Toxics Link
for a toxics-free world

IMPROVING PLASTIC MANAGEMENT IN DELHI

A Report on WEEE Plastic Recycling

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Toxics Link

for a toxics-free world

Toxics Link is an environmental organisation, engaged in disseminating information and help strengthening campaigns against toxic pollution, providing cleaner alternatives and bringing together group and people concerned with, and affected by, this problem.

"We are group of people working together for environmental justice and freedom from toxics. We have taken it upon ourselves to collect and share information about the sources and dangers of poisons in our environment and bodies, as well as about clean and sustainable alternatives for India and the rest of the world."

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Toxics Link

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List of abbreviations

ABS	Acrylonitrile butadiene styrene
BFR	Brominated Flame Retardant
BIS	Bureau of Indian Standards
CAGR	Compound Annual Growth Rate
EEE	Electrical and Electronic Equipment
EU	European Union
HBCD	Hexabromocyclododecane
HIPS	High Impact Polystyrene
ICT	Information and communications technology
INR	Indian Rupee
MSW	Municipal Solid Waste
NGO	Non-governmental organization
PA	Polyamide
PBDE	Poly Brominated diphenyl ether
PC	Polycarbonate
PP	Polypropylene
PPM	Parts per million
PPO	Polyphenylene oxide
PVC	Polyvinyl chloride
RoHS	Restriction of Hazardous Substances
SPI	Society of the Plastics Industry
TBBPA	Tetrabromobisphenol A
TPD	Tonnes per day
USEPA	United States Environmental Protection Agency
WEEE	Waste Electrical and Electronic Equipment

1. Introduction

1.1 Plastic in electrical and electronic equipment (EEE)

Plastic products have become an integral part of our daily life, as a basic need. The use of Plastic has become prevalent because it is inexpensive and it can be engineered with a wide range of properties. Plastic can be custom-designed for innumerable uses and can be molded into many shapes, including intricate small parts, and can be drawn into thin fibers. It is produced on a massive scale worldwide and its production crossed the 230 million tons per year globally in 2009 [1].

In India approximately 8 million tons of plastic products are produced every year (2008) [2]. Its broad range of application includes films, wrapping materials, shopping and garbage bags, fluid containers, clothing, toys, household and industrial products, and building materials.

Plastics are a significant constituent of electrical and electronic equipment (EEE), about 30% by weight [3]. Plastic in EEE is used for insulation, noise reduction, sealing, housings, interior structural parts, functional parts, electronic components. Its content varies enormously with the type of equipment and the kind of polymer used. According to a study in 2004, four polymers, namely ABS, polypropylene, polystyrene and polyurethane represent more than 70% of the plastics contained in waste electrical and electronic equipment(WEEE) [4].There are other polymers also used in EEE. Printed circuit boards are made of epoxy - fiber glass composite. PVC, used mainly in wires, is in minority, its relative share has significantly decreased over the last fifteen years. Although the proportion of plastics in the EEE has increased, the total weight of plastic contained in the EEE currently put on the market does not grow at the same rate because of the decrease in the average overall weight of equipment [4].

Table 1: Typical applications of plastic polymers in EEE [1]

Polymer	Application
ABS	Housings and casing of phones, small household appliances, microwave ovens, flat screens and certain monitors Enclosures and internal parts of ICT equipment
PS (HIPS)	Components inside refrigerators (liner, shelving) Housings of small household appliances, data processing and consumer electronics
PC	Housings of ICT equipment and household appliances Lighting
Epoxy Polymers	Printed Circuit Board
PP	Components inside washing machines and dishwashers, casings of small household appliances (coffee makers, irons, etc.) Internal electronic components
PPO (blend HIPS/ PPE)	Housings of consumer electronics (TVs) and computer monitors and some small household appliances (e.g. hairdryers) Components of TV, computers, printers and copiers
PC/ABS	Housings of ICT equipment and certain small household appliances (e.g. kettles, shavers)

Material and energy recovery are the two main recovery routes for plastics contained in the WEEE. Material recovery is either mechanical recycling or chemical recycling. Each recycling process generally consists of successive steps, e.g. pre-treatment, sorting and recycling. The diversity of polymers is a major obstacle in recycling of plastics contained in WEEE. Presence of additives, especially chemicals like halogenated flame retardants also pose a serious challenge in recycling and reuse of WEEE Plastic.

1.2 Waste Electrical and Electronic Equipment (WEEE)

Rapid change in information and communication technology and the increasing demand for consumer electrical and electronic equipments have led to a significant growth of electrical and electronic manufacturing industry worldwide in the last two decades. Although benefits of ICT and EEE are well known and recognized, little is known about the end of life management of such devices.

WEEE consists of discarded or end of life electronic and electrical equipments and includes computers, mobile phones, televisions and many small and large household and office equipments. WEEE or E-waste has seen exponential growth in recent times and currently around 40 million tones [5] are generated globally annually which is set to go up to 53 million by 2012, thus growing at a CAGR of 6 % [6].

WEEE contains several persistent, bio-accumulative and toxic substances including heavy metals such as lead, nickel, chromium, mercury and persistent organic pollutants such as polychlorinated biphenyls and brominated flame-retardants. This waste, when recycled in an improper way, releases toxins into the air, water and soil and thus puts human health and environment at risk. Improper management of WEEE may cause significant damage to human health and environment.

The rate of economic growth in India has been responsible for accelerating consumption and changing lifestyles of a certain section of the population. In the wake of liberalization, the beneficiaries of high growth rates and increasing prosperity are the expanding middle and upper income groups, which are enjoying an unprecedented increase in consumption, especially of non essential luxury and durable goods. This has led to more consumption as well as an increase in the replacement market, directly leading to the growing pile of electronic and electrical waste. A study in 2007 by GTZ-MAIT estimated around 0.35 million tons of e-waste generated in India annually [7]. Rough estimates suggest that India will generate 0.8 million tons by 2012 [8]. This is mostly processed and recycled in the informal sector with the use of crude waste management techniques, leading to health and environmental hazards.

To add to this, WEEE is also dumped in India through illegal imports. This trade of e-waste has adverse environmental and health implications in the downstream end of the EEE supply chain, as developing countries like India lack the infrastructure for sound hazardous waste management including recycling, or effective regulatory frameworks for hazardous chemicals and wastes management. This raises an equity issue of developing countries receiving a disproportionate burden of a global problem, without having the proper technology or infrastructure to deal with it.

1.3 Plastic in WEEE

The rapid rate of urbanization throughout the world has led to increasing amounts of waste and this in turn poses greater challenges for disposal. The problem is more acute in developing countries like India, where economic growth as well as urbanization is quite rapid. Management of e-waste is one such critical challenge faced by India in recent times. In the absence of a proper management system, around 95% of the e-waste recycled in the country is processed by the informal sector [7]. Various reports have highlighted the hazardous recycling processes carried out by the informal sector, which includes open burning and acid baths. These backyard operations have no measures in place for controlling toxic emissions or effluents, thereby posing a risk to health as well as environment.

Plastic, which is a major component of WEEE, has become a major threat due to its non-biodegradability and high visibility in the waste stream. Its presence in the waste stream poses a serious problem when there is lack of efficient end of life management of plastic waste. Though there have been some focus on widespread littering of plastic bags, packaging and its impacts on the landscape, there has been little focus on plastic recycling in the informal sector, the possible threats and environmental impacts. The issue of WEEE plastic recycling also assumes a greater challenge due to the presence of additives and chemicals like flame retardants.

Flame retardants are applied in plastics contained in telecommunication devices, computers, monitors, television sets and other consumer equipment as well as – to a lesser extent – in office equipment. The share of flame-protected plastics in WEEE over all categories has been estimated to amount to about 25% (by (Huisman et al., 2008).The subsets of these flame-retardants, called "Brominated Flame Retardants" (BFRs), are now the subject of intense scrutiny and various studies undertaken. There is enough evidence available to predict that some of the BFRs are likely to persist in our environment, bio accumulate in the food chain and in our bodies, and cause adverse health problems. In the past decade, scientists have detected BFRs both in human and wildlife tissues as well as in house dust, sediments, sewage sludge, air, soil, and water samples.

The impact on the health of humans of some BFRs like PBDE are fueling debate around the use of these chemicals in consumer products, especially electronics and an urgent need for the safe recycling of BFR contaminated plastics is perceived.

2. Objective and Methodology

2.1 Rationale of the study

Although there have been some studies in the past to quantify the amount of e-waste generated in India and to look at the processes of the informal sector, very little has been done to document the material recovery processes. Plastic has huge recycling potential and has fuelled a large recycling industry within the country, especially in the informal sector. The fate of contaminants like Brominated Flame Retardants, especially PBDEs which are known toxins, is still unknown. There are a few studies in the public domain on BFR contamination in the plastic material chain. One such study on cross contamination was undertaken by EMPA [19] for the European WEEE Forum.

This study attempts to document the recycling processes and investigate the contamination of the material supply chain and possible hazards, both in terms of health and environment, caused by the recycling operations of plastics waste in the informal recycling sector in Delhi, India.

The main objective of the project is to provide a broad overview on the material flows and document the recycling process of plastics, identify gaps in recycling processes, understand technologies applied and examine the possibility of any cross contamination of the material chain on account of mixing of waste materials from different products and sources. The study is indicative in nature and should provide an opportunity to investigate deeper into larger environmental and health impacts. The objective is to address issues of material supply chain, resource conservation and health and environmental impacts and provide suggestions for safer handling, recycling and disposal of chemical laden WEEE plastics, based on our research. The project also aims to create awareness among key stakeholders regarding the unsound environmental practices related to recycling of WEEE plastics and help them understand the need to evolve effective upstream and downstream measures to manage this.

The scope of the research is limited to the study of recycling of WEEE plastics. WEEE was selected, as BFR is widely used in EEE.

India is a huge country with 28 States and 7 Union Territories and the time frame in which this research was conducted was too short to study the recycling practices in the entire country. Considering this, the study focused on Delhi. The city of Delhi was chosen as it is among the largest metropolises in the country and provides a useful example of growth driven urban centers in the country, faced with increasing urban waste problems and more importantly because the city is one of the largest recycling hubs in the country.

The specific aim of the study is to

- To study the WEEE plastics recycling process in Delhi,
- Investigate and identify the possibility of cross contamination of the material supply chain with Brominated Flame Retardants.
- Identify gaps in the recycling processes if any.
- Identify environmental concerns on account of recycling practices.
- Options for policy engagement if any.

2.2 Methodology

The study has two distinct components, one being the documentation process of the complete recycling of the plastics generated from e-waste and the other being the lab testing of the materials and the report thereof.

The study employs the following methods, reviews of existing literature, unstructured interviews, exploratory surveys, site visits, and photo documentation to document the issues related to plastics recycling in Delhi and its adjoining areas. Experiences from earlier studies of Toxics Link in Delhi were used to plan this study.

The research was carried out in phases—

- Review of the existing literature: an extensive literature review was undertaken to collect information on plastic and its uses in EEE, BFR us age in EEE plastic and the related risks.
- Exploratory visits and unstructured interviews with the informal recyclers: Interviews were undertaken with traders, dismantlers and recyclers to enable us to understand the market flow and their trade practices. Informal discussions were carried out and emerging trails were followed to investigate such activities.
- Observations regarding the health and environmental impacts: Numerous visits were made to the plastic recycling units in and around Delhi to observe the practices and their related health and environmental impacts.
- A visit to document the recycling processes in the formal or authorised recycling units: A formal recycling unit was visited in the state of Tamil Nadu, to understand and document the processes.
- Interviews with selected stakeholders: Some important stakeholders from the industry and government were contacted during the study.
- Collection of samples and laboratory analysis of recycled plastic pellets for BFRs and heavy metals: The plastic pellet samples were collected from the informal recycling units in Delhi and sent to an accredited laboratory for testing for selected BFRs and heavy metals. The samples were tested for the commonly used BFRs for EEE.

2.3 Limitations

- The study was limited in nature as the field visits were confined to Delhi and its adjoining areas.
- The informal recycling sector which essentially denotes entrepreneurs or operators who do not have valid licenses or approvals from a designated authority to perform such activities. In India recycling activities are mostly handled in this informal or unorganized sector. This study relied on information collected from the field from the informal sector operators and most respondents were not very forthcoming, especially on information related to quantities and costs. Their reluctance to respond to any query from outside agencies stems from their apprehensions about losing their livelihood.
- Efforts were made to document formal sector practices but it proved extremely difficult to access these units as most recyclers were not open to allowing any visits to their premises. Since we did not get permission to visit a formal recycling plant in Delhi, we visited a plant in Tamil Nadu. The formal recyclers are companies or organizations who are engaged in recycling of plastics and have valid licenses from the designated authorities and follow norms or standards set for such recycling. They are also liable to pay all taxes to the government for their business activities.
- Recycling operations are carried out in a multitude of processes making it difficult to follow the trail of the material. This presented a major challenge in sample collection as it was difficult to pick up the same material along the entire process chain.
- There was also limitation in sample size due to resource constraints.
- There is very limited information on BFRs in India, hence very low interest among stakeholders and constraint in getting information from stakeholders.

3. WEEE Plastic and its recycling

3.1 Short overview on Plastic, its uses and types

Plastic is a relatively cheap, durable, and versatile material. These properties have led to its use in the creation of thousands of products, which have brought benefits to society in terms of economic activity, jobs, and quality of life. However, plastic waste can also impose negative externalities such as greenhouse gas emissions or ecological damage. It is usually non-biodegradable and, therefore, can remain as waste in the environment for a very long time; it may pose risks to human health and the environment; in some cases, it can be difficult to reuse and/or recycle.

There is growing evidence which indicates that substantial quantities of plastic waste are now polluting marine and other habitats. The widespread presence of these materials has resulted in numerous accounts of wildlife becoming entangled in plastic, leading to injury or impaired movement, and, in some cases, resulting in death. Concerns have been raised regarding the effects of plastic ingestion as there is some evidence to indicate that toxic chemicals from plastics can accumulate in living organisms and throughout nutrient chains. There is also some public health concerns arising from the use of plastics treated with chemicals.

There has been an average global increase in production and consumption of about 9% every year since 1950. From around 1.5 million tonnes in 1950, the total global production of plastics grew to 260 million tonnes in 2007 [9]. Global plastics production is estimated to have fallen from 245 million in 2008 to around 230 million tonnes in 2009 as a result of the economic crisis [1]. The EU accounts for around 25% of world production; China alone accounts for 15%. Polyethylene has the highest share of production of any polymer type, while four sectors represent 72% of plastics demand: packaging, construction, automotive, and electrical and electronic equipment. The rest includes sectors such as household, furniture, agriculture, and medical devices [1].

There are two basic types of plastic: thermosetting, which cannot be re-softened after being subjected to heat and pressure; and thermoplastic, which can be repeatedly softened and remolded by heat and pressure. Thermoplastic, also known as a thermo softening plastic, is a polymer that turns to a liquid when heated, and freezes to a very glassy state when cooled sufficiently. Thermosetting plastic, also known as a thermo set, is a polymer material that irreversibly cures. Scrap created when thermo set plastics are processed, therefore, must be discarded or used as fillers in other products. More recently plastics have been developed from plant materials and bacteria, so called bio-plastics, which are degradable.

There are about 50 different groups of plastics, with hundreds of different varieties. The SPI resin identification coding system is a set of symbols placed on plastics to identify the polymer type. It was developed by the Society of the Plastics Industry (SPI) in 1988, and is used internationally. The primary purpose of the codes is to allow efficient separation of different polymer types for recycling. These types and their most common uses are:

Table 2: Types of Plastic

Symbol	Resin type	Common uses
△ 1	PET	Polyethylene terephthalate - Fizzy drink bottles and oven-ready meal trays.
△ 2	HDPE	High-density polyethylene Bottles for milk and washing-up liquids.
△ 3	PVC	Polyvinyl chloride - Food trays, cling film, bottles for squash, mineral water and shampoo.
△ 4	LDPE	Low density polyethylene - Carrier bags and bin liners.

5	PP	Polypropylene - Margarine tubs, microwaveable meal trays.
6	PS	Polystyrene - Yoghurt pots, foam meat or fish trays, hamburger boxes and egg cartons, vending cups, plastic cutlery, protective packaging for electronic goods and toys.
7	OTHER	Any other plastics that do not fall into any of the above categories. - An example is melamine, which is often used in plastic plates and cups.

3.2 Plastic use in India

Plastic usage has grown rapidly in India, increasing from 61,000 tonnes per annum in 1960 to 4 million tonnes in 2001-02 [10] and on projected growth rates, standing at double that amount today (Central Pollution Control Board 1998). According to CPCB, 8 million tonnes of plastic was manufactured in 2008 [11]. Consumption of polymers in the country during 2010-11 stood at 10 million tons against the global level of 220 million tons. While the growth rate in its demand has been very high, the low starting point means that annual per capita amounts remain well below the other countries, especially the developed countries. Per capita plastic consumption in India stood at 6 kg/person in 2009 and is expected to reach around 12 kg/person by 2011[12]. In comparison, it is around 46 kg/ person in China, 100 kg per capita in North America and Western Europe [12, 13].

Plastics waste is a significant portion of the total municipal solid waste (MSW). But there are no accurate figures for the total amount of plastic waste currently generated in India. According to CPCB, approximately 10 thousand tons per day (TPD) of plastics waste is generated i.e., 9% of 1.20 lacks TPD of MSW in the country [14]. Since the current MSW generation is at 1.36 tonnes, the plastic waste would be around 12 thousand TPD. Approximately 60-80 % of post consumer use plastic waste generated within India is collected, segregated, and mechanically recycled by the informal sector scavenging and scrap chain [15]. Thermoplastics, constitutes 80% and thermoset constitutes approximately 20% of total post-consumer plastics waste generated in India [16].

According to the Bureau of Indian Standards (BIS) guidelines (IS:14534:1998) titled "Guidelines for Recycling of Plastics", the plastics waste shall be segregated as per the Codes 1-7 mentioned in the BIS guidelines (same as **Table 2**).

Interestingly, the imports of plastic scrap appear to be also on the rise in India. The table below (**Table 3**) shows the rise in two plastic categories in the last ten years.

Table 3: Plastic import to India [17]

S. No.	HS Code	Category	Quantity in Thousands & Unit in Kg.		
			1998-99	2003-04	2008-09
1.	391530	Waste parings & scrap of PVC	1210.86	4817.46	12223.53
2.	391590	Waste parings & scrap of other plastic	54178.85	81860.47	450294.59

Source: Department of Commerce, Govt. of India.

3.3 Use of Plastic in EEE

Plastics have become a key to innovation in the EEE industry, mainly due to its light weight property and lower costs. Initially only part of the housing, plastic now plays an important part in the equipment's entire construction and functionality, enabling reduced weight, miniaturization reduced production costs. Plastics are the second largest component by weight in EEE, accounting for approximately 30% of WEEE [3]. There are many types of plastics used in the manufacture of electrical and electronic equipment. The proportion and types of plastics used vary not only from one product category to another, but also among similar products manufactured in different years. The table below lists out plastic concentration in some categories of WEEE.

Table 4: Plastic concentration in WEEE [18]

Equipment Category	Ferrous metals	Non-ferrous metals	Glass	Plastics	Other
Large household Appliances	61%	7%	3%	9%	21%
Small household appliances	19%	1%	0%	48%	32%
IT equipment	43%	0%	4%	30%	20%
Telecom	13%	7%	0%	74%	6%
TV, Radio, etc.	11%	2%	35%	31%	22%

A wide variety of plastic materials are used by the EEE industry. The primary polymers are PVC, ABS, HIPS, PC, HDPE, PP, and nylon (ICER, 2000), and these can be found as single polymers or as laminates/composites. In addition to these, many other plastics whose details are secret or not well known contribute to the final composition of a plastic component (ENEA, 1995).

Some resins used in electrical equipment:

- ABS - telephone handsets, keyboards, monitors, computer housings
- Aikyd resins - circuit breakers, switch gear
- Amino resins - lighting fixtures

- Epoxy resins - electrical components
- Phenol formaldehyde - fuse boxes, knobs, switches, handles
- Polyamide - food processor bearings, adaptors
- Polycarbonate - telephones
- Polyesters - business machine parts, coffee machines, toasters
- Polyethylene (PE) - cable & wire insulation
- Polymethyl pentane - circuit boards, microwave grills
- Polyphenylene oxide - coffee machines, TV housings
- Polyphenylene suiphide - hairdryer grilles, element bases, transformers
- Polystyrene (PS) - refrigerator trays/linings, TV cabinets
- Polysulphone - microwave grills
- Polytetrafluoroethene - electrical applications
- PVC - cable and wire insulation, cable trunking
- Styrene acrylonitrile - hi-fi covers
- Urea formaldehyde - fuse boxes, knobs, switches

Plastics (such as equipment casings and bases) are the one major category of material components for which recycling opportunities are currently quite limited. This is because (1) numerous resin types are used in PC equipment, (2) plastic parts are not labeled according to their type and (3) the presence of chlorine and bromine compounds in some of the plastics requires measures for the protection of human health and the environment in operations where these plastics are shredded or heated. A wide variety of brominated flame retardants have been used as additives in some of the plastic components in PCs. Thus, opportunities for recycling needs to take into account, not only the particular resin types of the various parts, but also the types of flame retardants that are present in the plastics, as the safety of the recycling process may be affected.

3.4 Hazards in WEEE plastic

The disposal and recovery of plastics from WEEE is of considerable importance, especially from an environmental perspective. Plastics from WEEE may contain hazardous substances and give rise to high processing costs, depending on the disposal or recovery route and also toxic emissions due to improper recycling practices. In a study by EMPA Swiss Federal Laboratories for Materials Science and Technology, selected WEEE mixed plastic fractions were tested for hazardous constituents, regulated by the Directive 2002/95/EC of the European Parliament and of the Council on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS Directive) [19].

The sampling campaigns included 53 mixed plastic samples and were analyzed with regard to the four heavy metals (cadmium, (hexavalent) chromium, mercury and lead) and flame retardants (PentaBDE, OctaBDE, DecaBDE, DecaBB) which are regulated in the RoHS Directive. Besides RoHS regulated substances, other brominated flame retardants known to occur in electronics (HBCD, TBBPA), the total bromine content, the total phosphorus content and elements such as antimony were also included in the analyses. All the investigated mixed plastics fractions contained at least one substance regulated by the RoHS Directive in measurable amounts, indicating the hazards in the plastic fractions.

Previous studies have also identified various contaminants in WEEE plastics, including heavy metals, polybrominated biphenyls (PBB), diphenyl ethers (PBDE), as well as polybrominated dibenzodioxins and dibenzofurans (PBDD/F).

3.5 Brominated Flame Retardants

Plastics in WEEE may contain various additives, such as colors, stabililizers, flame retardants etc. These additives also include substances like brominated flame retardants (BFRs), varieties of which are known to be harmful.

Chemical flame-retardants are added to many materials and products to prevent or suppress ignition, or to limit the spread of fire once ignition occurs. A wide variety of chemicals and chemical families are employed as flame-retardants, including inorganic chemicals based on the elements phosphorus, aluminum, magnesium, zinc, and antimony, and organic chemicals based on bromine and/or chlorine (organohalogens), phosphorus (organophosphates), and nitrogen. Products containing bromine comprise a significant portion of the flame retardant market due to this element's effectiveness at suppressing ignition and stopping the spread of flame, and relatively low cost. BFRs are a family of 75 chemical substances with different properties, characteristics, and performance.

BFRs have routinely been added to consumer products for several decades in an effort to reduce fire-related injury and property damage. Recently, concern for this emerging class of chemicals has risen because of the occurrence of several classes of BFRs in the environment and in human biota. The widespread production and use of BFRs; strong evidence of increasing contamination of the environment, wildlife, and people; and limited knowledge of potential effects heighten the importance of identifying emerging issues associated with the use of BFRs. BFRs are used as additives in plastics in EEE to slow down or prevent the ignition of fire. It is estimated that flame retarded plastics make up around 5.5% of WEEE by weight, or 25% of all plastic used in EEE (Hedemalm *et al*, 1995). Of these flame retarded plastics; approximately 80% are treated with brominated flame retardants (ENEA, 1995).BFR's are designed into electronic products as a means of ensuring flammability protection. These are mainly used in printed circuit boards, components (such as connectors), plastic covers, and cables.

Since the 1970s, the electronics industry has been one of the largest consumers of polybrominated diphenyl ethers (PBDEs), about 40% of PBDEs are used in the outer casings of computers, printers and televisions and by far the largest volume of the PBDE mixture used as a flame retardant has been Deca-BDE. BFRs are not covalently bound to the structure, and can move into the environment. Hence, when these products reach the end of their useful lives, some disposal or recycling operations can release the bromine in other hazardous forms into the environment. These chemicals can turn into brominated dioxins when electronic waste, or other products containing these chemicals, are incinerated or combusted. Another risk factor is that the BFRs remain in the plastics and the plastic products made out of these recycled plastics, though it may not have been originally intended.

The major BFRs associated with the three main resins used in EEE (HIPS, ABS and Epoxy resins) are Decabromodiphenyl ether (DecaBDE) in brown goods, Tetrabromobisphenol-A (TBBPA) in data processing and office equipment; and, TBBPA in printed circuit boards.

3.6 BFR - Concerns

The concerns about Brominated Flame Retardants emerged in the 1970s when polybrominated biphenyls (PBBs) were discovered in the feed for dairy cattle, livestock, and poultry in Michigan, USA. Widespread PBB contamination of milk, meat, and eggs in the region resulted in the exposure of over 9 million humans to the toxicant. The U.S. government acted quickly, suspending the use of PBB flame-retardants in 1979. It is becoming increasingly evident that BFRs are similar to PBBs and another category of banned persistent, bio-accumulative toxicants—polychlorinated biphenyls (PCBs).

Brominated Flame-Retardants, especially PBDEs, are persistent in the environment and are liable to contaminate the food chain, animals, and people. The capacity of PBDEs to bio-accumulate in fatty tissue and bio magnify up the food chain, in combination with their persistence and toxicity make this class of chemicals of high concern to the environment and human health. Several BFRs, including certain PBDEs and HBCD, which are known for their toxic properties, are highly resistant to degradation in the environment. Some are now widespread and regarded as environmental pollutants, with higher levels generally found in the atmosphere and rivers close to urban and industrialized areas. Rapidly increasing levels have been measured in sediments, marine animals and humans, indicating a significant potential for damage to ecological and human health.

Controlled studies in laboratory animals show that some BFRs disrupt thyroid function, causing hyperactivity and problems with learning and memory. The impacts of BFRs on the humans who have been exposed to them have not been studied yet; however, the results in animals are likely to predict the impact on developing humans, e.g. fetuses and children. The scientific evidence available on PBDEs to date indicates that these chemicals share many common traits with PCBs, including animal studies linking them to immune suppression, cancer, endocrine disruption and neurobehavioral and developmental effects. PBDE levels now present in some humans are close to the levels shown in animals to have negative effects.

In a 2009 study, PBDEs levels in human milk samples were found to be higher in lactating mothers residing near municipal dumping sites compared with other locations. In another study PBDEs were found in slightly higher concentrations in e-waste recycling workers. There have been also some studies to measure atmospheric concentrations of PBDEs from dumping sites.

BFR release from EEE has also been a cause for concern. There have been studies to check the dust from computers to assess BFR release and also to check release during the recycling process. Indoor air in an electronics goods recycling plant in Sweden was found to be contaminated with higher concentrations of PBDEs compared to other workplace environments. BFRs especially PBDEs have the potential to form brominated dioxins and furans during the processing of waste plastics containing FRs (Schlummer *et al.*, 2006)

3.7 Heavy Metals in plastics

Heavy metals in plastics, notably cadmium, have been highlighted as a concern [19].

Cadmium

Cadmium sulphide and cadmium sulphoselenide are utilized as bright yellow to deep red pigments in plastics [25]. Both compounds are well known for their ability to withstand high temperature and high pressure without chalking or fading, and therefore are used in applications, where high temperature or high pressure processing is required, such as ABS, PA, PC or HDPE (International Cadmium Association, 2010). Another possibility for an import of cadmium into plastics, especially PVC, is the use of mixed barium- and cadmium carboxylates as stabilizing agents.

Chromium (VI)

In EEE, chromium (VI) is applied as a pigment in the form of lead chromate as well as in metal coatings protecting from corrosion and abrasion. Elementary chromium (Cr (0)) is applied in metalized plastics, which are used in the electronics -, the automotive - or the sanitary sectors [26].

Mercury

In EEE mercury is applied, amongst others, in batteries, thermostats, sensors, relays in switches, and discharge lamps. The application of mercury in electrical switches is no longer considered state of the art [25]. The use as a pigment in plastics was stopped many years ago; an application in plastics in the last few years is not known.

Lead

In EEE lead has been applied as a solder in printed circuit boards, in glass from cathode ray tubes (CRT), light bulbs or in electrical ceramics. Infrared remote control units can contain LED with lead selenide [25]. In plastics, lead compounds are applied as pigments and, as carboxylates, stabilizing agents. In an earlier study, for EEE, the share of lead containing plastics was exceptionally high with 30%, which was caused by the use of lead additives in the PVC isolation of cables. Lead was not only found in yellow, orange and red plastics, which can contain lead pigments, but also in plastics of (all) other colors [27].

3.8 Regulatory Framework

In India, though there are no specific legal frameworks to address the plastic fractions from WEEE, there are regulations which impact them indirectly.

Plastic Waste (Management and Handling) Rules, 2011

India's Ministry of Environment adopted new rules governing the management and disposal of plastic waste in 2011. The new rules include an extended producer responsibility system, which the country's plastics industry is opposing.

Some of the salient features of the new Rules are: ban on the use of plastic materials in sachets for storing, packing or selling gutkha, tobacco and pan masala; no food stuffs will be allowed to be packed in recycled plastics or compostable plastics; recycled carry bags to have specific BIS standards, color to the prescription by the Bureau of Indian Standards (BIS), uniform thickness shall not be less than 40 microns in carry bags, etc.

One of the major provisions under the new rules is the explicit recognition of the rule of waste pickers. The new rules require the municipal authority to constructively engage agencies or groups working in waste management including these waste pickers. This is the very first time that such a special dispensation has been made.

The Municipal authority shall be responsible for enforcement of the provisions of these rules related to the use, collection, segregation, transportation and disposal of post consumer plastic.

Guidelines on recycling of plastic waste

The Bureau of Indian Standards, New Delhi (BIS) has issued guidelines on recycling of plastics waste, including code of practices for collection. However, while formulating Indian standard specifications for various plastic products, used for critical applications like plastic piping system, water-storage tanks, packaging for food articles, a clause is included which reads "no recycled plastics waste shall be used". An exercise has also been carried out by the Ministry of Environment and Forest, in association with the Bureau of Indian Standards, to include use of recycled plastic waste wherever appropriate in the manufacture of plastic products; and this shall be specified accordingly in the relevant Indian Specifications.

E-Waste (Management and Handling) Rules, 2011

E-waste rules were notified in May 2011 and looks at both upstream and downstream aspects of waste arising from EEE. The rules, which will be effective from 1 May 2012, set out the responsibilities and procedures for key players including manufacturers, waste collection centers, consumer or bulk consumers, dismantlers, recyclers, and the authorities.

The rules also call for the reduction in the use of hazardous substances in the manufacture of EEE. Every producer of equipment listed in schedule 1 of the rule namely, information and telecommunications equipment and consumer electrical and electronics shall ensure that their products do not contain lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls, or polybrominated diphenyl ethers above a specified threshold. The threshold for cadmium is 0.01% by weight; for all other substances, the threshold is 0.1% by weight. The rules also apply to products imported into India. The reductions have to be achieved by May 2014, two years from when the rules apply.

The rules introduce the concept of Extended Producer Responsibility and place the responsibility of collection and recycling of E-waste on the manufacturers. On the downstream management, the rules do not specify any recovery or recycling targets.

International Regulatory Framework

The WEEE Directive

The Directive on Waste Electrical and Electronic Equipment aims at preventing WEEE, and where this is not possible, reusing, recycling, and recovering it so as to reduce its disposal. Furthermore, the Directive seeks to improve the environmental performance of all operators involved in the life cycle of electrical and electronic equipment. Amongst others, for eight of the ten WEEE categories defined in Annex IB, the WEEE Directive sets targets for recovery and for component, material and substance reuse and recycling. Plastics containing brominated flame retardants are listed in Annex II, which addresses those substances, preparations and components that have to be removed from any separately collected WEEE as a minimum.

The RoHS Directive

The Directive on the on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic equipment regulates the application of hazardous substances in new EEE falling under the categories 1, 2, 3, 4, 5, 6, 7, and 10 set out in Annex IA to the WEEE Directive (and to electric light bulbs, and luminaires in households). According to the RoHS Directive, member states must ensure that from July 1, 2006, newly marketed EEE does not contain cadmium, chromium (VI), lead, mercury, polybrominated biphenyls (polyBBs), and polybrominated diphenyl ethers (polyBDEs) above defined maximum concentration values (MCVs) for homogeneous materials.

In the RoHS recast, which comes into effect from July 21, 2011, the scope has expanded to include more electronics and electrical equipment, including medical devices and monitoring and control instruments. The target date for compliance of these products is 2014. Other electronics and electrical equipment not specifically covered by the revision will be expected to comply by 2019.The revised RoHS directive does not restrict any additional substances. However, as part of an ongoing requirement to review restricted substances, four materials have been identified for assessment: Hexabromocyclododecane (HBCDD), Bis (2-ethylhexyl) phthalate (DEHP), Butyl benzyl phthalate (BBP), and Dibutyl phthalate (DBP).

The Stockholm Convention

The Stockholm Convention, which has also been ratified by India aims at reducing and eliminating production, use and release of persistent organic pollutants (POPs). In May 2009, certain congeners contained in commercial PentaBDE and OctaBDE were added to Annex A of the Stockholm Convention. As a consequence of this, these chemicals are now officially classified as POPs and may no longer be produced. Furthermore, Article 6 of the Convention requires that wastes containing POPs be managed in a manner protective of human health and the environment.

Other BFR related Laws

The Japanese PRTR Law promotes voluntary improvements in the management of specific chemical substances and requires businesses handling such substances to report the release of such substances into the environment and to provide technical information on the properties and handling of such substances. Deca-BDE is mentioned in the PRTR law, which means that annual reports have to be produced on volumes imported, volumes used and quantities released in the environment on Deca-BDE.

In the US, production and use of Penta-BDE and Octa-BDE were voluntarily phased out by its producers in 2004 in cooperation with the US EPA. State legislations formalizing this phase-out have been adopted in California, Hawaii, Illinois, Maine, Maryland, Michigan, New York, Oregon and Rhode Island. There is no legislation restricting the use of TBBPA in the US. No federal action has been taken to limit or restrict the use of Deca-BDE; however a couple of states like Maine and Washington prohibit some select uses.

In June 2005, the Australian Ministry for Health and Ageing declared TBBPA and Deca-BDE "Priority Existing Chemicals (PECs)". As PECs, each of these Brominated Flame Retardants will be subject in the near future, to an assessment of their potential effects on human health and the environment, which will be conducted by the National Industrial Chemicals Notification and Assessment Scheme (NICNAS). The Australian authorities are currently compiling information on quantities and use of these substances from importers and producers.

Eco labels like the Nordic Swan, Blue Angel and European White flower also look at BFR content in products.

4. Exploratory Research Findings

This chapter focuses on the findings from the field visit conducted in Delhi. The information was collected mainly through observation in the field survey and through unstructured interviews.

This chapter also documents findings from a visit to a formal recycling unit in Chennai.

4.1 Plastic recycling in Delhi

Delhi is the largest recycling hub in India, may be one of the largest in the world as well, with waste flowing in from all parts of the country and also from outside the country. With availability of abundant cheap labour, migrants from poorer states like Uttar Pradesh and Bihar coming to the capital city in search of livelihood, the recycling sector has grown substantially in the last few decades, especially in the unorganized sector. The city deals in all kinds of scraps, with areas specializing in different kinds. There are markets for automobile waste (like Mayapuri), markets for e-waste (like Old Silampur, Mandoli) and markets for plastic (like Mundka, Bawana).

Plastic, whose consumption has gone up manifold in recent years in India, has been responsible for the creation of a new waste stream, Delhi being one of the important destinations of such waste. The existence of an economically viable recovery and recycling trade in plastics waste has triggered major growth in this sector. The following factors have contributed largely to this

- Existence of sufficient quantity of plastic waste, due to growing consumption and discard.
- Low labour and operation costs.
- Existence of a market for recycled raw material and goods made from it, largely due to a demand for cheaper products from low income groups

According to reports, around 1000 tons of plastic waste is generated in the city daily, from domestic, commercial and industrial usage [20]. Though there are no estimates for how much plastic waste flows in from other cities and countries, reports suggest that more than 2500 tonnes of plastic waste is recycled daily in the city [20]; indicating that a huge quantity of plastic comes from outside for processing. Interviews in the field indicate that the waste flows in primarily from states like Maharashtra, Gujarat, Tamil Nadu, Andhra Pradesh and West Bengal. Some of the major cities which send waste to Delhi are Mumbai, Chennai, Hyderabad, Indore, Lucknow, Kanpur and Chandigarh. This interstate or intercity movement of plastic or plastic contained waste includes domestic generation as well as imported waste, received in some of the port cities.

There are around 180 registered plastic recycling units in Delhi, which have been given licenses by the Pollution Control Committee. In spite of the presence of a large number of registered units in the city, plastic waste is mainly recycled by the informal sector here. Increasing waste volumes coupled with the growing 'urban poor' population, which is desperate for livelihood and some sort of entrepreneurship opportunities, has fuelled the mushrooming of informal recycling operations. Plastic recycling is seen as a good business in the informal economy because of the nature of the operations which are labour intensive and requires relatively unskilled workers. Also the start-up capital requirements are low.

Due to the informal nature of this sector, secondary data on the volumes recycled the annual turnover of the industry and the numbers of recycling units in operation in India are unavailable. It is difficult to estimate the number of plastic recycling units in the city as these are spread across the city. But our field visits indicate that there are around 7000 plastic processing units, with around 3300 units engaging in grinding, moulding and pellet making and the rest mainly into sorting of plastic waste. Out of the 3300 such units, close to 2500 units deal with scrap plastic or are engaged in plastic recycling.

The processes in the informal sector are very labour intensive and suited to developing countries with a large pool of cheap labour. These units in Delhi employ close to 20,000-25,000 people directly, but the number of people engaged indirectly may be much more. An earlier study (Haque 1999) estimates around 0.2 million persons are employed directly and indirectly in this industry, in India.

Plastic recycling rates in India, and in particular Delhi, are considered to be very high, close to 60 %, which is very high in comparison to most places worldwide. For the United Kingdom and Europe in general, plastic recycling rates stand at a dismal 7%; in Japan at 12% and in China recovers only 10% of its post consumer use plastic waste.

4.2 WEEE Plastic in Delhi

Delhi, the capital and one of the largest cities in India, does not have any proper e-waste assessment and there are no figures/data available on the quantity of e-waste generated in the city. Hence it becomes difficult to estimate the amount of WEEE plastic generated in Delhi. But we have tried to arrive at some rough estimate by looking at the total waste generation in the city.

According to Delhi Pollution Control Committee, around 7310 Tons per day (TPD) of municipal solid waste is generated in Delhi [21]. For India the estimate stands at around 136996 TPD [22]. Global estimation and studies have indicated that around 1-2% of municipal solid waste is E-waste. If we take this estimate, then the total generation of e-waste in the city would be around 73-146 TPD, meaning around 26000-53000 tonnes of e-waste generation annually.

The amount of plastic in EEE differs. The plastic content in e-waste, as an average, is assumed to be around 30% [3]. That would mean approximately 8000- 16000 tonnes of WEEE plastic generated in the city, that is around 22-44 TPD of WEEE plastic.

Since the obsolescence rate in India is assumed to be lower than the developed countries, we can assume that the total WEEE plastic generated in the city will be closer to 22 TPD (which is the lower estimate-**Table 5**). Given that the city generates 1000 TPD of plastic, this would mean that the WEEE plastic is around 2.2% of the total quantity.

Table 5: Minimum WEEE plastic generated in Delhi

Location	MSW (TPD)	E-waste (TPD) (1%)	E-waste (annually) in tonnes	WEEE Plastic (TPD)	WEEE Plastic (annually) in tonnes
Delhi	7310	73	26700	22	8000
India	136996	1370	500000	410	150000

Table 6 indicates the quantities of WEEE and WEEE plastic generated when e-waste forms around 2% of the total Municipal solid waste.

Table 6: Maximum WEEE plastic generated in Delhi

Location	MSW (TPD)	E-waste (TPD) in tonnes (2%)	E-waste (annually) in tonnes	WEEE Plastic (TPD) in tonnes	WEEE Plastic (annually) in tonnes
Delhi	7310	146	53290	44	15987
India	136996	2740	1000070	822	300021

The expected quantity of solid waste generated in Delhi will be about 12,750 TPD by 2015 (National Environmental Engineering Research Institute), which means around 46,000-93,000 tonnes/annum e-waste and around 14,000-28,000 tonnes/annum WEEE plastic by 2015.

It is also important to assess the quantity of WEEE plastic processed in the city. There is no information indicating that plastic waste or e-waste is flowing out of the city for processing, hence it is safe to assume that the 22 TPD of WEEE plastic generated in the city is mainly processed within the city. But it is important to find out if the quantity recycled in the units in Delhi every day is higher than these 22 tonnes.

Our sources in the field clearly mentioned that Delhi receives plastic wastes as well as e-waste for processing from all parts of the country, thus indicating that the quantity processed in the city is much higher than the generated quantity of 22 TPD. The attempt to arrive at the total quantity proved to be far more challenging as there are no records of the waste flows within the country. The field interviews suggest that the quantity coming in from outside is much more than the domestic generation, since WEEE is coming in the city from all parts of the country including large e-waste generation center s like Chennai, Mumbai etc.

We also tried to arrive at this quantity from visiting the recycling units and assessing the quantity of WEEE plastic processed in these units on an average. Almost all units in the informal sector mix plastic from different sources. For example, if there is ABS plastic in a mobile phone it is segregated as ABS and then mixed with other ABS which may be sourced from car accessories or some other products. Similarly for the other resins used in EEE. There are no separate process lines for the WEEE plastic and hence no records maintained. The units visited during the study were unable to specify the quantity of WEEE plastic they received. Therefore it is not possible to quantify the total quantity.

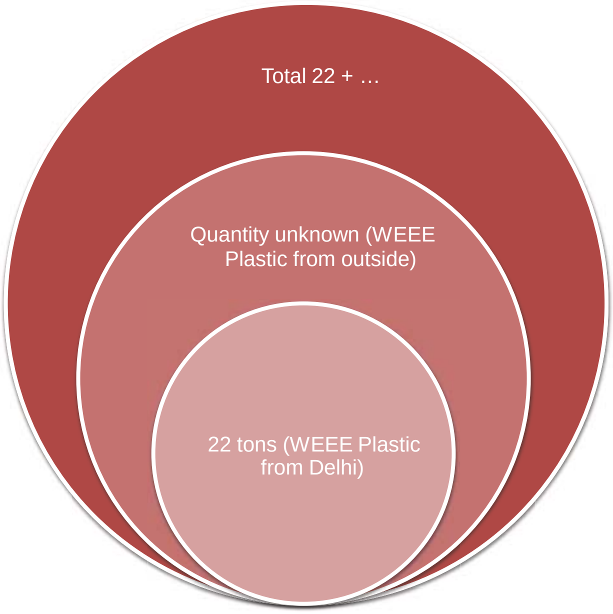


Figure 1: Total WEEE plastic processed in Delhi

4.3 Informal sector- markets and hotspots

The plastic waste trade and processing units are widely spread across Delhi. The WEEE plastic, as mentioned above, is not just from local domestic generation but the city also receives such plastic from outside the city.

In mapping the hotspots and markets for WEEE plastic, it is essential to include the areas dealing with trading and dismantling of e-waste. These markets and pre-processing units are part of the initial flow chain of WEEE plastic, before the waste reaches the areas where actual processing or recycling of plastic begins.

Areas like Shastri Park, Old Silampur, Turkman Gate and Old Mustafabad are big centers for e-waste pre-processing. In the small units located in these areas, e-waste is dismantled and segregated. These are then picked up by some large traders in the area, who sell it further to the plastic recycling units. Most of the WEEE plastic, segregated in these areas, are sold to the units located in other parts of the city; except in Old Mustafabad which has some plastic grinding units as well. Some areas like New Silampur and Beta Hazipur specialize in wires and are the areas where these are stripped to separate copper (or aluminum) and plastic (mainly PVC). The plastic is then sorted and sold to traders dealing with plastic.

The plastic processing units are spread geographically, with units in the northern, eastern and western part of Delhi (Figure 2). Mundka is one of largest plastic scrap hubs in the city, with estimated more than 4000 units in the area, engaged in sorting, cleaning, trading and processing of plastic waste. This includes registered and unregistered units. There are no units engaged in moulding or making new plastic products in this area. These 4000 units, spread across a 4 km stretch, are dealing with all kinds of plastic scrap. Among these around 3800 units are mainly engaged in sorting and cleaning operations. These sorting operations are mainly in open plots, each plot shared by multiple units. These plots or units have hardly any concrete structures, usually only protected on top by temporary cloth or plastic coverings.

Figure 2: Plastic recycling hotspots in Delhi

Figure 3: A typical unit in Mundka

Bawana is a new industrial area on the outskirts of Delhi which houses many clusters of units engaged in reprocessing plastic waste. Though this is a newly developed industrial cluster, it has large areas with provision for around 16000 units. Currently only 3500 industrial units are operating, out of which around 1000 units are plastic processing units. Among these 90% deal with plastic scrap, the rest work on fresh resins. Bawana is notified as an Industrial area by Delhi State Industrial and Infrastructure Development Corporation Limited (DSIIDC). The plastic reprocessing units in Bawana are larger units engaged in the operation of grinding, pellet making and moulding.

Another major plastic re processing hub in Delhi is Narela, which is around 4-5 km from Bawana. This is one of the earliest recognized industrial areas in Delhi, notified in 1978, with around 3300 planned plots. According to the President of the Narela Industrial complex welfare association, an association looking after the interests of the units in the area, around 2800 plots is occupied and functional. Around 850 units process plastic, among which 480 deal with plastic scrap. These units are also mainly grinding, pellet making and moulding. There are around 70% pellet making units and 25% of them are doing both pellets and moldings.

Shahdra and its adjoining areas of Vishwas Nagar, Jhilmil Industrial Area, Friends Colony Industrial Area and Damodar Park are also major hubs for plastic processing. This large area comprises of some industrial clusters as well as residential colonies. The units in this hotspot mainly deal with PVC resin, with lots of plastic remains from wires flowing to this part of the city. There are around 800 plastic processing units in this area, 500 units are engaged in re processing.

Some key locations in Delhi where plastic scrap pre-processing and processing operations take place, are Kirti Nagar, Mayapuri Industrial Area, Inderlok, Karawal Nagar, Patpargunj, Udyog Nagar, Okhla, Anand Parvat, Mandoli, Joharipur, Najafgarh and Poot Kalan. There are around 500 units in these areas, mainly into pellet making and moulding. Some of these areas are notified as industrial areas, whereas some of them are residential.

Figure 4: Plastic Market in Delhi

Another important area in the plastic recycling business is Sadar Bazaar, being one of the largest wholesale markets in the city, dealing mainly with household items. This market is subdivided into various sub markets, specializing in various products or items. Bahadurgarh Road is a lane in this busy crowded market which is dedicated to plastic with more than 100 shops. All kinds of fresh and recycled pellets, different resins, colors and quality, can be bought here in huge quantities.

Many moulding units situated in areas like Bawana, Narela, etc buy pellets from this market.

The field study also indicated some linkages between formal and informal plastic recycling units. This is likely also because of their co-existence in the same areas. The material from the plastic units in the informal sector was at times picked up by the formal recycling units directly for pellet making or for moulding. Also, the pellets from the informal recycling units were sold in the common market like Sadar, from where they could be picked up by formal or informal recycling units. The reverse seemed unlikely as the costs in the formal units are expected to be higher.

4.4 Informal sector- players

The informal sector of the plastic reprocessing business constitutes different players at different stages of waste management. This is similar to any waste stream hierarchy and may also include several traders or middle men at the higher levels (Big Kabaddi wala onwards).

Ragpickers (locally also called 'Kachrawala' or 'Binnewallahs') –Ragpickers or Waste pickers constitute the bottom layer of waste recycling in Delhi and form the base of the large informal recycling pyramid. Delhi is estimated to have around 1, 00,000 Ragpickers [22], constituting of men, women and children. Pickers collect waste just by picking it up from public places such as garbage dumps, streets or landfills and earn their livelihood by selling collected and sorted waste to higher levels. Among the recyclables, plastic is a relatively significant material for waste picking. Occurrences of finding WEEE plastic in public places, except wires at times, are rare and hence Ragpickers are not really big players in the WEEE plastic pyramid.

Small traders (locally also called as 'Thiawalas') - The Thiawalas usually pick up waste from Ragpickers and have some space to carry out sorting and cleaning operations. They, in turn sell these sorted materials to large dealers or large kabaddi shops. They also have little access to WEEE plastic.

Waste Collectors (locally also called 'Kabaddiwalas') – The collectors are also at the bottom of the waste pyramid, but their operations are different from the Ragpickers. The collector goes around the generators of waste, for example households, small offices, shops etc, and purchases their waste by paying cash. In contrast to Ragpickers, they need to have some operating capital to buy material and earn profit by selling it to others at the higher level in the pyramid. Only males are known to be in this occupation in Delhi (or in India).The collectors, mostly, have access to better material constituting of metal, plastic and paper. WEEE plastic does reach the collectors, as they collect small WEEE from generators.

Figure 5: Waste Hierarchy in the informal sector for WEEE plastic in Delhi

Kabaddi or Junk shops - There are two different levels of Scrap shops or Kabaddi shops, small and large. The small Kabaddi shops are spread across the city and have presence in almost all localities. They buy materials from many local 'Kabaddiwalas' and then sell them further to a larger 'Kabaddi shop. The owner may employ couple of people to help him in this.

The larger Kabaddi shops are limited in number and in addition to small Kabaddi shops, also receive sorted waste from Thiawalas. They also pick up waste directly from offices or establishments. At both these levels WEEE and WEEE plastic are dealt with. The large Kabaddi shop may receive EEE as a whole which he will sell to specific traders dealing with that or may receive plastic parts, from repair shops or other places, which he collects and sells to a plastic trader. There are around 4-5 workers in these kind of junk shops.

Trader/Dealer/Wholesaler - Till the level of Kabaddi shops, all players deal with all kinds of recyclables. At the trader or dealer level it becomes specialized. A plastic waste dealer purchases waste from junk shops, institutions, shops and industries. The trader also has direct linkages and can pick up material from imports or buy from auctions. A plastic dealer will directly put the plastic in the material chain which includes sorting, cleaning, grinding and pellet making whereas an EEE dealer will sell it to a dismantler who separates the plastic to put it in the plastic chain. Traders also tend to sell working EEE to refurbishers and get more money in this.

Dismantler - Non-working WEEE equipments are usually bought by dismantlers, who break open the equipment and separate the components. Working components might be cannibalized, but plastic scraps are usually collected and sold in the plastic chain. The dismantlers mostly separate different plastic resins before selling them, as segregated plastic fetches a better price.

Recyclers - The recycling chain of plastic consists of several traders, waste sorters, grinders and pellet makers. After material trading at a commission basis (most times more than once), plastic usually ends up with waste sorters who separate different types of plastic, based on their experience and some indigenous methods. After sorting, these are sold to grinders who do a further segregation and cleaning before the cutting and grinding process. These are then channelized to pellet makers. The pellet makers receive waste from dismantlers and traders directly. They also have linkages in other cities and receive waste from there directly. The sorted and grinded pellets then go through the extrusion process for making pellets. The recycled pellets are either sold directly to the moulding units in the city or are sold to traders in the city dealing in plastic. The recycled pellets are also sold to plastic traders in the other cities.

The workers in these units are usually paid according to their skill levels, for example in a unit in Bawana, we found that the salary is divided in three categories helper Rs. 4500/-, skilled labour Rs.6000-6500/- and supervisors Rs.7000/-per month. The units usually work in two shifts each being of 12 hours duration. There are many workers in these units who are also paid daily wages, ranging from 100-150 rupees.

4.5 Plastic Recycling process in the informal sector

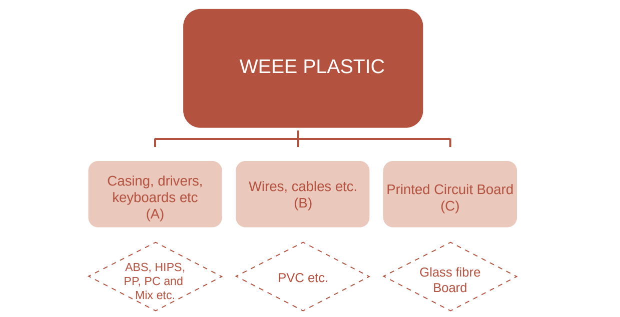
The different steps in recycling of plastics in the informal sector are melting, shredding, and granulation of largely post use plastic waste. If we look at WEEE plastic, it can be categorized into three broad categories, based on their process flows.

A. Casing, drives, keyboards etc, which are primarily made of ABS, HIPS, PP, PC or at times mix of two types of plastic resins (for example ABS+PC).

B. Wires and Cables, made of PVC, LDPE, HDPE etc

C. Printed Circuit Board made of glass fiber epoxy resin.

Figure 6: Plastic in WEEE



The three different categories are treated in a separate manner in the recycling chain, and hence the need to categorise them.

Category A- A large portion of the plastic content in WEEE comes from casings (computer, television, mobiles, printers etc) and parts like keyboards, mouse, drives etc. These are mainly made of resins like ABS, HIPS, PC and PP. At times, these are mixed containing more than one resin type (for example 80% ABS and 20% PC or vice versa).

Stage 1- These casings and other parts are removed by the dismantlers, who are operating in areas like Shastri Park, Silampur and Mustafabad in Delhi. The workers at a dismantling unit, who may earn around 100-150 rupees per day, dismantle it manually and sell the plastic by weight, at a uniform rate. At times, to get a better price, they separate it resin wise (ABS, HIPS or PC) based on what is written on the plastic part or mainly using their experience.

Stage 2- These are then sold to traders, who pass it on to waste sorters, mainly present in Mundka. Small traders buy untreated maal (material) and pass it on to sorters, who specialize in classifying and segregating tons of undifferentiated plastic into more than 40 different categories that sell from 2 INR/kg to 200 INR/kg (0.04- 4.25 USD). It is important to note that there are different lines of processes for different types of resins. The reason is mainly economical, as the segregated plastic fetches a better price. WEEE plastic is one of the plastics among hundreds of others dealt by these sorters.

The workers have different ways of recognizing resins, for example, chemical testing, sound, and smell or through burning. Generally, visual methods and judgments are employed to differentiate between the types of plastics. When these methods are proven insufficient, the plastic is broken and smelled or burnt and the nature of the smell or fire decides the type. The mixed plastic is then categorized with the main resin categories based on their concentration, for example if there is a plastic with 80% ABS and 20% PC, it is put along with ABS, whereas if there is plastic with 20% ABS and 80% PC, it joins PC. At times, these are additionally segregated color wise. This helps to achieve a uniform color of the recycled pellets but more importantly it ensures uniformity of the scrap being recycled. The sorters also separate plastics which are recycled earlier. By a thumb rule the more times the plastic is recycled the more it becomes darker and dull. The sorters do try and segregate the FR plastic at times because of economic reasons, but there might be mixing at this stage as their ways are rudimentary.

Stage 3- The sorters sell the segregated plastic to the grinding units, mainly situated in areas like Mundka, Karawal Nagar and Bhopura. There are some grinding units in Bawana and Narela also. Most grinders specialize in few resin types and also do a final round of segregation before the plastic part is subjected to cutting or reduction in size process. This cut plastic is then put into a grinding machine for further reduction in size.

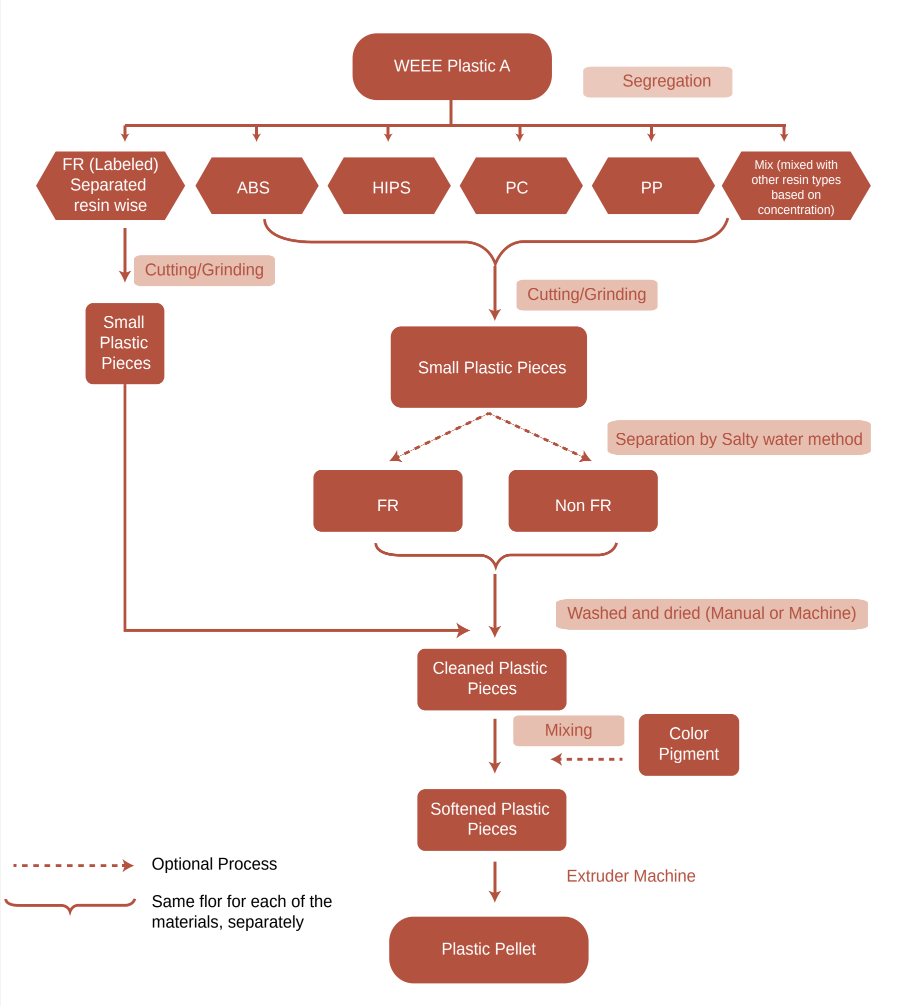
Just prior to the grinding process, some of the units separate the FR and non FR plastic. This largely depends on the volume of FR plastic available with them and their hands on experience on identifying it. If the grinding unit has FR plastic in small quantities, they mix it with the non FR one. Some of the units indicated that they mix it in the ratio of around 10:1, indicating deliberate contamination. The demand for FR plastics can also drive the process of separating FR and non FR plastics. The demand for FR plastics can originate from manufacturers who could be manufacturing casings for monitors or radio transistors and products of this nature.

Few units visited by the research team found the sorters / recyclers meticulously following the process of using a salt water bath for separating FR and non FR plastics. These units use the salt water flotation for carrying out this separation. They prepare a salt water solution and pass the shredded plastics through this solution of salt water. FR plastic sinks and settles at the bottom of the tub and non FR plastics floats upwards, which is then separated. The concentration of salt water solution is also prepared based on their experience and they do not follow a prescribed norm or percentage of water to salt. During the process of floatation, salt is additionally added to the mixture whenever there is any addition of water, to maintain the appropriate concentration of the solution. There could be some errors in following this process but by and large the process is relatively effective in separating these plastics.

These grinded plastic pieces are then sun dried and sold to pellet manufacturing units.

Figure 7: Salty water separation in a unit in Delhi

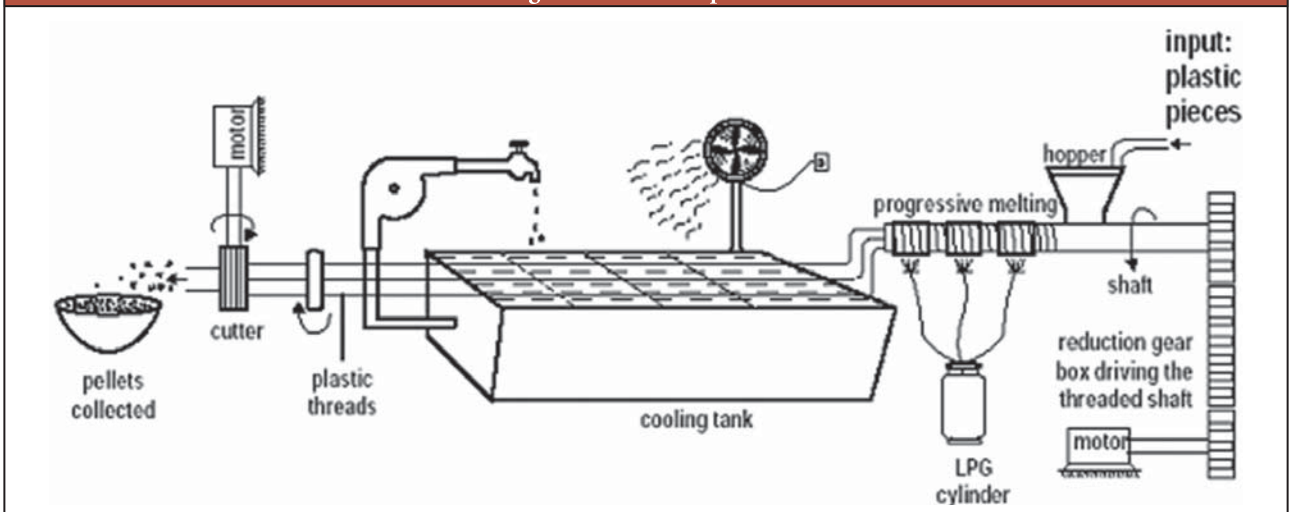
Figure 8: Recycling flow of category A



Stage 4- At the pellet making units, the plastic granules are washed and cleaned to remove impurities like dust, through manual or mechanical processes. The cleaned pieces are dried in a dryer or in the open, after which they treated in a mixer. The friction and the heat generated, in the mixture machine makes the material soft and pliable for further processing. Chemicals are also added to enhance the sheen or the gloss of the material (The units surveyed were unable to name these chemicals). Black color is usually added to this mixture unless there is a specific requirement for the pellets to be produced in a particular color. After preliminary processing, the recycling of plastics involves extrusion to make new pellets. For polymer processing extrusion is the most important step. In the extrusion of plastics, raw thermoplastic material is gravity fed from a top mounted hopper into the barrel of the extruder. The material enters through the feed throat (an opening near the rear of the barrel) and comes into contact with the screw. The rotating screw forces the plastic pieces forward into the barrel which is heated to the desired melt temperature of the molten plastic. Extra heat is contributed by the intense pressure and friction taking place inside the barrel. There were different ways used for heating, some units used LPG cylinder and some use electrical heating. Most units (especially the ones using LPG cylinder) rely on experience to control the temperature as the heating devices have no temperature recording devices. Few units which have temperature recording devices attached achieve around 250-300°C, depending on the plastic type.

Though FR plastic is separated at various levels, there is possibility of contamination at each stage, either due to deliberate mixing or due to improper ways of segregation. In the extrusion machine if the mixture contains a high percentage of FR plastic, there is a possibility of it getting stuck in the dye, attached just before the cooling tank. The

Figure 9: Extrusion process



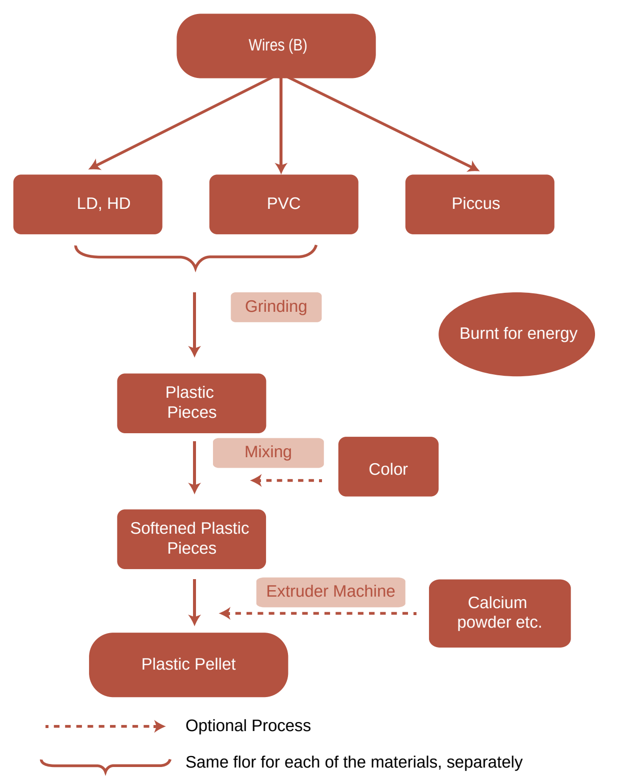
pellet making units usually change this dye during processing of FR plastic.

The output from this is passed over a cooling tank, and flows out in the form of strings, which are finally cut into granules or danas or pellets by the use of a cutter attached at the output end. These pellets are then packed and either shipped directly to the plastic product manufacturers or to marketplaces like Sadar where they are sold as pellets.

A visit to Sadar, the plastic market, revealed that the dealers here deal with all kinds of virgin and recycled pellets, some specializing in some particular resin, the other in some other. Most shops do not stock recycled pellets with FR, but some of them were ready to take orders of the same and supply them within a week. Unavailability of FR resins in the market did raise doubts about the fate of the recycled FR contaminated plastic. Mixing of the entire plastic chain did seem a possibility, since our field studies indicated lack of segregation (FR and non-FR) and also deliberate mixing. The other reason could be that the FR resins are directly picked up by moulding units, to be used in products which require flame retardants. Another possibility was export of these pellets directly to EEE manufacturing countries, though this could not be confirmed during this study.

Category B: Wires are part of both electrical as well as electronics and do find their way in the informal sector. These are usually made of PVC plastic, but may be made of LDPE, HDPE and Piccus (local name). The plastic from the wires is segregated resin wise and may also be separated color wise if the quantities are large. The important point to note here is that there is no separation on the basis of FR content.

Figure 10: Recycling flow of category B



The PVC, LDPE and HDPE follow the same route of recycling, cutting and grinding followed by pelletisation. The interesting bit to note here is that PVC dealers and processors are usually very specialized and deal with only that resin type. Calcium Carbonate powder is usually added at the mixing stage to improve the quality of plastic pellets. Chemicals like Chlorinated Paraffin oil and DOP/DP are also added during mixing. Recycled PVC pellets are 50% consumed in Delhi and the remaining sold to mainly states like Jammu Kashmir, Madhya Pradesh, Haryana, Rajasthan and states in the South.

Piccus is not recycled and is generally sold per kg (3-8 rupees per kg) or thrown away to be finally used as a fuel replacement.

Wires and Cables- Areas like Behta Hazipur and New Silampur specialize in dealing with wires and cables. The traders in these areas buy these in bulk (50-200 tonnes), mainly through auctions, from Delhi as well as other parts of the country. These are then given to local people on job work (paid depending on the quantity done) for separating plastic and metal. The rates vary from 1-7/kg, depending on the variety of the waste. The locals pick up these to take to their homes and the whole family is engaged in the process of separation. Around 500-600 families are involved in this, in these areas. The process includes scraping off the plastic with a blade or burning the wire (if the wire is very thin).

Category C: The printed circuit boards are made of glass fiber epoxy resin; epoxy is a thermoset plastic and hence not conducive for recycling. The printed circuit boards go through a process of open burning or an acid bath to recover valuables like copper. In the burning method, the board (after removal of valuable components) is put to fire to expose layers of copper and the burnt remains of the board are usually dumped e.g. in the neighboring fields. In the acid

Figure 11: Remains from the Printed circuit board

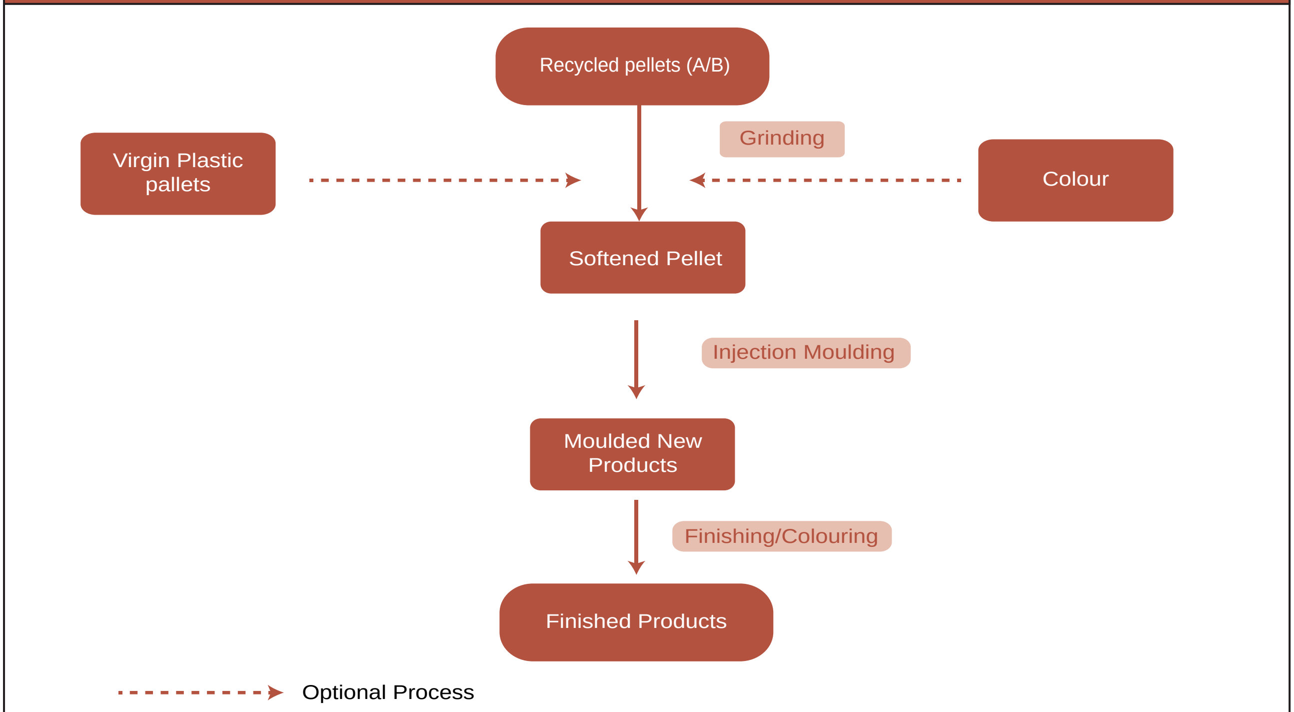
bath process, used for single layer or double sided PWBs, the copper is dissolved and the cleaned epoxy boards are the remnants. These are used as insulator sheets to make bobbins for transformers used in invertors, radios and chargers etc, returned to companies for reuse to be dumped in the neighborhood.

Waste Plastic- Materials like Bakelite and rubber from WEEE usually having no value are either burned to recover energy or are dumped. For example a keyboard dealer in Shastri Park told us that the 5% of the keyboard consists of rubber and he generated around 50-60 kg/week of rubber waste, which was sold to a lead melting unit as a fuel replacement.

The moulding units usually function in two modes. In the first one, the unit receives an order for moulding certain products of a specified number. In this case they arrange for the raw material themselves and charge for the total product. In the other case, the order is for a certain product but the raw material is also provided along with it, in which case the moulding units charge a job work based on a per piece basis.

During moulding, if some products require FR plastic, the units acquire recycled FR to make those products. It is highly uneconomical to add flame retardants to normal recycled plastic as the cost increases by around 50-60 Indian rupees/ kg (1.09-1.30 USD).

Figure 12: Moulding process



Moulding: The steps in the moulding process (mainly injection moulding) usually remain the same irrespective of plastic resin types.

The pellets from secondary plastic are put into a mixer to soften them. At this stage virgin plastic pellets may be added depending on the requirement of the product to be molded. Usually these are mix of 50-75% of recycling pellets and rest of fresh pellets. It also depends on whether the plastic pellets are first time recycled pellets or have been recycled several times. If the required quality of the new plastic product is not very high, it may be made entirely of the recycled pellets. Most units claimed that the same product could not be made from the recycled pellets. Color can be also added at this point in the mixing machine, depending on the product. Though there are no prescribed quality standards, these units go by experience and on requirement from the buyer.

The softened pellets are then put through a moulding machine, injection moulding in most units, to get new products. The product finishing and coloring is done before the products are ready to be packed and dispatched.

Table 7: Possible contamination points

Stages of Operation	Points of possible contamination
Stage 1 (Dismantling)	■ Most units do not separate FR plastic.
Stage 2 (Sorting)	■ FR plastic separated at times, but primarily resin based separation.
Stage 3 (Grinding)	■ Some separation done based on basic knowledge. ■ Salt water separation after grinding to separate FR plastic in very few units. ■ Deliberate mixing of FR plastic with normal plastic
Stage 4 (Pellet making)	■ FR batches run separate. ■ No FR separation process for mixed plastic
Moulding	■ FR batches run separate. ■ No FR separation process for mixed plastic

The final product of the units, be it pellets or products, is generally produced only on an order basis. The majority of the units even purchase the scrap only after receiving order for either pellets or products with specifications. Depending on the order specifications in terms of type, desired strength, purpose, color and shape the nearest suitable type of scrap is either purchased or sorted from the mixed waste in-house. Some of the units also accept job work wherein the scrap is purchased and sent for processing to the recycling unit by a concerned party. In such cases the task for the recycling unit is to provide labor, service and machinery and the flat rate per kg of plastic recycled is charged.

4.6 Impacts of Recycling

In India, there has been little work to study the health risks on workers in various occupations, especially in the informal sector. Since recycling is mainly carried out in the unorganized or informal sector, its risks are mainly unknown.

In this study, we have tried to observe the practices in the field and evaluate the health and environmental risks. A previous study done on plastic recycling in Bangalore also suggests similar concerns [24].

Physical conditions- The informal recycling units visited during the research were of varying sizes, depending mainly on the kind and magnitude of operations. The sorting units for plastic waste are spread across in large areas, being shared by a number of operators, with small sections having temporary roofs. All sorts of plastic waste are strewn around in these units, with a large number of women, sitting on the ground and carrying out segregation and sorting processes mostly with their bare hands. The grinding operations also take place in open areas, with only a small roofed portion provided. The grinding machine is placed in this covered part, with no provision for any exhaust to throw out the dust particles generated during the process.

The pellet making and moulding units, visited during the field research, were mostly in enclosed areas. These operative units generate heat due to the mixing and extrusion processes, the mixing process also generates a lot of dust particles. The units have no ventilation system, resulting in high temperature and dust within the unit. The noise levels in these units, especially in the grinding and mixing operations is also quite high.

The layouts of the units are unplanned and hence most units have hardly any space to move around swiftly.

Working conditions- Inadequate safety and health standards and environmental hazards are particularly evident in the case of the informal sector recycling operations. Some of the most prevalent problems are: poor lighting, lack of ventilation, excessive heat, poor housekeeping, inadequate work space and working tools, lack of protective equipment, exposure to hazardous chemicals and dust and long hours of work.

Since dyes and chemicals are used as additives during the recycling, the workers are constantly exposed to them and the exposure levels may be very high, given the fact that most of the units are poorly ventilated. Caustic soda and other cheap detergents are used for cleaning. Before rinsing they are washed with bare hands. This operation would require a worker to keep her/his hands in soap solution for long hours and may result in skin problems. The soap solution is used several times before it is finally disposed of into open drains. Addition of color pigment is also a point of concern, as the pigments used are of low quality. Constant exposure to toxic dyes and chemicals in a non-ventilated environment may increase the exposure risks. Carbon black is usually added to make the material black in color. Carbon black usually tends to deposit everywhere, and can also be inhaled and deposited in the lungs.

Figure 13: A typical grinding unit in Delhi

Figure 14: Dust particles flying in a pellet making unit

Poor working environment include inadequate premises and often very unsatisfactory sanitation facilities, as well as practically non-existent occupational health practices. There are no personal protective equipments used by the workers. During grinding, at times, the workers cover their nose and mouth with a piece of ordinary cloth.

The major source of generation of effluents is the washing and cleaning process. Wastewater is generated during the recycling process when the plastic scrap is cleaned to remove the dirt and foreign matter adhering to it. The quantity and characteristics of wastewater generated cannot be generalized, and depends to a large extent on the contents of the plastic scrap. Soap solution is used to clean the scrap, and it is reused several times before it is finally disposed in open drains. This water needs treatment before proper disposal into the drains but is released into open drains without prior treatment.

Awareness of the adverse long-term effects of poor and hazardous working conditions is very low among the informal sector workers.

- The units are usually very small in size. Lack of space for easy movement makes it congested and may lead to accidents.
- Adequately designed ventilation to quickly remove the gaseous products and heat is generally not present.
- There is no personal protection equipments used during most of the operations, increasing the risk of exposure to the workers.
- Grinding scrap is a noisy operation. Sometimes noise level may go really high and impact the hearing power.
- Both the grinding process as well as the mixing process, before the final pellet making, release particles. The particles flowing in these small congested units can cause respiratory ailments.
- When hard plastic components containing brominated flame retardants are shredded, workers can be exposed to dust containing these chemicals.
- After preliminary processing, the recycling of plastics involves extrusion to make new products. The use of heat in the extrusion of plastics containing brominated flame retardants can cause the formation of brominated furans and dioxins.

4.7 Economics in the informal sector

The plastic recycling business in Delhi is big, as this is the largest, both in terms of volume and in terms of economics, in the country. The National Plastics Waste Management Taskforce Report (Ministry of Environment and Forests, 1997) valued the informal scrap sector's annual turnover at Rupees 25, 000 million (approx. 500 Million USD). Since the plastic usage and consequent disposal has increased many times in the last two decades, we can safely assume that this amount must have also increased substantially.

Plastics' recycling is an attractive business in India due to availability of cheap labour. The cost of recycling one ton of HDPE plastics in is around 190 USD while the same would cost 10 USD in Delhi.

The study of the plastic chain in the Delhi recycling market does not give too much insight into the real profit margins of each player since the informal sector is highly guarded on this and is not willing to share the economics at each level. But the important finding was that each player in this value chain works for at least 10-15% margin, though the traders at times work for higher margins. The table below indicates some costs.

Almost all transactions/trade are based on weight, where the material is sold and bought in kilograms (kg s) or tons. There are few exceptions like in the case of keyboards, where the initial trader sells it to a dismantler on a piece cost (around 20 rupees per piece).

One interesting point to note here is that though at the dismantling units and the subsequent links, the price for FR loaded plastic waste is lesser as compared to non FR plastics, we found the price of FR plastic to be high in the pellet market. The FR plastic was also not available easily, and was only available on demand.

There is a huge market for the products made out of the recycled pellets, sold in the local Delhi market as well as sent to other cities and towns in India. These also have a market in countries like Bangladesh and Saudi Arabia.

Table 8: Economics of recycling trade (Purchase price-all figures in INR/kg)

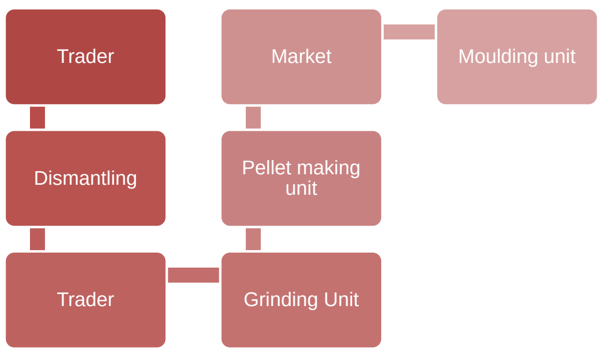
Plastic Resin	Dismantler	Plastic Scrap Dealer	Grinding unit	Pellets Factory	Market
ABS	20-25	25-36	30-45	35-60	40-85
HIPS	15-25	22-30	25-40	30-55	35-70
PVC	10-20	10-35	15-65	25-70	
PP	10-15	18-30	20-40	30-50	35-60

4.8 Business prototypes

The plastic reprocessing business in Delhi operates using different prototypes. It is important to consider this as it helps us in understanding the diverse flows and the possibility of contamination at various levels. Mentioned below are different types observed in the field, which are also represented figuratively. The boxes in red are essentially e-waste stage of the business, whereas the blue marks plastic business.

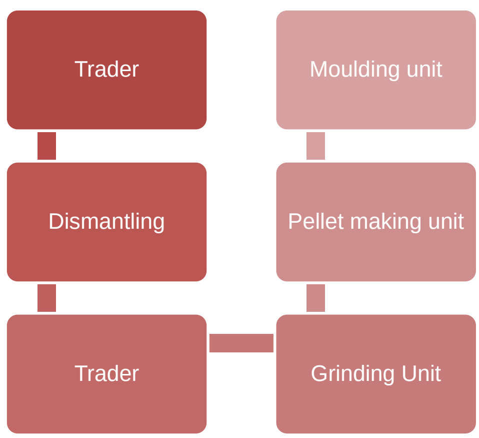
Type 1: In this business prototype, each step of the operation is carried out by a different player (fig 3), meaning a trader picks up e-waste from different sources like an auction or small collectors or from import. This waste is then sold to a dismantler who breaks it open to remove parts and segregate them. The separated plastic is then sold further to a trader, who specializes in plastic and sells it to a grinding unit. In most of the locations the grinding unit also goes through segregation or a sorting process, whereby the bought plastic is separated resin wise and ground separately to get better prices. This ground plastic is then sold to a pellet making unit, which processes it through an extruder machine to get recycled plastic pellets. The plastic pellets are ready to be sold to traders/shops in the market where they are sold to moulding units, completing the whole business chain.

Figure 15: Business Prototype- Type 1



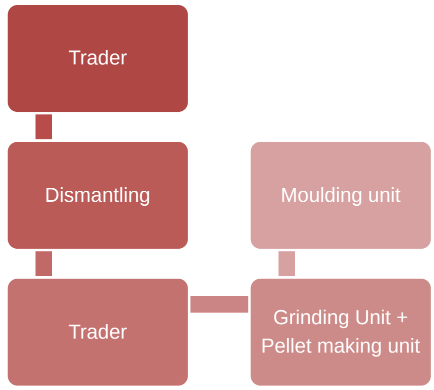
Type 2: This type is similar to Type 1, where each operation or activity is carried out by a different player/company. The only difference in this type is that the recycled pellets are directly sold to mounding units instead of the intermediate market trader or shop (fig 4). The pellet making units have either a regular arrangement with the moulding units or the moulding units visit directly, scouting for the kind of resins they require.

Figure 16: Business Prototype- Type 2



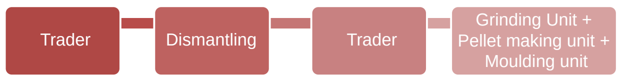
Type 3: This is a slight variation from the earlier versions, as the grinding and pellet making processes are carried out by a single operator. Though the figure below (fig 5) depicts that the pellets going directly to the moulding units, there can be also a small variation whereby the pellets are picked up by traders who in turn sell it to the moulding units.

Figure 17: Business Prototype- Type 3



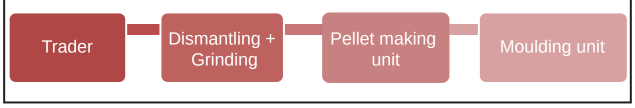
Type 4: The city also has large informal plastic recycling units, where the grinding, pellet making and the moulding processes happen under one roof. This forms our Type 4 (fig 6).

Figure 18: Business Prototype- Type 4



Type 5: This final business prototype looks at some operations (mainly in areas like Old Mustafabad) where the grinding unit is attached to the dismantling unit. These units essentially buy WEEE and separate the plastic to grind it. These units also buy plastic from other small dismantlers. The other recovered materials from WEEE are sold to traders specializing in those and plastic, after grinding, is sold to pellet making units (fig 7).In this type also, a small variation is possible, where there is an intermediate trader between the pellet making unit and moulding unit.

Figure 19: Business Prototype- Type 5



4.9 New Products

Reprocessed plastic is used by various industries especially by low cost manufacturers. The plastic depending on its grade, which is decided on the basis of how many times it has been recycled, is molded into different products. For example if the plastic is being recycled for the first time, it can be used to make the same product again with the addition of virgin plastic. But after recycling it couple of times, the grade reduces and then it is used to manufacture other low cost goods where the quality of plastic required is not of a very high standard.

The products, made from recycled pellets in the informal sector, mostly do not specify if the product is made of a particular resin and if they contain flame retardants. This is critical from the point of view of contamination.

An interesting observation in the field is the use of PVC plastic from different sources, including wires of WEEE to make slipper soles.

4.10 Formal sector Plastic Recycling

Ambika Plastics is a plastic recycling company located in Gummudipoondi which is 50 km s north from Chennai. It was established in the year 1992 by a local entrepreneur.

The facility handles about 350 tonnes of plastic in a year and estimates about 10% is from e- waste. The various types of plastics handled by the facility includes PC, ABS, HIPS, PPE, PC Alloy , Nylon 6 etc .They adopt both manual and testing methodologies to identify and segregate the type of plastics.

Process

The mixed plastic scrap is first segregated manually. The plastic scrap portion which needs testing is tested and segregated. Then each type of plastic is shredded for size reduction and stored separately. The simple plastic is now fed into the extruder and heated at 230 degree Celsius. The melted lump form is then passed to the baby extruder which produces strands. Then the strands are passed through the cooling tank. To get the final product, the strands are fed into the pelletizer which gives 4 mm pellets.

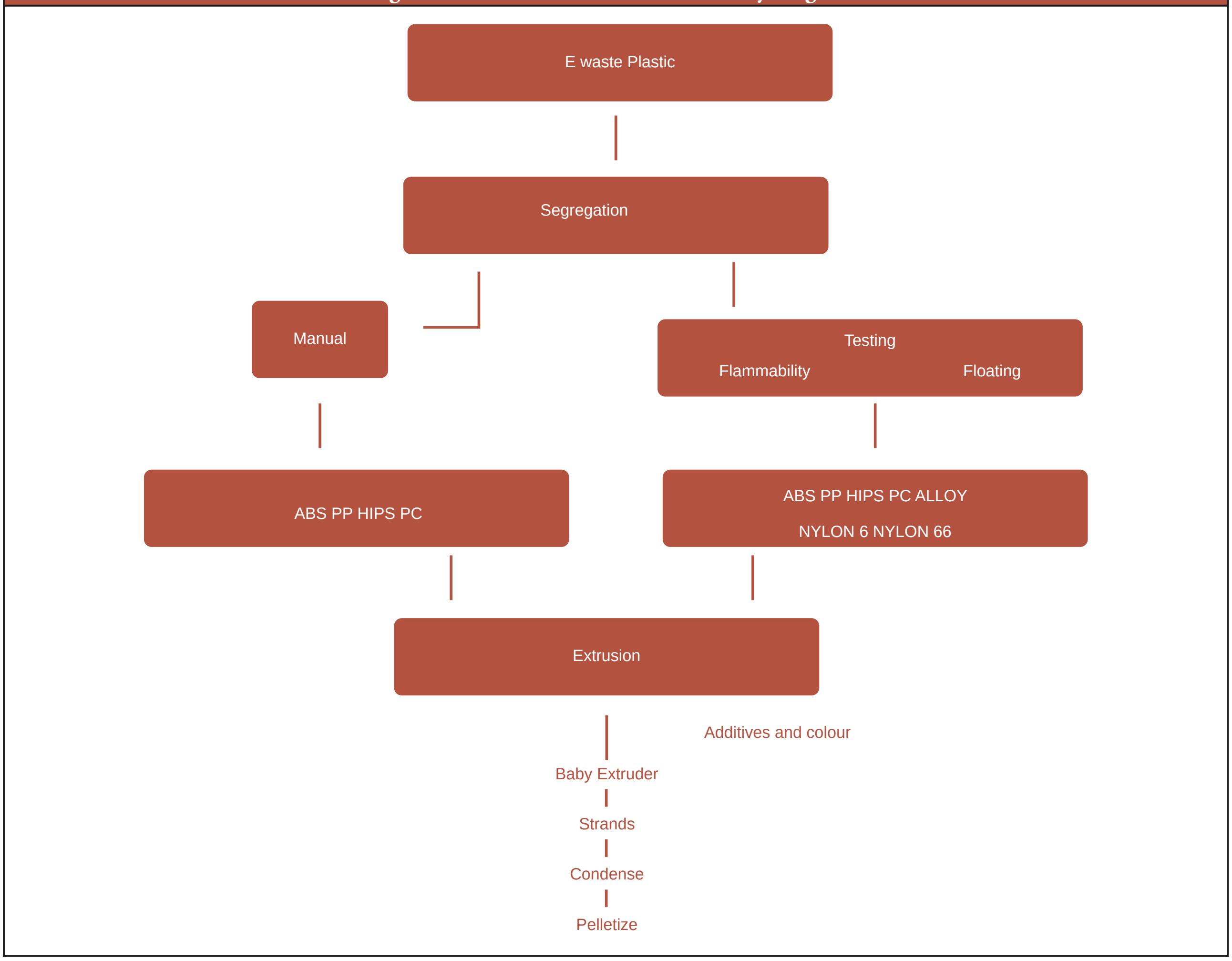
Market

The pellets are supplied to buckle manufacturing companies, wheel manufacturers and plastic compounders.

Non recyclables

Alloy material is very difficult to recycle. Those plastics which are not recyclable are sent for oil extraction.

Figure 20: Process flow in the formal recycling unit



4.11 Key Findings from the field study

- Plastic recycling is a big economic activity.
- Around1.5 lakh tons to WEEE plastic generated in India annually.
- Delhi is one of the largest recycling hubs.
- 8 ,000 tons WEEE plastic generated in Delhi, a lot more recycled in the city.
- Mainly recycled in the informal sector. 20,000-25000 work force directly engaged.
- No stringent separate flows for contaminated plastic.
- No health or environment norms in place.
- Non-recyclables are often burned for energy recovery.
- The recycling chain is contaminated with BFR and heavy metals (lead, cadmium, mercury and chromium) which have toxic properties.
- Field research suggests that there is dispersion and dilution of these additives.
- Current practices pose a challenge in terms of managing BFR plastic effectively.

5. Sampling and Analysis

5.1 Material & Methods

Plastic Sampling

The samples were randomly collected from the different areas of Delhi; from the recycling and plastic sorting units, pellet making and moulding units of Zilmil, Johripur, Narela, Vishwas Nagar, Karaval Nagar, Mundka and Bawana (**Figure 2**). Pellets readily available for sale at the main pellet market of Sadar Bazaar in Delhi were also collected to check for heavy metal and BFR concentration/contamination.

Sampling locations were determined and preferred on the basis of field survey (see chapter 4). Mainly the focus of sampling was to investigate and identify the possibility of cross contamination of the material supply chain with BFR .The field survey carried out for documenting the process of plastic recycling was a determining factor in identification of sampling spots. Samples were collected from both categories A (Key board and casings) & B (wires) categories are presented in section 4.5 and Fig 7, 8 & 9 . These spots are an important part of the recycling and molding process since the possibility of material, contamination is higher as documented in the field study. A total 53 samples were

Figure 21: Material flow for Plastic (ABS/HIPS/PC) recycling process

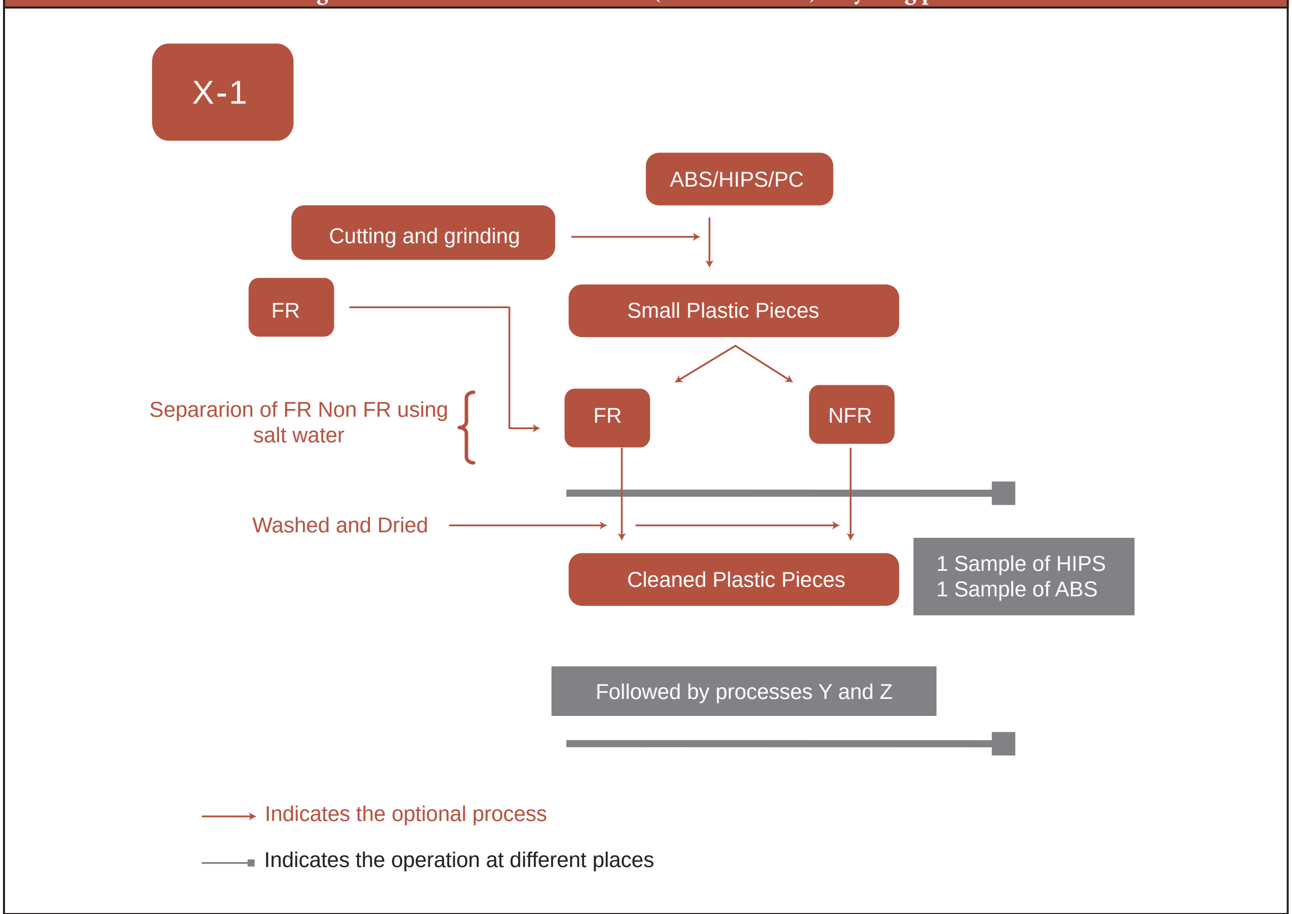
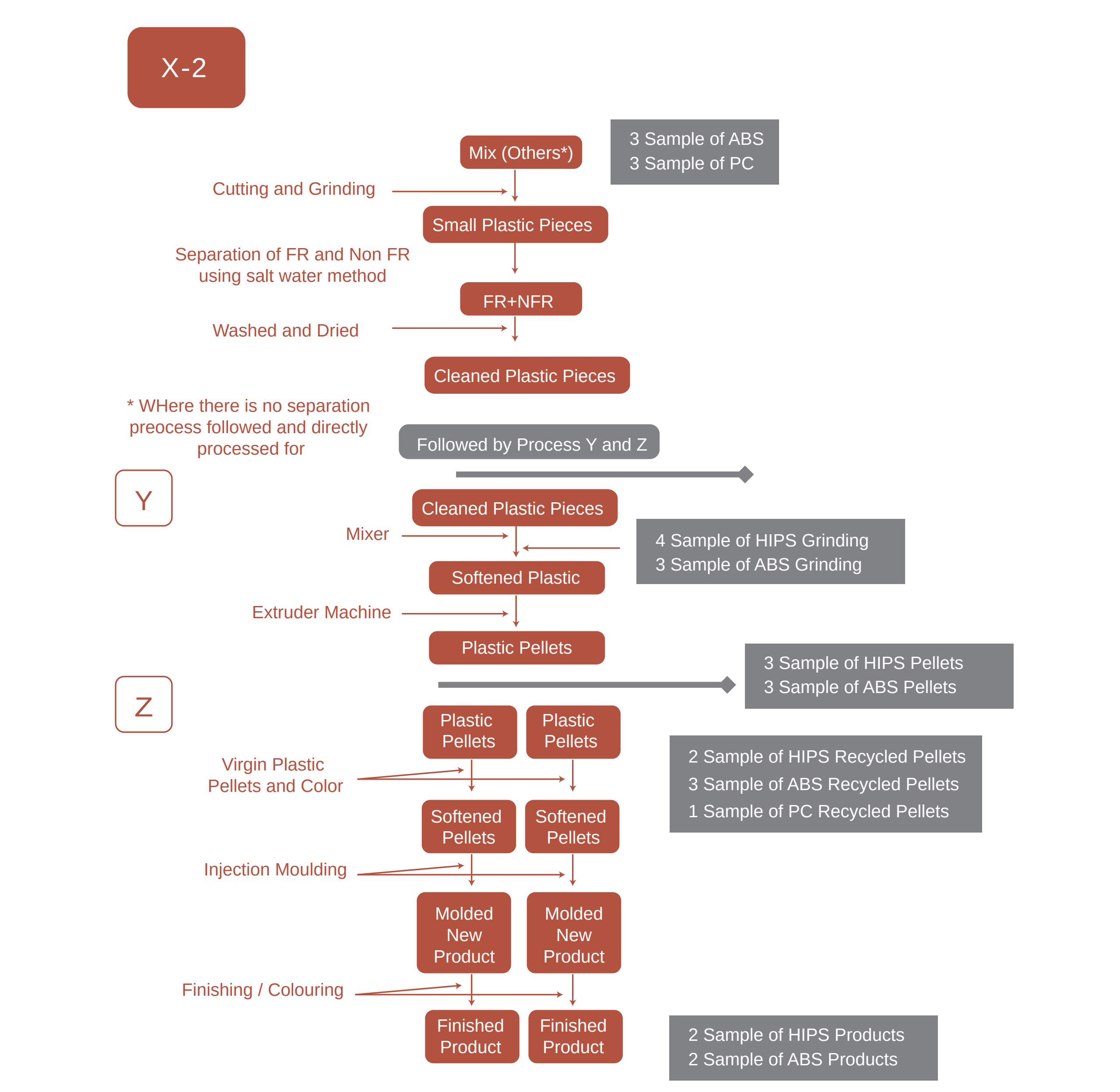


Figure 22: Material flow for Plastic (mixed) recycling process



collected from the study area, out of which only 44 samples (rest of the samples were duplicate) were sent to an accredited laboratory in Delhi to test for BFR (different congeners of PBDE and PBB) and heavy metal covered under RoHS using standard operating procedure i.e. IES 62321 (111/54/CDV). Details of sampling are presented in section 5.1. **(Figure 21, Figure 22 and Figure 23)**

5.2 Chemical Analysis

Sample Preparation

The samples to be analyzed must be of a uniform material, e.g. a polymer, a metal or electronics.

I. Manual Cutting

Manual cutting is suitable for rough cutting and preparation of samples for further reduction. Samples are precut to a size of no more than 2 × 10 × 10 cm^3.

a) Electronics: Samples are precut to a size of 4 x 4 cm^2 using heavy plate shears.

b) Polymers: Samples are precut to a size of 5 x 5 mm^2 using heavy plate shears or scissors.

Thin polymer foils are to be cut into small pieces with a shear.

II. Coarse grinding /milling

Coarse grinding is suitable for reduction of samples to ~ 1 mm in diameter. Cool the samples if needed with the liquid nitrogen.

III. Very Fine Grinding of Polymers and Organic Materials

This procedure is suitable for reduction of samples as small as 500 µm or less in diameter (not suitable for metal, glass, or similar hard-sharp materials). Approximately 3 g to 10 g of rough-cut (3 mm to 5 mm sections) of material to be ground is placed into the sample tube to about 2/3 to 3/4 full. Add the grinding rod and secure the ends of the vial.

Determination of PBB and PBDE in Polymers by GC-MS

I. Sample extraction

a) Quantitatively transfer approx. 100 mg +/- 10 mg of the sample into the extraction thimbles. Record the weight to the nearest 0.1 mg.

b) Depending on the type of polymer, different solvents should be used for extracting PBBs and PBDEs from polymers. If the nature of the polymer is unknown, Toluene should be used as a universal solvent. For specific polymers the following solvents should be used: ½ Toluene for ABS (Acrylonitrile Butadiene Styrene), HIPS (High Impact Polystyrene) and PC/ABS (Polycarbonate/ Acrylonitrile Butadiene Styrene) ½ Propanol for Polyamides and Polyesters ½ 5/25 Dichloromethane/ cyclohexane (B.P. 40 C/81 C) for Polyolefins

c) The sample is transferred through a funnel into the extraction thimble. In order to ensure a quantitative transfer, the funnel is rinsed with approx. 10 mL of solvent.

d) In order to prevent the sample from floating, the thimble is closed with glass wool. Approx. 60 mL of solvent is put in the 100 mL round-bottomed flask, the equipment is covered with aluminum foil to exclude light and the sample is extracted for about 16 hours in a Glass sohxlet apparatus.

e) The solvent extract is cooled and concentrated to 5 ml using rotary vacuum evaporator. Density of methanol and toluene can be neglected in this case in the calculation.

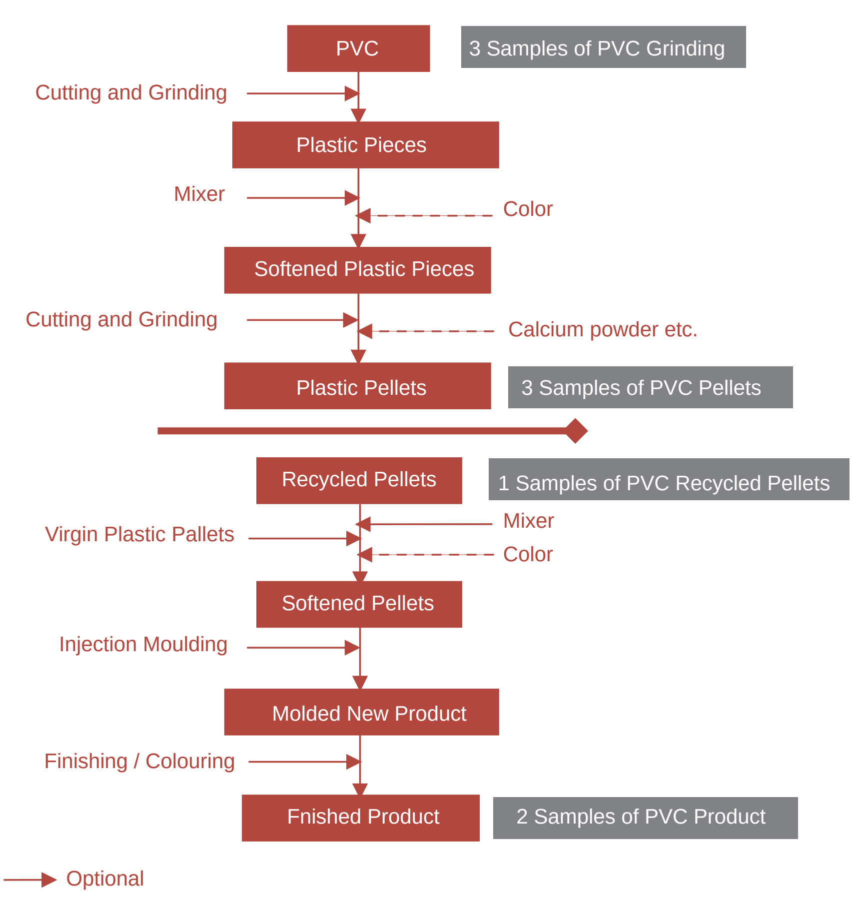
NOTE: If the solution exhibits turbidity due to the matrix, this can be reduced by adding 1 mL of methanol. The difference between the density of methanol and toluene can be neglected in this case in the calculation.

II. Filtration

Place 2-3 gm anhydrous sodium sulfate on glass wool in a glass funnel and wash it with 10-15 ml toluene.

Pass solvent concentrate to remove moisture and rinse the flask by toluene and adding it to the sodium sulfate, collecting dried solvent extract in to a clean & dry round bottom flask.

Figure 23: Material flow for Plastic (PVC) recycling process



Concentrate to 5 ml using rotary vacuum evaporator. Transfer extract into the 10ml volumetric flask and make up the final volume to 10ml using toluene.

III. GC-MS Analysis

The final extract is transferred into the glass vial. Inject 1 µL of the sample solution into the GC/MS, and analyze it. Peaks are identified on the basis of their retention time in the chromatogram and the MS spectra generated for the peak.

Different conditions might be necessary to optimize a specific GC-MS system to achieve effective separation of all calibration congeners and meet the QC and MDL requirements. The following parameters have been found suitable:

A) **GC column**: non-polar (phenyl-arylene-polymer equivalent to (5 % phenyl)-methylpolysiloxane), length 30 mt; internal diameter 0.25 mm; film thickness 0.25 µm

B) **Split/splitless Injector**: 280 °C, 1.0 µL splitless, 1 min splitless time.

C) **Carrier**: Helium, 1.0 mL/min, constant flow.

Oven: 110°C for 2 min., 40 °C/min ramp to 200 °C, 10 °C/min ramp to 260 °C, 20 °C/min ramp to 340° C for 2 min.

D) **Transfer line**: 300 °C.

E) **Ion source temperature**: 230 °C.

F) **Ionisation method**: Electron Ionization (EI), 70 eV.

The analysis of PBBs and PBDEs is carried out in SIM (Selected Ion Monitoring) Modus with the mass traces (the underlined mass traces have been used for quantification) given below.

Reference masses for the quantification of PBBs

Ions monitored in the extract

Mono-BB 231.9 233.9

Di-BB 309.8 311.8 313.8

Tri-BB 387.8 389.8 391.8

Tetra-BB 307.8 309.8 467.7

Penta-BB 385.7 387.7 545.6

Hexa-BB 465.6 467.6 627.5

Hepta-BB 543.6 545.6 705.4

Octa-BB 623.5 625.5 627.5

Nona-BB 701.4 703.4 705.4 (863.4)

Deca-BB 781.3 783.3 785.3 (943.1, 215.8, 382.6, 384.5)

( ): Optional ions; Bold: Quantification ions; Underlined: Identification ions.

Reference masses for the quantification of PBDEs

Ions monitored in the extract

Mono-BDE 247.9 249.9

Di-BDE 325.8 327.8 329.8

Tri-BDE 403.8 405.8 407.8

Tetra-BDE 323.8 325.8 483.7

Penta-PDE 401.7 403.7 561.6

Hexa-BDE 481.6 483.6 643.5

Hepta-BDE 559.6 561.6 721.4

Octa-BDE 639.5 641.5 643.5 (801.3)

Nona-BDE 717.4 719.4 721.4 (879.2)

Deca-BDE 797.3 799.3 799.3 (231.8, 398.6, 400.5, 959.1)

( ): Optional ions; Bold: Quantification ions; Underlined: Identification ions

Heavy Metals

I. Determination of Hexavalent Chromium (Cr VI) by Colorimetric Method in Polymers and Electronics

A) Extraction

Take about 5 g of sample and measure its weight accurately to 0.1 mg. Place the sample in a clean suitable digestion vessel. Alternative sample amounts may also be used for samples with potentially very low or very high Cr (VI) concentrations.

To each sample, add 50±1 mL of digestion solution measured with a graduated cylinder. Also add approximately 400 mg of $MgCl^2$ dissolved in 0.5 mL of 1.0Mol/L phosphate buffer to each sample.

It is optional to add $MgCl^2$ to the solution if the analytical techniques used can correct for the possible method induced oxidation/reduction of chromium. For polymer samples that appear to "float" on the surface of the digestion solution, 1-2 drops of a wetting agent (e.g. "Triton X") may be added at this time to increase the sample wetting during digestion. Cover all digestion vessels with watch glasses or plastic covers.

Stir while heating the samples continuously to 90-95 °C, and then maintain the samples at 90- 95 °C for at least 60 minutes with constant stirring.

B) Filtration

Gradually cool each solution to room temperature with continued agitation. Transfer the contents quantitatively to the filtration apparatus; rinsing the digestion vessel with three successive portions of DI water. Transfer the rinsates to the filtration apparatus. Filter through a 0.45 µm membrane filter. If the filter becomes clogged using the 0.45 µm membrane filter, a large pore size filter paper (Whatman GFB or GFF) may be used to prefilter the samples. Rinse the inside of the filter flask and filter pad with DI water and transfer the filtrate and the rinses to a clean 250 mL vessel. Keep the filtered solid on filter membranes for possible use in assessing low Cr (VI) matrix spike recoveries. Store the filtered solid at 4 ± 2 °C.

With constant stirring while monitoring the pH, slowly add concentrated nitric acid solution to the 250 mL vessel drop wise. Adjust the pH of the solution to 7.5±0.5.

Remove the stirring device and rinse, collecting the rinsate in the beaker. Transfer quantitatively the contents of the vessel to a 100 mL volumetric flask and adjust the sample volume to 100 mL with DI water. Mix well. The sample digestates are now ready to be analyzed.

C) Color development and measurement

a) Transfer 95 mL of the digestate to be tested to a clean 100 mL vessel. Add 2.0 mL diphenylcarbazide solution and mix. Slowly add H_2SO_4 solution to the vessel and adjust the pH of the solution to 2±0.5. Transfer quantitatively the contents of the vessel to a 100 mL volumetric flask and adjust the sample volume to 100 mL with DI water. Let stand 5 to 10 minutes for full color development.

b) Transfer an appropriate portion of the solution to a 1 cm absorption cell and measure its absorbance at 540 nm with a colorimetric instrument.

c) Correct the absorbance reading of the sample by subtracting the absorbance of a blank carried through the color development procedures.

d) From the corrected absorbance, determine the mg/L of Cr (VI) present by reference to the calibration curve.

e) Construct a calibration curve by plotting corrected absorbance values against µg/mL of Cr (VI). Either linear regression or quadratic fitting can be applied to establish a calibration curve. The correlation coefficient (R2) of the curve shall be larger than 0.99, or a new calibration curve should be built.

II. Determination of Mercury in Polymers, Metals and Electronics by CV-AAS, AFS, ICP-OES, and ICP-MS

A) Wet Digestion (Digestion of metal materials and electronics)

Wet digestion is recommended for the digestion of metal materials and electronics, exempting metal materials containing significant amounts of silica (Si), zirconium (Zr), hafnium (Hf), titanium (Ti), tantalum (Ta), niobium (Nb) or tungsten (W). For these materials and for plastics, a microwave digestion is recommended.

a) Approximately 1 g sample is weighed into the reaction vessel and 30 mL conc. HNO_3 is added. The vessel is furnished with a reflux cooler and an absorption vessel (on the top of the reflux cooler) containing 10 mL 0.5 Mol/L HNO_3, before a temperature program is started to digest the samples for 1h at room temperature and for 2h at 90 °C. After cooling to room temperature, the content of the absorption tube is put into the reaction vessel and the obtained solution is transferred into a 250 mL volumetric flask and filled up with 5 % (m/m) HNO_3 to the mark (if the sample is digested completely).

b) For ICP-OES and ICP-MS measurements the obtained sample solution may be diluted with water to the appropriate concentration levels.

c) If the sample is not digested completely (e.g. printed wiring boards), the sample is filtered over a 0.45 µm filter and the solid residue is washed four times with 15 mL 5 % (m/m) HNO_3. The obtained solution is transferred into a 250 mL volumetric flask and filled up with 5 % (m/m) HNO_3 to the mark.

d) If there are sample remnants on the filter, they shall be weighed to determine if they represent a significant fraction of the mass of the original sample. If so, they shall be tested for the presence of the analyte.

NOTE: It may be possible to measure the remnants using X-ray fluorescence spectrometry, if the detection limit is sufficiently low.

B) Microwave digestion

A microwave digestion is recommended for the following materials:

=> Metals containing significant amounts of silica (Si), zirconium (Zr), hafnium (Hf), titanium

(Ti), tantalum (Ta), niobium (Nb) or tungsten (W)

=> Polymers

=> In cases, where the available sample amount is smaller than 0.5 g

NOTE 1: It is highly recommended to weigh in same sample amounts and same type of samples in one digestion run.

NOTE 2: Hg may be determined in the same solution with Pb and Cd obtained by closed system for acid decomposition.

a) About 100 mg of the material are weighed into a PTFE-TFM or PFA-TFM vessel. 5 mL of conc. HNO3, 1.5 mL 50 % (m/v) HBF4 solution, 1.5 mL 30 % (m/m) H2O2 and 1mL water is added. The vessel is closed and the sample is then digested in the microwave oven following a digestion program specified in advance. An example for a suitable microwave program is given in the annex.

b) After cooling the vessel to room temperature (approximately required time: 1 h), it is opened and the solution is filtered over a glass microfiber filter (0.45 μm) into a 25 mL flask, washed and filled up to the mark with distilled water.

c) If there are sample remnants on the filter, they are weighed to determine if they represent a significant fraction of the mass of the original sample. If so, they are be tested for the presence of the analyte.

NOTE: It may be possible to measure the remnants using X-ray fluorescence spectrometry, if the detection limit is sufficiently low.

C) Standard preparation / Stock solution preparation

ICP-OES

Standard solution: Take 1 mL of mercury standard solution, (corresponding to 1000 μg Hg) into a 100 mL volumetric flask; add 1 - 2 drops of potassium permanganate (5 % (m/v) KMnO4) and fill up to the mark.

NOTE 2: 1 % (m/v) Au solution can also be used instead of potassium permanganate.

Sample Analysis

Analyze the method blank, samples solutions and spiked samples solution. Every sample should be determined twice and the relative standard deviation should be no more than 5 % and the recovery of spiked samples should be between 95 % and 105 %.

If the sample solution concentration does not fall within the range of the calibration standards, prepare a serial sample dilution or additional standards to bracket the sample concentration.

NOTE: For CV-AAS measurements the standard or digestion solution is to be transferred into the hydride system beaker. The measurement is conducted using the instrument manufacturer's instructions. For measurements with ICP-OES, ICP-MS or AFS, the digestion solution can be determined directly.

CV-AAS

100 μL of the sample solution is given to 10mL 1.5 % (m/m) HNO_3 and the measurement is done.

III. Determination of Lead and Cadmium in Polymers by ICP-OES, ICP-MS, and AAS

A) Dry ashing method

a) When the sample does not contain halogen compounds (information may be available from previous screenings)

   The sample is measured into a crucible mounted in the hole in the heat resistant thermal insulation board. The crucible is then heated gently with the burner in a hood for proper ventilation, taking care that the sample is not ignited. When the sample has decomposed to a charred mass, heating is gradually increased until the volatile decomposition products have been substantially expelled and a dry carbonaceous residue remains. The crucible and its contents are then transferred to the muffle furnace at 450 ± 25 °C, with the door left slightly open to provide sufficient air to oxidize the carbon. Heating is continued until the carbon is completely oxidized and a clean ash is obtained. The crucible and its contents are then removed from the furnace and allowed to cool to an ambient temperature. 5 mL of nitric acid are added, and the resulting solution is transferred to a 50 mL volumetric flask and filled with water up to 50mL. The resulting solution is the concentrate sample solution. The concentrate sample solution may be diluted with water to the appropriate concentration level for each measurement apparatus. If an internal standard is to be used, it has to be added before filling up: for a final volume of 50 mL, internal standard of 500 μL for ICP-OES, and 500 μL for ICP-MS, respectively, has to be added before filling up.

b) When the sample contains significant amounts of halogen compounds (information may be available from previous screening experiments)

   The sample is measured into a crucible. 10 to 15 mL of sulfuric acid is added, and the crucible and its contents are heated slowly on a hot plate or sand bath until the plastic melts and blackens. 5 mL of nitric acid are then added, and heating is continued until the plastic degrades completely and white fumes are generated. c) After cooling, the crucible is placed in a muffle furnace maintained at 450 ± 25 °C and the sample is evaporated, dried, and ashed until the carbon has been completely incinerated. After ashing, 5 mL of nitric acid are added, and the resulting solution is transferred to a 50 mL volumetric flask and filled up with water to 50 mL. The resulting solution is the concentrate sample solution. The concentrate sample solution may be diluted with water to the appropriate concentration level for each measurement apparatus. If an internal standard is to be used it has to be added before filling up: for a final volume of 50 mL.

c) If there are sample remnants, they are separated by a centrifuge or a filter. The residues have to be checked by appropriate measurements (e.g. XRF) in order to confirm the absence of the target elements.

NOTE: This method does not apply for fluorocarbons.

B) Preparation of laboratory reagent blank

Procedure identical to sample preparation is executed concurrently without sample.

C) Measurement of sample

After development of the calibration curve, the laboratory reagent blank and the sample solution are measured.

If the sample concentration is above the range of the concentration curve, the solution shall be diluted to the range of the calibration curve ensuring an appropriate acidification of the calibration standards and measured once again.

Measurement precision is checked with standard substance, calibration solution, etc., in regular intervals (such as once every 10 samples). If necessary, a calibration curve is developed again.

NOTE: If sample is diluted to the range of calibration, it has to be assured, that the internal standard concentration in the diluted sample solution is adjusted to the standard solution.

5.3 Results

The data related to total concentrations of heavy metal and Brominated flame-retardants found in the different samples are presented in **Table 9** and **Table 10** respectively.

Table 9: Total BFR concentrations in plastic samples

SN	Sample Number	Sample Location	Chain	BFR	Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total BFR concentration in Plastic
1	1	-	PVC grinding (wires)	PBBs	-	-	-	-	24.4	-	-	-	-	-	24.4
				PBDEs	-	-	-	-	-	18.9	-	-	-	-	18.9
2	2	-	PVC pellets	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
3	8	-	PVC grinding (Plug)	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
4	9	-	PVC Pellets	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
5	23	-	PVC Grinding	PBBs	-	-	-	-	25.1	-	-	-	-	-	25.1
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
6	24	-	PVC Pellets	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
7	25	-	PVC Product (Chappal)	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
8	37	-	PVC+PP, Fresh Pellets (for speaker cover)	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
9	38	-	PVC+PP, product (speaker cover)	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
10	6	Z	HIPS Recycled Pellets	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
11	7	Z	HIPS Product (Radio)	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
12	10	Y	HIPS grinding (mixed) Came from Bhopura	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	31.6	-	-	-	31.6

13	11	Y	HIPS pellets	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	18.2	12.3	-	-	-	30.5
14	28	Y	HIPS Grinding	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
15	29	Y	HIPS Pellets	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
16	36	X-1	HIPS Grinding - After salt separation	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
17	41	Y	HIPS Grinding (Mixed)	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	23.6	-	-	-	23.6
18	42	Y	HIPS Pellets from mixed grinding	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
19	45	Z	HIPS Pellets for radio cabinet	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
20	46	Z	HIPS Product Radio cabinet	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	21.4	-	-	44.2	46.7	112.3
21	47	Y	HIPS black colored grinding	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	18.9	-	-	-	18.9
22	12	Y	ABS grinding (Computer Cabinet) white colored-No salt water separation	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	35.8	35.8
23	13	Y	ABS Pellets (Near to grinding plant) white colored-No salt water Separation	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
24	14	X-2	ABS Waste (Mobile)	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	14.3	24.7	-	-	-	39.0
25	15	X-2	ABS+PC waste (Mobile)	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
26	30	Z	ABS Moulding Pellets	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
27	31	Z	ABS Product (Mudguard)	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
28	18	X-2	ABS Waste (Charger)	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
29	26	Y	ABS grinding waste (mix of A/C, battery)	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	42.9	-	-	-	-	42.9
30	27	Y	ABS Pellets	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
31	35	X-1	ABS Grinding After salt separation	PBBs	-	-	-	98.5	-	-	-	-	-	-	98.5
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
32	48	Z	ABS Pellets Black for mixer part	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	36.2	-	40.3	49.8	126.3
33	49	Z	ABS Product (Mixer Part)	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	33.2	47.4	-	-	-	80.6
34	22	Y	ABS+PC Mix (D) Grinded	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
35	33	Y	ABS+PC Mix (D) Pellets	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	32.68	-	-	-	32.68
36	16	X-2	PC+ABS waste(Mobile)	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-

37	17	X-2	PC waste(Mobile)	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
38	21	X-2	PC waste(Charger)	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
39	34	Z	PC Pellets Recycled (called natural due to cleaned a- transparent appearance)	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
40	32	-	Piccus	PBBs	-	-	-	-	29.7	-	-	-	-	-	29.7
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
41	50	-	ABS Pellets from the Sadar Bazar	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	-	-	-	-	-	-
42	51	-	ABS Pellets from the Sadar Bazar	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	24.5	31.4	-	-	-	55.9
43	52	-	HIPS Pellets from Sadar Bazar - Off white	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	27.8	38.9	-	-	-	66.7
44	53	-	ABS Pellets from the Sadar Market - Green Colored	PBBs	-	-	-	-	-	-	-	-	-	-	-
				PBDEs	-	-	-	-	-	20.7	27.4	-	-	-	48.4

BFR and its congeners in plastic

Among all 44 plastic samples, 41% (18 samples) samples were found positive for BFR. The observed concentration of BFR varied from 18.9 ppm to 126.3 ppm. The minimum detectable level (MDL) of the instrument is 10 ppm. The average BFR content of all the samples is 10.7 ppm + 25.7

BFR in PVC plastic – A total of 9 samples of PVC plastic were analyzed but only two samples (sample number 1 and 23) contained BFR. The concentration varied from 43.3 ppm to 25.1 ppm. These samples were collected from the grinding units of Zilmil and Narela respectively. (**Figure 24**)

BFR in HIPS plastic- A total of 12 samples were analyzed to check BFR concentration. Out of which 5 (42%) samples were found to contain BFR. It varied from 18.9 ppm to 112.3 ppm. The lowest BFR concentration was observed in sample number 47, which was collected from the grinding unit of Karaval Nagar and the highest BFR concentration was observed from sample number 46, which was collected from the moulding unit of Karaval Nagar. (**Figure 25**)

BFR in ABS plastic –A total of14 samples were analyzed to check BFR concentration. Out of which 7 (50%) samples were found to contain BFR. It varied from 32.68 ppm to 126.3 ppm. The lowest concentration of BFR was observed in sample number 33, which was collected from a grinding unit in Mundka and the highest concentration of BFR was observed in sample number 48, which was collected from the grinding unit of Karaval Nagar. The sample collected from Narela grinding unit was processed through salt separation method to segregate BFR laden plastic but the lab result did suggest the presence of 98.5 ppm of BFR (**Figure 26**). This result indicated the gaps in the separation of BFR plastics through salt water separation.

BFR in PC plastic – None of the samples of PC plastic was found above MDL.

BFR in Market pellets - Four samples (ABS-white, ABS-black, HIPS and ABS-green) were collected from the Sadar Bazaar. Out of which ABS-black, HIPS and ABS-green found 55.9 ppm, 66.7 ppm and 48.4 ppm of BFR respectively. ABS-white pellets were not found above MDL. (**Figure 27**)

Figure 24: Concentration of BFR in PVC

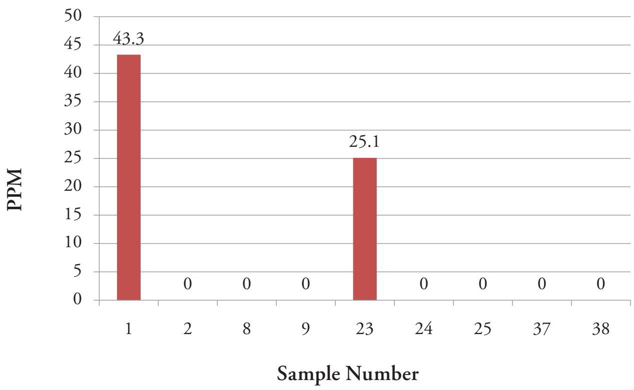


Figure 25: Concentration of BFR in HIPS

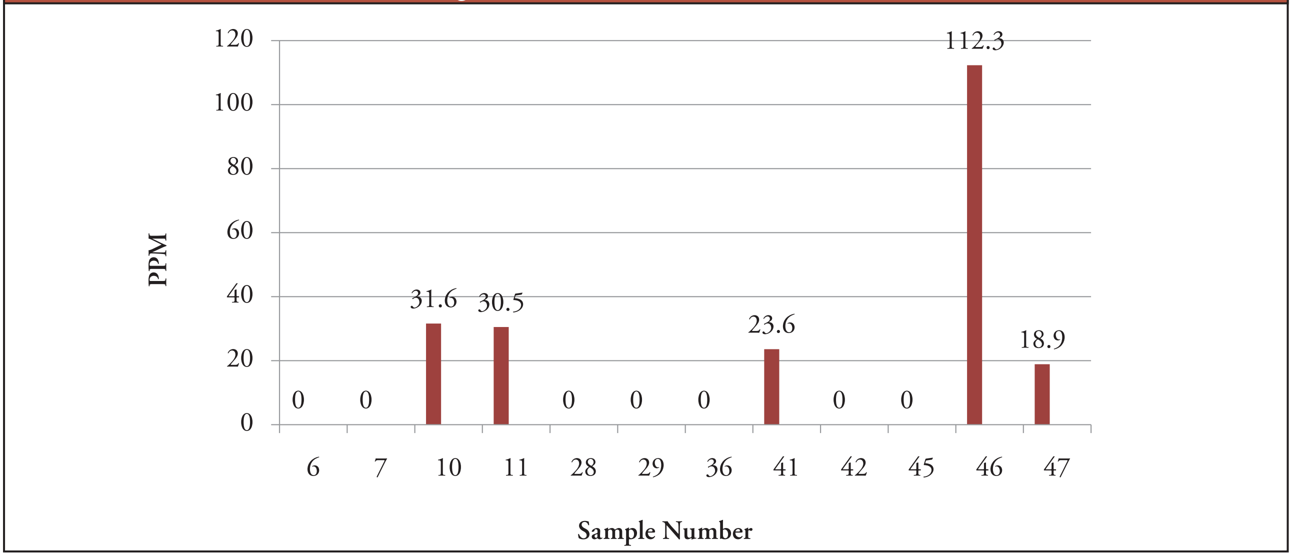


Figure 26: Concentration of BFR in ABS

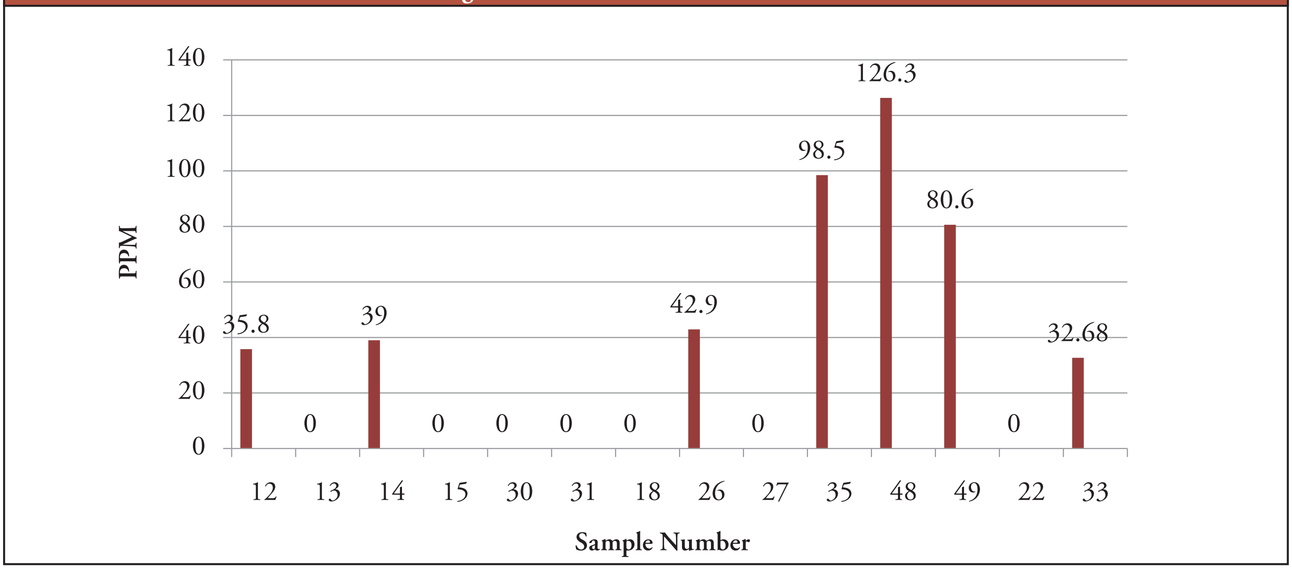
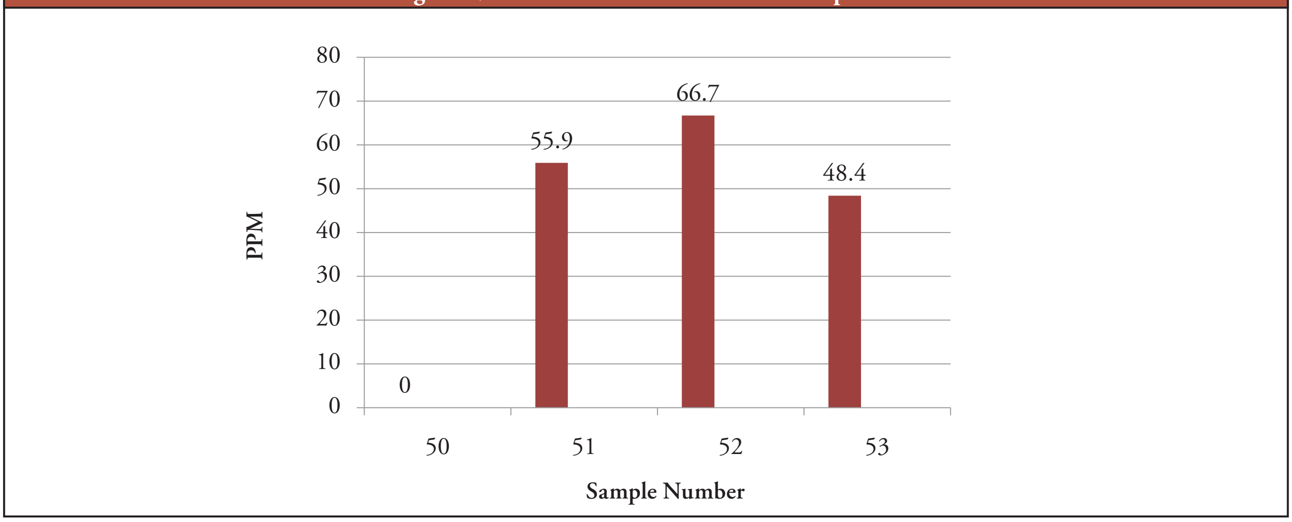


Figure 27: Concentration of BFR in market pellets



PBB's and PBDE's in Plastic – Out of all sample only four samples were found positive for PBB's, these are sample number 1, 23, 35 and 32 and the PBB's observed concentration was 24.4, 25.1, 98.5 and 29.7 respectively. Likewise 15 samples were found positive for PBDE's, the concentration of PBDE's varied from 18.9 ppm to 126.3 ppm (**Figure 28** and **Figure 29**). From the analysis it was also observed that, only one sample was positive for Tetra Brominated Biphenyls was present in one sample and Penta Brominated Biphenyls in 3 sample. On the other hand 9 Hexa Brominated Diphenyl Ether was observed in a samples where as Hepta Brominated Diphenyl Ether in 11 samples. Nona Brominated Diphenyl Ether and Deca Brominated Diphenyl Ether were observed in 2 and 3 samples respectively (**Figure 30**).

Figure 28: Concentration of PBB's in different sample

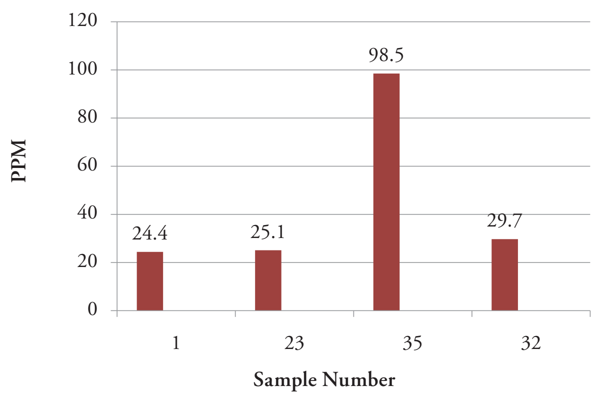


Figure 29: Concentration of PBDE's in different sample

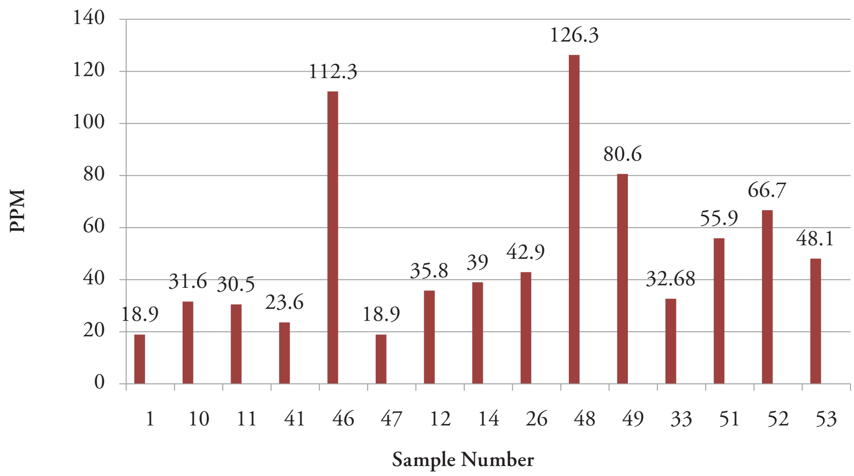
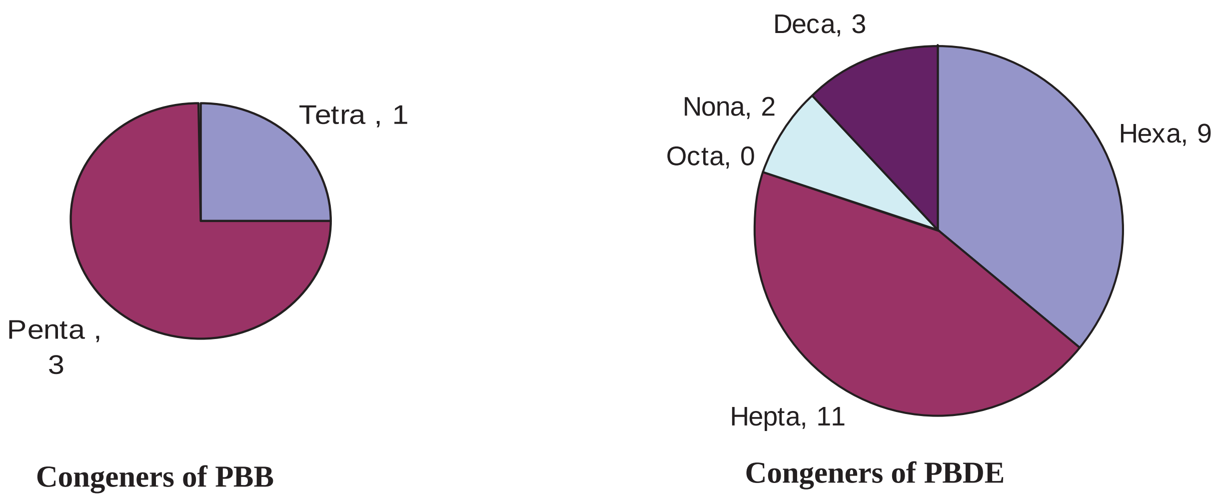


Figure 30: Observed congeners in PBB and PBDE



BFR concentration found along the recycling chain

a) Grinding – A total of 12 samples were collected from the grinding process out of which 8 (76%) samples were observed positive for BFR and the observed range varied from 18.9 ppm to 98.5 ppm. (**Figure 31**)

b) Pellets – A total of 19 samples were collected, out of which 15 samples were collected from the grinding and moulding unit and 4 random samples were collected from market (Sadar Bazaar). Out of the 19 samples only 6 samples (3 from grinding and moulding and 3 from market) were observed positive for BFR. (**Figure 32** and **Figure 34**)

c) Product –A total of 6 samples of different products were collected from different units, out of which only 2 (33%) samples were found positive for BFR. (**Figure 33**) The observed range varied from 80.6 ppm to 112.3 ppm.

Figure 31: BFR concentration in grinded material

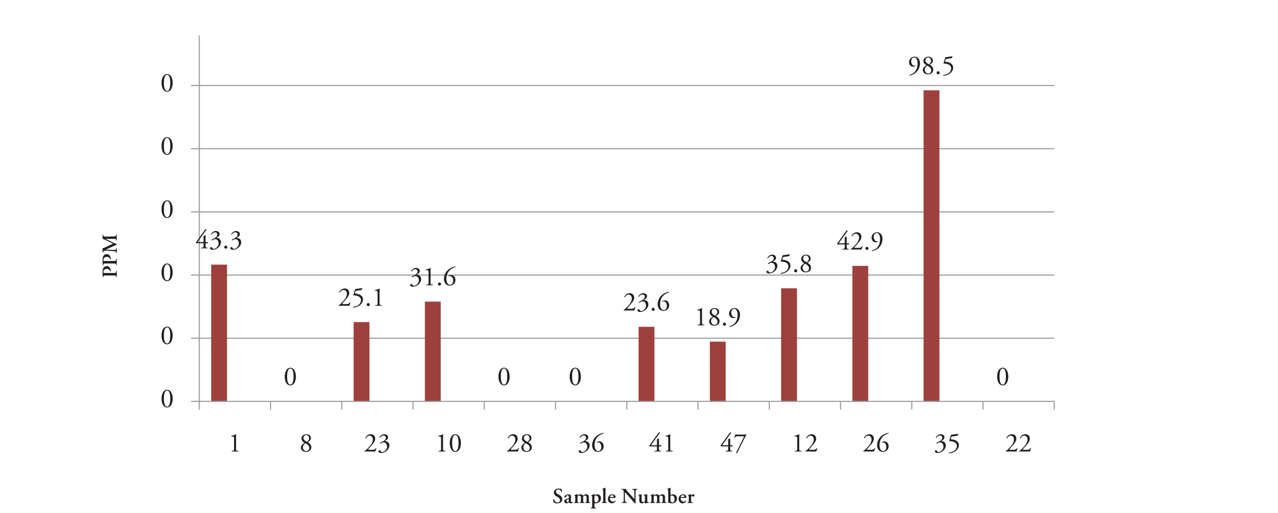


Figure 32: BFR concentration in pellets

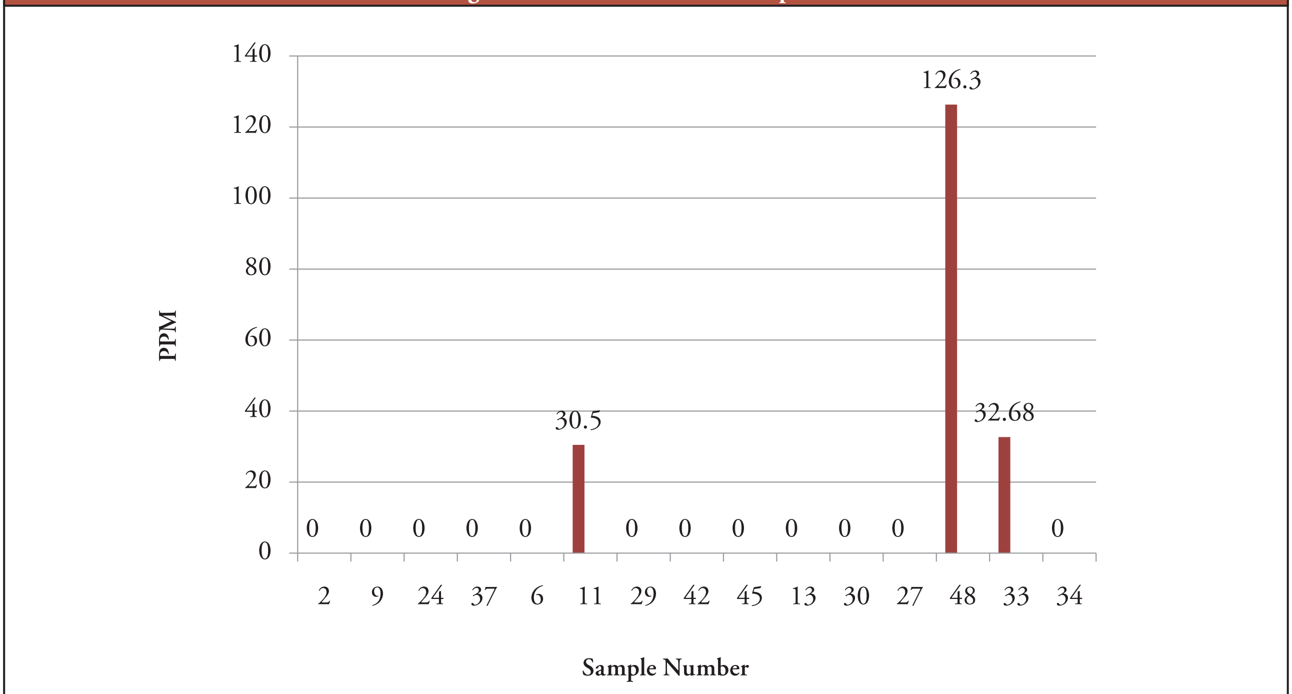


Figure 33: BFR concentration in product made from recycled pellets

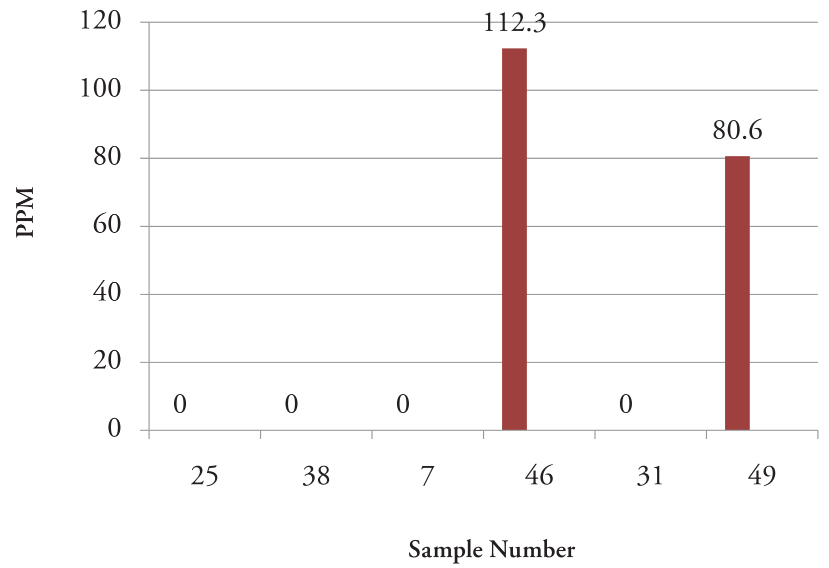
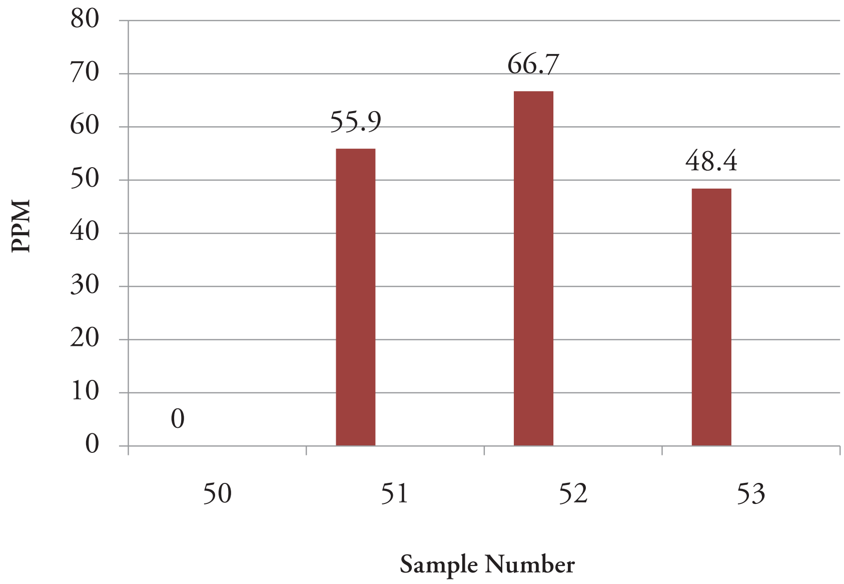


Figure 34: BFR concentration in pellets available in market



Possible losses and variation in BFR concentration in the recycling and molding process

In the present study samples were collected from different recycling and moulding units of the Delhi area. Samples were taken along the recycling chain from waste material to new products made out of secondary plastics in order to identify a possible evolutional change in BFR concentrations along with all processes. This includes collecting samples from grinding material and pellets retrieved from recycling units, as well as pellets and final products retrieved from moulding units. From the results it could be observed that in some cases there is a variation in BFR concentration, which is discussed bellow.

In ABS plastic resins, samples of grinded plastic were found to contain up to 43.3 ppm of total BFR concentration. However pellets made from the same plastic when tested for BFR, but did not reflect presence of BFR. (**Figure 35A**) Likewise in other units in Narela (recycling and moulding at same unit) BFR concentration was found at 25.1 ppm in grinded plastic, but the analysis of pellets and products thereof did not indicate any BFR content. (**Figure 35B**) This indicates a possible loss of BFR content from plastics during the process.

In HIPS plastic resins used in a moulding process not much difference in BFR concentrations were found between pellets and product (31.6 ppm and 30.5 ppm respectively) (**Figure 36C**). In a grinding unit of Johripur, grinded material did not contain any BFR but its pellets contained 23.6 ppm of BFR. (**Figure 36D**) Likewise in a moulding unit of Karaval Nagar BFR was not detected in the pellets, while its product contained 112.3 ppm of BFR. (**Figure 36E**)

In ABS plastic resins samples of grinded material collected from Karaval Nagar found 35.8 ppm of BFR but in pellets collected from same unit BFRs were not detected. (**Figure 37F**) In another grinding unit of Narela, BFR concentrations in grinded material were detected at 42.9 ppm; however pellets from same did not contain any BFR. A very surprising thing is that although the grinded sample were separated using the salt separation method from BFR containing plastic BFRs were still detected (**Figure 37G**). In a moulding unit of Karaval Nagar little variation in BFR concentration was found between pellets and product (126.3 ppm of BFR in pellets and 80.6 ppm of BFR in products, respectively). (**Figure 37H**). In another grinding unit of Mundka grinded material did not contain any BFR but pellets in the same unit were measured at 80.6 ppm of BFR. (**Figure 37I**)

Explanations for the above observations may include: a). Processes run at high temperature for the production of pellets and final products might lead to transformation of BFRs into other substances and as a consequence to a decrease of BFR concentrations. b). Laboratory analysis were done with a detection limit of 10 ppm, hence BFR concentrations below that level are not considered in our results. c) As the sampling campaign was of an indicative nature, homogenous and representative could not be achieved. Hence variation in BFR concentrations might also be due to the heterogonous nature of the sampling material.

Figure 35: Variation of BFR concentration in Recycling and moulding process in PVC

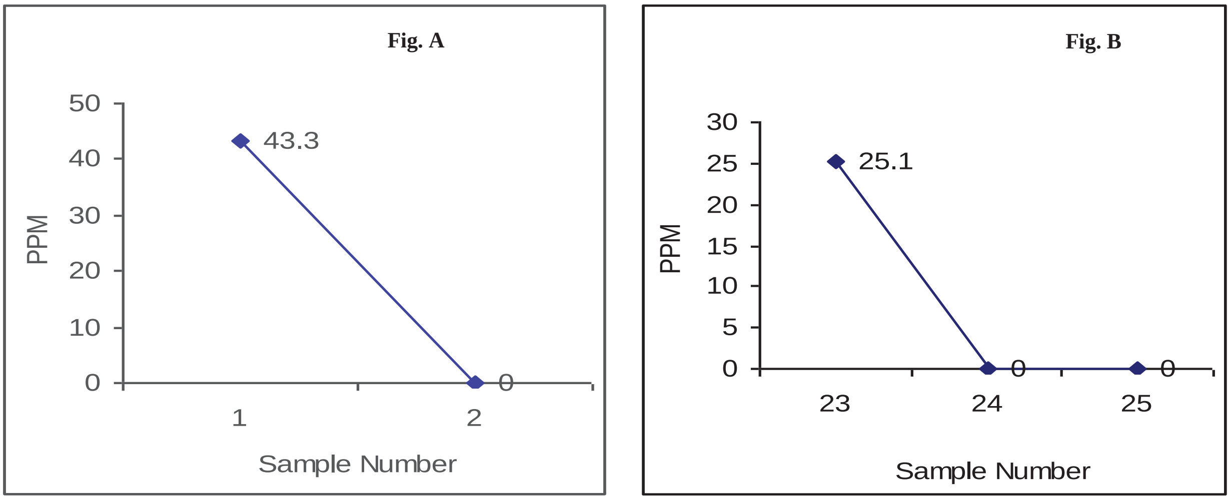


Figure 36: Variation in Recycling and moulding process in HIPS

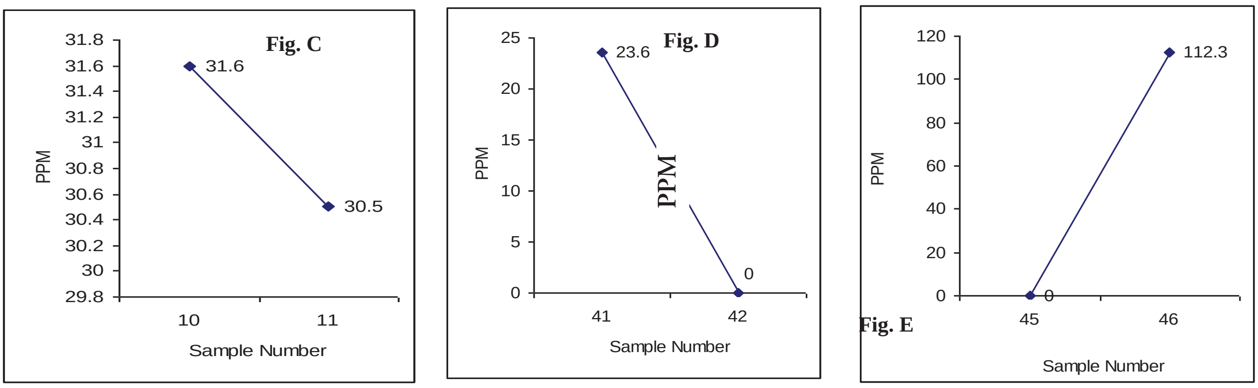


Figure 37: Variation in Recycling and moulding process in ABS

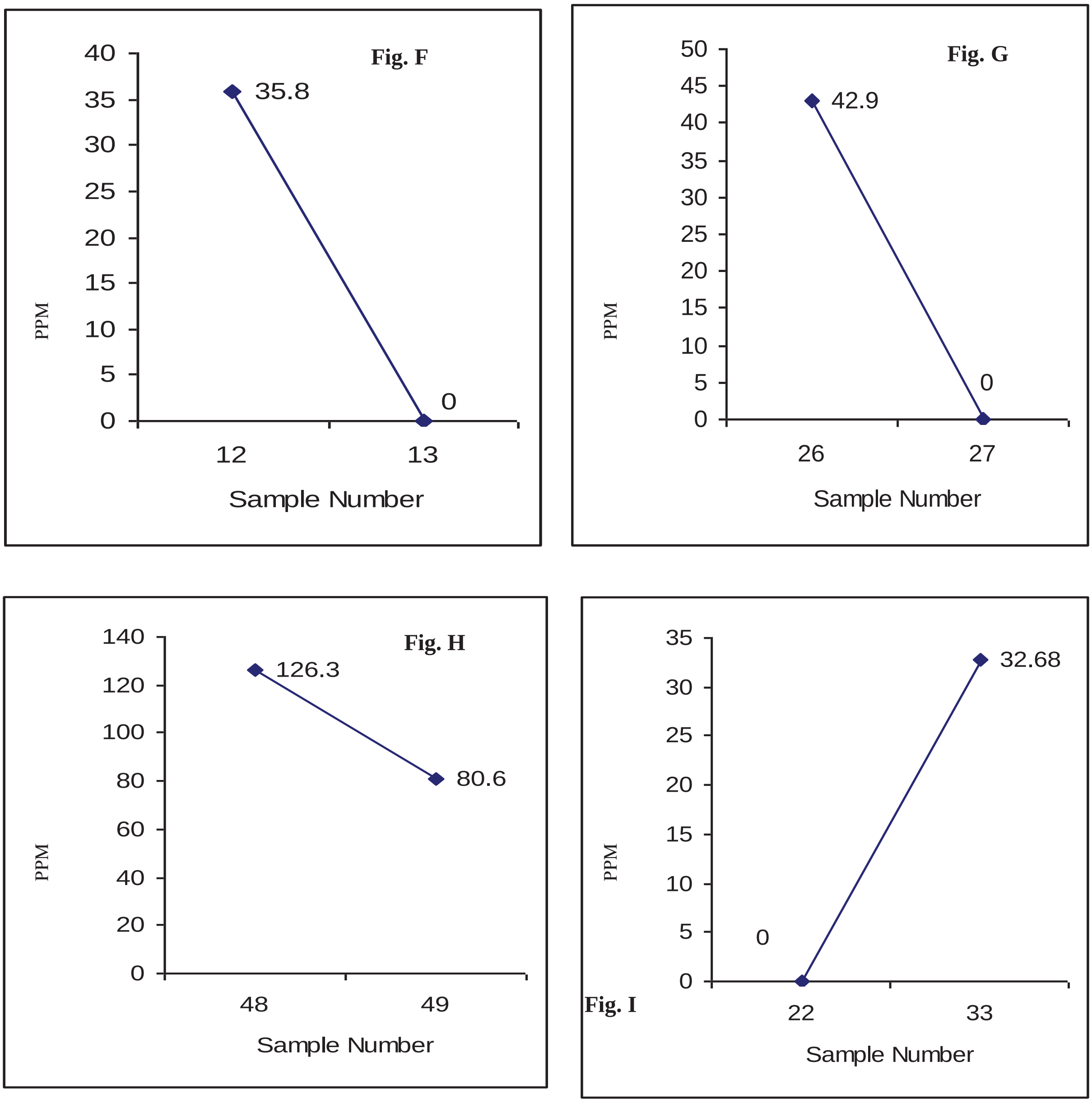


Table 10: Heavy metal in the samples

Sample Number	Chain	Pb (ppm)	Cd (ppm)	Hg (ppm)	Hex Cr (ppm)
1	PVC grinding (wires)	1319.0	28.0	<1.0	<1.0
2	PVC pellets from grinded wires	4309.0	18.0	<1.0	<1.0
8	PVC grinding (plug)	7.0	11.0	<1.0	<1.0
9	PVC pellets from grinded plugs	2778.0	20.0	<1.0	<1.0
23	PVC grinded material	482.0	18.0	<1.0	<1.0
24	PVC Pellets from grinded material	881.0	26.0	<1.0	<1.0
25	PVC product (Chappal/Shoe)	514.0	31.0	<1.0	<1.0
37	PVC+PP, fresh pellets (for speaker cover)	20.0	4.0	<1.0	<1.0
38	PVC+PP, product (speaker cover)	22.0	6.0	<1.0	<1.0
6	HIPS recycled pellets	48.0	25.0	<1.0	<1.0
7	HIPS product (Radio)	52.0	21.0	<1.0	<1.0
10	HIPS grinding (mixed) received from Bhopura grinding unit	441.0	35.0	<1.0	<1.0
11	HIPS pellets	47.0	12.0	<1.0	<1.0
28	HIPS grinded material	9.0	25.0	<1.0	<1.0

29	HIPS pellets from grinded material	6.0	16.0	<1.0	<1.0
36	HIPS grinded material - After salt separation	73.0	19.0	<1.0	<1.0
41	HIPS grinded material (Mixed plastic)	39.0	7.0	<1.0	<1.0
42	HIPS pellets from mixed grinded material	84.0	27.0	<1.0	<1.0
45	HIPS pellets for radio cabinet	66.0	22.0	<1.0	<1.0
46	HIPS product (Radio cabinet)	84.0	31.0	<1.0	<1.0
47	HIPS black colored grinded material	23.0	5.0	<1.0	<1.0
12	ABS grinded material (Computer cabinet) white colored-No salt water separation	25.0	5.0	<1.0	<1.0
13	ABS pellets (Near to grinding plant) white colored-No salt water Separation	20.0	9.0	<1.0	<1.0
14	ABS waste (Mobile covers)	7.0	21.0	<1.0	<1.0
15	ABS+PC waste (Mobile covers)	8.0	15.0	<1.0	<1.0
30	ABS moulding pellets	73.0	19.0	<1.0	<1.0
31	ABS product (Mudguard)	109.0	15.0	<1.0	<1.0
18	ABS waste(Charger covers)	6.0	15.0	<1.0	<1.0
26	ABS grinding waste (mix of A/C, battery)	293.0	40.0	<1.0	<1.0
27	ABS pellets	74.0	21.0	<1.0	<1.0
35	ABS grinded material - After salt separation	79.0	44.0	<1.0	<1.0
48	ABS pellets black for mixer part	87.0	19.0	<1.0	<1.0
49	ABS Product (Mixer part)	74.0	13.0	<1.0	<1.0
22	ABS+PC mix grinded material	7.0	15.0	<1.0	<1.0
33	ABS+PC mix pellets	60.0	5.0	<1.0	<1.0
16	PC+ABS waste(Mobile covers)	21.0	14.0	<1.0	<1.0
17	PC waste(Mobile covers)	20.0	21.0	<1.0	<1.0
21	PC waste(Charger covers)	8.0	20.0	<1.0	<1.0
34	PC recycled pellets (called natural due to cleaned and transparent appearance)	14.0	3.0	<1.0	<1.0
32	Piccus	177.0	23.0	<1.0	<1.0
50	ABS pellets purchased from the Sadar bazar	40.0	22.0	<1.0	<1.0
51	ABS pellets purchased from the Sadabazar	51.0	33.0	<1.0	<1.0
52	HIPS pellets purchased from Sadar bazar - Off white	122.0	88.0	<1.0	<1.0
53	ABS pellets purchased from the Sadar bazar - Green Colored	39.0	25.0	<1.0	<1.0

Heavy metal in Plastic

In the present study only lead and cadmium were found in all type of samples in varying concentration (6.0 ppm to 4309.0 ppm and 3.0 ppm to 88.0 ppm respectively) and mercury and hexavalent chromium were found below detectable level (1.0 ppm).

Lead in PVC plastic-The observed range of lead varied from 7.0 ppm to 4309 ppm, the lowest lead concentration was observed in sample number 8 which was collected from Johripur recycling unit and the highest lead concentration was observed in sample number 2, collected from Zilmil grinding unit (**Figure 38**). Three samples of PVC were found to exhibit excessive lead levels much beyond the permissible RoHS maximum concentration value of 1000 ppm.

Lead in HIPS plastic-The observed range of lead concentration was from 6.0 ppm to 441.0 ppm, in which the lowest lead concentration was in sample number 29, which was collected from the grinding unit of Narela and the highest lead concentration was in sample number 10, which was collected from the grinding unit of Karaval Nagar. (**Figure 39**)

Lead in ABS plastic- The observed range of lead concentration varied from 6.0 ppm to 293.0 ppm. The lowest lead concentration was observed in sample number 18, which was collected from Mundka and the highest lead concentration was observed in sample number 26, which was collected from grinding unit, Narela (**Figure 40**).

Lead in PC plastic- The observed range of lead concentration varied from 8.0 ppm to 21.0 ppm, the lowest lead concentration was observed in sample 21, and the highest lead concentration was observed in sample number 16. Both the samples were collected from Mundka. (**Figure 41**)

Lead in market sample- The observed range of lead concentration varied from 39.0 ppm to 122.0 ppm. (**Figure 42**)

Figure 38: Lead concentration in PVC plastic

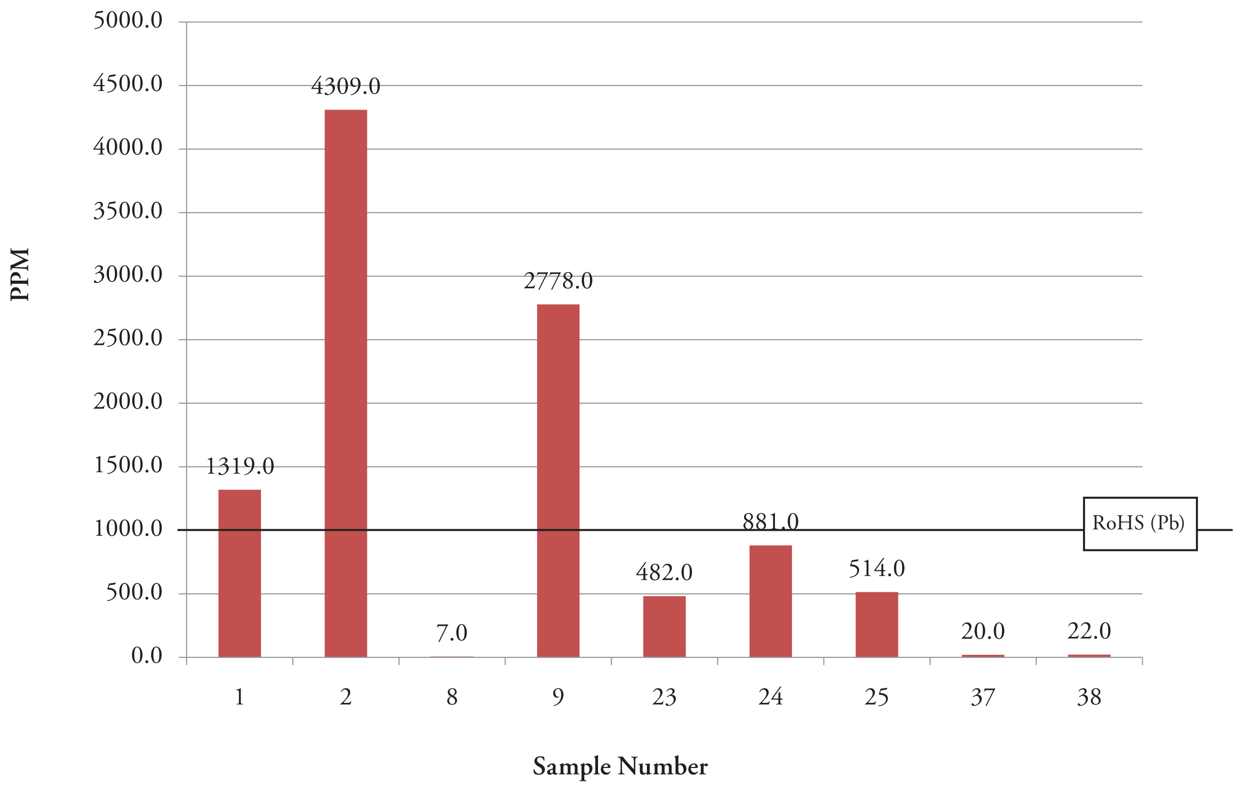


Figure 39: Lead concentration in HIPS plastic

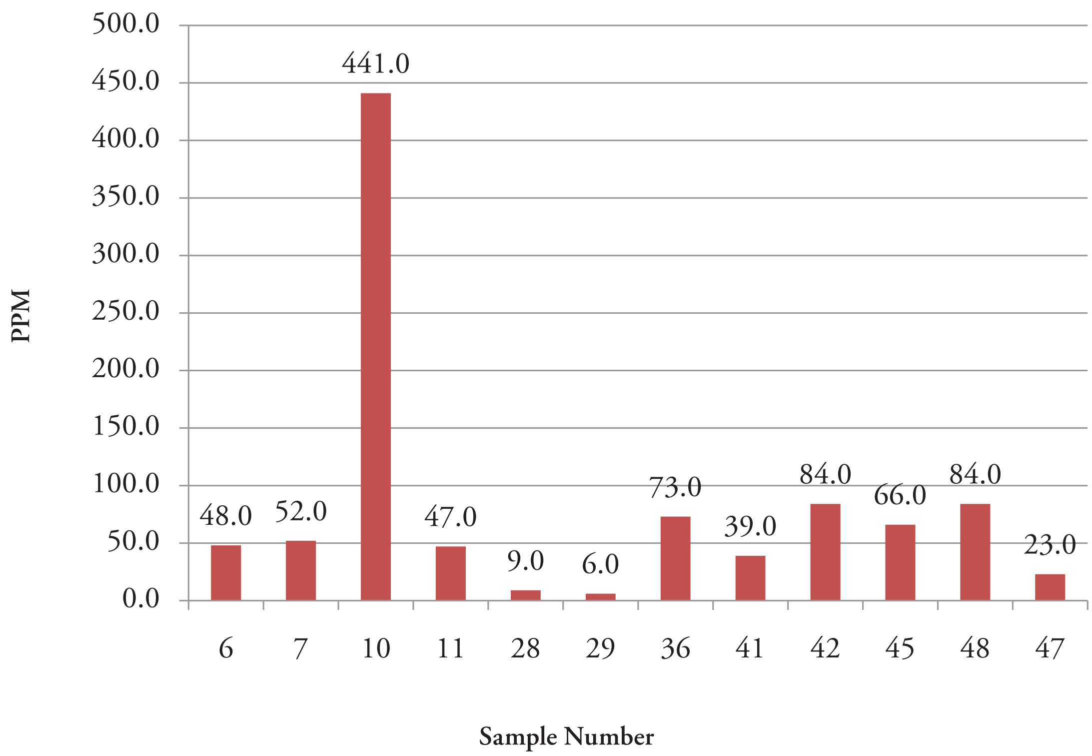


Figure 40: Lead concentration in ABS plastic

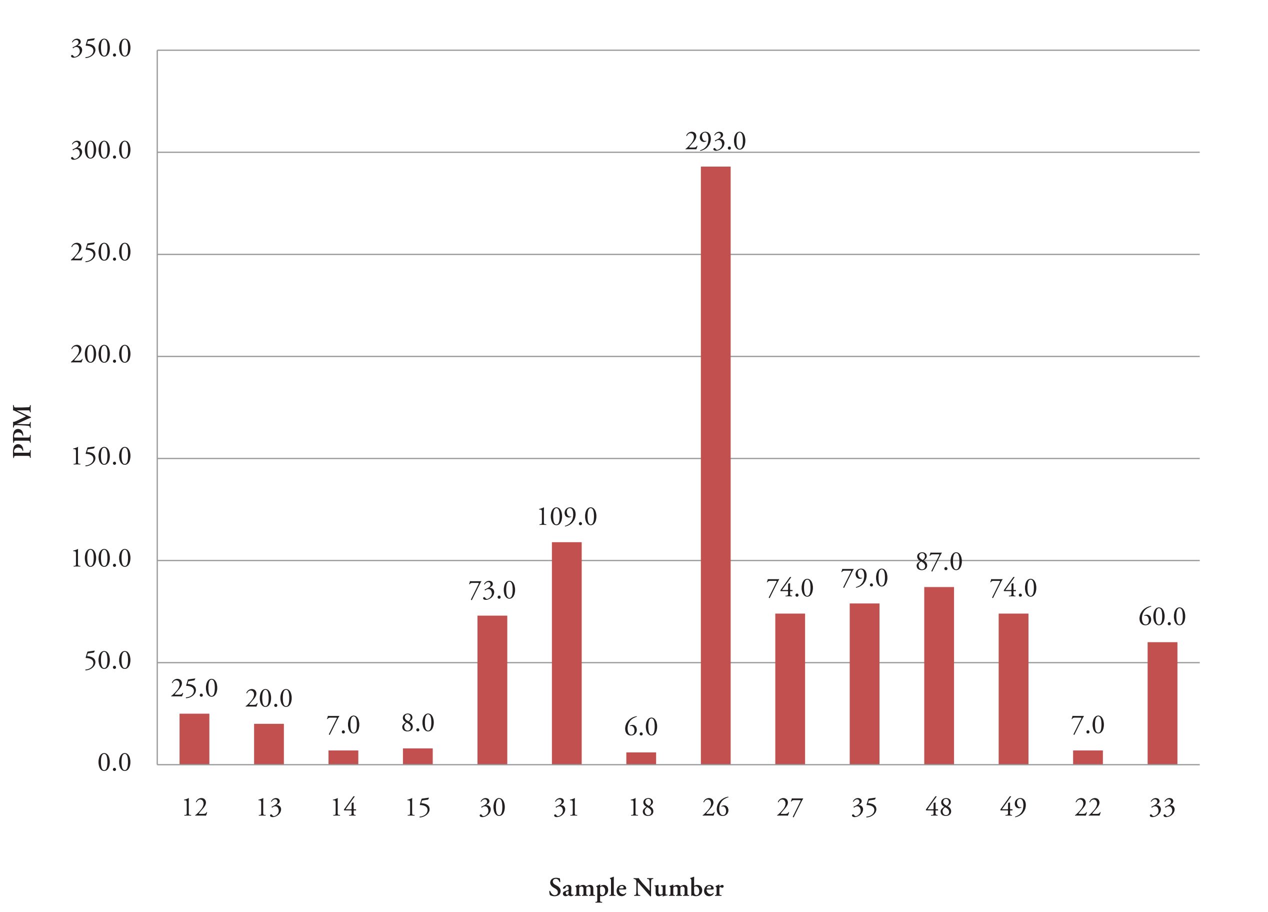


Figure 41: Lead concentration in PC plastic

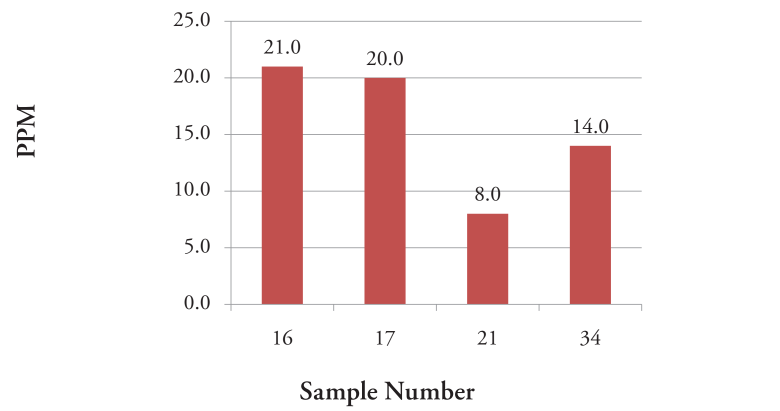
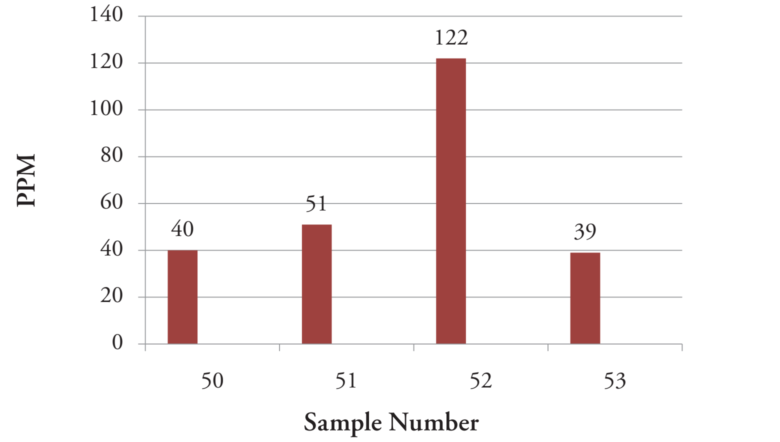


Figure 42: Lead concentration in market sample



Cadmium in PVC plastic-The observed range of cadmium varied from 4.0 ppm to 31.0 ppm, the lowest cadmium concentration was observed in sample number 37 which was collected from Vishwas Nagar recycling unit and the highest cadmium concentration was observed in sample number 25, which was collected from the grinding and moulding unit of Narela. (**Figure 43**)

Cadmium in HIPS plastic-The observed range of cadmium concentration was varied from 5.0 ppm to 35.0 ppm, in which the lowest cadmium concentration was observed in sample number 47, which was collected from the grinding unit of Karaval Nagar and the highest cadmium concentration was observed in sample number 10, which was collected from the grinding unit of Karaval Nagar. (**Figure 44**)

Cadmium in ABS plastic- The observed range of cadmium concentration varied from 5.0 ppm to 44.0 ppm. The lowest lead concentration was observed in sample number 33, and the highest cadmium concentration was observed in sample number 35. Both the samples were collected from different processes of Mundka. (**Figure 45**)

Cadmium in PC plastic- The observed range of cadmium concentration varied from 3.0 ppm to 21.0 ppm, the lowest lead concentration was observed in sample number 34, and the highest lead concentration was observed in sample number 17. Both the samples were collected from Mundka. (**Figure 46**)

Cadmium in market sample- The observed range of cadmium concentration varied from 22.0 ppm to 88.0 ppm. (**Figure 47**)

Figure 43: Cadmium concentration in PVC plastic

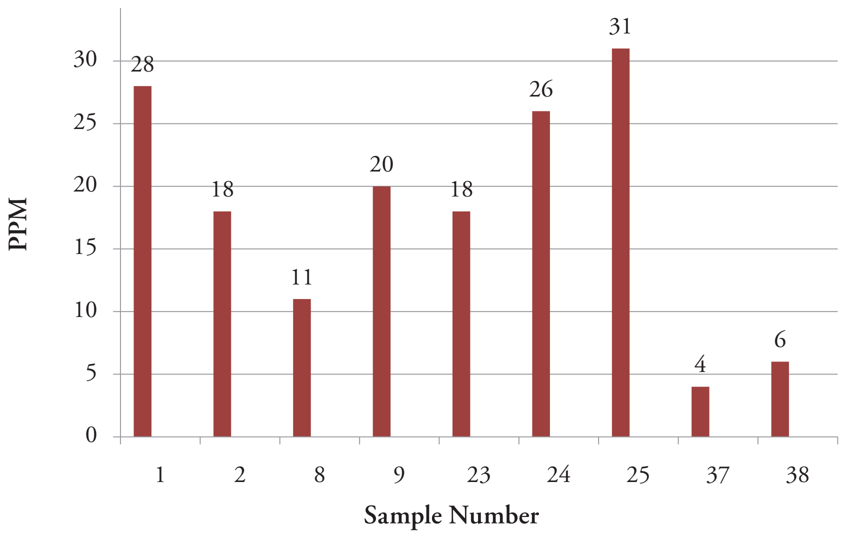


Figure 44: Cadmium concentration in HIPS plastic

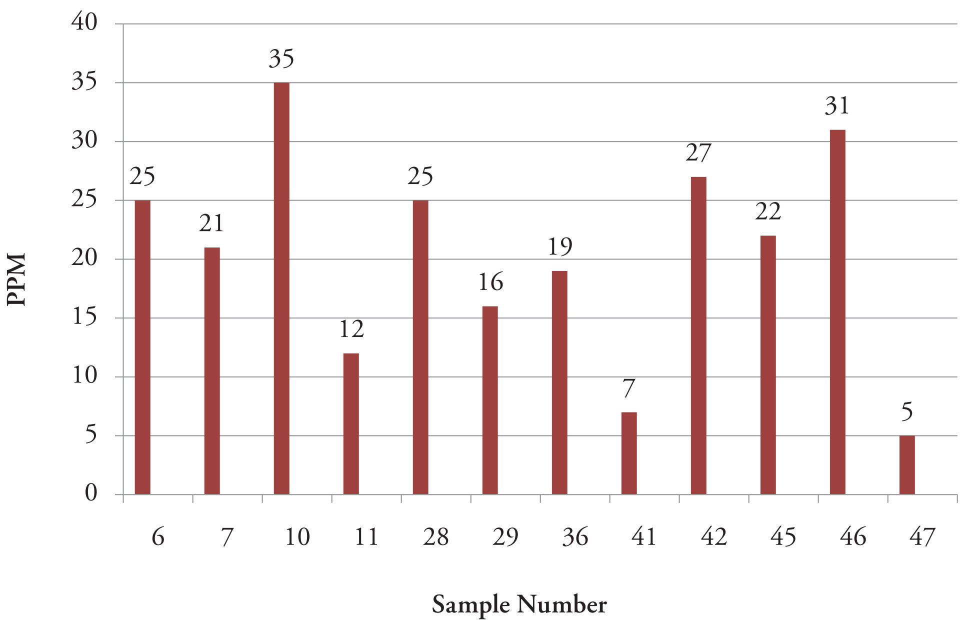


Figure 45: Cadmium concentration in ABS plastic

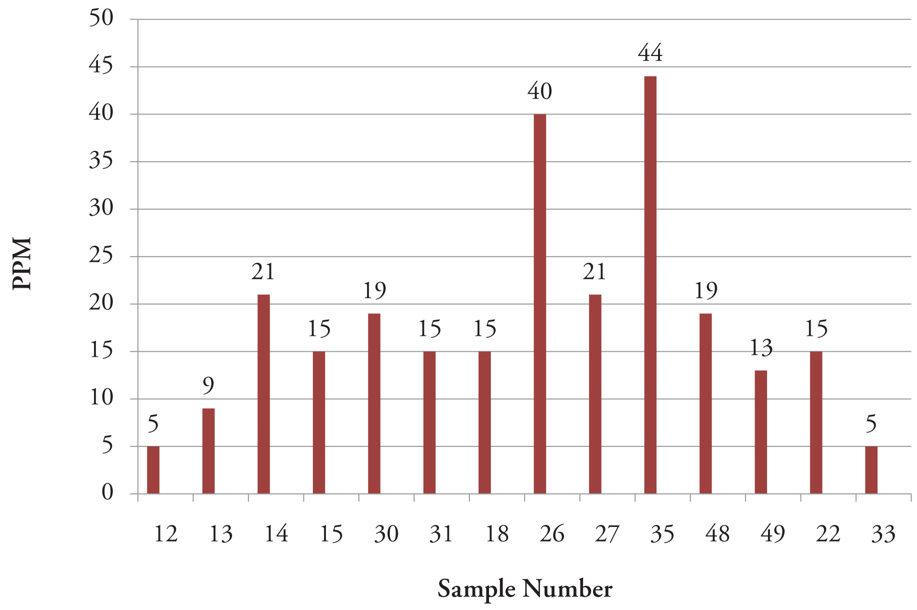


Figure 46: Cadmium in PC plastic

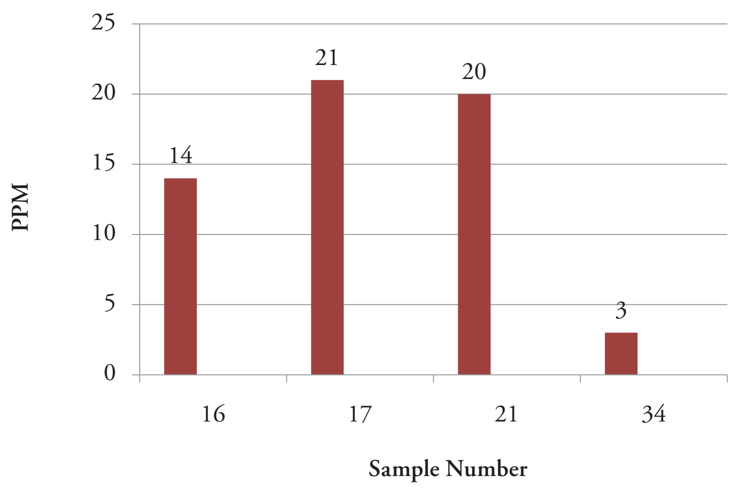
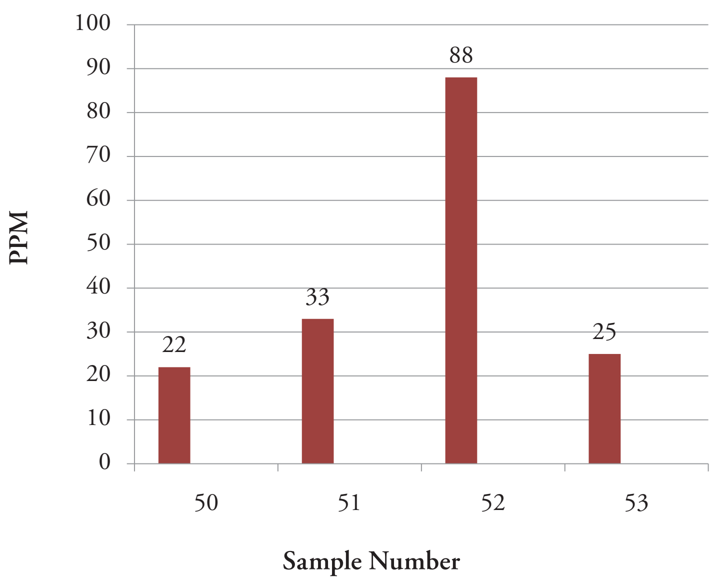


Figure 47: Cadmium in Market sample



Discussion

In the present study approximately 41% samples (18 out of 44 samples) were found positive for BFR. The concentration flow of BFR showed variation at different levels but within the RoHS maximum concentration limit i.e. 1000 ppm. In some grinding units, the grinded material showed presence of BFR but the pellets of the same unit (either same material or batch) showed less or nil BFR concentration than grinded material, which suggests or indicates loss of BFR in the process due to high heat. Likewise in one moulding unit, it was found that the recycled pellets did not have any BFR (or may be less than detectable level i.e. <10.0 ppm) but products in the same unit detected BFR concentration, which clearly indicates that BFR or BFR containing pellets are mixed in the process and it could be the possible source of chain contamination when next recycled. In most of the recycling units BFR plastic are separated using salt separation method, but surprisingly one sample of ABS grinded material (after salt separation process) found 98.5 ppm of BFR, suggesting inadequacy in the separation process. A collected Piccus samples was also found to contain BFR (29.7 ppm). Piccus is not used for further recycling; hence cross-contamination into products is not expected: However there are still serious concerns about environmental pollution, as Piccus is openly burnt in the environment. The random recycled pellets samples collected (known as non BFR) from market (Sadar Bazaar) showed BFR presence in three out of four samples which clearly indicates BFR contamination (last process). Use of these pellets from market is likely to contaminate the material chain. In the study overall two congeners of PBB and four congeners of PBDE are observed and most of the samples have Hexa and Hepta BDE.

The heavy metals like lead and cadmium were observed in all most all samples in varying levels and mercury and hexavalent chromium were not detected or below detectable level (<1.0 ppm). Three samples of PVC plastic showed the lead concentration higher than RoHS maximum concentration value i.e. 1000 ppm (Fig. 5.7A) but the other plastics reported lead levels within limit and cadmium in all samples were also within limits. Cadmium RoHS maximum concentration value is 100 ppm. Lead and cadmium are added to make the rigid type of PVC which is more soft, durable and flexible may be due to this reason a very high concentration of lead (1319 ppm, 4309 ppm and 2778 ppm) were observed in some PVC (wire) samples. Otherwise PVC is naturally hard substance.

6. Conclusion and Recommendations

Plastic recycling in India is a significant economic activity on account of generations of large volumes of plastic waste and the inherent potential of recyclability of plastics provides a good livelihood opportunity for a large number of urban poor. Plastics' recycling in the current scene in India uses low end technology hence capital and infrastructure costs are kept at their minimum. There is also an added environmental benefit on account of reuse of materials leading to conservation of resources and reduction in carbon foot print. However recycling of a few types of plastics which are laden with toxic additives can pose serious environment and health issues.

The issue of plastic recycling gets more complex because of the additives and contamination and the linked toxicity threat. Certain varieties of Brominated Flame Retardants have been regularly added to plastic used in EEE, hence increasing the risk of leaching of such toxic chemicals during the process of recycling such materials. There is enough evidence on the harmful effects of these chemicals and some of these have been categorized as POPs and are required to be phased out. Some of these chemical compounds can have very serious ecological impacts if released into the environment.

With the WEEE growing rapidly in India, the plastic contribution from WEEE has also grown substantially in recent times. The existing vibrant recycling industry of India has been engaged in recycling plastic for a long period, the WEEE plastic has just been added to that pile. Unaware of the toxicity related to some of the additives, this plastic is routinely recycled along with the other plastic waste, thereby raising a concern about cross contamination.

Brominated Flame Retardants and its impacts have received little attention in India. Though there have been some studies to check accumulation of PBDEs in human milk samples as well as human serum samples, also studies to detect concentrations in soil, atmosphere and marine animals, there has been no study to evaluate the risk of cross contamination.

The current study was carried out by Toxics Link in two parts, i.e. field research and lab analysis of the samples collected. The results indicate that, in formal as well as informal, plastic recycling units there are hardly any procedures to decontaminate the plastic or prevent cross contamination. Presence of BFRs like PBDEs and PBBs and heavy metals like lead and cadmium in lab analysis clearly point out towards the increasing risk of absence of such decontamination. Varying concentrations of PBDE and PBE found in the recycled plastic pellets point towards two major findings. Firstly, that though some of these chemicals have been phased out in developed countries, they are still being used in the products sold in India. Secondly, the entire plastic recycling chain is getting contaminated by these kinds of additives. Lab detection of the chemicals in the samples which were being sold in the plastic market as Flame retardant free is particularly alarming. The varying concentrations also probably indicate towards release of the chemicals during the recycling process, thereby raising the concern of occupational safely.

The study does have its limitations in terms of geographical area and sample size. But the findings clearly give us a basis to warrant a larger study to investigate the extent of cross contamination and also look at the repercussions of the same.

The positive part is that there are new materials and product design techniques available in the market today that can replace the use of some of these harmful BFRs.

The following recommendations will help spur the rapid adoption of currently available safer materials and catalyze the search for more environmentally friendly flame retardants. Also, it is important to note that BFRs are present in historical and current EEE. And hence we also need to come out with safer management practices and monitoring systems.

1. As a priority, we recommend a ban and phase-out in manufacture and use in products of PBB and Penta, Octa

and Deca PBDE . Studies across the globe have indicated the risks associated with the usage of these chemicals and several countries have already banned their usage.

2. Some studies also indicate the toxic effects of other BFRs. Studies should be conducted on health and environmental impacts of these and if those studies indicate risks, regulatory agencies should take early action to phase them out.
3. There should be recycling guidelines for electronic products to ensure that BFRs are not continually put into new products and that workers are protected. Materials containing brominated compounds need to be separated from other materials to reduce contamination of those materials that can be recycled and reused in new products.
4. Products must contain information on materials and chemicals. This would help in separating contaminated plastic and keeping the recycling chain cleaner.
5. There is an urgent need for generating awareness among plastics recyclers on harmful impacts of toxics used in plastics.

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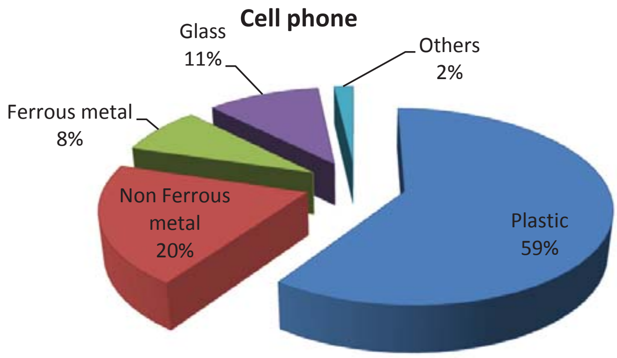
8. Annexure

8.1 Annexure 1: Plastic in WEEE

Figure 48: Plastic in cell phone



8.2 Annexure 2: Plastic Recycling in the informal sector (pictorial)

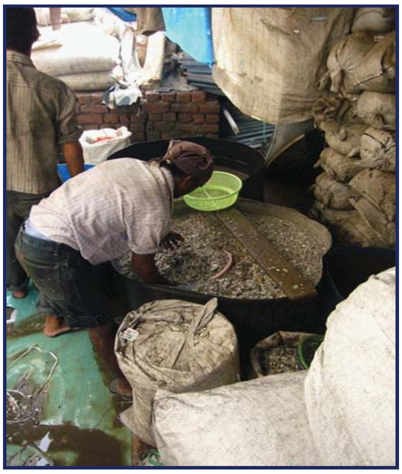
Figure 49: Recycling process

Storage of the WEEE Plastic

Segregation of the Plastic by category

Cutting and Grinding of the Plastic by category

Differentiate the ground Plastic in plain and FR by use of salty water.



Dry the ground Plastic in open area

Packing and storing of the ground Plastic

Washing the ground Plastic by hand or machine in the pellet making units

Drying the ground Plastic by dryer or in the open

Treat the dry ground Plastic in mixture machine – making it softer and more pliable.

Soft plastic put into an Extruder Machine for making string. Use of a water tub for cooling of the string and then cutting it by a cutter machine into pellets.

Storing and selling the pellets to the market and the industries

In industries, mixing and adding the color to the pellets in the mixture.

Manufacturing the product by mold in the molding machine

Products

8.3 Annexure 3: Status of Plastic Industry in India

Table 11: Plastic units in India- State wise [10]

S. No.	Name of State Pollution Control Board / Pollution Control committee	Total No. of Plastic Manufacturing & Recycling Units
1.	Andhra Pradesh	462
2.	Arunachal Pradesh	0
3.	Assam	33
4.	Bihar	81
5.	Chhattisgarh	37
6.	Goa	68
7.	Gujarat	200
8.	Haryana	10
9.	Himachal Pradesh	83
10.	Jammu & Kashmir	0
11.	Jharkhand	18
12.	Karnataka	308
13.	Kerala	504
14.	Maharashtra	411
15.	Manipur	3
16.	Madhya Pradesh	207
17.	Meghalaya	3
18.	Mizoram	0
19.	Nagaland	5
20.	Orissa	40
21.	Punjab	118
22.	Rajasthan	124
23.	Sikkim	0
24.	Tamil Nadu	1941
25.	Tripura	23
26.	Uttar Pradesh	281
27.	Uttaranchal	0
28.	West Bengal	240
29.	Andaman & Nicobar	0
30.	Chandigarh	121
31.	Daman & Dadra & Nagar Haveli	0
32.	Delhi	147
33.	Lakshadweep	0
34.	Pondicherry	43
	Total	5511

8.4 Annexure 4: Sampling

Details of sampling

Resins	Total samples	Chain	Individual samples	Rational
PVC	10	Grinded	3	■ There is no separation (FR, NFR) process
		Pellet making	3	■ To check FR concentration in pellets
		Recycled Pellets	1	■ Pellets are use to make product other than wires
		Product	2	■ If BFR in any plastic since thee is no separation, whole batch will get contamination
		Piccus	1	■ No recycling process in piccus only open burning which may release of FR
ABS/ HIPS/ PC	30	Waste pieces	6	■ Waste pieces from WEEE
		Grinded	7	■ No salt water separation
		Grinded	2	■ Salt water separation
		Pellet Making	6	■ To check FR in plain recycled pellets
		Moulding-recycled pellets	5	■ To check whether there is any FR contamination in normal Pellets
		Moulding-product	4	■ To check whether there is any FR contamination in normal products
Market	4	Pellets	4	■ Random pellets in the market to check the contamination
Total	**44**			

Details of sampling

Resin	Date	Sample Details
PVC	27/06/11	PVC grinding (wires) from Zilmil
	27/06/11	PVC pellets from Zilmil
	28/06/11	PVC grinding (Plug) from Johripur
	28/06/11	PVC Pellets from Johripur
	5/7/11	PVC Grinding from Narela
	5/7/11	PVC Pellets from Narela
	5/7/11	PVC Product (Chappal) from Narela
	15/7/11	PVC+PP, Fresh Pellets (for speaker cover) from Vishwas Nagar
	15/7/11	PVC+PP, product (speaker cover) from Vishwas Nagar
HIPS	28/06/11	HIPS Recycled Pellets from Johripur
	28/06/11	HIPS Product (Radio) from Johripur
	28/06/11	HIPS grinding (mixed-Bhopura) from Karaval Nagar
	28/06/11	HIPS pellets from Karaval Nagar
	5/7/11	HIPS Grinding from Narela
	5/7/11	HIPS Pellets from Narela
	14/7/11	HIPS Grinding - After salt separation from Mundka
	15/7/11	HIPS Grinding (Mixed) from Johripur
	15/7/11	HIPS Pellets from mixed grinding from Johripur
	15/7/11	HIPS Pellets for radio cabinet from Karaval Nagar
	15/7/11	HIPS Product Radio cabinet from Karaval Nagar
	15/7/11	HIPS black colored grinding from Karaval Nagar
ABS	28/06/11	ABS grinding (Computer Cabinet) white colored-No salt water separation from Karaval Nagar
	28/06/11	ABS Pellets (Near to grinding plant) white colored-No salt water Separation from Karaval Nagar
	1/7/11	ABS Waste (Mobile) from Mundka
	1/7/11	ABS+PC waste (Mobile) from Mundka
	7/7/11	ABS Moulding Pellets from Bawana
	7/7/11	ABS Product (Mudguard) from Bawana
	1/7/11	ABS Waste(Charger) from Mundka

	5/7/11	ABS grinding waste (mix of A/C, battery) from Narela
	5/7/11	ABS Pellets from Narela
	14/7/11	ABS Grinding After salt separation from Mundka
	15/7/11	ABS Pellets Black for mixer part from Karaval Nagar
	15/7/11	ABS Product (Mixer Part) from Karaval Nagar
	1/7/11	ABS+PC Mix Grinded from Mundka
	14/7/11	ABS+PC Mix Pellets from Mundka
PC	1/7/11	PC+ABS waste(Mobile) from Mundka
	1/7/11	PC waste(Mobile) from Mundka
	1/7/11	PC waste(Charger) from Mundka
	14/7/11	PC Pellets Recycled (called natural due to cleaned and transparent appearance) from Mundka
Piccus	-	-
ABS 1	19/7/11	ABS Pellets from the Sadar Bazar
ABS 2	19/7/11	ABS Pellets from the Sadar Bazar
HIPS	19/7/11	HIPS Pellets from Sadar Bazar - Off white
ABS	19/7/11	ABS Pellets from the Sadar Market - Green Colored

Total concentration of heavy metal

Resin	Date	Chain	SN	Sample Number	Pb (ppm)	Cd (ppm)	Hg (ppm)	Hex Cr (ppm)
RoHS limit					**1000 ppm**	**100 ppm**	**1000 ppm**	**1000 ppm**
PVC	27/06/11	PVC grinding (wires) from Zilmil	1	1	1319.0	28.0	<1.0	<1.0
	27/06/11	PVC pellets from Zilmil	2	2	4309.0	18.0	<1.0	<1.0
	28/06/11	PVC grinding (Plug) from Johripur	8	8	7.0	11.0	<1.0	<1.0
	28/06/11	PVC Pellets from Johripur	9	9	2778.0	20.0	<1.0	<1.0
	5/07/11	PVC Grinding from Narela	23	23	482.0	18.0	<1.0	<1.0
	5/07/11	PVC Pellets from Narela	24	24	881.0	26.0	<1.0	<1.0
	5/07/11	PVC Product (Chappal) from Narela	25	25	514.0	31.0	<1.0	<1.0
	15/07/11	PVC+PP, Fresh Pellets (for speaker cover) from Vishwas Nagar	37	37	20.0	4.0	<1.0	<1.0
	15/07/11	PVC+PP, product (speaker cover) from Vishwas Nagar	38	38	22.0	6.0	<1.0	<1.0
							<1.0	<1.0
HIPS	28/06/11	HIPS Recycled Pellets from Johripur	6	6	48.0	25.0	<1.0	<1.0
	28/06/11	HIPS Product (Radio)* from Johripur	7	7	52.0	21.0	<1.0	<1.0
	28/06/11	HIPS grinding (mixed-Bhopura) from Karaval Nagar	10	10	441.0	35.0	<1.0	<1.0
	28/06/11	HIPS pellets from Karaval Nagar	11	11	47.0	12.0	<1.0	<1.0
	5/07/11	HIPS Grinding from Narela	28	28	9.0	25.0	<1.0	<1.0
	5/07/11	HIPS Pellets from Narela	29	29	6.0	16.0	<1.0	<1.0
	14/07/11	HIPS Grinding - After salt separation from Mundka	36	36	73.0	19.0	<1.0	<1.0
	15/07/11	HIPS Grinding (Mixed) from Johripur	41	41	39.0	7.0	<1.0	<1.0
	15/07/11	HIPS Pellets from mixed grinding from Johripur	42	42	84.0	27.0	<1.0	<1.0
	15/07/11	HIPS Pellets for radio cabinet from Karaval Nagar	45	45	66.0	22.0	<1.0	<1.0
	15/07/11	HIPS Product Radio cabinet from Karaval Nagar	46	46	84.0	31.0	<1.0	<1.0
	15/07/11	HIPS black colored grinding from Karaval Nagar	47	47	23.0	5.0	<1.0	<1.0
							<1.0	<1.0
ABS	28/06/11	ABS grinding (Computer Cabinet) white colored-No salt water separation from Karaval Nagar	12	12	25.0	5.0	<1.0	<1.0
	28/06/11	ABS Pellets (Near to grinding plant) white colored-No salt water Separation from Karaval Nagar	13	13	20.0	9.0	<1.0	<1.0
	1/07/11	ABS Waste (Mobile) from Mundka	14	14	7.0	21.0	<1.0	<1.0

	1/07/11	ABS+PC waste (Mobile) from Mundka	15	15	8.0	15.0	<1.0	<1.0
	7/07/11	ABS Moulding Pellets from Bawana	30	30	73.0	19.0	<1.0	<1.0
	7/07/11	ABS Product (Mudguard) from Bawana	31	31	109.0	15.0	<1.0	<1.0
	1/07/11	ABS Waste(Charger) from Mundka	18	18	6.0	15.0	<1.0	<1.0
	5/07/11	ABS grinding waste (mix of A/C, battery) from Narela	26	26	293.0	40.0	<1.0	<1.0
	5/07/11	ABS Pellets from Narela	27	27	74.0	21.0	<1.0	<1.0
	14/07/11	ABS Grinding After salt separation from Mundka	35	35	79.0	44.0	<1.0	<1.0
	15/07/11	ABS Pellets Black for mixer part from Karaval Nagar	48	48	87.0	19.0	<1.0	<1.0
	15/07/11	ABS Product (Mixer Part) from Karaval Nagar	49	49	74.0	13.0	<1.0	<1.0
	1/07/11	ABS+PC Mix Grinded from Mundka	22	22	7.0	15.0	<1.0	<1.0
	14/07/11	ABS+PC Mix Pellets from Mundka	33	33	60.0	5.0	<1.0	<1.0
							<1.0	<1.0
PC	1/07/11	PC+ABS waste(Mobile) from Mundka	16	16	21.0	14.0	<1.0	<1.0
	1/07/11	PC waste(Mobile) from Mundka	17	17	20.0	21.0	<1.0	<1.0
	1/07/11	PC waste(Charger) from Mundka	21	21	8.0	20.0	<1.0	<1.0
	14/07/11	PC Pellets Recycled (called natural due to cleaned and transparent appearance) from Mundka	34	34	14.0	3.0	<1.0	<1.0
							<1.0	<1.0
Piccus	-	-	32	32	177.0	23.0	<1.0	<1.0
							<1.0	<1.0
ABS 1	19/07/11	ABS Pellets from the Sadar Bazar	50	50	40.0	22.0	<1.0	<1.0
ABS 2	19/07/11	ABS Pellets from the Sadar Bazar	51	51	51.0	33.0	<1.0	<1.0
HIPS	19/07/11	HIPS Pellets from Sadar Bazar - Off white	52	52	122.0	88.0	<1.0	<1.0
ABS	19/07/11	ABS Pellets from the Sadar Market - Green Colored	53	53	39.0	25.0	<1.0	<1.0

8.5 Annexure 5: Workshop Report

Workshop Background

E-waste has emerged as a critical waste issue globally, with the growing quantity of waste and the problems arising out of its toxic nature. In India, it is estimated that around 4.8 lakh tonnes of e-waste is generated annually, with 95% of the waste handled by the informal sector. Plastic, one of major constituents of E-waste, has a huge potential for recycling and is also recycled mainly in the unorganized sector in India. Presence of additives and chemicals in plastic waste and its recycling processes raises concerns of human health and environment.

Toxics Link, an environmental NGO, is dedicated to bringing toxics related information into the public domain, both relating to perspectives from the ground as well as exchanging global information. We have been involved in the area of Municipal, Medical and Hazardous waste management issues for several years now. Electronic waste (E-waste) has been another important issue that Toxics Link has been engaging in for last few years.

As a part of flagging the issue Toxics Link in collaboration with Swiss Federal Laboratories for Materials Science and Technology (EMPA), State Secretariat for Economic Affairs SECO and Swiss Plastics Association has been engaged in studying the WEEE plastic recycling in India and organized a multi-stakeholder workshop, in association with the partners to discuss the initial findings of this study and to seek inputs on the same.

The participants of the workshop include the representatives of the Central Pollution Control Board, EEE and recycling industry, Educational and Research Institutes and Civil Societies.

The overall objective of the workshop was to sensitize the participants on the environmental and health concern emerging from improper recycling of chemically contaminated plastic, in particular chemical like brominated flame retardant (BFR) present in electronic products. The workshop provided a platform to all the stakeholders for a healthy discussion, knowledge and experiences sharing.

Inaugural Session

The inaugural session started with the welcome address given by **Mr. Ravi Agarwal** (Director, Toxics Link). In his address, he briefed about the study on plastics in Waste Electrical and Electronic Equipment (WEEE) undertaken by Toxics Link that deals into the issue of waste management in a very specific way and focuses on one particular aspect of waste i.e. Brominated Flame Retardants (BFR) contaminated plastic waste.

Brominated Flame Retardants are highly toxic .They have adverse long term impacts and are liable to contaminate the environment. They are a part of the plastics especially the electronic plastics to make them fire resistant. BFRs continue to stay in the recycled pellets and thus also in the products made out of these recycled pellets. Since WEEE also is illegally imported to India, this is a local problem having global ramification.

Mr. Agarwal further elaborated on the three important components of managing waste:

1. Waste in connection to the idea of resource use where one must manage waste in a way that minimizes waste creation.
2. Issue of managing waste- collection, management and processing. In India waste is being managed by many economic actors mainly by the informal sector but with new consumption and new concentration of waste it requires special efforts and cannot be managed in the classical ways.
3. And a battery of legislations dealing with Hazardous waste, Medical waste, Lead waste, E-waste.

He shared that what is contained in waste is a much neglected issue particularly in the public realm as it is less visible, less apparent in terms of health and environment. Even when these wastes are collected and recycled the toxicity remains intact to a considerable extent that can only be diluted, imposing a serious challenge. Dealing with the waste is an important task and requires serious long term efforts that what municipality alone can do. It requires attention of all the stakeholders, the industry, the government and the recycling and the processing industry as well as the Civil Societies.

Martin Strub (Deputy Chief, Swiss Embassy),congratulated Toxics Link, the Swiss Federal Laboratory for material testing and research, EMPA for the initiative of the research study. He said that Switzerland has played a pioneering role in the management of sustainable material recycling and their recovery through waste management. Swiss institutions and experts have been instrumental in designing the European E-waste regulation and have developed widely accepted knowledge and expertise in this regard. Besides, Switzerland has carried successful recycling programs in India. According to him, the study on plastic recycling constitutes another significant component of co-operation with India and endeavors to bring forth successful collaboration in future of plastic recycling in India.

He said that plastics play a major role in today's life. However, production and use of plastics bear disadvantage and risk when wrongly disposed. The littering of plastic waste in nature also leads to the emission of chemicals in air, water and soil. In many countries plastic waste is collected and brought to recycling efficiently but only for economically viable plastics. The recovery of secondary raw materials and production of new products often takes place in the informal or semi- formal sector.

On behalf of the Swiss government, he requested Toxics Link in collaboration with EMPA to make an in depth analysis of the current situation in India and suggest possible ways forward.

He said that the study confirmed cross contamination from BFRs and heavy metals. However, there are opportunities for improvement with sustainable management of plastics waste and their risks can be efficiently dealt with.

Rolf Widmer (EMPA) introduced EMPA and said that they have been involved in E-waste management for past twenty years and one of the largest program initiated by them is called the Swiss E-waste program to keep track of the mass balance of E waste flowing through the country. He further elaborated on the Indo-German Swiss E-waste project (2003-2008) where they accessed the situation, proposed and planned improvement steps and implemented them in pilot projects.

He further elaborated on the project of plastic recycling in Delhi and said that he would like to improve the quality management in plastic recycling in Delhi in order to enhance sustainability.

He said that the project seeks for better integration of the existing plastics recycling sector into the globalized market for secondary raw materials and the focus lay on issues related to cross-contamination of problematic substances along the recycling chain of plastics (mainly from WEEE) in all relevant processes.

He then gave an insight into the amount of plastics recovered in Europe and the types of recovery. According to him plastic waste is a global issue and said that a large amount of plastic waste in Europe is shipped to China and India. This requires a global approach in order to improve the entire chain and ensure that the player in a country like India is fit to be placed in the global chain.

Dr. Saroj, (Director, MoEF), appreciated EMPA and Toxics Link for the focused work on E-waste. She also shared some of her experiences of the recent past and said that she has been hearing from all the countries especially the developed countries. India certainly is trying to mobilize the collection system, speeding up the monitoring system and setting up committee. In the

She further said that the disposal of plastic and E-waste is a major concern. Every Indian should understand the repercussion of any waste especially E-waste and there was a need for awareness generation through radio and electronic media on the issue.

Mr. Satish Sinha (Associate Director, Toxics Link), gave vote of thanks to all the delegates and the participants of the workshop. He said that the study is the first in the country done on BFR in plastics. He thanked EMPA for building co-operation with Toxics Link and for building a knowledge sharing platform through collaborated work. He urged that there was a need to come up with substantial data to determine the concerns, the environmental loads and the control mechanism to address them.

Technical Session

Dr. D.P. Amalnerkar, (Executive Director, Center for Materials for Electronic Technology) said about the ambitious project at Hyderabad Laboratory where the primary concern was the extraction of precious metals.

There were four speakers in the session, namely Dr. Mathias Schluep, (Technology & Society Lab, and EMPA), Priti Mahesh (Senior ProgrammeOfficer,Toxics Link) and Dr. PrashantRajankar (Senior Programme Officer, Toxics Link) and Ravi Kumar Agarwal(All India Plastic Industries Association).

Dr. Mathias Schluep, (Technology & Society Lab, and EMPA), started technical session by his presentation on "WEEE plastics in Europe." Dr. Mathews briefed on the plastic study done recently for WEEE forum in Europe. He said that there was a demand for the study to clarify BFR and the ways of recycling them. He also elaborated on the structure, types and application and concentration of BFR, as specific flame retardants are applied to specific plastics.

According to him the disposal and recovery of plastic is significant both financially and commercially and also in terms of environmental implication as plastics from E Waste contain hazardous substance like heavy metals and BFR.

He further said that the study showed that no WEEE plastics are free from heavy metals and BFR, though some are above the limits and some are below and in order to hold the dissipation of hazardous substance, mixed plastics and WEEE should have strict quality management. He recommended that plastic should be traced throughout the recycling chain from the point where they are generated up to the point where they are reintegrated into the products. To avoid a dissipation of hazardous substances into plastics and the environment, mixed plastics from WEEE should subject to a strict quality management. The chemicalsshould either be taken out of the plastics or the contaminated plastics should be disposed properly.

Ms.Priti Mahesh (Senior Programmer Officer, Toxics Link), made a presentation on "Toxic Flows in WEEE Plastic". Priti briefed on the objectives and methodology of the study, in which plastic recycling system was studied to understand the environmental and health hazards as well as to look at the possibility of cross contamination. She further elaborated on the key findings of the study and said that an around 1.5 lakh tonne of WEEE plastic is generated in India annually that is mainly recycled in the informal sector. She also gave an insight on plastic waste flow and mapped the major hub of plastic waste recycling in Delhi. She also talked on the waste hierarchy in the informal sector starting from the waste collectors (Kabaddiwalas) at the base to the recyclers and the various Business Prototypes.

She further elaborated on the recycling process carried out by the informal sector and its adverse impacts and said that even in the formal sector the processes were very similar and segregation of BFR contaminated plastic was absent. There was no stringent separate flow for contaminated plastic, thereby increasing the probability of contamination of the entire plastic stream. She elaborated that the study points out towards lack of occupational health or environment norms. She also briefed the audience on the identified possible contamination points, which guided the sampling process in the study.

The key findings are:

- Plastic recycling is a big economic activity
- Around1.5 lakh tonnes to WEEE plastic generated in India annually
- Delhi is one of the largest recycling hub
- 8 ,000 MT WEEE plastic generated in Delhi, a lot more recycled in the city
- Mainly recycled in the informal sector. 20,000-25000 workforce directly engaged
- No stringent separate flows for contaminated plastic
- No health or environment norms in place
- Field research indicates dilution and dispersion

Dr. Prashant Rajankar (Senior Programme Officer, Toxics Link), made a presentation on the "Experimental Finding of BFR Study" where he elaborated on the observation and the laboratory results and said that field research and lab results suggest that there is dispersion and dilution of the additives like BFR and heavy metals. He said that current practices pose a challenge in terms of managing BFR plastic effectively.

He shared the data on the Concentration of PBB and PBDE's in different sample, BFR in Grinded-Pellets-Recycled Product and the presence of Heavy metal like Lead and Cadmium.

The key findings of the laboratory research are:

- Positive BFR samples 18 (41%)
- BFR concentration was varied from 18.9 ppm to 126.3 ppm
- The average all sample is 10.7 ppm $\pm$ 25.7
- Only 2 congeners (Tetra and Penta) of PBB detected
- Only 4 congeners (Hexa, Hepta, Nona and Deca) of PBDE detected
- Hexa and Hepta congeners are more
- Pellets has lesser amount of BFR than grinded material
- Product has the lesser amount of BFR than pellets
- None of the samples found BFR exceeds RoHS maximum concentration value (1000 ppm).
- Piccus sample contain BFR 29.7 ppm (piccus does not recycle only burning)
- Lead and cadmium were found in all type of samples in varying concentration (6.0 ppm to 4309.0 ppm and 3.0 ppm to 88.0 ppm respectively)
- Mercury and hexavalent chromium were found below detectable level (1.0 ppm).
- Lead concentration was higher in three samples of PVC plastic (out of 44 plastic samples)

Mr. Ravi Kumar Agarwal (All India Plastic Industries Association), who represented plastic recycling industry, shared the industry perspective on the issue and said that when waste recycled pellets that contain FR is mixed with fresh pellets to make any equipment like computer board the FR comes down to manageable levels. According to him the enormity of the problem is less as the per capita consumption is less and thus manageable. However, management of plastic waste is a serious issue due to inadequate infrastructure and lack of awareness on the part of the consumers.

He said that the bottlenecks lay in collection and segregation. Although there are guidelines on recycling, laid down by the Bureau of Indian Standards of Plastics, they can only be followed by the modern recycling facilities. In his view the government should correct the collection, segregation and disposal system of E-waste and there was a need for implementation of these guidelines. He said that if the plastic waste is collected as a resource it will be useful or else it will degenerate the environment. He emphasized on the need of an awareness campaign and proper infrastructure.

After this session there was a small interactive session with the audience. Questions were raised on the kind and varieties of products made from the recycled plastics. Question was raised on the route of the export process of the products made from the recycled plastics and if it was exported directly or through the transit route.

There were lot of queries on the nature of plastics and the presence of WEEE in the plastic sample collected. The participants were keen to know about the percentage of WEEE in plastics. Few questions were raised on the process of the study.

Panel Discussion

There was a panel discussion chaired by Dr J. Kamyotra, (Member Secretary, Central Pollution Control Board) and Co chaired by Rolf Widmer(EMPA). The other panelists were, Mathias Schluep, (EMPA), Satish Sinha, (Toxics Link), Ravi Kumar Agarwal, (AIPIA).

Rolf talked on the risk of certain additives present in the plastics that flows from one end to the other end of the products, if not controlled. He said that some of these additives are POPs persistent and heavy metals that bio-accumulates wherever they can and thus need some concrete action. He invited the panelist and the audience to give some recommendations and come up with the ways of solving the issue.

Mr. Satish Sinha (Associate Director, Toxics Link) said that these additives tend to find its way and contaminate the environment. He said that in India this posed a challenge where it is done by the informal sector and suggested the need for a monitoring system. There are regulations that will come into effect from 2012 and that the producers were already putting in place the collection centers, and that the WEEE plastics will get collected separately which will be in the formal sector and thus segregation won't be a problem and can be separately recycled. However, some of the most developed countries have regulation in place but the results are bleak and have a plastic regime that is contaminated. He said that regulation is just one trigger in the whole process.

Dr J. Kamyotra, (Member Secretary, Central Pollution Control Board) said that there are examples in the country where the public like the ragpickers have been included in the system for instance in case of plastic waste management in Bhopal. He said that extended producers responsibility must identify the responsibilities of all the players involved and the producers should be involved directly or indirectly.

He suggested that there should be synergy in the interest and the law to bring fort the impacts.

The audience participated vividly in the discussion and several substantial ideas / proposals were added to the brainstorming of this panel discussion. Dieter Mutz GIZ-ASEM suggested that there was a need for finding a market mechanism which will allow the semi-structured or the informal sector to manage BFR in an improved way. He said that there are many pesticides used in India of which the producer's take the responsibility by paying for their disposal somewhere either in India or in some other country. There is a big fund available in order to get rid of these pesticides. He said that something similar should be done in case of the EEE waste. Further there should be incentive for bleeding out the toxics materials. According to him we needed a market mechanism to deal with the past as we have a regulation in place to deal with the future. He also emphasized on the need of life Cycle Assessment- a mechanism, absent in India.

Lakshmi Raghupati, a Consultant said that regulation was not going to solve the problem as it is just one step ahead. The enforcement of regulation and the preparedness for regulation holds importance and there was a need to discipline the Recycling System.

While Mr. Shashi Bhushan Pandit, said that the waste pickers are mostly from the informal sector and the rules do not reach these actual players. Solid Waste Management Policy by the government has a very good model of Public Private Partnership (PPP), but the model actually excludes the public and the partnership is with the corporate rather than public. He suggested that Public Municipal Collector should be involved in the system as the marginalized sector being the actual player is thrown at the periphery. Even the new rule on E Waste has no space for the informal sector.

Key recommendations

There were numerous recommendations on managing BFR and other toxic flows in WEEE coming out of the discussions; they are summarized in the list of key recommendations below:

- Generally there is agreement among the participants about the need to improve the management of BFR and heavy metals in the Indian WEEE streams.
- Legislative Framework: it was agreed that the existing legal framework seems sufficient (e.g. new E Waste rule). However, law enforcement will require substantial efforts. It was agreed that there is a need for an adequate monitoring system, which will allow a continuous assessment of the material flows and the efficiency of the segregation and disposal of the toxic fractions / substances.
- Awareness and Education: it was agreed that there is little to no awareness, knowledge and knowhow about this issues amongst the key stakeholders and the general public. There is a need for specific awareness campaigns and education especially targeting informal sector. An awareness/education campaign should be a joint campaign between the government (national, municipal), producers (plastic materials as well as EEE) and their associations. Though it is an obligation by law it should be made explicitly mandatory.
- Responsibilities: it was agreed that there is a need to co-ordinate the efforts for improving the situation. Various means were discussed such as a multi level enforcement agency, definition stakeholder's roles and ways to check / sanction (non-)conformity.
- Business opportunities: it was agreed that the current complex plastic recycling system can only be transformed via a 'stick & carrot' approach. Besides improving the law enforcement it is paramount to find market mechanisms which would allow de-toxifying the secondary plastic streams as a business. A number of alternative business models were discussed e.g. buying toxic substances (BFR plastics) via a special fund to bleed them out of the material loop. Such funds are existing and used in the context of greenhouse gas emission reduction. Such models should be tested in specific pilot projects.

Agenda

Workshop
On
"Toxic Flows in WEEE Plastic"

26th August 2011
Gulmohar, India Habitat Center, Lodi Road, New Delhi

1000 – 1030	Registration	
1030 – 1130	Inaugural Panel	
	Welcome & Special Address	Ravi Agarwal, Toxics Link
	Project background and role of partners	Rolf Widmer, EMPA
	Address	Mr. Martin Strub, chargé d´ Affaires a.i. of Switzerland
	Address by Chief Guest	Sh. Rajiv Gauba, Joint Secretary, Ministry of Environment & Forests, Government of India
	Vote of Thanks	Satish Sinha, Toxics Link
1130 - 1145	Tea/Coffee Break	
1145 - 1300	Technical Session: Chaired by Dr. D.P. Amalnerkar, Executive Director, C-MET	
1145 - 1200	RoHS regulated substances in mixed plastics from WEEE	Mathias Schleup, EMPA
1200 - 1245	Plastics recycling study findings India	Priti Mahesh & PrashantRajankar, Toxics Link
1245 – 1300	Plastics recycling overview India	Ravi Kumar Agarwal, All India Plastic Industries Association
1300 - 1345	Panel discussion: Chaired by Dr J. Kamyotra, Member Secretary, Central Pollution Control Board	
	Panelists: Mathias Schleup, EMPA, Satish Sinha, Toxics Link, Ravi Kumar Agarwal, AIPIA	
1345 - 1430	Lunch	

List of Participants

	Name	Organization	Address
1.	Amit Chadha	MAIT	4th Floor, PHD House, Opp. Asian Games Village, New Delhi-110 016
2.	Amit Jain	IRG System South Asia Private Limited	K-71, 1st Floor, Hauz Khas Enclave, New Delhi-110016
3.	Ankit Chaturvedi	Earth Sense Recycle Pvt. Ltd.	Plot No.225, Sector-VI, IMT Manesar, Gurgaon, Haryana - 122 051
4.	Ankush Gupta	NISTADS	Room No. 206, NISTADS, R. K. Krishnan Marg, Pusa Gate, New Delhi.
5.	Arjun Balakrishnan	Panasonic India Pvt. Ltd.(PI)	No. 88, 6th Floor, " SPIC building Annexe", Mount Road, Guindy, Chennai - 600032
6.	Ashish Chaturvedi	GIZ-ASEM	A-33 Gulmohar Park, New Delhi-110049
7.	Bharti Chaturvedi	Chintan	C-14, Lajpat Nagar III, 2nd Floor New Delhi -110024
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9.	D. P. Amalnerkar	C-MET	Panchawati, Off Pashan Road. Pune : 411 008.
10.	Dr. Saroj, Director	MoEF	Paryavaran Bhavan, CGO Complex, Lodhi Road, New Delhi - 110 003
11.	Dieter Mutz	GIZ-ASEM	A-33 Gulmohar Park, New Delhi-110049
12.	John Dunham	US Embassy	Shantipath, Chankyapuri, New Delhi - 110 021
13.	Shri. J. S. Kamyotra Member Secretary	CPCB	Parivesh Bhawan, CBD-cum-Office Complex East Arjun Nagar, Delhi - 32,
14.	Lakshmi Raghupati	Consultant	GIZ, A-33 Gulmohar Park, New Delhi-110049
15.	M.R.P. Reddy	C-MET, Hyderabad	
16.	Mattia Celio	Embassy of Switzerland	Chandragupta Marg, Chanakyapur, New Delhi - 110021
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18.	Panchalini	Chintan	C-14, Lajpat Nagar III, 2nd Floor New Delhi -110024
19.	Neha Lalchandani	The Times of India	
20.	Niloufer Shroff	Department of IT	Electronics Niketan, 6, C. G. O. Complex, New Delhi-110003
21.	Param Prakash	A2Z Recycling	Plot No. 44, Sec-32, Institutional Area, Gurgaon-122001
22.	Prabhjot Sodhi	CEE	C-40, Ground Floor, South Extension-II, New Delhi-110049
23.	Pradeep Dadlani	SYCOM	Vatika, 6 Kaushalya Park, HauzKhas, New Delhi - 110016
24.	Pranshu Singhal	Nokia	1st Floor, Tower-A, SP Infocity, Plot No. 243, UdyogVihar Phase-1, Gurgaon
25.	Priya Ghose	US Embassy	Shantipath, Chankyapuri, New Delhi - 110 021
26.	Rachna Arora	GIZ-ASEM	A-33 Gulmohar Park, New Delhi-110049
27.	Rajendra Kumar Kaushal	IIT Delhi	Department of Civil Engineering, I. I. T. Delhi
28.	Rakeshwar Bhardwaj	Greenscape	512, Elegance Tower, Plot No, 8 Non Hierarchical Commercial Centre, Jasola, New Delhi-110025
29.	Ravi Kumar Aggarwal	All India Plastic Industries Association	203, Hansa Tower, 25-Central Market, Ashok Vihar Phase-1, Delhi-52
30.	Ravi Shankar Behera	Embassy of Sweden	Nyaya Marg, Chanakyapuri, New Delhi 110 021
31.	Rekha Grover	Department of IT	Electronics Niketan, 6, C. G. O. Complex, New Delhi - 110003
32.	S. John Robert	Earth Sense Recycle Pvt. Ltd.	Plot No.225, Sector-VI, IMT Manesar, Gurgaon, Haryana - 122 051
33.	S. K Nigam	CPCB	Parivesh Bhawan, CBD-cum-Office Complex East Arjun Nagar, Delhi-32
34.	Sharon S Ahmed	GIZ-ASEM	A-33 Gulmohar Park, New Delhi - 110049
35.	Shashi Bhushan Pandit	HRA	B-12A, Lane No.02, East Nathu Colony, Shahdara Delhi-110093
36.	Sonia Duhan	A2Z Recycling	Plot No. 44, Sec-32, Institutional Area, Gurgaon-122001
37.	Supriya Bhardwaj	SYCOM	Vatika, 6 Kaushalya Park, Hauz Khas, New Delhi - 110016
38.	Suresh Kennit	Embassy of Switzerland	Chandragupta Marg, Chanakyapur, New Delhi - 110021
39.	Suresh Khanna	ELCINA	422,Okhla Industrial Area Phase-III, New Delhi
40.	S Suresh Kumar	Student	
41.	Pooja Pandey	Student, JNU	Room no. 206, Godavri Hostel, J. N. U. New Delhi
42.	U. P. Mulik	C-MET	Panchawati, Off Pashan Road. Pune-411 008.
43.	Vijaya Kumar,	E-Parisaraa Pvt. Ltd.	No. B-41 / 1, III Stage, Peenya Industrial Estate, Banglore-560058
44.	Vinay Jain	Narela Relocation Industrial Welfare Association	F-2764, DSIDC, Narela, Delhi-110040
45.	Upasana Choudhry	Hewlett Packard	Tower D, 6th Floor, Global Business Park, M. G. Road, Gurgaon.
46.	Rajender Kumar	HRA	B-12A, Lane No.02, East Nathu Colony, Shahdara Delhi-110093
47.	Dr. Sharad	MoEF	Paryavaran Bhavan, CGO Complex, Lodhi Road, New Delhi - 110 003
48.	Ranjan Banerjee	Birla Tyres	Khedi Mubarak Pur, Laksar, Haridwar-247663
49.	Vinodbabu	CPCB	Parivesh Bhawan, CBD-cum-Office Complex East Arjun Nagar, Delhi-32
50.	Anand Kumar	CPCB	Parivesh Bhawan, CBD-cum-Office Complex East Arjun Nagar, Delhi-32
51.	Martin Strub	Government of Switzerland	
52.	Rolf Widmer	EMPA	
53.	Mathias Schluep	EMPA	
54.	Ravi Agarwal	Toxics Link	
55.	Satish Sinha	Toxics Link	
56.	Priti Mahesh	Toxics Link	
57.	PrashantRajankar	Toxics Link	
58.	Vinod Kumar Sharma	Toxics Link	
59.	Rambha Tripathy	Toxics Link	
60.	Piyush Mohapatra	Toxics Link	
61.	Rajeev Betne	Toxics Link	
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