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EDITED BY
Tomaso Fortibuoni,
Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA), Italy

REVIEWED BY
Anju Baroth,
Eaton Corporation, India
Eleni Iacovidou,
Brunel University London, United Kingdom

*CORRESPONDENCE
Trisia Farrelly
✉ t.farrelly@massey.ac.nz

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Policy implications for gaps in traditional plastic waste material flow analysis: Palmerston North, New Zealand

Trisia Farrelly[1]* and Takunda Yeukai Chitaka[2]

[1]Social Anthropology Programme, School of People, Environment, and Planning, Massey University, Palmerston North, New Zealand, [2]School of People, Environment, and Planning, Massey University, Palmerston North, New Zealand

The Basel Plastic Waste Amendments reflect growing global concern about the illegal plastic waste trade as waste colonialism. Comprehensive analyses of plastic waste material sources, pathways, and fates are needed for effective plastic waste trade policy. Plastics waste flows from Palmerston North, New Zealand to Malaysia highlight potential gaps in plastic waste trade policies. The authors recommend strengthening New Zealand's national waste policy framework and the Basel Convention's Plastics Amendments by basing policy responses on critical transboundary plastic waste material flow analyses, establishing harmonized definitions including "recyclable" and "environmentally sound recycling"; regulating contamination thresholds and container inspections; and waste trade traceability, transparency, compliance, enforcement, and remediation; reclassifying fluorinated polymers and thermosets as "hazardous"; and prioritizing principles of prevention, proximity and precaution over future investments in the management of plastic waste.

KEYWORDS

plastic waste, Basel Convention Plastic Waste Amendments, Basel Convention, waste colonialism, New Zealand, material flow analysis, global plastics treaty

Introduction

Since 1988, more than a quarter of a billion tons of plastic waste has been exported around the globe (Environmental Investigation Agency, 2021, p. 19). Plastic waste exports are a widespread waste management practice in OECD countries and yet importing countries are increasingly receiving contaminated and otherwise unrecyclable plastic waste designated as "recyclable". However, only an estimated 10% of all plastic waste ever produced has been diverted for the intention of recycling. The vast majority (~76%) has accumulated in landfills or the natural environment while about 14% has been incinerated (Geyer, 2020, p. 27–28).

China was the biggest importer of post-consumer plastics globally until it became overwhelmed by supply (Wang et al., 2020). Brooks et al. (2018, p. 3) estimated that in 2016, plastic waste imports to China contributed an additional 10.8% to the waste generated locally. China's National Sword policy, enforced in 2018, banned imports of a range of plastic wastes and highlighted waste dumping as a global phenomenon. China's policy was precipitated not only by the increasing volumes of waste sent to China, but also the increasing rates of contamination of those shipments. Contaminants can include dirt, liquids, non-recyclable plastics and other materials.

When importing countries receive shipments of waste that do not reflect export documentation or contain contaminated bales, they may declare these illegal and send them back to the exporter. However, financial guarantees may be difficult to obtain in which case shipments may be landfilled, dumped, or burned in the absence of safe and responsible waste management alternatives (Franklin-Wallis, 2019). Mislabeled or contaminated shipments of plastic waste returned to exporters can be redirected to other non-OECD countries (Wood, 2019). In addition to the financial, environmental, human health, and human rights impacts, the trafficking of plastic waste can hinder development by fueling corruption, and other forms of organized crime and poverty in some countries (INTERPOL, 2020). The illegal waste trade can also divert valuable resources away from zero waste responses. The illegal plastic waste trade is big business: "With an estimated worth of up to €15 billion in the EU alone, the illegal trade in plastic waste is facilitated by a serious lack of transparency and accountability that operates in the sector" (Environmental Investigation Agency, 2021, p. 5).

China's National Sword policy saw a huge diversion of plastic waste imports to South and Southeast Asian countries, prompting them to implement their own national policies and legislation to discourage the illegal trade of plastic waste throughout 2018 and 2019. These countries are now also presenting similarly high plastic waste mismanagement rates as China: Malaysia (57% mismanaged), Indonesia (83%) and Thailand (75%), while Turkey send 90% of their waste to landfill (Environmental Investigation Agency, 2021, p. 7). "Almost all countries that receive or have received large quantities of imported plastic waste are those that also have some of the highest mismanagement rates in the world" (Environmental Investigation Agency, 2021, p. 9).

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (the Basel Convention) is an international treaty designed to reduce the movements of hazardous wastes between nations (specifically from developed to less developed countries), and to promote national waste management self-sufficiency. In 2019, in response to increasing cases of the illegal trade in plastic waste, the 14th Conference of the Parties to the Basel Convention unanimously adopted the Plastic Waste Amendments. The adoption of the Amendments was bound by 186 states and the European Union (Secretariat of the Basel Convention, 2019). The Plastic Waste Amendments to the Convention introduces the changes to the Convention including the following new categories for plastic waste:

> *Annex II: Y48*, lists plastic waste, including mixtures of such wastes, that are subject to the prior informed consent (PIC) procedure (excluding those that would fall under A3210 or B3011).
> *Annex VIII: A3210*, clarifies the scope of plastic waste presumed to be hazardous and therefore subject to the PIC procedure.
> *Annex IX: B3011* replaces B3010 and *clarifies the type of plastic wastes presumed not to be hazardous* plastic waste destined for recycling in an environmentally sound manner and almost free from contamination and other types of waste[1] that remain excluded from the PIC procedure (certain single polymers or mixtures of PE, PP and/or PET).

The Plastic Waste Amendments specify that plastic exports must meet specific criteria or be subject to PIC. Basel's prior informed consent (PIC) procedure is based on four key stages: notification, consent and issuance of movement document, transboundary movement, and confirmation of disposal as per Article 6, paragraph 1 of the Basel Convention and Decision VIII/18 of COP8 (Basel Convention, 2006). However, the PIC process is ineffective when accurate identification of plastic wastes remains a challenge and when there an ongoing lack of agreement about what constitutes hazardous plastic wastes. Evidence of ineffective contamination assessments is seen in ongoing transboundary flows of Y48 which can be buried in shipments labeled as paper waste and textiles and in refuse-derived fuel (RDF).

According to the Amendments, PIC is required except for the following criteria: single separated and non-halogenated [e.g., no polyvinylchloride (PVC)] polymers except cured resins and six fluorinated polymers that are destined for recycling/reclamation of organic substances which are not used as solvent (R3, Annex IV); "almost free from contamination"; or mixed polyethylene (PE), polypropylene (PP), and polyethylene terephthalate (PET). All other mixed plastic waste is subject to PIC. Breach of any of the articles of the Basel Convention, including the Plastic Waste Amendments is considered illegal waste trade.

In addition to ongoing challenges associated with PIC procedures is the lack of definition of "almost free from contamination" within the text of the Convention. This lack of definition leaves member states with the responsibility of setting their own contamination limits while respecting the spirit of the Convention. In the absence of clear guidance on contamination thresholds, a risk is presented to receiving countries who feel compelled raise their contamination thresholds where they have entered into trade relationships with more powerful countries (a cause and symptom of ongoing waste colonialism). Vague references to contamination rates in the Convention also poses a risk to exporting member states when their contamination threshold may be considered higher than "almost free from contamination".

Exemption for PIC procedures also requires that Annex II plastics are not only almost free from contamination but also free from "other types of waste". Annex II, VIII, and IX imply that 'other types of waste' are plastics other than "mixtures of plastic waste, consisting of polyethylene (PE), polypropylene (PP) and/or polyethylene terephthalate (PET), provided they are destined for separate recycling of each material and in an environmentally sound manner".

While some changes in the global waste trade have been made, three and a half years after COP 14, transboundary movements of plastic waste continue to sustain waste colonialism. For example, the Bamako Convention (1991) was signed by 25 African

1 I.e., consisting almost exclusively of waste of one type of plastic polymer as per Annexes II, VIII, and IX.

countries in response to the failures of the Basel Convention at that time (UNEP, 2019). The Basel and Bamako Conventions emphasize power imbalances in the transboundary movement of waste. The discourse around waste colonialism often centers on corporate imperialism, the neoliberal phenomenon of international corporate expansion, corporate manipulation of production and consumption patterns (Pratt, 2011), and corporate influence over policy and society (Prahalad and Lieberthal, 2008). In short, waste colonialism draws attention to the power structures embedded within the movement of waste, including plastic waste.

This paper draws on the findings of a material flow analysis of plastic waste conducted by the second author in the city of Palmerston North New Zealand in 2019. The case study highlights some weaknesses in municipal and national traditional plastics material flow analyses, ongoing challenges associated with the Plastic Waste Amendments to the Basel Convention three and a half years after coming into force as well as national and international waste trade policy.

The paper starts with some of the weaknesses in the traditional application of plastics material flow analyses and how the transparency and traceability of plastic waste could more be more effectively captured. A harmonized definition of "environmentally sound management" which is currently lacking in the Basel Convention would support the transparency and traceability of municipal and national plastic waste flows. A case is then made for New Zealand and other Basel member states to set their own regulated contamination thresholds to support accurate municipal and national plastics waste flow analyses and contamination assessments. Finally, the authors argue for the identification of hazardous chemicals in municipal and national plastics waste flow analyses.

Plastics material flow analysis

NZ has not been an innocent in growing cases of waste dumping in non-OECD countries as waste colonialism. In 2020, NZ exported 58% of our plastic waste exports by value to Malaysia, Indonesia, the Philippines, Thailand, and Vietnam: a 22% increase since China's National Sword policy was enforced. High levels of contamination in NZ's plastic waste exports were made public when, in 2019, Indonesia sent five containers of plastic waste back to NZ due to an unacceptably high rate of contamination. However, they were lost in transit and were never repatriated (Woolf, 2019).

Material flow analysis is an analytical method to quantify flows and stocks of materials or substances within a system. Effective material flow analyses could significantly contribute to strengthening policy to stop hazardous and illegal trade in plastic waste. However, research quantifying flows of plastic waste rarely expand system boundaries beyond domestic borders and seldom investigate the fates of waste post-export (Van Eygen et al., 2017; Eriksen et al., 2020). For example, a study conducted on the flows of PET, PE, and PP in Europe to evaluate the potential for a circular economy for plastics simply present plastic waste exports as "losses" (Eriksen et al., 2020). Furthermore, the fate of traded waste is commonly characterized according to its intended or theoretical fate as "recyclables". Therefore, seldom is a determination made about the volumes of exported plastic waste "responsibly recycled" in the receiving country.

Some studies have analyzed the domestic flows of plastic waste in NZ (MfE, 2009; Eunomia, 2018; WasteMINZ, 2020). However, there is limited information on the characteristics of this waste. In particular, the waste is rarely characterized beyond "recyclables": resin 1 PET and 2 High Density Polyethylene (HDPE), respectively, and "mixed plastics" resins 3–7. In addition, little is known regarding the fate of NZ's plastic waste exports. A study commission by NZ's Ministry for the Environment reported "limited transparency" in the plastic waste industry (Eunomia, 2018, p. 24). The lack of data transparency is a significant barrier to comprehensive and transboundary material flow analyses of traded plastic waste and is exemplified by vague references to "recyclable" plastic waste.

Transparency, traceability, and "environmentally sound management"

The recyclability of plastic waste is based on a number of characteristics including polymer type, product design, and presence of additives and/or impurities including colorants, flame retardants and other materials or polymer types (e.g., multilayer) (Faraca and Astrup, 2019; Hahladakis and Iacovidou, 2019), as well as external contaminants. "Recyclability" is also contingent on collection and sorting, and the ability of waste managers to secure markets as was the case in Palmerston North. While many polymers are theoretically recyclable and designated as "recyclable" in source countries, this does not mean receiving countries have the available resources, capacity, or technology to recycle those polymers either at all, at a particular time, or in a manner that is safe for the environment and human health.

There is a lack of transparency regarding the fate of exported plastic waste at municipal level in NZ. The Palmerston North City council requires the broker based in Australia to ensure buyers in Malaysia are legitimate recyclers. However, when the Waste Operations Supervisor (pers. comm, 2020), was asked if they could be confident that all the waste exported to Malaysia was recycled and not dumped/landfilled and/or burned, they were unable to respond with any certainty.

In 2019, consumers in Palmerston North, NZ generated 2,679 tons of plastic waste (Figure 1). One thousand nine hundred and eighty tons formed kerbside waste which consists of unrecyclable plastic waste and some recyclable plastic which may have ended up in that stream due to human error when categorizing waste. Recyclable plastic is collected in two ways; by kerbside pick-up (614 tons) or *via* drop-off sites (85 tons) where the public can bring their recyclables.

Of the 2,679 tons of plastic waste generated in Palmerston North, 83.1% was landfilled, whilst 349 tons were sent for local recycling and the remaining "recyclable" plastic waste materials were exported to Malaysia. However, Malaysia has exceeded its capacity to import other country's plastic waste. While Malaysia has an installed recycling capacity of 515,009 tons, in 2021 it imported, on average, 835,000 tons of plastic waste each year in addition to an estimated 2.4 million tons of plastic waste produced domestically (Environmental Investigation Agency, 2021). This goes some way

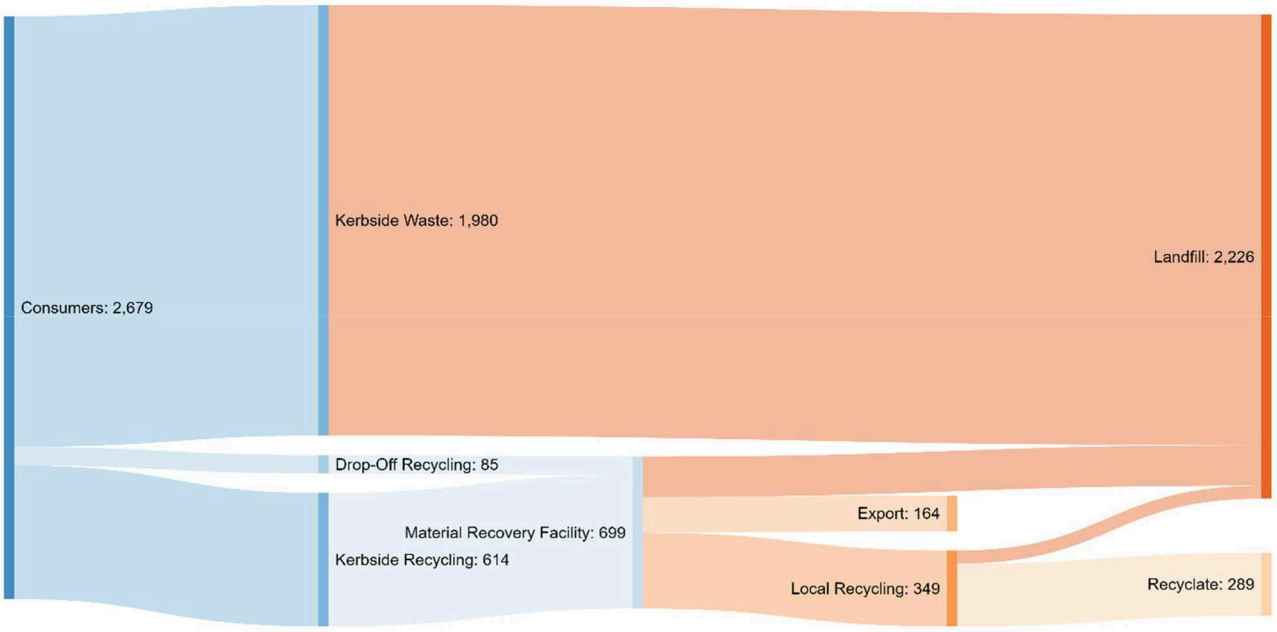

FIGURE 1
Plastic waste flows from Palmerston North in 2019.

to explaining why, of the plastic waste exported from Palmerston North to Malaysia in 2019, only an estimated 37% was "potentially recycled" in the best-case, dropping down to 11% in the worst, where the unrecycled waste is either dumped, landfilled, or burned.

The Palmerston North City Council operates a material recovery facility (MRF), based at the Awapuni Resource Recovery Park, where mixed (i.e., plastic, paper, glass, and metal) recyclable materials are sorted and diverted to treatment as appropriate. The material recovery facility sorts plastic waste into five categories:

- PET Clear (bottles)
- HDPE Natural (milk bottles)
- HDPE Colored (janitorial)
- PP (ice cream and yogurt containers)
- Mixed Plastics (PET, PVC, LDPE, PP, PS, and Other)

The recyclables are manually sorted, with PET, HDPE and PP separated individually from the stream while it is transported along a conveyer belt. The final stream constitutes "mixed plastics". PET contributed 38.1% to plastic collected in 2019 (shown in Figure 2), whilst HDPE contributed 26.4% and PP 11.6%. Whilst Palmerston North accepts all plastic resin types, they reported no solid LDPE items (e.g., container lids and squeezable bottles). PET, HDPE and PP are diverted to local recyclers as far as possible whilst the "mixed plastics" are exported to Malaysia for recycling.

The Basel Convention Amendment lists are difficult to distinguish not only because of the lack of clarity regarding the phrase "almost free from contamination", but also the lack of agreement about "environmentally sound management" of plastic waste. The Basel Plastic Waste Amendments includes provisions for the "environmentally sound management" (ESM) which the Basel Convention as "taking all practicable steps to ensure that

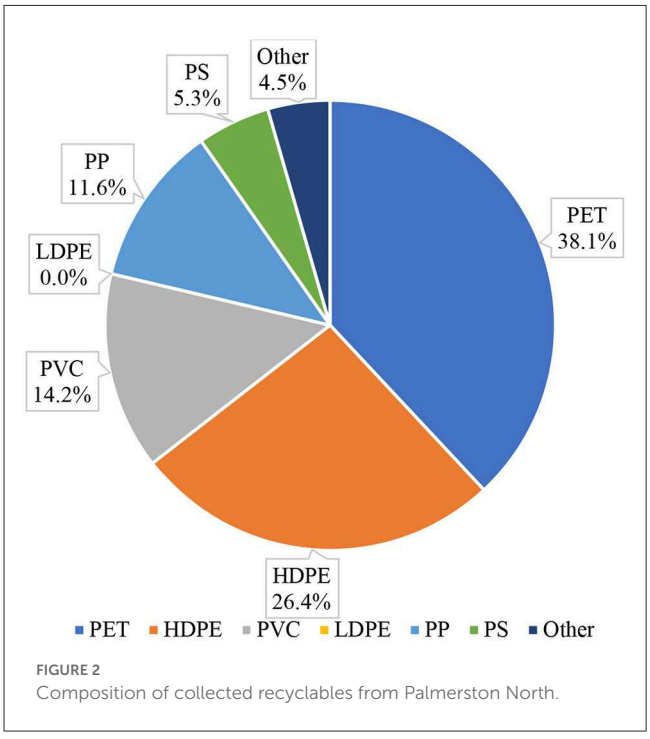

FIGURE 2
Composition of collected recyclables from Palmerston North.

hazardous wastes or other wastes are managed in a manner which will protect human health and the environment against the adverse effects which may result from such wastes" (UNEP, 2014, p. 11). However, what those steps should be are matters of ongoing debate. In addition, the proximity principle of the Basel Convention's preamble states that "hazardous wastes and other wastes should, as far as is compatible with environmentally sound

and efficient management, be disposed of in the State where they were generated" (UNEP, 2014, p. 17). However, this principle is disregarded in the case of plastic waste trade, particularly where OECD country waste is sent to non-OECD countries where there is capacity for "environmentally sound and efficient management" of any kind is lacking.

Some plastics and additives are not yet listed as hazardous in the Amendments, yet are hazardous when thermally treated, and cannot be recycled in an environmentally sound manner. Yet, the Amendment states that B3011 and Y48 bales (subject to PIC) must be "destined for recycling in an environmentally sound manner and almost free from contamination and other types of wastes". In addition, it is not clear how the new Basel rules relate to RDF which contain hazardous polymers and additives. The new Basel Convention Amendments require trade controls for all mixed plastic wastes not destined for environmentally-sound recycling. However, RDF classified as an "alternative fuel" containing PVC and other hazardous halogenated plastics is routinely exported for burning (e.g., to fuel cement kilns) rather than recycling. "Recycling" is also vaguely defined in the Convention as "recycling/reclamation of organic substances which are not used as solvents (R3 in Annex IV, sect. B)". From this definition, recycling does not assume "mechanical recycling" and may also imply processes marketed by the petrochemical industry as "chemical/advanced recycling". Indeed, thermal (pyrolysis and gasification) and solvent-based recovery processes for plastic waste have been marketed as novel "chemical recycling" or "advanced recycling" (GAIA, 2022, p. 2). These technologies present environmentally *un*sound waste management due to extremely high energy requirements, dioxins, and other hazardous emissions, including as contamination and other outputs, and microplastic emissions (Shen et al., 2021; Yang et al., 2021).

A small intersessional working group of the Basel Convention co-led by China, Japan, and the United Kingdom prepared a draft of updated technical guidelines on the environmentally sound management of plastic wastes (UNEP/CHW.15/6/Add.7) (UNEP, 2022a). However, GAIA (2022, p. 1) suggest these guidelines provide more confusion than clarity.

Contamination thresholds and assessments

As has been noted, "contamination" of recyclable plastic waste remains vague in the Convention, and acceptable contamination rates are not stipulated. NZ's export rules do not state a contamination threshold. Exporters are only required to match or better that of the receiving country (if, indeed, the receiving country has declared a contamination threshold). A lack of standardized monitoring and reporting means there are limited data on types of plastic waste exported and contamination rates. China's contamination threshold before their plastic waste import ban was 0.5%. Their contamination rate is now set to 0% and Indonesia has a 2% contamination threshold (Basel Action Network, 2022). If Palmerston North is an indication of contamination levels in NZ's national plastic waste exports (16–25%), much of NZ's plastic waste is not likely to meet the Conventions requirement that exports are "almost free from contamination".

The Convention does not require exporters or importers to comply with standardized contamination assessment methods, nor reporting protocols. Nor does it identify those responsible for assessing contamination rates (either exporter prior to shipping or importer on arrival at destination). In the case of Palmerston North, infrequent and irregular audits are conducted of mixed waste bales for export *via* a randomized sampling system. Comprehensive assessments are costly, and the onus often lies largely on non-OECD receiving countries to assess shipments on receipt (Basel Action Network, 2022). For example, Malaysia returned 3,000 tons of plastic bales to the UK, Saudi Arabia, and Canada in 2019 due to improper labeling (Shrikanth and Palma, 2019).

The need to distinguish uncontrolled plastic waste (B3011) from controlled wastes (Y48) under the Basel Convention is an ongoing challenge. Plastic products originally holding toxic contents (such as janitorial products) may be co-mingled with plastic waste destined for the manufacture of food or beverage containers. A broad range of grades and/or polymer qualities are potentially captured in mixed bales including the presence of additives and colorants which influence "environmentally sound" "recyclability". The World Trade Organization's Harmonized Commodity Description and Coding System (HS) is an internationally recognized classification system for the international trade of good used by customs authorities. The HS comprises about 5,000 commodity groups. Each of these groups are identified by a six-digit code. Countries can refer to these codes in establishing national import/export rules.

Countries can continue to mislabel contaminated bales of otherwise recyclable plastic waste with hazardous plastic waste, and thereby, exploit the HS code classifications of exported plastic waste (Dominish et al., 2020, p. 18). For example, plastic waste exported from NZ from 2017 to 2019 was classified as either polymers of ethylene or styrene, or as general plastic waste (i.e., HS heading 3,915 which encompasses all plastic waste types) (Figure 3). Enforcement is further complicated by the broad definitions of "waste" applied across member states. For example, the EU Waste Framework Directive

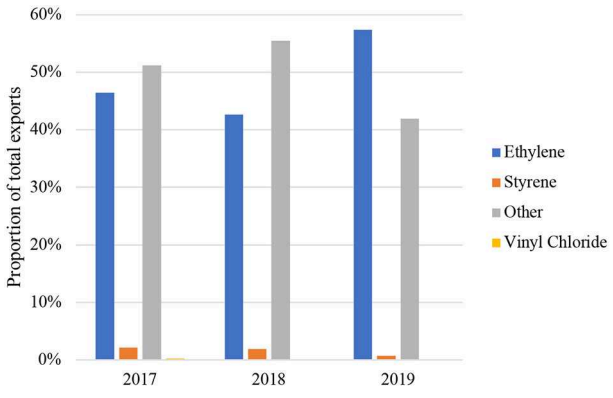

FIGURE 3
Plastic waste exports by HS code classification (adapted from Stats NZ). The "Other" category refers to mixed plastics wherein the resin type is not specified.

Article 3 (European Union, 2008) does not distinguish between "second hand" or "waste". The Waste Shipment Regulation (WSR) transposes the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (Basel Convention) into EU law. In addition, different countries use different coding systems. For example, EU countries can use the WSR codes or the HS codes (D'Amato et al., 2019).

In 2017, polyvinyl chloride (PVC) was also reported as an exported plastic waste stream in New Zealand (NZ). However, it was not identified by HS coding in subsequent years. This suggests PVC was no longer separated from other plastic types during collection and sorting and that Palmerston North exported "mixed plastic" waste constituting a mixture of PET, PVC, PP, PS and Other (resin code 7) plastic types reported under the HS code for "Other" plastic waste. Under the Basel Convention's Plastic Waste Amendments, these mixed bales from Palmerston North were contaminated by PVC and PS and, therefore, subject to PIC. PVC is a halogenated polymer and the additives used renders it "hazardous" under the Convention. PVC therefore contaminates single or mixed bales of plastic waste rendering them "unrecyclable" as this would affect their chemistry and thus their mechanical properties (Braun, 2002, p. 2172). Should the mixed bales be used as RDF, the presence of PVC would introduce contaminants resulting in the release of harmful carbon monoxide and hydrogen chloride gases (Choi, 2004, p. 49). Nevertheless, PVC continues to be traded by some countries without PIC:

A shipment of PVC plastic…that left Newark on February 16 (2021) for Gujarat, India, could potentially run into obstacles under Basel rules because India is a Basel signatory, and PVC trade is restricted under the rules (Tabuchi and Corkery, 2021).

Polyvinyl chloride (PVC) and polystyrene (PS) have been listed alongside polyurethane (PU) and polycarbonate (PC) as "priority" pollutants, the most "problematic" of all plastics and thus requiring classification as "hazardous" materials (Rochman et al., 2013). PS, for example, is particularly difficult to recycle and it contains toxic constituents including its building blocks, styrene monomer, a suspected carcinogen (World Health Organisation, 2019). PS, PVC, PC, and PU "can be carcinogenic and can affect organisms in a similar way to the hormone estrogen" (Rochman et al., 2013, p. 170; Farrelly and Shaw, 2017). The Basel Plastics Amendments has recognized the problematic nature of these plastics by requiring PIC for their trade.

Parties to the Basel Convention may have different interpretations of the types of plastic scrap and waste that is covered by Basel listing Y48 and requiring PIC. While exemption from PIC implies that bales should not be contaminated by "other wastes" as other than "mixtures of plastic waste, consisting of polyethylene (PE), polypropylene (PP) and/or polyethylene terephthalate (PET)", Y48 plastic wastes continue to cross borders uncontrolled, and contaminated with "other wastes" other than plastics including and paper and cardboard; and plastic waste has been found buried in paper waste, in refuse-derived fuel (RDF), and as textile waste shipments (e.g., B3011 Annex IX listings) (IPEN, 2022a).

The Palmerston North Waste Operations Supervisor reported their mixed waste bales as "desirable" due to the prospect of receiving PET in the form of food trays, which, at the time were not being separated for domestic recycling. This is what has been referred to by waste exporters as "sweetening" the bales. This supports the findings of a recent NZ study which reported that exporters admitted that they regularly add "sweeteners" to low value mixed plastic bales in the form of higher value resins (i.e., PET and HDPE) (Eunomia, 2018, p. 22). Furthermore, it is speculated that receiving countries rely on cherry picking the valuable plastic waste from the mixed stream and dumping or burning the rest. A recent study estimated that only 16% of PET bottles consumed in Malaysia are collected for recycling (GA Circular, 2019). This contradicts the global trend in which PET bottles are widely collected for recycling along with polyethylene (PE) and polypropylene (PP) (Moh and Abd Manaf, 2014). For example, in South Africa, where PET bottle collection rates surpassed 50% in 2015 and continue to rise (PETCO, 2022). Therefore, "sweetening" mixed bales with PET may conversely be considered "contamination" in shipments destined for Malaysia.

Fluorinated polymers, condensation products, and thermosets

The fluorinated polymers, condensation products, and thermosets listed in Annex IX have several Annex III hazardous characteristics and contain additives with hazardous characteristics (Ozaki et al., 2000; Jiang et al., 2010; GAIA, 2020a,b; Lohmann et al., 2020) and yet they are exempted from the Y48 listing of plastic wastes in Annex II because it is assumed they can be "recycled in an environmentally sound manner and almost free from contamination and other types of wastes" in the destination country (IPEN, 2022b). Many of these polymers are unrecyclable and all trigger human health and environmental concerns during thermal degradation (GAIA, 2020b; IPEN, 2020).

Fluorinated polymers belong to a family of chemicals called per and polyfluorinated alkyl substances (PFAS) which are known for their toxicity and include several persistent organic pollutants recognized under the Stockholm Convention (OECD, 2018; Korzeniowski and Buck, 2019). In August 2022, the US EPA issued a proposal to designate two PFS [perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS)] hazardous substances under Comprehensive Environmental Response, Compensation, and Liability Act or "Superfund" (EPA, 2022). Polytetrafluoroethylene (PTFE) as a fluoropolymer and thermoset (cured resin) was not exempted from Y48 and thus requires PIC. However, thermosets and condensation products (a subset of thermosets), cannot be reprocessed (recycled) through thermal treatments, and due to their application, products made from PTFE are not free from contamination and other types of waste. Therefore, fluorinated polymers do not meet the Y48 listing criteria; nor do they qualify for exemptions (IPEN, 2022b).

The lead author communicated the hazardousness of fluorinated polymers and thermosets to NZ's Ministry of Foreign Affairs and Trade in the public consultation period prior to the transposition of the Basel Plastic Waste Amendments into national legislation. The NZ Government decided not to restrict these polymers in its domestication of the Amendments

in to NZ's Imports and Exports (Restrictions) Prohibition Order (No. 2) 2004 (MfE, 2020; Parliamentary Counsel Office, 2022).

Actionable recommendations

The authors propose national material flow analyses of plastic waste are needed that extend beyond NZ's national borders, as demonstrated by the case of Palmerston North. These national material flow analyses should assess exported shipments of plastics labeled "recyclable" to ensure that the contents are not just theoretically recyclable but recyclable in practice in the receiving country at the time of trade. Data transparency would be greatly supported by harmonized definitions of "recyclable plastic," "contamination," and "environmentally responsible recycling".

Municipal and national material flow analyses should critically assess whether plastic waste shipments are destined for "environmentally sound recycling". The authors consider the only responsible way to recycle plastic waste' to be plastic to plastic (P2P) mechanical recycling limited to PE, PP, and PET. Basel member states should be required to quantify volumes of exported plastic waste that are guaranteed to be responsibly recycled in the receiving country. This should factor in the capacity of the importing country to recycle a resin type at a particular time. The work of the intersessional working group of the Basel Convention to prepare a draft of updated technical guidelines on the environmentally sound management of plastic wastes (UNEP/CHW.15/6/Add.7) (UNEP, 2022a) should be delayed enabling more time to strengthen the guidelines. The guidelines could be strengthened by clearly identifying plastic waste streams that fall under the plastic amendments including multiple Basel Annex IX entries for uncontrolled wastes that could overlap with controlled plastic wastes (especially the Y48 listing); clarifying the difference between environmentally *sound*, and environmentally *unsound* recycling and other forms of plastic waste management; accounting for climate emissions; clearly defining "contamination" distinguish uncontrolled (B3011) from controlled plastic wastes (Y48) (GAIA, 2020a). The growing scientific evidence illustrating the environmental and human health harms of thermal recovery technologies should be included in the Basel Convention's incineration guidelines (D10 and R1).

Countries that export plastic waste as "responsible waste management" must expand the scope of their system boundaries in plastic waste material flow analysis if they are to accurately reflect the fate of their plastic waste in receiving countries. In the case of Palmerston North, it was found that only 11–37% of exported plastics were potentially recycled. Essentially, Palmerston North city is externalizing the cost of its own inability to manage plastic waste onto other non-OECD countries. Expanding the scope of plastic waste flow analyses will more accurately reflect the efficacy of toxic-free circular economies for plastics and support the faithful domestication of member states' obligations to the Basel Convention. Expanding the scope of plastic waste flow analyses will also illuminate the need for Palmerston North and countries like NZ to establish circular systems and responsibly manage their own domestic waste in the spirit of the Basel Convention's proximity principle.

Improved waste trade traceability and transparency from municipalities such as Palmerston North as well as national monitoring, evaluation, and reporting as part of NZ's National Plastics Action Plan would improve material flow analyses of exported plastic waste while ensuring plastic waste exports are destined for environmentally responsible waste management that is also protective of human health and rights.

Further, the monitoring of plastic waste flows should include total exports actually recycled to ensure a system of accountability between the exporter and the recycler.

"Recycled" plastic waste should be reported as the volume of plastics an importer can convert to recyclate for P2P mechanical recycling instead of the volume received by the recycler. This would account for the weight contribution of contaminants in waste plastics which, in the case of Palmerston North, ranged from 16 to 25%.

A binding international standard for contamination limits in global plastic waste flows would resolve the problem of the currently vague definition of "almost free from contamination and other wastes" and that OECD countries bear the responsibility for rigorous container inspections to identify and report contamination rates prior to export. These inspections would be part of an enhanced programme of regulatory compliance optimization and liability for Basel members. Countries who export plastic waste that does not meet the criteria of the Basel Plastic Waste Amendments must be liable for the full cost of repatriation and remediation if necessary. Setting clear contamination definitions and thresholds would offer greater clarity and certainty for municipalities such as Palmerston North, exporters, and importers and would support the avoidance of liability.

Fluorinated polymers and thermosets including condensation products must be accounted for in all plastic waste material flow analyses. Due to their known hazardousness, the authors advocate for the exclusion of these polymers from Annex IX of the Basel Convention. Despite their exclusion from Y48, Palmerston North, NZ and other exporters and exporting countries should list fluorinated polymers and thermosets as restricted plastics in their own import/export rules and municipal policies and ban their export to non-OECD countries to reflect the Basel Convention Ban Amendment (UNEP, 2022b). A binding international standard for contamination limits should clearly state "free from contaminants including hazardous and toxic materials, substances, and other wastes" and exporters should bear the burden of proving the absence of these contaminants.

Based on decision BC-14/9, the Conference of Parties requested the Basel Secretariat to propose the amendment of the HS to identify 10 waste types (Basel Convention, 2011; Basel Action Network, 2022). This could help municipalities and national customs distinguish between waste streams and shipments of B3011 and Y48 plastic waste. Additional codes should accommodate waste-based or alternative fuels such as RDF. Enforcement measures should be in place to ensure exporters correctly use the current HS codes, namely 382,510 for municipal waste or 3,915 for plastic wastes.

Conclusion

The authors have identified significant weaknesses in the plastics waste flow analysis of one municipality, Palmerston North, NZ. New Zealand's national waste policy framework nor import-export rules require the kind of comprehensive assessments of plastic pollution leakage at municipal and national levels needed to understand the true pathways and fates of plastics and to strengthen plastic waste trade policies to protect human rights and health, and the environment in receiving countries. The authors also identified ongoing weaknesses in the Basel Plastic Waste Amendments which could be resolved with clarity and harmonization of key definitions, improved data collection, greater transparency in the monitoring and reporting of plastic waste flows, particularly from OECD countries to non-OECD countries.

The authors' recommendations would significantly address weaknesses in national and international plastic waste trade policy and reduce illegal plastic waste trade activities. However, ultimately, the most effective responses to transboundary waste dumping are preventative measures based on the precautionary and proximity principals and supported by the global plastic pollution treaty approved at the fifth session of the United Nations Environment Assembly. The priority must be on preventing the production of unnecessary and toxic plastics that cannot be safely mechanically P2P recycled. This will require investing more heavily in responses that focus on the top of the waste hierarchy to establish prevention, reduction, reuse, refill, and repair systems that support a toxic-free global circular economy (Zaman and Newman, 2021; Blumhardt and Prince, 2022).

Author contributions

TC and TF conceptualized and designed the case study. TC conducted the research for the case study, analyzed the data, and approved the final submission. TF drew on the conclusion of the study to conceptualize and write the first draft of the policy brief. Both authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Basel Action Network (2022). *Plastic Waste Transparency Project*. Available online at: https://www.ban.org/plastic-waste-transparency-project (accessed September 30, 2022).

Basel Convention (2006). *Article 6, Paragraph 1 of the Basel Convention and Decision VIII/18 of COP 8*. Available online at: http://www.basel.int/Portals/4/Basel%20Convention/docs/techmatters/forms-notif-mov/vCOP8.pdf (accessed October 3, 2022).

Basel Convention (2011). *Harmonized System Codes for Wastes*. Available online at: http://www.basel.int/Implementation/HarmonizedSystemCodes/Overview/tabid/2390/Default.aspx (accessed February 26, 2023).

Blumhardt, H., and Prince, L. (2022). From lines to circles: reshaping waste policy. *Policy Quart.* 18, 71–80. doi: 10.26686/pq.v18i2.7577

Braun, D. (2002). Recycling of PVC. *Prog. Polym. Sci.* 27, 2171–2195. doi: 10.1016/S0079-6700(02)00036-9

Brooks, A. L., Wang, S., and Jambeck, J. R. (2018). The Chinese import ban and its impact on global plastic waste trade. *Sci. Adv.* 4, 1–8. doi: 10.1126/sciadv.aat0131

Choi, W.-Z. (2004). Development of waste plastics-based RDF and its combustion properties. *Geosyst. Eng.* 7, 46–50. doi: 10.1080/12269328.2004.10541219

D'Amato, A., Peleari, S., Pohjakallio, M., Vanderreydt, I., and Zoboli, R. (2019). *The European Environment Information and Observation Network (Eionet)*. Belgium: Boeretang.

Dominish, E., Retamal, M., Wakefield-Rann, R., and Florin, N. (2020). *Environmentally Responsible Trade in Waste Plastics Report 1: Investigating the Links Between Trade and Marine Plastic Pollution*. Prepared for the Department of Agriculture, Water and the Environment (2020). Available online at: https://www.dcceew.gov.au/sites/default/files/documents/ert-waste-plastics-report-1.docx (accessed September 25, 2022).

Environmental Investigation Agency (EIA). *The Truth Behind Trash: The Scale and Impact of the International Trade in Plastic Waste* (2021). Available online at: https://eia-international.org/report/the-truth-behind-trash-the-scale-and-impact-of-the-international-trade-in-plastic-waste/ (accessed June 24, 2022).

EPA (2022). *EPA Proposes Designating Certain PFAS Chemicals as Hazardous Substances Under Superfund to Protect People's Health*. United States Environmental Protection Agency. Available online at: https://www.epa.gov/newsreleases/epa-proposes-designating-certain-pfas-chemicals-hazardous-substances-under-superfund (accessed October 5, 2022).

Eriksen, M. K., Pivnenko, K., Faraca, G., Boldrin, A., Astrup, T. F. (2020). Dynamic material flow analysis of PET, PE, and PP flows in Europe: evaluation of the potential for circular economy. *Environ. Sci. Technol.* 54, 16166–16175. doi: 10.1021/acs.est.0c03435

Eunomia (2018). *National Resource Recovery Project: Situational Analysis Report*. Auckland: Eunomia Research and Consulting Ltd.

European Union (2008). *European Union Waste Framework Directive 2008/98/EC*. Available online at: https://www.legislation.gov.uk/eudr/2008/98/article/3 (accessed February 26, 2023).

Faraca, G., and Astrup, T. (2019). Plastic waste from recycling centres: characterisation and evaluation of plastic recyclability. *Waste Manag.* 95, 388–398. doi: 10.1016/j.wasman.2019.06.038

Farrelly, T. A., and Shaw, I. C. (2017). "Polystyrene as hazardous household waste", in *Household Hazardous Waste Management*, eds. D. Mmereki (London: IntechOpen).

Franklin-Wallis, O. (2019). '*Plastic Recycling is a Myth*': *What Really Happens to Your Rubbish*. Guardian. Available online at: https://www.theguardian.com/environment/2019/aug/17/plastic-recycling-myth-what-really-happens-your-rubbish (accessed August 30, 2020).

GA Circular (2019). *Full Circle: Accelerating the Circular Economy for Post-Consumer PET Bottles in Southeast Asia*. Singapore: GA Circular.

GAIA (2020a). *Transposing the Basel Convention Plastic Waste Amendments: Challenges and Recommendations: Policy Briefing*. Available online at: https://www.no-burn.org/wp-content/uploads/Policy-briefing_Transposing-the-Basel-Convention-plastic-waste-amendments_November-2020.pdf (accessed September 25, 2022).

GAIA (2020b). *Submission on Fluorinated Polymers and Cured Resins Listings on Annex IX of the Basel Convention*. Available online at: http://www.basel.int/Implementation/Plasticwaste/Callforinformation/FollowuptoBCCOP14/tabid/8350/Default.aspx (accessed June 30, 2022).

GAIA (2022). *GAIA Brief – June 2022: Plastics at Basel COP15*. Global Alliance for Incineration Alternatives. Available online at: https://www.no-burn.org/wp-content/uploads/2022/05/GAIA-brief_Plastics-at-Basel-COP15_English.pdf (accessed June 24, 2022).

Geyer, R. (2020). "Production, use, and fate of synthetic polymers," in *Plastic Waste and Recycling*, eds T. M. Letcher (Cambridge, MA: Academic Press), 13–32.

Hahladakis, J. N., and Iacovidou, E. (2019). An overview of the challenges and trade-offs in closing the loop of post-consumer plastic waste (PCPW): focus on recycling. *J. Hazard. Mater.* 380, 120887. doi: 10.1016/j.jhazmat.2019.120887

INTERPOL (2020). *Strategic Analysis Report. Emerging Criminal Trends in the Global Plastic Waste Market Since January 2018*. INTERPOL Lyon: General Secretariat. Available online at: https://www.interpol.int/en/content/download/15587/file/INTERPOL%20Report%20_criminal%20trends-plastic%20waste.pdf (accessed June 30, 2022).

IPEN (2020). *Basel Convention Submission of Information on the Following Plastic Waste Referred to in Entry Y48 in Annex II and Entry B3011 in Annex IX to the Convention*. Available online at: http://www.basel.int/Implementation/Plasticwaste/Callforinformation/FollowuptoBCCOP14/tabid/8350/Default.aspx (accessed June 30, 2024).

IPEN (2022a). Plastic waste fuels. Serious implications across South East Asia, As Australia kicks the 'waste' can down the road. *Int. Pollut. Elimin. Network (IPEN)*. Available online at: https://ipen.org/sites/default/files/documents/ipen-plastic-waste-fuels-v1_1aw-en.pdf (accessed June 30, 2024).

IPEN (2022b). *Plastic Waste and Y48 Exemptions: Cured Resins, Condensation Products, and Fluoropolymers Do Not Meet the Criteria*. Available online at: https://ipen.org/sites/default/files/documents/plastics-fact-sheet-noy48exemption-v1_3-en.pdf (accessed October 5, 2022).

Jiang, X., Li, C., Chi, Y., and Yan, J. (2010). TG-FTIR study on urea-formaldehyde resin residue during pyrolysis and combustion. *J. Hazard. Mater.* 173, 205–210. doi: 10.1016/j.jhazmat.2009.08.070

Korzeniowski, S., and Buck, B. (2019). *The PFAS Universe: Uses, Classification and Degradation*. FluoroCouncil. Available online at: http://theic2.org/article/download-pdf/file_name/2019-01-28_The%20PFAS%20Universe%20Webinar%2030Jan2019_FINAL_1p.pdf (accessed June 24, 2022).

Lohmann, R., Cousins, I. T., DeWitt, J. C., Gluge, J., Goldenman, G., Herzke, D., et al. (2020). Are fluoropolymers really of low concern for human and environmental health and separate from other PFAS? *Environ. Sci. Technol.* 54, 12820–12828. doi: 10.1021/acs.est.0c03244

MfE (2009). *Solid Waste Composition: Environmental Report Card*. Wellington: Ministry for the Environment. Available online at: https://environment.govt.nz/assets/Publications/Files/Environmental-Report-Card-Solid-Waste-Composition.pdf (accessed June 1, 2022).

MfE (2020). *Managing the Trade in Plastic Waste: New Zealand's Approach to Implementing Amendments to the Basel Convention*. Wellington: Ministry for the Environment. Available online at: https://environment.govt.nz/assets/Publications/Cabinet-papers-briefings-and-minutes/cabinet-paper-final-policy-proposals-to-implement-amendments-to-the-basel-convention-to-better-manage-the-international-trade-in-plastic-waste.pdf (accessed June 20, 2022).

Moh, Y. C., and Abd Manaf, L. (2014). Overview of household solid waste recycling policy status and challenges in Malaysia. *Resour. Conserv. Recycl.* 82, 50–61. doi: 10.1016/j.resconrec.2013.11.004

OECD (2018). *Toward a New Comprehensive Global Database of Per- and Polyfluoroalkyl Substances (PFASs): Summary Report on Updating the OECD 2007*. List of Per-and Polyfluoroalkyl Substances (PFASs). Organisation for Economic Cooperation and Development. Available online at: https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV-JM-MONO(2018)7anddoclanguage=en (accessed June 17, 2022).

Ozaki, J. I., Djaja, S. K. I., and Oya, A. (2000). Chemical recycling of phenol resin by supercritical methanol. *Indust. Eng. Chem. Res.* 39, 245–249. doi: 10.1021/ie9904192

Parliamentary Counsel Office (2022). *NZ's Imports and Exports (Restrictions) Prohibition Order (No 2) 2004*. Available online at: https://www.legislation.govt.nz/regulation/public/2004/0202/latest/DLM271758.html (accessed June 24, 2022).

PETCO (2022). *2021 Highlights*. PET Recycling Company. Available online at: https://petco-annual-review.co.za/highlights-2021/ (accessed September 29, 2022).

Prahalad, C. K., and Lieberthal, K. (2008). *The End of Corporate Imperialism*. Harvard Business Review Press. Available online at: https://hbr.org/2003/08/the-end-of-corporate-imperialism (accessed October 6, 2022).

Pratt, L. (2011). Decreasing dirty dumping? A re-evaluation of toxic waste colonialism and the global management of transboundary hazardous waste. *Environ. Law J.* 41, 147–180.

Rochman, C. M., Browne, M. A., Halpern, B. S., Hentschel, B. T., Hoh, E., Karapanagioti, H. K., et al. (2013). Classify plastic waste as hazardous. *Nature* 494, 169–171. doi: 10.1038/494169a

Secretariat of the Basel Convention (2019). *Basel Convention Plastic Waste Amendments*. Available online at: http://www.basel.int/Implementation/Plasticwaste/PlasticWasteAmendments/Overview/tabid/8426/Default.aspx (accessed November 16, 2020).

Shen, M., Hu, T., Huang, W., Song, B., Qin, M., Yi, H., et al. (2021). Can incineration completely eliminate plastic wastes? An investigation of microplastics and heavy metals in the bottom ash and fly ash from an incineration plant. *Sci. Total Environ.* 779, 146528. doi: 10.1016/j.scitotenv.2021.146528

Shrikanth, S., and Palma, S. (2019). *Malaysia to Return 3,000 Tonnes of Contaminated Plastic Waste*. Financial Times. Available online at: https://www.ft.com/content/b6bd62e0-811d-11e9-9935-ad75bb96c849 (accessed June 24, 2022).

Tabuchi, H., and Corkery, M. (2021). *Countries Tried to Curb Trade in Plastic Waste. The U.S. Is Shipping More*. New York Times. Available online at: https://www.nytimes.com/2021/03/12/climate/plastics-waste-export-ban.html (accessed June 24, June 24, 2022).

UNEP (2014). *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. Protocol on Liability and Compensation for Damage Resulting from Transboundary Movements of Hazardous Wastes and their Disposal*. Texts and Annexes. Available online at: https://www.basel.int/Portals/4/Basel%20Convention/docs/text/BaselConventionText-e.pdf (accessed October 5, 2022).

UNEP (2019). *The Bamako Convention*. Available online at: https://www.unenvironment.org/explore-topics/environmental-rights-and-governance/what-we-do/meeting-international-(7) (accessed June 24, 2022).

UNEP (2022a). *Technical Guidelines: Technical Guidelines on the Environmentally Sound Management of Plastic Wastes*. Available online at: http://www.brsmeas.org/20212022COPs/MeetingDocuments/tabid/8810/language/en-US/Default.aspx (accessed September 23, 2022).

UNEP (2022b). *Report of the Open-ended Working Group of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal on the Work of its Twelfth Meeting (face-to-face segment, 4–6 April 2022)*. UNEP/CHW/OEWG.12/16/Add.1.UNEP.

Van Eygen, E., Feketitsch, J., Laner, D., Rechberger, H., and Fellner, J. (2017). Comprehensive analysis and quantification of national flows: the case of Austria. *Resour. Conserv. Recycl.* 117, 183–194. doi: 10.1016/j.resconrec.2016.10.017

Wang, C., Zhao, L., Lim, M. K., Chen, W. Q., and Sutherland, J. W. (2020). Structure of the global plastic waste trade network and the impact of China's import ban. *Resour. Conserv. Recycl.* 153, 104591. doi: 10.1016/j.resconrec.2019.104591

WasteMINZ (2020). WasteMINZ Territorial Authorities Officers Forum. *The Truth About Plastic Recycling in Aotearoa New Zealand in 2020*. 1–10. Available online at: https://gohealthy.co.nz/media/1990/the-truth-about-plastic-recycling-report.pdf (accessed June 24, 2022).

Wood, J. (2019). Plastic waste from Western countries is poisoning Indonesia. *World Econ. Forum* 8–11.

Woolf, A. (2019). *Recycled Plastic Dumped Overseas is Being Sent Back, and Residents Want No More*. Stuff. Available online at: https://www.stuff.co.nz/environment/116083000/recycled-plastic-dumped-overseas-is-being-sent-back-and-residents-want-no-more (accessed September 5, 2020).

World Health Organisation (WHO) (2019). *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans* vol. 121. Styrene, styrene-7,8-oxide, and quinoline. Available online at: https://publications.iarc.fr/582.978-92832-0188-5 (accessed November 16, 2022).

Yang, Z., Lü, F., Zhang, H., Wang, W., Shao, L., Ye, J., et al. (2021). Is incineration the terminator of plastics and microplastics? *J. Hazard. Mater.* 401, 123429. doi: 10.1016/j.jhazmat.2020.123429

Zaman, A., and Newman, P. (2021). Plastics: are they part of the zero-waste Agenda or the toxic-waste Agenda? *Sustain. Earth* 4, 4. doi: 10.1186/s42055-021-00043-8