SUSTAINABLE RECYCLING INDUSTRIES

Feasibility study for a certification of sustainably recycled plastics in India

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Summary

India possesses a vibrant and efficient recycling sector. This sector enables the country to recycle around 60% of its plastic waste and achieves recycling rates much higher than common in European countries. This high recycling rate is largely due to the presence of the informal sector which consists of a multitude of small businesses and self-employed persons with no or little legal recognition and social protection.

Being driven by the low-cost structures in the informal sector, quality considerations often play a minor role during recycling due to little demand for high quality recycled materials. This also causes the recycling of plastics containing concerning substances which should not be recycled again. Also, measures to protect the health and safety of the workers as well as the environment are often lacking completely or implemented insufficiently.

Formal plastic recycling businesses struggle to compete with these low-cost structures, especially if they intend to follow or surpass the social and environmental legal requirements to produce more sustainably recycled plastics. In addition, they remain largely associated with informal actors and the associated practices due to their need to source collected and sometimes partially processed plastic waste.

A certification scheme for sustainably recycled plastic flakes and granules might be an important element to support the transition towards a more sustainable plastic recycling sector. This scheme would ensure that the services provided by sustainable recyclers can be verified, certified and made visible. If a demand for high-quality recycled plastic can be fostered and if it can be met by certified products, then the recyclers producing certified materials could also run economically sustainable businesses.

This feasibility study was conducted to collect the necessary sectorial background information for developing such a product certification scheme. Together with stakeholders, four key areas needing consideration for a scheme were defined. Potential stakeholders for a certification were defined, a characterization of the Indian plastic recycling sector with a focus on the structure and economic situation was undertaken and an overview on controlled chemicals in plastic waste as well as on traceability challenges and solutions of plastic waste fractions moving through the recycling sector was undertaken. As such, this study focuses on the "soft" factors of a certification and does not concern itself with the technical material quality for recycled plastics. While this is a common issue, rarely any general requirements can be given, as each potential user of recycled materials will have different requirements.

The study identified a large potential set of beneficiaries and potential recycling entities to be certified. In addition, a couple of NGOs active in the field of plastic recycling are expected to be important partners. Certification of recycled plastic products might be complicated due to the rather diverse business models and extents of vertical integration. However, the processes required to recycle plastics are comparatively easy to implement sustainably and are fairly linear, which should simplify equal certification even if these processes are spread through a whole value chain. Controlled chemicals including flame retardants, heavy metals and phthalates are present in waste plastics and they have to be appropriately managed. However, the distribution of these substances in different waste streams are fairly well known and thus do not represent an insurmountable challenge.

Specifications of single downstream buyers are much more difficult to follow as they usually do not include concentration limits but require proofs that the material was never in contact with certain

materials. Traceability is a required element for any product certification scheme, as many of the concerns related to the sustainability of recycled plastics do not reside in the last step of production but rather in the (partially informal) value-chain. Approaches on how traceability challenges are addressed in various contexts are given and a potential roadmap for implementing traceability in the plastic recycling value-chain is presented.

The success of a certification scheme is directly linked to its credibility and transparency, which will require that the certification scheme follows international best practices. Apart from the need to create a stable demand in certified products, the certification scheme for recycled plastics may require initial external seed funding since certification fees can only be collected once environmentally and socially responsible businesses are profitable. Adopting international best practices in designing the certification scheme may help in obtaining this seed funding.

A transition towards a more sustainable plastic recycling sector cannot be driven by a stand-alone certification scheme. Companies willing to invest their own resources in moving to more sustainable production need to have access to various supporting mechanisms, especially regarding the issues most difficult to implement, such as the management of controlled substances, traceability mechanisms, support for formalisation and access and participation in a functioning market for high-quality materials. In addition, the overall plastic recycling and manufacturing sector also needs to be engaged in order to create an environment conductive for adopting high quality recycled plastics and reduce related environmental risks.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

CPCB – Central pollution control board

GP – Guidance Principles for the Sustainable Management of Secondary Metals

MoEFCC – Ministry of Environment, Forest and Climate Change

Glossary

Kabaddi-wallah – itinerant buyers of waste doing door-to-door collection

Kabaddi-wallah shop – entity, where waste is sorted and resold

Tikri Kalan – large plastic scrap market in the outskirts of Delhi

1. Introduction

By international comparison, India recycles a large percentage of its plastic waste, with a recycling rate estimated at around 60% (WBCSD, 2016). Polluting disposal practices such as open burning and littering of non-recycled plastics are however widespread, leading to air, water and soil contaminations that harm millions of inhabitants (Figure 1). India's rapid economic growth is accompanied by an increasing demand for plastic-containing products such as electronic and electrical equipment, product packaging, and various household items. Issues related to the management of plastic waste will therefore become ever more important.

That India can be called a recycling nation is largely due to the presence of the informal sector: A multitude of small businesses and self-employed persons with no or little legal recognition organised along value chains from collection (e.g. by *Kabaddi-wallahs*[1] and waste pickers[2]) to aggregation, sorting and processing units. This sector provides recycled plastics to the Indian industry at the lowest cost possible and employs many marginalized groups (WBCSD, 2016). Despite being generally considered to be poorly skilled, this sector`s workers have developed a wide variety of cost-effective skills (Haarman and Gasser, 2016).

While being generally considered a sustainable activity, plastics recycling can be conducted in more or less sustainable ways. Locked in an endless "race to the bottom", the recycled materials of the informal sector are often of poor quality or do not come with product specifications. This directly supports a view common in India, which holds that recycled plastics have to be low-quality material and should thus only be used in cheap and low-quality goods. Similar views used to be held globally. However, these views are changing due to the recent development of a sector focusing on providing high-quality recycled plastics. The transformation of the plastic recycling sector has mostly been driven by the economic potential of high-quality recycled plastics. While this potential has always been present, industry-led supporting mechanisms had a considerable impact on speeding up this transformation.

Figure 1: Issues in Indian plastic waste management: littered river (left), urban warming fires (middle), open burning outskirts (right).

Beside quality issues, informal plastic recycling as done in India is associated with multiple environmental and social problems. Widespread harmful practices include working without protective equipment, open dumping of production wastes and effluents, uncontrolled recycling of fractions containing hazardous substances and child labour. While recyclers are sometimes aware of health, social and environmental risks, they usually lack the incentives do improve the situation (Toxics Link 2012, 2016).

Various formal plastic recycling businesses in India understand the business opportunities of high-quality recycled plastics, whose revenues could eventually finance more sustainable practices in

[1] itinerant buyers of waste

[2] Waste pickers collect of valuable wastes such as plastics from landfills and public spaces.

their businesses and value chains. Acting as seed points, they could potentially catalyse the transformation towards a more sustainable Indian plastic recycling industry. However, these businesses struggle dearly to gain a footing in today's Indian plastic recycling market as their products are currently indistinguishable from less sustainably recycled plastics: There are currently no supporting mechanisms which would make their efforts visible.

A certification system for intermediate recycled plastics such as flakes and granules might be a suitable mechanism to support this transition. Companies should be able to sell their certified products for a premium, having the additional value generated recognized by the market. To be truly transformative for the sector, the certification would have to soundly reside on all pillars of sustainability. It should try to capture the economic potential of higher quality recycling and include social as well as environmental requirements.

It is also a key challenge to design the certification scheme in a way that allows informal businesses and self-employed collectors to participate, enabling them to formalize and improve their processes and well-being. If not, the certification would exclude the groups potentially benefitting the most of it and having the largest investment in the plastic recycling economy

This report is a feasibility study for developing such a product certification scheme. The approach taken resembles and is inspired by the ISO Guidance Principles for the sustainable management of secondary metals (the "GP", ISO IWA 19, 2016). As suggested in the name, the GP's focal material streams are metal containing wastes. Plastic wastes are a bulky and low-value material compared to metal waste and its transport to processing units is generally a costly component of recycling. Supply chains of plastic waste materials tend to be more local than for metals, requiring a much more localised approach than envisioned in the GP.

2. Methodology

During the preparation of this study, various stakeholders were approached to learn what they consider to be key challenges for implementing a certification scheme. This also included a joint consultation workshop which coveredvarious industry representatives and waste experts from the private sector and the NGO Sahaas at the CII Waste Management Summit in Mumbai, November 24, 2016. During the workshop four key challenges for a certification were identified:

- *Relevant stakeholders:* How many potential beneficiaries for a certification exist? What other stakeholders and potential partners are there for a certification? Section 3.1 describes the results of a web and network-based stakeholder mapping performed as part of this study.
- *Characterization of the Indian plastic recycling industry:* What challenges are there in the Indian plastic recycling sector? What are the barriers for more sustainable plastic recycling? Section 3.2 describes the business models and challenges faced by seven recycling entities in Delhi and Hyderabad, which were analysed in detail for this report. Three of the visited entities were registered, three were unregistered and one was a semi-registered[3], ensuring that the whole variability of the industry could be captured.
- *Handling and presence of hazardous substances in waste plastics:* What requirements are there, how can they be met and which support mechanisms might be useful? Section 3.3 describes the results of a performed literature study on international requirements and interviews conducted with industry stakeholders on requirements faced by the local industry.
- *Traceability in the local context:* How can international practices be adapted to local challenges? How could traceability mechanisms be implemented? Section 3.4 describes the results of a literature review on international practices in traceability and local challenges faced by the industry.

Additional information collected which did not make it into the study is available in the Annexes. Annex I contains a full list of stakeholders identified. Annex II contains a detailed description of each of the visited recycling entities. Due to the sensitivity of the economic data provided on these units, the identities of these units is kept confidential

Because of the cultural western background of the authors, it is inevitable that the report is influenced by a western perspective of thinking. Please take this into account while reading.

[3] A “registered” entity / business is formally recognised as it has registered its operation with the government as required by the Plastic Waste Management Rules, 2016. A semi-registered business operates parts of his activities under registration, while running other aspects without registration.

3. Results and Discussion

3.1. Stakeholder mapping for a certification process

3.1.1. Recycling Industry

In the annual report 2014/15 of the Central Pollution Control Board (CPCB, 2015) on plastic recycling all federal states and union territories were asked to provide information about any registered as well as unregistered entities within their state (see Annex I, Table 4). A total of 1.404[4] registered and 217 unregistered entities are reported throughout India, but this information is scarce at best: 15 out of 36 states did not report any information and another five reported zero entities. Only eight states provided numbers of unregistered entities, which are generally lower than the reported number for registered units. These numbers have to be considered highly dubious, as alone for the Delhi area the amount of unregistered plastic recycling units has been estimated at a total of 7000 (Toxics Link, 2012).

While incomplete, the data shows that there are at least 1600 plastic recycling entities in the country which the government is aware of and which have registered and many more known by NGOs or formal plastic recyclers who often obtain plastic waste from informal actors (see chapter 3.2). Those entities may be potential stakeholders and beneficiaries for a certification of sustainably recycled plastic, but many may also be reluctant to provide access to outsiders. Interviews and observations suggest that many registered units operate exactly the same way as unregistered units, except having obtained the necessary CPCB-certification. Obtaining the CPCB-certification is generally considered too easy by the formal plastic recyclers and NGO representatives interviewed. The certification is based only on providing a filled form to the respective State Pollution Control Board, but no subsequent control visits. A certification would have to include regular visits to ensure proper implementation of its voluntary and legally binding requirements to be credible.

3.1.2. NGO`s

India has many NGOs which are working in the field of solid waste management. In this study eight NGOs, which might be potentially interested in contributing to a plastics certification, have been identified (Annex I, Table 5). Only entities with an up-to-date web page are listed. Three of the NGO`s are working since decades in the field, while four have founded themselves during the last years. Toxics Link, Chintan, Saahas and Plastic for Change were contacted and met during the research and are aware of the attempt to create a certification. The other four were found by recommendations and internet research. For a credible certification, the acceptance of the standard and contribution to its development by some of these NGOs is key.

3.1.3. Waste workers organizations

Often, waste workers form organizations with the intent of obtaining more visibility and power in the ongoing political dialogues. The forms of organizations are diverse, i.e. associations, trade unions and cooperatives are the most common ones found (Annex I, Table 6). Several organizations for the empowerment of women, engaged in the process of formalizing informal waste workers have been identified, which were only included in the list, if waste management was considered their primary concern.

[4] calculation error in original document. The original document refers to 1425 total entities.

The listed organizations represent at least 72.500 formalized waste pickers, which can be expected to be only a small percentage of the mostly informal waste picker community (Hasiru Dala, 2016). As official legal recognition of the contribution of waste pickers in waste policy is still very new in India[5], a considerable rise of organizations and numbers of formalized waste pickers can be expected in the next years and certification schemes for recycled plastics should provide a role to such organizations.

3.2. Characterization of the Indian plastics recycling sector

3.2.1. Characterization of the studied exemplary entities

In total, seven recycling units were visited and documented in detail. Of these, three units focused on sorting (case 1-3) and three on extruding (case 5-7), while one unit (case 4) was performing both activities. The focus lay on recording the variability of different value-chains and as such focused on documenting both registered and unregistered examples for both process steps. A detailed summary of each entity is given in Annex II.

Table 1: Economic situation of the studied plastic recycling entities

Case study	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Process	SORTING			BOTH	EXTRUDING		
Status	Unregistered	Unregistered	Registered	Semi-reg.	Unregistered	Registered	Registered
Output [t/mo]	10-15	200	150	100	<200*	100	500
Number of fractions	60	10-15	5	5-10	2	8	1 (3-4)[6]
Employees	6-8	25*	20	20	30	12	ns
Salary [INR/day]	300-350	♂:400 ♀:200	425	500-700	ns	500-5000	ns
Purchase Price [INR/kg]	10-20	20	23-25	40-50	40-50	10-80	ns
Sale price [INR/kg]	20-40	35-65	30-50	60-70	60-70	20-90	ns
Est. profit [INR/mo]	ns	100-150.000	<0	150.000	ns	<0	<0

*ns = not specified, * = estimated value*

Output: Registered as well as unregistered businesses were commonly found to produce 100-200 t /mo of output (cases 2-6). Case 1 has a lower output of 10-15 t/mo and is a *big kabaddi-wallah shop* in an informal settlement. Case 7 is the largest company visited, using state-of-the-art technology with a capacity of 1000 t/mo. Due to the lack of demand it is currently running on half capacity.

Output fractions: The number of sorted fraction differs strongly between the entities. While case 1 is sorting into 60 types of plastics, case 2, 3 and 4 sort between five and 15 types. Case 6 accepts many plastic types for processing but does not sort them further. Case 5 and 7 are fully specialized and only process a single type of material, either of industrial (case 5) or post-consumer origin (case 7). As a general rule, registered entities tend to handle fewer types of waste, being generally located higher in the value chain, where material has been pre-sorted more.

[5] The revised Solid Waste Management Rules of 2016 mention waste pickers for the first time as a relevant part of India's waste management system and include provisions for supporting their work and formal inclusion. The revised plastic waste management rules, as a legislation of equal footing, however do not mention waste pickers.

[6] future amount: case 7 is currently building up a new processing unit

Employees: All entities employ both women and men except case 1 (men only). The number of employees dealing exclusively with plastic materials typically ranges between 8 and 30. In sorting units, more employees may be present handling also other materials such as paper and glass.

Salary: The salary of employees ranges from 200 to 700 INR/d. Unregistered entities (case 1-2) generally pay less than the legal minimum wage of 374 INR/d for unskilled workers (Delhi Govt., 2017), while formal and semi-formal businesses adhere to minimal wage laws. Case 2 reported a considerable wage gap between female and male workers, where female workers were paid less than minimum unskilled wage. Formal businesses generally pay wages in compliance with legal regulations also for semi-skilled and skilled labour.

Product prices: The product prices show a high variability in purchase and sale due to a high diversity of different material qualities and resins. Formal businesses pay slightly higher prices than unregistered entities, because they already try to pay above market price to establish customer loyalty and achieve a continuous material inflow. Unregistered units can react more flexibly to market shortages due to long-term business connections, lower quality requirements and short term labour agreements. Formal businesses generally struggle in such conditions due to higher fixed costs, higher quality requirements and limited availability of downstream buyers willing to pay a higher sale price.

Profit: Unregistered entities` profit range between 50.000 and 150.000 INR/month (based on estimations for case 1 and 5), while all interviewed registered companies self-report losses attributed to high investment costs, lack of clients and market competitiveness.

The observed informal sector units follow a multitude of distinct business models. While some add value by extensive sorting of their material (case 1 and 2), others process only single pre-sorted materials (case 5 and 7). Case 2 used to be a supplier of case 6. Requiring high-quality input, case 6 successfully trained case 2 to improve their sorting practices. Although case 6 stopped buying from case 2, the improved sorting methods (e.g. separation per colour and new high value streams) are still in use as other buyers for the high-quality material could be found. This indicates that in some cases there already is a demand for higher sorting quality. In some cases, the incentive structure may thus already be appropriate for better sorting and what is lacking is external support and training to implement better sorting practices.

The observed formal companies generally follow legal regulations, try to build up fair market conditions and provide high-quality recycled plastics. While they sometimes have customers willing to pay an appropriate market price for high-quality recycled plastics, these sales often do not compensate for losses produced from working with other customers not willing to pay this premium. While there is a general tendency trying to evade the informal sector, there are also examples where cooperation has been mutually beneficial. A challenge reported by formal companies is that international companies often prefer working directly with informal sector actors to show their social commitment but then rarely see themselves as a potential user of the recycled materials. A certification scheme should try to leverage the engagement of international companies, transforming their relationship to that of a functioning supply chain generating local value.

3.2.2. Characterization of the value chain

The observed seven cases show a high variability in terms of upstream sourcing, conducted in-house processes and downstream processing (Table 2). Case 1 and 2 represent the early stages of the value chain. They represent the *kabaddi-wallah shops*, whose supply chain includes direct links with *kabaddi-wallahs* and waste pickers.

Table 2: Supply chains of the studied plastic recycling entities described as processes conducted upstream, in-house and downstream.

Case Study	1	2	3	4	5	6	7
Sourcing	waste pickers *kabaddi-wallah*	waste picker scrap dealers	*kabaddi-wallah shops* door-to-door industrial	*Tikri Kalan*	industrial	industrial *kabaddi-wallah shops*	formal sorting *kabaddi-wallah shops*
In-house	sorting	sorting grinding	sorting	sorting grinding depollution extruding molding	grinding extruding	depollution grinding extruding	depollution grinding
Downstream	Trading to *Tikri Kalan*	Extruding molding	grinding extruding molding	n/a	molding	molding	extruding molding

Some of the registered and unregistered units successfully circumvent having links to *kabbadi-wallahs* or waste pickers. They prefer (case 3 and 6) or exclusively (case 5) deal with industrial waste or build up their own collection systems for post-consumer waste, which can be digitally monitored (case 3). Case 2 sources from local village scrap dealers, which obtain their materials directly from private households, where intermediate collectors are less prevalent due to smaller structures.

In the above cases tracing of materials can be at least partly guaranteed. When plastic is bought from the open market such as *Tikri Kalan*[7], it was impossible to further trace the materials origin within the scope of this study.

As well as sourcing, in-house processing shows a high variability. Sorting is mostly done in dedicated business units and not performed by processing entities. Processing entities take influence on sourcing entities to ensure that their quality requirements are met (case 6 and 7). The quality of applied process steps in extruding facilities differs highly. While sorting is in all cases done manually with different quantities of sorted plastic types, the process quality in manufacturing differs a lot due to applied technologies and available instruments. Some of the registered extruding facilities apply high-tech solutions including automatically monitored production systems, the use of different melting temperatures for different resins, process ventilation and water cooling systems to mention only a few (case 6 and 7)[8]. The unregistered entities are following the same procedure, but with less process controls (case 4 and 5).

Downstream processing of flakes resp. granules is not as diverse as sourcing and in-house processing. Basically, the flakes need to be extruded, moulded and distributed. The visited extruding entities sell the produced units either directly to molding facilities, are molding components or consumer products themselves or sell it to the open market.

[7] *Tikri Kalan* is a large, authorized plastic scrap market in the outskirts of Delhi. Traders pay their tax through their plot rental fee and the trading of plastics does not require a specific license from the government.

[8] The case studies are not a representative mix of the overall Indian plastic recycling industry and more advanced units are over-represented.

Traders do not play an essential role in five of seven characterized cases[9]. Traders appropriate a part of the margin and are known to often haggle over previously communicated prices. The described entities thus often try to circumvent traders and replace their function of collecting and aggregating materials of the same type through their own initiatives. Yet, trading markets like *Tikri Kalan* remain a very vital part of the plastic recycling economy, being able to centrally collect and seasonally store plastics. Traders in *Tikri Kalan* were not interested in sharing information when visited for this study. Some background information on the plastic trading business and *Tikri Kalan* in particular can be found in a Master Thesis of Daniel Kroiss (2016). Further work is however needed to determine the potential role trading hubs could play in a certification scheme, as they are also present in Mumbai, Hyderabad and other big cities throughout India.

3.3. Controlled chemicals relevant to plastic recycling

Plastics used in the production of consumer goods are not made up of a single compound, but are usually a finely adjusted mixture of the base polymer (like PP or ABS) and a set of additives. These additives are mixed into the base polymer during the production of the "master-batch", homogenized intermediary products with its properties exactly matched for its intended use. Common additives include pigments, stabilizers, flame retardants etc. (Toxics Link, 2016). In addition to additives, the polymerization of monomers often requires harmful catalysts to control the reactions.

Additives and residual catalysts are mostly not chemically bound to the polymer. Thus they are potentially mobile and can leach into the environment or into products. Some of the chemicals used as additives and catalysts from the past have negative impacts and they have thus been phased out or are currently being phased-out (Toxics Link, 2016).

Product safety regulations are an important tool for policymakers to speed up the replacement of certain chemicals. Two regulations with an international impact on the content of chemicals in plastics are the EU Regulations Restriction of Hazardous Substances Directive (2011/65/EU, RoHS) and the Registration, Evaluation, Authorization and Restriction of Chemicals Regulation (1907/2006/EC, REACH). RoHS limits the use of hazardous chemicals in new electronic equipment and is implemented in most jurisdictions and also India. REACH is the general chemical safety regulation and covers all sectors, but so far mostly relevant in the European Union.

Recyclers are often confronted with the issue that some of the material they receive still contains hazardous chemicals which are no longer accepted in new products. Table 3 lists a set of chemicals which are restricted under the REACH and RoHS regulation, relevant concentration values and their main occurrence after PlasticsEurope (2010), focusing on groups relevant in non-PVC applications. In the case of RoHS, the limits are "hard" values. Recycled plastics not conforming to the limits are thus banned for use in electronic and electrical appliances.

REACH uses a general limit value of 0.1% or 1000 ppm for most chemicals contained in solid materials. The limits are however "soft", i.e. it may be possible to bring recycled plastic not fulfilling the thresholds into market, but this requires that downstream processors are informed according in line the requirements for prior informed consent (PIC) described in the regulation.

For certain critical applications, the same limits may still be "hard". For example, plasticized parts of toys and childcare articles have to contain less than 0.1% of the restricted phthalates DEHP, DBP

[9] In general, informal recyclers tend to be highly dependent on traders (Toxics Link, 2012).

and BBP[10]. This is mostly relevant for plasticized PVC, where phthalates are or were commonly used in very high concentrations (up to 30%). In terms of controlled chemicals, PVC is probably the most difficult polymer to recycle sustainably: In India's domestic PVC production, it is still common to use lead as a stabilizer[11] (typical concentrations of 0.5 to 1.0%, Toxics Link, 2016) and as such the primary industry should first move to safer stabilizer alternatives, for example on a Calcium-Zinc base, as is currently happening in Europe (Vinyl Plus, 2014).

Brominated flame retardants such as PBDE and PBBs remain an issue when trying to build a business in recycling e-waste or other concerned streams. The specific housings contaminated with BFRs are however well known and there are simple and verified technologies for separating BFR-laden plastics from a waste stream (e.g. Wäger et al., 2012, Haarman and Gasser, 2016). BFRs are not only relevant from a product view, but also from a waste view as they are listed in the Stockholm Convention of Persistent Organic Pollutants (Toxic Links, 2016).

Table 3: Hazardous additives potentially limiting the recycling of plastics in an international context

Chemical family	**Halogenated Flame Retardants (HFRs)**	**Heavy Metals**	**Phthalates**
Use	reduce flammability	stabiliser, pigment	plasticiser, PP-catalyst
RoHS-Substances (2011/65/EU)	Polybrominated Biphenyls and Diphenyl ethers (PBBs and PBDEs, each <1000ppm).	Chromium (IV), Mercury, Lead: each <1000 ppm Cadmium: <100 ppm	n/a
REACH-Substances (1907/2006/EC) generally <0.1% or 1000 ppm	Hexabromocyclododecane (HBCDD) Tris(2-chloroethyl) phosphate (also a plasticizer)	Lead chromate Lead chromate molybdate sulphate (red) Lead sulfochromate (yellow) Chromium Trioxide (under consultation)	Benzylbutylphtalate (BBP) Bis(2-ethylhexyl)phtalate (DEHP) Dibutylphtalate (DBP) Diisobutylphtalate
concerned streams	BDE: e-waste and other heat-generating applications. HBCD: construction Tris: diverse	Widely used in consumer goods such as packaging and toys Most PVC (Pb, Cd as stabilizers) HDPE (CrO_3, Catalyst)	PP PET-bottles PVC (flexible, >10%)
Hazard Class (REACH)	CMR, PBT	CMR	CMR

CMR: Carcinogenic, mutagenic, and/or toxic for reproduction. PBT: Persistent, bioaccumulative and toxic substances.

The restricted phthalates were also used in PP as catalysts and have been detected in PET-bottles obtained from recycled material. In PP, phthalate catalysts are used in concentrations of 1 ppm and are often only detected in concentrations not exceeding 0.15 ppm (Borealis, 2016). PP input material

[10] The website https://echa.europa.eu/addressing-chemicals-of-concern/restrictions/substances-restricted-under-reach provides a concise overview over the REACH status of certain substances.

[11] As of 25.01.2016, Synergy Additives, "India's Leading Polymer Additives Manufacturer", lists several lead-based stabilizers on their product list: http://www.synergyadditives.com/

for recycling is thus not of specific concern regarding phthalates. However, PP like any other polymer can be contaminated with phthalates, if improperly handled and processed.

An example for contamination with phthalates is the case of PET (Sax, 2010): Although the full name (Polyethylene tere*phthalate*) may suggest the presence and use of phthalates in PET, the terephthalate used in PET is a chemically different substance. Still, phthalate leaching form PET-bottles has been described multiple times. No leaching could however be detected in virgin PET-bottles. This has led to the suggestion that the cross-contamination occurs during the bottle-to-bottle recycling processes practiced in the EU and USA.

The hard limits of REACH rarely directly impact plastic recyclers as they will not bring finished products into the market. Also, following good practice, recycled plastics are generally not desired to be used in such critical applications, with only few well controlled instances being allowed. This is in line with the Indian approach to consumer safety in which Indian Standards specify that recycled material should not come into contact with food (IS 14534:1998). A general problem is however conforming to the process of prior informed consent mandated by REACH, whose implementation can be very demanding (Umweltbundesamt UBA, 2012). In Europe, the European plastic recyclers association thus developed and operates a tool supporting recyclers to prepare the necessary documentation[12] and provides access to compliance experts[13]. Similar supporting mechanisms by industry associations may be required in India as well, although some information may already be publicly available. One such example is the Pharos Project,[14] which lists international hazard ratings on 25 toxicity endpoints for over 45.000 chemicals.

As a voluntary certification scheme will only be implemented by a part of the industry, it will be important to ensure that plastic containing hazardous chemicals are not just simply moved to non-certified material streams where they will cause similar damage. As such, a core element of the certification system should be to ensure that recyclers using material streams of concern need to dispose an appropriate amount of contaminated plastics to contribute to the removal of concerning chemicals from plastics.

3.4. Traceability

3.4.1 International use and application

Traceability is the ability to verify the history, location or application of a lot of materials by means of documented or recorded identification (adapted from ASME, 2015). The ability to trace materials through the supply chain is the key requirement to monitor the general conditions and actual processes with which the material is treated. As such, traceability is not only a useful tool to alleviate concerns related to sustainability, but also regarding product safety, quality, supply chain management and legal compliance (“traceability concerns”). Traceability also enables that systemic optimization potentials within a supply chain can be identified and acted upon and thus promise increased productivity and an overall market advantage (Luning et al., 2006).

Traceability schemes guarantee that traceability concerns can be appropriately alleviated through credible documentation. Traceability schemes are a system of procedures, methods and

[12] http://www.sdsrtool.com

[13] http://plasticsrecyclers.eu/reach-plastics-recyclers

[14] https://www.pharosproject.net/

management applied to achieve traceability of the concerned material (after ISO IWA 19, 2016). The GP list a set of traceability requirements necessary for any claims to be made, which may be a useful starting point to consider for any certification for plastics:

- *Transparency requirements:* The policy on the chain of custody or any other traceability scheme needs to be publicly available to scrutinize the certification of plastics. Certified entities need to identify a specific point of contact / manager who is responsible for the implementation of the policy.
- *Documentation requirements:* A set of information uniquely identifying material lots, its suppliers and processes conducted or planned to be conducted with it needs to be kept.
- *Material accounting schemes*: Different material accounting schemes exist and are described, including *physical segregation*, *mass balance* and *book and claim*.

3.4.1. Local traceability concerns and challenges

During the stakeholder interviews and discussions, 'traceability' was repeatedly mentioned as a core requirement for claims made about recycled plastics and thus any certification. In further discussions, it became clear that the understanding of 'traceability' differed considerably between the stakeholders. For the interviewed industry stakeholders, the issue of traceability was generally reduced to specific traceability concerns required by customers and were generally at loss how to sufficiently prove their conformity to these requirements.

A selection of traceability concerns is displayed in Figure 2. It is based on the traceability concerns of a single registered Indian recycling company looking to sell their products to international brands. It thus needs to comply with international requirements while matching them to the Indian reality of waste plastic collection and trade. Depicting one of the most complex and advanced examples encountered during the study, the figure also includes the traceability concerns identified in other companies studied.

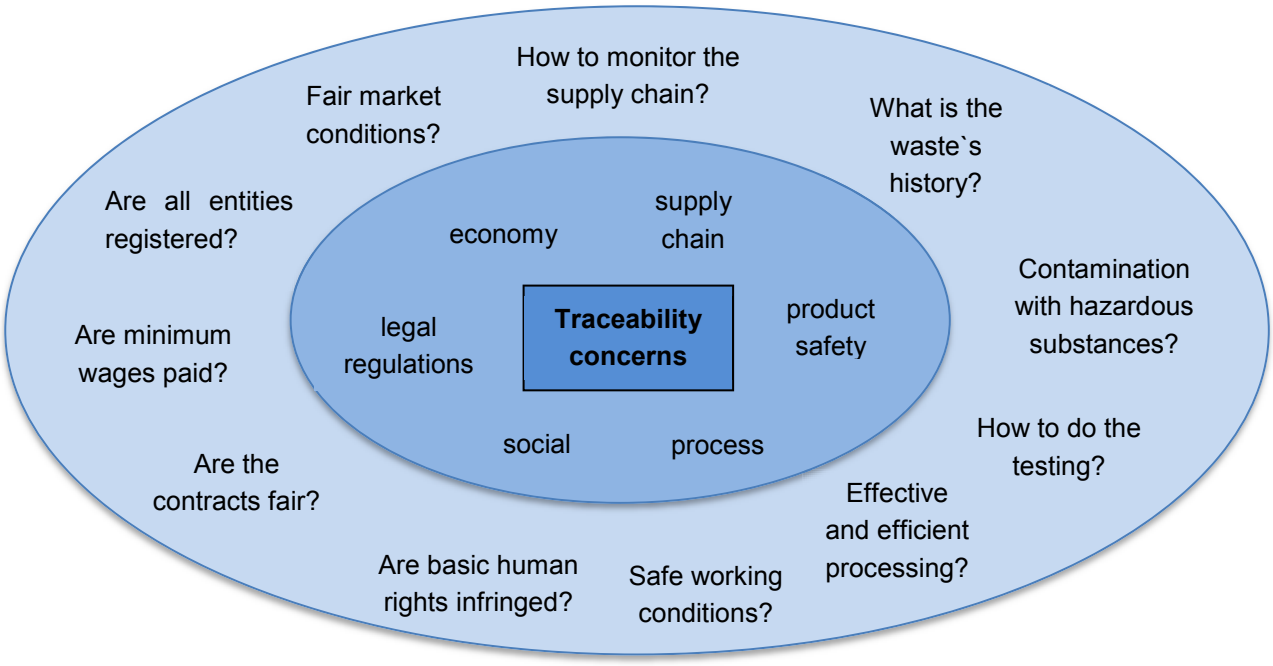

Figure 2: Traceability concerns in the context of plastic recycling in India

During the discussions, two issues specific to the sector and local situation were repeatedly mentioned. The first sector-specific challenge is related to the pervasive presence of informal actors in most of the plastic waste supply chains in India. The informal sector both complicates the implementation of traceability schemes and is as well the source of many of the traceability concerns, such as child labour and working conditions described by Chintan (2004).

As discussed before, recyclers trying to implement full traceability in their supply chains have so far only been able to do so by circumventing the informal sector completely. This is achieved by creating vertically integrated services (household to recycled plastic) or sourcing post-industrial waste only.

The second specific challenge is related to the material itself. In recycling plastics, any additives or contaminants not removed end up in the final product. As chapter 3.3 details, this includes the presence of phased-out hazardous additives in plastic waste. The experience of Europe shows that hazardous additives can mostly be managed through background knowledge on the types of applications the additives were used in and the appropriate selection and segregation of input streams. As additives are used in a relative specific and static manner, few measurements are usually considered sufficient to characterise specific streams. A considerable issue in small-scale recyclers is that they may use the same machinery for several polymer types for different applications, which may increase the risks for cross-contamination.

The presence or contact with controlled or unwanted chemicals, i.e. in the form of residual contents in bottles is a related issue. Requirements of this sort generally do not originate in consumer safety laws, but in the commitments made by certain downstream manufacturers. As such, the list of chemicals may differ between the downstream manufacturers. There are no established common limit values as is the case for additives and no publicly available lists of chemicals concerned.

A typical requirement in this category may be that the recycling company needs to prove that the recycled material has never been in contact with a specific chemical, requiring complete traceability plus detailed knowledge of where specific chemicals are employed in both industry and households. Producers of post-industrial waste can also be asked to confirm in writing that none of the chemicals of concerns are used on the premises. Whether measurements can play an effective and efficient role regarding this problem depends on both the specific requirements to be met and the chemical in question. A “no-touch” requirement cannot be fulfilled with measurements. Measurements for chemicals which are commonly used in many applications may probably require too much effort to be cost-effective as many different streams would have to be tested.

Despite having made a tremendous effort in implementing traceability in their supply chains, the studied plastic recyclers have struggled to meet their own expectations as well as those of local and international downstream manufacturers. A certification scheme designed for the Indian reality should thus not only introduce additional requirements, but also provide a unified and adapted, yet still internationally credible, approach to traceability. For international credibility, the localized approach should be informed by international development such as the ISO IWA 19 Guidance Principles, which provide general tools and mechanisms how informal sector activities can become a part of traced waste streams. To ensure that all sustainability aspects are considered, a mapping of the above listed concerns to the Guidance Principles may also be advisable.

The certification scheme should also provide additional support mechanisms geared to the specific challenges faced in the Indian plastic recycling sector. This may include:

- Broadly agreed-upon guidance on which activities can remain partly formalised, transition mechanisms and a sensible amount of traceability required (household waste is generally of a similar composition and it is not necessary to know in which exact household the material originated form).
- The ongoing formalization of waste pickers but could enable a complete tracing of post-consumer waste in the future, if direct collaborations with formalised cooperatives are supported through the certification scheme.
- Technical support, documents and information concerning the use and application and presence of hazardous additives in plastics as wells as chemicals deemed undesirable by downstream manufacturers.
- As the reliability and turn-around speed in Indian laboratories is often unsatisfactory, guidance on trustworthy laboratories might be useful.
- To decrease the need for costly measurements, knowledge of the presence of hazardous materials should be *codified* as much as possible in the certification itself. For example, if a certain waste material is known to contain a specific hazardous substance, it could be excluded for the certification, require appropriate handling or even disposal.

3.4.2. Local traceability schemes

The implementation of a traceability scheme requires the identification of as many entities in a specific supply chain as possible. Graphical representations may be useful to appropriately display the relationships between each entity. While the focus should lay on the mapping of upstream relationships due to the concerns related to the informal sector, downstream mapping should also receive attention due to the potential to optimize products and fulfil requirements of downstream actors.

An example of how such a representation could look like for an entity engaged in extrusion is given in figure 3. It clearly represents suppliers as well as customers of the unit to several tiers and displays the material flows. As described before, traders can be present between any processing steps. Such identification is necessary to obtain a profound understanding of the individual case as well as hotspots where traceability may be limited or difficult to achieve. Performed initially, such a mapping may produce many white spaces. Changing business relations and interventions geared towards improving traceability should – over time – result in less and less white spaces and full traceability of the material.

Questionnaires can be used to compile additional information along the value chain. An initial round of questionnaires could either limit itself to identify additional relationships or already be used to identify or evaluate the responsiveness of business partners when faced with traceability concerns. For traceability concerns included in a certification scheme, the certifying body could develop questionnaires. As an example, the questions for identifying contamination risks could look as following:

- In what application was the material used before?
- For how long was it used?
- Was the material used once or multiple times before?
- Where does the material originate from?
- Has the material been recycled before?

- How was it processed?

Answers received on the questions above should allow determining the contamination risks of different materials sourced and further actions can be planned, which may include measures to decrease the contamination risk, analytical measurements or the documentation of practices both up- and downstream in the supply chain.

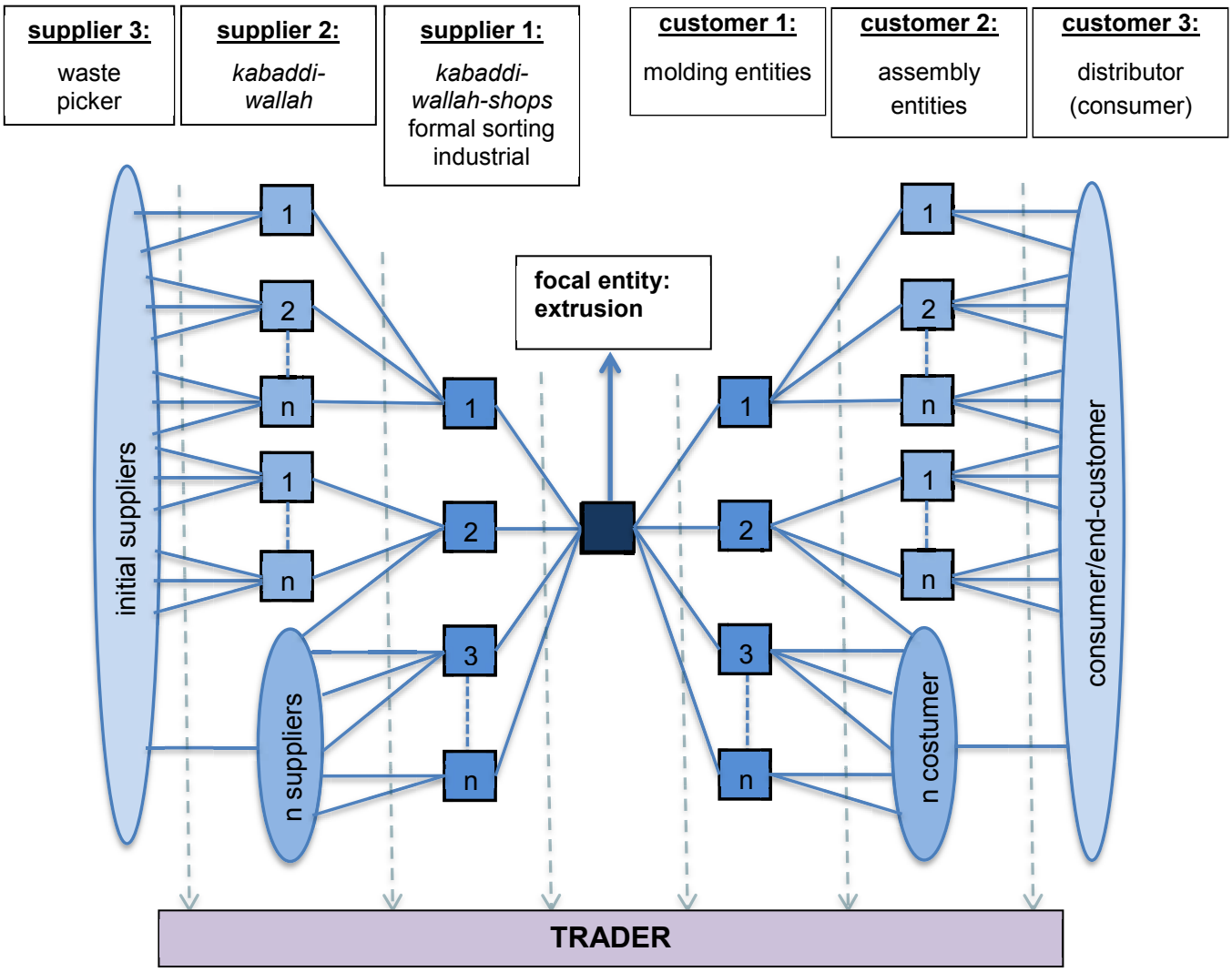

Figure 3: Example of a graphical representation of value chains a plastic extrusion entity is involved in (Adapted from Lambert and Cooper, 2000)

Identifying suitable and accepted tracing mechanisms applicable to local conditions may prove to be challenging. While tracing does not have to be based on a technological solution and could be entirely based on a paper mechanism, new technological approaches employing the wide penetration of mobile phones in the Indian society should also be considered. An example is the software developed by FairStone, a German organisation, certifying the responsible sourcing of stones from India (FairStone, 2015). The software relies on the scanning of QR-codes to track batches of materials. As plastic waste is generally handled in batches, such an approach could also be suitable for plastics. To ensure traceability, it will however be important that individual batches can also be traced in an end-product produced from several batches.

Mobile-based tracing solutions offer considerable advantages. Such solutions do not depend on the presence of offices nor good literacy of the user and may thus be easier and cheaper to implement compared to low-tech solutions. Also, such solutions offer the possibility to implement close feedback loops between trading partners. Mobile solutions may not require dedicated solutions and upfront investment in developing them. Storing chat logs of established communication applications could in some cases be sufficient for documenting batch-related information.

4. Conclusions and Suggestions

4.1. Addressing the key challenges of developing a certification scheme

According to the stakeholder mapping and previous interactions with both formal and informal recyclers, there is considerable demand in the plastic recycling industry for improving processes if an economic benefit can be realised. How this benefit can be generated has to be further evaluated by working with potential users of recycled plastics and encourage them to perform trials regarding the suitability of recycled plastics in their product lines.

Even if only a small percentage of all the plastic recycling units will welcome a certification, the number of units to be coached and supported remains considerable. However, as many of these units are of a rather small size and since most often the formal and more advanced units are not profitable, the question remains how the development and implementation of a certification scheme and the necessary overhead in a certification agency could be covered. External funding may provide the initial boost, but a potential certification agency would have to develop a business model, which ensures a sustainable operation of the certification process and its supporting mechanisms in the long-term.

The plastic recycling entities analysed for this report represent the wide variety found all over India. While this variety may be discouraging for building a certification scheme, it also presents an opportunity: The vibrant industry is always looking to improve its profitability and will take notice, if entities investing in improving their processes benefit economically. The variety of business models also hides the fact that plastic recycling requires relatively simple technological and resides on a few basic processes (collection, sorting, cutting, washing and extrusion) for which simple guidance may be sufficient to also cover certain traceability concerns in the chain.

The presence of controlled chemicals in recycled plastics presents a challenge for the marketability of recycled plastics. The list of substances regulated by international or regional laws but is remarkably short and their occurrence in the waste stream is relatively well known. While some analytical tests may be required to credibly show that products are below required limits, the frequency of these measurements should not be too high to render any recycling uneconomic and orient themselves on the international state-of-the-art, which often limits itself to a few measurements for each product and input material per year in streams where there is an actual concern. Of greater concern is the implementation of requirements by single downstream buyers of recycled plastics, especially the “no-touch” requirements. A certification agency should facilitate the dialogue between recyclers and users of recycled products on how these requirements can be implemented and thus ensure an even playing field for all certified parties.

In a first round of implementing the certification, full traceability of the materials may often not be achievable. It will thus be very important to experiment and test different traceability mechanisms, which would – once identified to be suitable – have to be implemented properly by the certified recyclers. This should be supported by the process of describing the value chains of the individual units as shown in Figure 3. While traceability concerns are one of the main reasons why a certification may be done, developing the context-appropriate methodology should be first and could be outstanding in international comparison. An exchange of experiences, or obtaining training from initiatives looking to implement traceability in a similar context, such as the implementation partners of ISO IWA 19 and Fairstone, could be useful to learn which mechanisms have been useful or not.

4.2. Governing structure

The development of the certification scheme should be conducted in a transparent process which allows access to every stakeholder NGOs, Waste worker organisation, industrial bodies representing waste producers, recyclers and potential users of the final products as well as governmental organisations. In a multi-stakeholder process, all mentioned parties should be able to participate in designing the certification. To ensure international credibility, it may be advisable to follow the recommendations and join the ISEAL alliance, whose credibility principles represent the international consensus on elements required in impactful, credible and effective certification schemes[15] and includes requirements such as repeated review and adaption of the certification procedures and criteria.

4.3. Framework elements of the certification

This feasibility study does not propose a specific list of criteria required for the certification as these criteria will have to be developed locally. Based on the description of the plastic recycling sector, general suggestions for the overall framework of a certification can however be made:

- *Levelled structure:* Products should be certified on different levels, where the highest level represents state-of-the-art supply-chain, process and product management. This will ensure a lower barrier of entry for recycling businesses and at the same time ensure that there is an incentive for further improvements once the certification has been awarded.
- *Stepwise approach:* Following the ISO IWA 19 GP, a stepwise approach in implementing improvements should be followed. This includes that each business under certification should develop a plan with the certification agency on how it wants to improve its operations. To ensure an equal playing field, the pace of changes expected needs to be transparently defined. While minimal requirements (i.e. following the legal requirements plus any basic requirements of the certification scheme) are important and should be implemented in a credible manner, time should also be given for the businesses to adopt these requirements. This is especially important to ensure that informal businesses can participate in the certification.
- *Repeated assessment and handholding:* Implementing a step-wise approach requires that the businesses under certification are re-assessed repeatedly to determine how they have advanced. Repeated interactions will ensure that supporting mechanisms can be adequately targeted towards the needs of individual businesses.
- *Compensatory measures:* During the starting phase of the certification and possibly also for a longer term, full traceability and assurance of specific traceability concerns may not be feasible. Compensatory measures should thus be given a clear role in the certification to adequately support the sectors transformation. For example, if it cannot be guaranteed that the plastic was collected by a worker registered in an organisation, funding may have to be given to existing waste worker organisations to expand into a certain area or support the establishment of an independent organisation. Social funds replenished by the certified businesses and co-owned by cooperatives and the – now formal - businesses could then be used to finance improvements in the value chain.

[15] http://www.isealalliance.org/about-us

4.4. Support mechanisms

While a certification may be a suitable methodology to spur transformation of a sector, it will not do so on its own. The study has revealed several needs of the industry, where supporting mechanisms may be necessary to ensure that the industry can implement requirements of a certification scheme. In addition to the specific measures mentioned within this report, the following overall services may be a useful addition:

- *Formalisation support:* Moving from informal to formal business operations can be challenging as a multitude of local laws and requirements have to be known and followed. A certification agency should, in cooperation with a set of local focal businesses, ensure that formalisation procedures can be appropriately planned (i.e. through checklists and handholding) and use their power as innovative industry representatives to ensure access to the required governmental bodies.

- *Local industry networks:* The burden of transformation should not rest on the focal businesses and the certification agency alone, but it should utilize the inherent drive towards more profitable operations. Local industry networks may already exist or can be formed to act as self-help groups. Meetings of these networks can be rendered more interesting, if they are combined with activities which may have a direct economic payoff, such as waste and material exchanges.

- *Promoting supply of waste plastics to certified businesses*: A key challenge for certified businesses will be to obtain a continuous supply of raw materials. A certification agency has a partial responsibility that the certified business have access to waste and can continue operation. It may be fruitful to convince decision makers to introduce requirements that waste plastics shall only be given to certified entities by certified supply chains. These decision makers may be from other certification schemes (i.e. for Green Businesses), industrial bodies, industrial area cooperatives or sustainability responsibles of large manufacturing companies.

- *Promoting demand for high-quality recycled plastics:* Another key challenge of certified businesses will be to develop markets for high-quality recycled plastics to ensure that the certification costs can be recovered through a functioning market. Visibility of the achievements of certified companies may have to be supported, for example through prizes and fairs. Interaction meetings between recyclers and manufacturers may be a useful tool to spread the adoption of recycled plastics.

Only if an environment conductive for transforming the plastic recycling sector as a whole can be fostered and the barriers of individual companies to participate in this transformation are reduced, a more sustainable plastic recycling can become reality in India.

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Annex I: Identified stakeholders

Table 4: Number of registered and unregistered plastic recycling entities known to the central government (CPCB, 2015).

No.	federal state/	registered entities	unregistered entities
1	Andhra Pradesh	63	19
2	Arunachal Pradesh	nil	ns
3	Assam	ns	ns
4	Bihar	31	55
5	Chhattisgarh	12	nil
6	Goa	21	nil
7	Gujarat	612	0
8	Haryana	ns	ns
9	Himachal Pradesh	nil	nil
10	Jammu and Kashmir	63	1
11	Jharkhand	nil	4
12	Karnataka	ns	ns
13	Kerala	ns	ns
14	Madhya Pradesh	28	nil
15	Maharashtra	ns	ns
16	Manipur	9	nil
17	Meghalaya	3	nil
18	Mizoram	nil	nil
19	Nagaland	3	ns
20	Odisha	19	nil
21	Punjab	164	70
22	Rajasthan	ns	ns
23	Sikkim	ns	ns
24	Tamil Nadu	ns	ns
25	Telangana	193	15
26	Tripura	41	nil
27	Uttar Pradesh	34	53
28	Uttarakhand	ns	ns
29	West Bengal	92	ns
30	Andaman and Nicobar Islands	nil	nil
31	Chandigarh	ns	ns
32	Dadra and Nagar Haveli	ns	ns
33	Daman and Diu	ns	ns
34	Lakshadweep	ns	ns
35	Delhi-NCR	ns	ns
36	Puducherry	16	nil
Total	all regions	1.404	217

Table 5: Identified NGOs potentially interested in the certification.

Organisation / Location	Website / Contact	Comment / Self-Description
Chintan, Delhi	http://www.chintan-india.org/ Bharati Chaturvedi, Imran Khan	interested in the process of developing a certification, email and personal contact was established
Saahas, Bangalore	http://saahas.org/ http://saahaszerowaste.com/ Wilma Rodriguez	engaged in the developing process and very interested in filling the gap of sustainable plastic recycling
Plastic for change, Bangalore	www.plasticsforchange.org/ Andrew Almack / Akash Shetti	just starting their worldwide project in India, working on possibilities to strengthen the marketing of recycled plastics
Thanal, Kerala & Himalay	http://thanal.co.in/ n/a	no contact made, but recommended as effectively working in waste prevention, e.g. Zero Waste Kerala
Jan Vikas Society, Indore	http://janvikassociety.com/ n/a	The urban environment becomes filthy as the residents carelessly throw the solid waste of every sort into the open. The waste pickers collect these waste materials and sell them to recycling units after sorting and grading them. The waste pickers play the role of keeping the city clean of the waste that people throw out. There are two such recycling centers of plastic that are functioning under the supervision of Janvikas Society.
Waste Wise Trust, Bangalore	http://good-roots.org/ n/a	Waste Wise Trust (WWT) is a non-profit organization founded in 2003, that provides socially and environmentally responsible solid waste management services to the corporate sector and residential communities in Bengaluru. They have more than 20 years of experience working on behalf of informal waste pickers and their families, and promoting environmental sustainability through integral solid waste management.

Table 6: List of worker organisations in the waste sector

Organisation / Location	Website and number of members	Description
Safai Sena, Delhi	http://www.safaisena.net/, >10.000	Safai Sena means An Army of Cleaners. We are a registered group of waste pickers, doorstep waste collectors, itinerant and other small buyers, small junk dealers, and other types of recyclers. Safai Sena's vision is that adult waste handlers must be able to upgrade their work to green jobs: good for the environment, safe work, respected recognized and clean.
All India Kabadi Mazdoor Mahasangh, Delhi and North India	http://www.aikmm.org/, >40.000	AIKMM is a platform for informal waste collectors and recyclers to organize. We work in six states across north India, convening programs that focus on workers' rights to livelihood, safety, and health.
Hasiru Dala, Bangalore	http://hasirudala.in/, www.hasirudalainnovations.com/ >7.500	Hasiru Dala is a membership based non-profit organization of waste pickers and other informal waste workers. Hasiru Dala strives to integrate marginalized informal waste workers including waste pickers in the solid waste management framework by utilizing their expertise in the domain.
KKPKP, Pune	http://www.kkpkp-pune.org/ ~10.000	Kagad Kach Patra Kashtakari Panchayat is a trade union. It brings together waste pickers, itinerant waste buyers, waste collectors and other informal recyclers. We recover, collect, categorise and sell scrap materials. We also provide garbage collection, composting and related waste management services. Our members are self-employed workers.
SwaCH, Pune	http://www.swachcoop.com/ >1500	SWaCH Seva Sahakari Sanstha Maryadit is India's first wholly-owned cooperative of self-employed waste pickers or waste collectors and other urban poor. It is an autonomous enterprise that provides front-end waste management services to the citizens of Pune.
Parisar Bhagini Vikas Sangh, Mumbai and Pune	http://streemuktisanghatana.org/programs/parisar-vikas/ >3500	The Parisar Vikas program was launched in the year 1998 by the Stree Mukti Sanghatana with the cooperation of the Municipal Corporation of Greater Mumbai (MCGM). The program aims to address the problems of waste management and of self-employed women engaged in the tasks of collecting waste.
Citizen consumer and civic Action Group Chennai	https://www.cag.org.in/our-work/solid-waste-management n/a	It is aimed at filling gaps in knowledge and understanding about waste, it's management and the actors involved through both qualitative and quantitative research. Our primary focus at this time is the role and contribution of 'waste-pickers' or informal waste workers (popularly known as 'rag pickers') in the city's waste scenario.
Dalit Bahujan Resource Center, Villages of Andhra Pradesh	http://dbrcindia.org/	Dalit Bahujan Resource Centre (DBRC) is a resource centre working with the Dalit, Adivasi and Bahujan communities with the special focus on women, children, unorganized sector and the most vulnerable communities in Andhra Pradesh. DBRC closely works with activists, professionals, academicians, thematic experts, social researchers and community-based organizations who are working for Dalit Bahujan empowerment nearly for the last two decades.

Annex II: Detailed Description of the visited entities

***Case study 1**: sorting - small, unregistered*

The unregistered, family based recycler is focused on sorting post-consumer plastics and paper. The recycling facility is set in a marginalized Muslim community. The contact was made by Toxics Link and the unit owner was not present during the visit, but it was possible to see the site and talk to the workers. They work on a daily basis of 300-350 INR/day. They live in the same area and their main threat are demolition activities of marginalized areas by the government. The unsorted waste is bought from waste pickers for 10-20 INR/kg and sold for 20-40 INR to Traders from Tikri Kalan or a bigger *kabaddi-wallah-shop*. Monthly an amount of 5-10 tons is sorted into up to 60 different categories. As visible on the photos, the surrounding area of the *kabaddi-wallah* reveals severe social and environmental problems in the neighborhood.

Photo 1: way to recycling facility

Photo 2: overview recycling

Photo 3: plastic sorting section

Photo 4: sorted fraction

Photo 5: sorted HDPE fraction

Photo 6: sorted fraction

Photo 7: end-product: batch

Photo 8: end-product: batch

Photo 9: end-product: batch

***Case study 2**: Sorting - medium, unregistered*

The unregistered, family based recycler is specialized on post-consumer plastics. The sorting and grinding facility is supplied by another family related collecting facility two hours-drive from there. The sorting facility is supplied with 60-70 different plastic items, collected by waste pickers and little, local village scrap dealers (1,5 tons/month and unit, handed in by private households). The waste is sorted into 10-15 different plastic types. Trained by a registered company, sorting was improved by color separation and sorting some very specialized categories as e.g. transparent bottlenecks from alcohol bottles (retail price: 65 INR/kg). Unsorted dry waste is bought for 20 INR/kg and the earnings of sorted categories range from 35-65 INR/kg. The 200 tons/month sorted waste is then sold to 5-10 formal and unregistered extruding facilities. Workers are paid on a daily basis, females 200 INR/day and males 400 INR/day, whereby females work in sorting and males in grinding and loading. Employment as well as client relations are stable over years, but in most cases contracts do not exist. The entities profit ranges from 100-150.000 INR/mo.

Photo 10: overview sorting

Photo 11: overview sorting facility

Photo 12: one of three sorting points

Photo 13: high-value fraction

Photo 14: Grinder

Photo 15: end-product: batch blue

Photo 16: end-product: batch green

Photo 17: end-product: batch red

Photo 18: end-product: batch yellow

***Case study 3**: sorting – medium, registered*

The formal company is mainly sorting post-consumer plastics and papers. The manually sorted material is pressed into bales and then sold to formal extruding facilities. The company build up an internet platform to establish a collection system, based on door-to-door service with an own fleet of trucks. Private persons and communities can book a weekly collection of eight different waste types and get paid per kg. Additionally, they also source from waste pickers and *kabaddi-wallahs*, paying fair market prizes. They always pay 1-3 INR/kg over marketprize for unsorted waste and request their suppliers to engage new suppliers to enlarge their network. They pay a higher amount per kg, when the amount of waste they receive from one supplier is high (e.g. 500 kg instead of 20 kg), because of saved logistic costs. Unsorted plastic waste is bought for 16-18 INR/kg. 35 women and men are employed in sorting and logistics. The employees` salary comes to 425 INR/day, regardless gender. Until now, many types of plastic cannot be sorted because of a lack of knowledge and inability to invest in technology. Cardboard drinking boxes (Tetra Pak) are sent to Mumbai, where it is grinded and pressed into fibre boards. Laminated plastics are sent to cement kilns. The company is conscious about traceability issues and tries to develop a sustainable business model, but is still making losses.

Photo 19: overview recycling facility

Photo 20: overview recyclingfacility

Photo 21: sorting section

Photo 22: end-product: batch PET

Photo 23: end-product: batch Tetra

Photo 24: further processing: Tetra board

Case study 4: extruding – medium, informal

The semi-registered recycler is focused on post-consumer e-waste. Plastics containing BFRs are sorted out using sink/float, but are mixed into the main stream again depending on demand. The business includes four recycling units, whereby only the molding unit is registered. The three unregistered units are two sorting and one extruding facility. The waste is bought from Traders of Tikri Kalan for 40 -50 INR/kg and then sorted, grinded, extruded and molded. With every process step (sorting, grinding and extruding) a value of 8-10 INR/kg is gained. The material is sold on demand after every process step, so as sorted material, flakes, granules or molded products. 2-3 recycled end-products are produced as e.g. parts for waterpumps. Granules and recycled products are sold on demand with contract. Women are employed in sorting and packaging and all workers are employed on a daily basis, while earning 500-700 INR/day. 100-150.000 INR/month is earned as profit with a total amount of 100 t/month output. The unit owner is open to investments for improving the recycling process, but needs further assessment.

Photo 25: sorting facility

Photo 26: batches of grinded material

Photo 27: sorting of 10 different types

Photo 28: depollution with sink/float

Photo 29: batches of granules

Photo 30: end-product: molded part of water pump

Case study 5: Extruding – medium, semi-registered

The unregistered, family based recycler is specialized on industrial waste. The family controls about 30 recycling units throughout India. In the visited unit only industrial automobile waste is recycled and directly collected from companies. The waste is bought for 40-50 INR/kg and the extruded granules sold for 60-70 INR/kg to the open market. The visit was concluded quickly as the responsible person was slightly reluctant to share more information.

Photo 31: industrial automobile waste

Photo 32: directly sourced at fount

Photo 33: grinder

Photo 34: intermediate product: varnished flakes

Photo 35: extruder with automation

Photo 36: end-product: granules

Case study 6: extruding – medium, registered

The formal company is specialized on post-consumer plastics. The company is building up a broad database of the *kabaddi-wallahs* in the ten main recycling areas of the city (five marginalized areas, some mingled with industrial sites). The company is paying fair market prices and trained selected sorting entities to improve their quality of sorting. They also source from industrial waste, searching for continuous inputs and closed loop-business relationships to guarantee a constant quality of their products. Because of their will to experiment, their input is very variable with purchase prices from 10-80 INR/kg to sale prices from 20-90 INR/kg. With a capacity of 100 tons/month and an investment volume of 59 million INR, the entity is struggling to provide a high quality of ~10 resins for saleable market prizes. Machines and processes are on high-technical standard. The company is interested in an environmental as well as social certification and openly shares its needs and requirements concerning the development of such a certification system. They pay wages from 500-5000 INR/day and employ about twelve men and women.

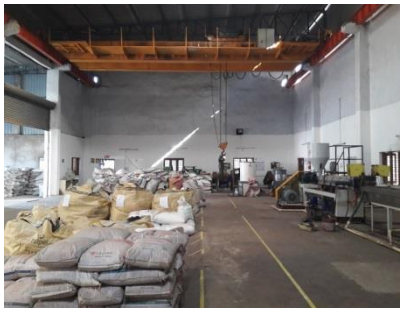

Photo 37: production hall

Photo 38: potential source material (bags, industrial waste)

Photo 39: potential source material (industrial waste)

Photo 40: additives: pigment blue

Photo 41: end-product granules

Case study 7: extruding - large, registered

The formal company is specialized on PET-recycling. From bales of bottles, they are producing flakes and selling them to ~15 extruding facilities. It`s process technology is internationally state-of-the-art,orientated on the US-American ASTM international D6288-09 standard. The maximum capacity is 1000 tons/month, but the plant is currently running on half capacity due to a lack of clients. Every 500 kg are tested on the existence of hazardous substances on a 50 ppm level. Currently, they are building a second recycling facility with an extruding capacity of 600 t/mo. The current investments costs are 148 million INR. The company is interested in an environmental as well as social certification and willing to participate in stakeholder meetings.

Photo 42: incoming source material

Photo 43: manual pre-sorting

Photo 44: flakes washing and drying section

Photo 45: waste water treatment

Photo 46: end-product: PET-flakes

Photo 47: laboratory for testing

Photo 48: batches for selling

Photo 49: filling of batch

Photo 50: trials end-product: granules