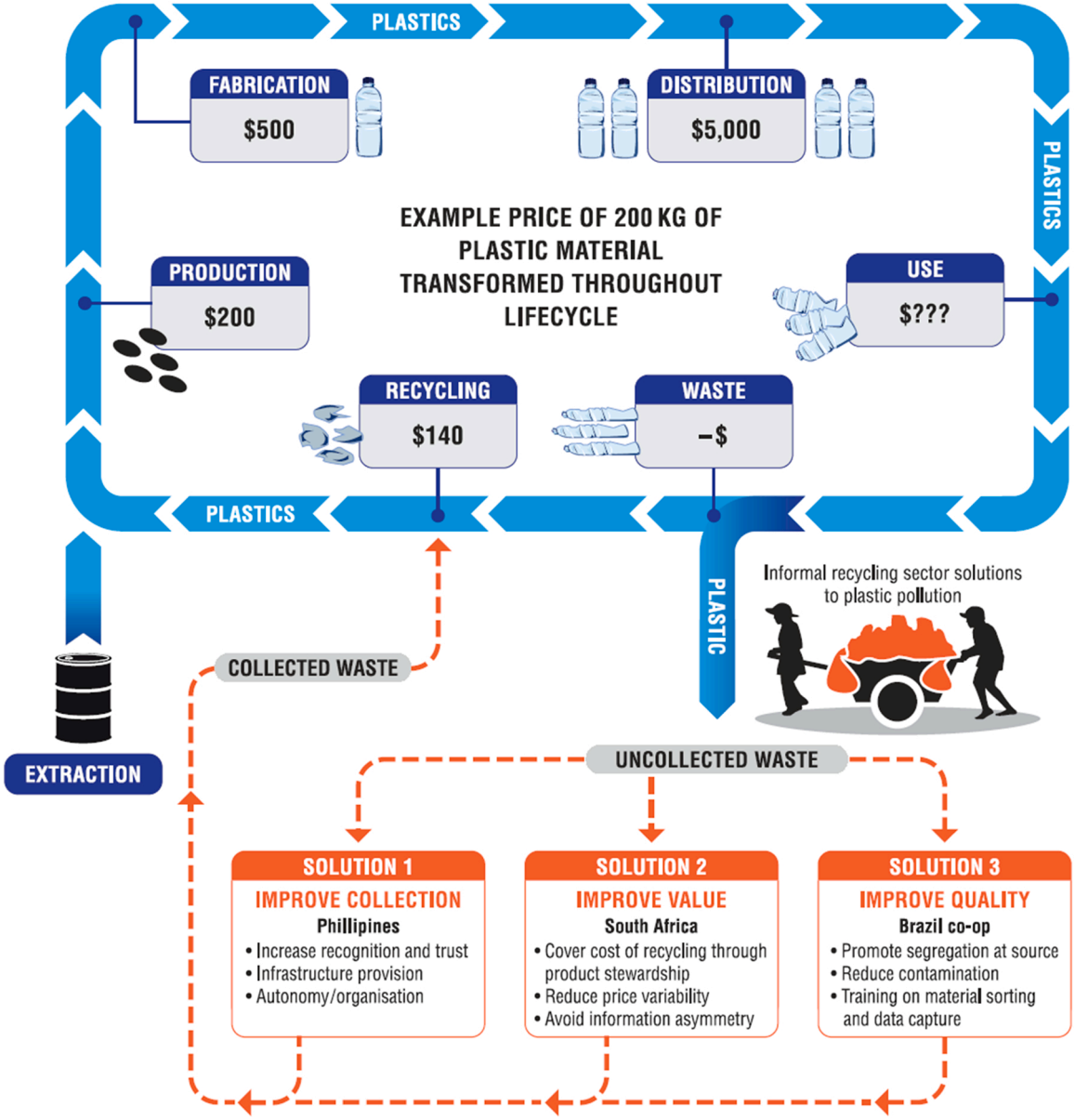

Fig. 2. Plastic materials and products have different value at each stage of its life within a circular economy. Sufficient value should be available to be appropriated by those who collect, sort, and clean the materials, and the waste pickers need support in delivering this service at scale (Solution 1). The massive drop in value when plastic items become waste, and its direct competition with virgin material on price, does not help its collection for recycling at scale. This needs fixing, for example by product stewardship schemes such as (extended) producer responsibility (EPR)(Rutkowski, 2020), whilst prices should also reflect the environmental harm of particular items (Solution 2). By better understanding the necessary quality of recyclables, higher quantities of more suitable recycled materials can be targeted (Solution 3). All three solutions combined can serve as levers to prevent plastics pollution in a cost-effective, rapid, and socially responsible way.

1. Expand and improve IRS collection;
2. Improve revenue from recycled materials;
3. Improve materials quality.

If these efforts are targeted at the particularly damaging types of plastics, we can substantially reduce the impacts of plastic pollution in the near term, whilst implementing other long-term improvements such as packaging innovations or formal waste collection infrastructure. Below, we address this three-pronged approach to linking the informal sector and plastic pollution and provide a successful example for each.

3.1. *Expanding and improving IRS collection*

Virtually all recycling in low-income countries is accomplished by the informal sector, of which many diverse roles exist (Velis et al., 2017a). Simplifying, most waste picking occurs at dumpsites, where material is concentrated and collection is performed by unorganized individuals and marginalized communities (Fig. 3A). However, the most valuable items are often recovered from the streets or doorsteps of householders. One key transformative action therefore needed is enabling waste pickers to move away from dumpsites and street picking, becoming collection service providers, itinerant waste buyers and sorters in organized environments and entrepreneurial structures they own and run (Velis et al., 2012) (Fig. 3B). This is the case in Metro Manila in the Philippines where the IRS cooperative known as Linis Ganda organized waste pickers to collect recyclables directly from households whilst simultaneously strengthening the links with waste dealers and encouraging waste segregation at source (Wilson et al., 2009). Likewise, the SWaCH cooperative in Pune, India formed a pro-poor Public Private Partnership (PPP) with the municipal

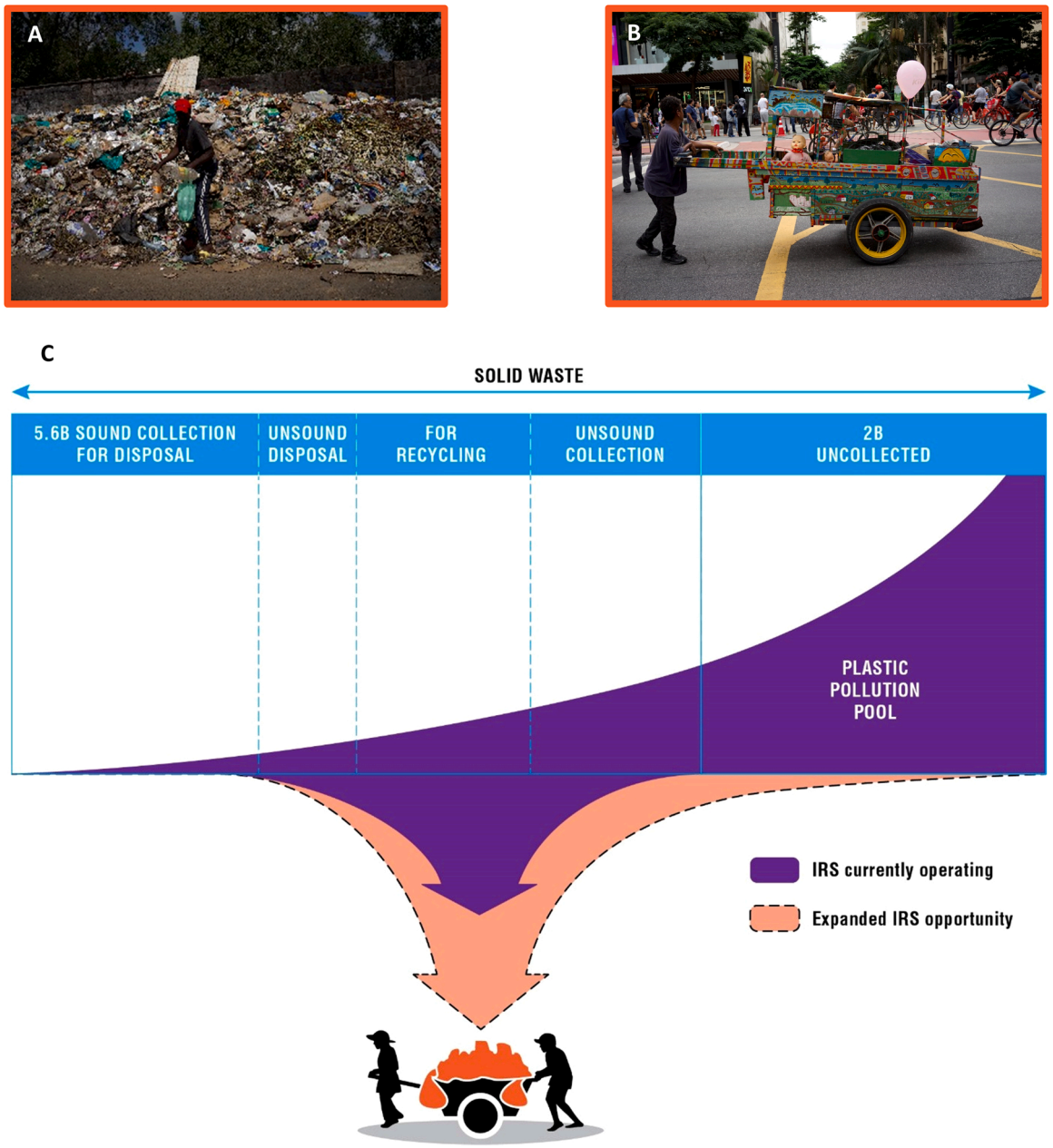

Fig. 3. (A) Mismanaged solid waste is the major source for plastics pollution. Unorganized waste pickers are targeting plastics material for recycling, but often under problematic and sub-optimal conditions, as in this case in Dandora informal settlement in Nairobi, Kenya. (B): Collecting plastics for recycling before entering the environment by an organized informal recycling sector (IRS) is a much more effective and affordable solution, whilst also improving working conditions. An IRS door-to-door collector has elaborately decorated their cart to make a statement in the streets of Sao Paulo, Brazil. Photo rights: ©Authors. (C)**:** Fate of after-use municipal solid waste plastics worldwide (waste quantities represented by areas not in scale). Environmentally sound disposal is unavailable to around 3 billion people, whose solid waste becomes (plastics) pollution (purple shows where IRS is currently involved in waste management). The informal recycling sector already recycles substantial quantities in the absence of formal mixed collection or recycling services. With revenue incentives, organization and support, the IRS could collect massive quantities (dotted line depicts expanded IRS opportunity) of after-use plastics in a timely, effective and affordable way for recycling, preventing it from becoming plastic pollution.

administration to provide door-to-door collection services to around half of all households, including many informal settlements where waste collection is typically more challenging. The cooperative earns income from charging households collection fees, whilst further supporting their income from the sale of recyclable materials (Chikarmane, 2012).

Supporting the informal sectors efforts and encouraging the provision of door-to-door collection has the potential to benefit the working conditions and livelihoods of the informal sector, whilst simultaneously reducing plastic pollution from uncollected waste by promoting improved collection services (Fig. 3 C). Furthermore, organizing the IRS into cooperatives/ associations or other micro-business structures increases market material knowledge and hence incomes in the sector. Simple innovations such as smartphone applications like Cataki (2019) in Sao Paulo, Brazil, have assisted people in locating material for collection. By supporting network organization among the waste pickers and creating a trust market with households, these systems make provision of collection services by the informal sector economically viable. The systems also assist pickers in achieving fair market value for materials, as price information can be shared across the network. Issues with digital access may limit this solution but use of smartphones is

already extensive amongst the World's poor – e.g. for electronic wallet and microfinancing purposes in Africa.

3.2. Improving revenue from recycled materials

Interventions to recover the full cost of collecting and returning after-use plastics into the production cycle are fundamental prerequisite for reducing plastic pollution. The price of reclaimed (secondary) material is typically substantially lower than the price of primary plastics. If this material is to not to be dispersed in the environment and it is to be reclaimed in a circular economy, it must be valued in a way that makes it financially comparable to primary plastic. Simply put, if the positive (saving in primary resources) and negative (damage from 'environmental leakage') costs are not incorporated into the price of secondary goods placed on the market, the economics of recycling do not stack up. Incorporating averted harm or damage into the 'value' placed on plastics can incentivize collection of such items prior to them being lost into the environment.

Incentives could be provided to expand recovery activities, targeting high environmentally damaging items, including those that are currently considered unrecyclable. In this way, regulation of the materials market could help to correct for the inability of the free market to incorporate the cost of collection, treatment, or environmental harm from plastics at the end of life.

This inclusion of environmental harm costs in product/services pricing has already proven to be a success in reducing plastic pollution, such as the deposit refund/return scheme implemented in Estonia that targets heavily littered items such as plastic bottles (Balcers et al., 2019). Additionally, in South Africa, the plastics industry has implemented a voluntary Extended Producer Responsibility (EPR) scheme to promote PET recycling by the IRS (Godfrey and Oelofse, 2017; PETCO, 2017). In doing so, the informal sector is protected from price fluctuations, allowing the development of a reliable supply chain. In the absence of such protection, during periods of low prices, workers shift to other activities, causing disruption in the supply of recycled materials, thus preventing the establishment of an economically viable supply chain. This system has resulted in collection rates of 65% for the targeted material (PET) and provides livelihoods for thousands of people (PETCO, 2017).

New systems and sustainability analysis methodologies have recently been developed to quantify the 'value' of plastic waste and its removal more broadly (e.g. to include social, environmental and economic aspects) and in a circular economy context (Millward-Hopkins et al., 2018a, b). Such approaches can help us understand how value in relation to plastic items is generated, appropriated and destroyed, enabling us to intervene to retain this value, incentivizing collection and thus reducing environmental and economic damage.

3.3. Improving material quality

Plastics recovered from dumpsites rather than collected at source (e.g. door to door) are more likely fouled by organic or other waste, which poses major challenges in conventional recycling systems. By transitioning to door-to-door collection and encouraging segregation at source, physical contamination (non-targeted materials / items) can be reduced and therefore the quality and value of the item increased. For example, improvement of material quality through segregation at source is the most influential area for intervention, as demonstrated though value chain analysis of the Zabaleen informal recycling sector in Cairo, Egypt (Jaligot et al., 2016).

Waste pickers are world experts in recognizing after-use plastics types and instantly assessing on the spot their recyclability. For example, in a collection and sorting cooperative in Brazil, pickers can quickly sort plastics into 17 grades, reflecting secondary plastic market needs and end-use outlets (Purshouse et al., 2017). This is partly feasible as financial support is provided by the regional government to operatives in the form of salaries for delivering 'environmental services' (Rutkowski and Rutkowski, 2015) (see solution 2). Enabling standardized descriptions and quantification of secondary plastics quality, and training waste pickers in these skills will increase the chance for materials to be recovered rather than lost to the environment.

4. Synergies between solutions – Addressing systemic complexity

We recognize that the three-pronged solutions proposed are inevitably a simplification of a highly complex system, featuring also considerable variability across the world. Despite such complexities, we maintain that these three areas of intervention could be the core elements in addressing plastic pollution by means of the IRS, enabling functional and sustainable solutions. Similarly, although presented here as separate solutions, in reality significant overlap and synergies exist between each of them. For example, by pricing plastics at a level that reflects the appropriate value of plastic pollution prevention, the economics would shift in favor of increasing collection services to recover this valuable material. Likewise, by focusing on improving material quality through segregation at source, improvements to the value of after-use plastics are realized and therefore the price is also increased. Enabling door-to-door collection by informal collection services or itinerant buyers would also provide benefits to material quality by encouraging direct interaction and education of households by the IRS (Rutkowski and Rutkowski, 2015).

5. Legitimizing the informal sector reduces poverty

There is considerable evidence that the IRS can be empowered to provide affordable, high-quality collection and sorting services (Velis, 2017; Velis et al., 2012). We also acknowledge the considerable challenges around marginalization, exploitation, abuse, child labor, and reduced community health due to picking from dumpsites and working without any personal protective equipment (Cook and Velis, 2021; Velis, 2017; Velis and Cook, 2021; Velis et al., 2012). However, with appropriate economics in place, organized services (such as cooperatives, associations or community-based organizations) can be deployed at scale to capture a sizable proportion of plastics that are mechanically recyclable. Legitimization and wider inclusion of the IRS has been applied extensively across Latin America, with tools currently available to assist with such processes (The Economist Intelligence Unit, 2017; Velis et al., 2012). This approach has resulted in reduced poverty and enhanced societal inclusion for organized IRS, where employed.

6. A rapid, inexpensive, just and scalable solution

Addressing underlying systemic failures is key to reducing plastic pollution (Velis et al., 2017b). Legitimizing and integrating waste pickers mobilizes an incredibly valuable source of human capital. Our three-pronged framework provides a roadmap for tapping the unrealized potential of the informal waste sector to contribute an effective, rapid, inclusive, and inexpensive solution to prevent plastics pollution. This needs to be combined with long-term efforts to innovate plastic materials and product design to enable sustainable circularity and to support material recovery.

Simple interventions in the framework provided can dramatically reduce plastic pollution and benefit the livelihoods of millions of waste pickers by improving collection, price/revenues and material quality. Examples of how to achieve these changes include moving from collection at dumpsites to door-to-door collection, choosing incentives that economically address the misfit between the value in recovered plastics and current pricing, and improving material identification. This shift may have significant benefits for the workers, while at the same time addressing the key source of plastic pollution: unmanaged waste dumped along streets or in the environment. By targeting these

interventions at the waste items with the highest leakage rates and environmental and wider damages, it is feasible to address the global plastic pollution problem.

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Author Contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. All authors contributed equally. Dr Costas Velis secured the funding for the UoL visit to CISRO and associated researcher's time.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Dr Costas Velis serves as Leader for the Marine Litter Task Force, established by the International Solid Waste Association (ISWA).

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