2005

RECYCLING OF ELECTRONIC WASTES IN CHINA & INDIA: WORKPLACE & ENVIRONMENTAL CONTAMINATION

REPORT

GREENPEACE

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GUIYU, CHINA - 8 MARCH 2005 - A MIGRANT WORKER STRIPS WIRES FROM E-TRASH IN A JUNK YARD IN GUIYU IN GUANGZHOU PROVINCE.

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authors K. Brigden, I. Labunska, D. Santillo, & M. Allsopp, *Greenpeace Research Laboratories, Department of Biological Sciences, University of Exeter, Exeter EX4 4PS, UK*

design & layout Tania Dunster, kÏ design, Sweden

contact persons
communications mdunlop@diala.greenpeace.org
campaign zeina.alhajj@int.greenpeace.org

DELHI, INDIA - 11 AUGUST 2005 - YOUNG WORKERS AT AN E-WASTE RECYCLING YARD IN DELHI.

executive summary

introduction Expansion of the global market for electrical and electronic products continues to accelerate, while the lifespan of the products is dropping, resulting in a corresponding explosion in electronic scrap.
As noted by UNEP (2005)*:

"Every year, 20 to 50 million tonnes of electrical and electronic equipment waste ("e-waste") are generated world-wide, which could bring serious risks to human health and the environment. While 4 million PCs are discarded per year in China alone."

This rapidly growing "e-waste" stream presents additional difficulties because a wide range of hazardous chemicals are, or have in the past been, used in components of electrical and electronic devices, and these subsequently create substantial problems with regard to handling, recycling and disposal of obsolete products.

The European Union (EU), Japan, South Korea, Taiwan and several states of the USA have introduced legislation making producers responsible for their end-of-life products. The EU has banned the use of certain hazardous substances in electrical and electronic products from July 2006, to facilitate safer recycling.

For the present, however, the "e-waste" recycling sector in many parts of Asia remains largely unregulated. It is also poorly studied with regard to its impacts on the environment and on the health of recycling workers and surrounding communities.

design of the study This study was designed to provide a snapshot of workplace and environmental contamination from a selection of industrial units and dump sites associated with the electronic waste-recycling sector in China and India. A total of more than 70 samples were collected during March 2005 from sites located in the vicinity of Guiyu Town, Guangdong Province in southern China and in the suburbs of New Delhi, India. Samples included industrial wastes, indoor dusts, soils, river sediments and groundwater from typical sites representing all major stages routinely employed in the dismantling, recycling and final disposal of electrical and electronic wastes (i.e. storage, component separation, plastic shredding, acid processing/leaching, open burning and residue dumping) in both countries.

summary of key findings Results confirm that all stages in the processing of electrical and electronic wastes have the potential to release substantial quantities of toxic heavy metals and organic compounds to the workplace environment and, at least to the extent studied, also to surrounding soils and water courses. Among the toxic heavy metals most commonly found in elevated levels in wastes from the industry, as well as in indoor dusts and river sediments, were those known to have extensive use in the electronics sector, i.e.

* lead and tin, most probably arising in large part from solder and, in the case of lead, batteries
* copper, for example from wires and cables
* cadmium, from a variety of uses including batteries and solder joints
* antimony, most probably from use of antimony trioxide as a flame retardant additive in plastics and resins as well from use in electrical solders

Many other metals associated with the electronics industry were also relatively abundant in many samples, including barium, chromium, cobalt, gold, mercury, nickel, silver and zinc.

The range of organic contaminants identified in waste and sediment samples also reflected current or historical use in electrical and/or electronic goods, including brominated, chlorinated and phosphorus-based flame retardants, phthalate esters and esters of long-chain organic acids. Polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs) were particularly in evidence, as well as many other organic chemicals, some containing chlorine or bromine, which could not be reliably identified. Given the crude methods employed in much of the recycling sector investigated, it is likely that some of these chemicals arose as products of incomplete combustion or of chemical reactions occurring in complex mixed wastes.

Key results according to the different activities and processes employed in the "e-waste" recycling sector in both China and India, as well as brief information on the hazards of some of the chemical groups investigated, are summarised on the following page.

* UNEP (2005) "E-waste: the hidden side of IT equipment's manufacturing and use". Early Warnings on Emerging Environmental Threats No. 5, United Nations Environment Programme

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component separation and solder recovery Samples of dust collected from the floors of three solder recovery workshops in Beilin, Region of Guiyu (China) contained high levels of a variety of metals compared to background levels, particularly lead and tin, as well as copper, antimony and, in some cases, cadmium and mercury. One such sample comprised 29.3% by weight tin, 7.6% lead and 1.1% copper. For all dusts collected from the workshops in China, the concentrations of lead were hundreds of times higher than typical levels recorded for indoor dusts in other parts of the world.

lead (Pb) is widely used in electronic goods, as a major component of solders (as an alloy with tin) and as lead oxide in the glass of cathode ray tubes (televisions and monitors), as well as in lead-acid batteries. Its compounds have also been used as stabilisers in some PVC cables and other products. Lead is highly toxic to humans, as well as to animals and plants. It can build up in the body through repeated exposure and have irreversible effects on the nervous system, particularly the developing nervous system in children.

A similar picture was apparent in the component separation workshops sampled in India. Dusts from general separation workshops contained the same metals at levels which, though somewhat lower than those recorded in China, were nevertheless still greatly elevated (5-20 times) over background levels. Dust samples from battery dismantling workshops in Mayapuri and Buradi districts were particularly heavily contaminated, the former containing 8.8% by weight lead and the latter 20% cadmium. This last figure is around 40 thousand times higher than levels typical for indoor dust samples.

cadmium (Cd) occurs in electronics both as cadmium metal, in some switches and solder joints, and as cadmium compounds in rechargeable batteries, UV stabilisers in older PVC cables and “phosphor” coatings in older cathode ray tubes. Like lead, cadmium can accumulate in the body over time, with long-term exposure causing damage to the kidneys and bone structure. Cadmium and its compounds are known human carcinogens, primarily through inhalation of contaminated fumes and dusts.

Of the dust samples from the Indian workshops analysed for organic contaminants, all contained the persistent organic pollutants PCBs (more than 35 individual congeners in each case), chemicals once widely used in electrical and electronic applications (among others), though now banned from new uses throughout the world. One of these three samples, namely that from a workshop in Shashtri Park, also contained two congeners of the brominated flame-retardants PBDEs, still in use over much of the globe. In all three cases, a substantial proportion (52-69%) of all organic chemicals isolated from the dust samples could not be identified. A single sample of dust collected from a Shashtri Park workshop in the previous year also showed the presence of PCBs among a complex mix of other organic contaminants.

Until the late 1970s, PCBs (polychlorinated biphenyls) were widely used in insulating fluids for electrical transformers and capacitors, as well as flame-retardant plasticisers in PVC and other polymer applications. They are highly persistent and bioaccumulative chemicals, rapidly becoming widespread through the environment and building up several thousand-fold in body tissues of wildlife. PCBs exhibit a wide range of toxic effects including suppression of the immune system, liver damage, cancer promotion, damage to the nervous system, behavioural changes and damage to both male and female reproductive systems.

A preliminary study in Beilin (China), in which dust samples were collected from the houses of two solder-recovery workers and from one household having no connection with the industry, indicated the potential for the home environment to become contaminated with chemicals from the workplace (e.g. as a result of contamination of work clothing). Even though the houses were remote from the solder recovery works themselves, levels of copper, lead, tin, antimony and, to a lesser degree, cadmium were higher in the dusts from the two solder-workers’ houses than in the single control house sampled. This indicative result illustrates the need for further research into contaminant exposure in the homes of workers in this sector.

MUYU, CHINA - 13 FEBRUARY 2004 - A MIGRANT WORKER REMOVING COPPER FROM AN AIR-CONDITIONING UNIT, THEN RECYCLING THE REMAINING ALUMINIUM IN MUYU, TAIZHOU CITY, ZHEJIANG PROVINCE.

MUYU, CHINA - 13 FEBRUARY 2004 - A MIGRANT WORKER POURING LIQUID ALUMINIUM INTO MOULDS IN MUYU, TAIZHOU CITY, ZHEJIANG PROVINCE.

Contamination of the environment beyond the workplace was also indicated by the results of analysis of street dusts from several locations around the recycling district of Shashtri Park in Delhi, compared to those of two other, more residential areas. Although results for heavy metals were somewhat less conclusive, three of the four road dusts collected in the Shashtri Park area contained traces of PCBs, chemicals which were not detectable in road dust from either Kailashnagar or Safourjung districts.

mechanical shredding Sediments accumulating in discharge channels arising from mechanical shredding facilities in the Guiyu town of China contained variable but generally very high levels of heavy metals as well as complex mixtures of organic contaminants. Discharge channel sediments from one such facility close to the Guiyu to Nanyang road, and from two similar facilities close to the Chendiandian to Guiyu road contained elevated levels of copper (between 9500 and 45900 mg/kg), lead (4500-44300 mg/kg) and tin (4600-33000 mg/kg) as well as antimony (1390-2150 mg/kg), nickel (150-2060 mg/kg) and cadmium (13-85 mg/kg). For copper, lead, tin, nickel and cadmium, these levels are between 400 and 600 times higher than would be expected for uncontaminated river sediments. For antimony, the levels are around 200 times higher than background. Wastewater collected from one of the two Chendiandian to Guiyu road facilities, consisting of a thick slurry of particulates suspended in water, was also found to contain high concentrations of these and other heavy metals.

Common organic contaminants in these wastes included the brominated flame retardant compounds PBDEs. A total of 43 PBDE congeners, from tribrominated to hexabrominated, were isolated from the sediment sample taken from the wastewater ditch of the facility close to the Guiyu to Nanyang road. A similar range of PBDEs was found in two samples of sediment collected from the waste channel serving one of the two facilities close to the Chendian to Guiyu road. Traces of PBDEs were also detectable in the wastewater/slurry flowing from this facility to the channel at the time of sampling.

PBDEs (polybrominated diphenyl ethers) one of several classes of brominated flame retardants used to prevent the spread of fire in a wide variety of materials, including casings and components of many electronic goods. They are environmentally persistent chemicals, some of which are highly bioaccumulative and capable of interfering with normal brain development in animals. Several PBDEs are suspected endocrine disruptors, demonstrating an ability to interfere with hormones involved in growth and sexual development. Effects on the immune system have also been reported.

Both sediment samples from this channel also contained the hormone-disrupting chemical nonylphenol (in one case, as an isomeric mixture). Furthermore, one of these samples (that collected closer to the facility itself) contained a diversity of phthalate esters, chemicals used as plasticisers in a range of polymers (especially PVC), including the known reproductive toxins dibutyl phthalate (DBP) and di(2-ethylhexyl) phthalate (DEHP). This sample also contained residues of the hazardous organophosphorus flame retardant triphenyl phosphate (TPP), as well as two closely related chemicals which may be contaminants in, or primary degradation products of, TPP preparations.

It was not possible to collect wastewater from the channel serving the other shredding facility on the Chendian to Guiyu road. Nevertheless, a sample of sediment from this channel revealed the presence of a diverse array of chlorinated and mixed chlorinated/brominated benzenes and chlorinated naphthalenes. The presence of the chlorinated naphthalenes may well arise from their former use as flame retardant additives in plastics and rubbers, though they have had a diversity of other uses.

nonylphenol (NP) is a chemical most widely known as a breakdown product of nonylphenol ethoxylate (NPE) detergents, though it has reportedly also been used as an antioxidant in some plastics. It is a strong endocrine disruptor, capable of causing intersex (individuals with both male and female characteristics) in fish. Nonylphenol can also build up through the food chain and may be capable of causing damage to DNA and even sperm function in humans.

Although no similar facilities were identified and sampled in India, a single sample of shredded plastic waste collected from a workshop in Zarfarabad did contain PBDEs and the organophosphate flame retardant TPP, as well as traces of nonylphenol. Whereas concentrations of most metals were relatively low in this sample, antimony was present at a significant level (124 mg/kg), probably reflecting the presence of antimony trioxide in the plastic components being shredded (thought to be mainly keyboards and monitor housings).

antimony (Sb) is a metal with a variety of industrial uses, including as a flame retardant (as antimony trioxide) and as a trace component of metal solders. In some forms, antimony shows many chemical similarities to arsenic, including in its toxicity. Exposure to high levels in the workplace, as dusts or fumes, can lead to severe skin problems and other health effects. Antimony trioxide is recognised as a possible human carcinogen.

acid processing/leaching Several samples of acidic solid waste collected from open pits within two facilities located in Longmen village (China) and engaged in acid processing/leaching of electronic waste contained expected high levels of several heavy metals. These included lead (350-5400 mg/kg), tin (640-3600 mg/kg), copper (230-6600 mg/kg), antimony (360-1590 mg/kg) and nickel (27-940 mg/kg). These levels of copper, lead and tin are more than 100 times higher than typical background values for uncontaminated soils and sediments. Three of these four solid waste samples were found to contain traces of a number of chlorinated benzenes, while two also contained significant residues of PCBs and PBDEs.

Phthalate esters were also in evidence, along with, in one of the four acid waste samples (collected from an open pool within one of the two facilities), a brominated nitrophenol of unknown origin. Highly acidic wastewater collected from the same open pool contained five different phthalate esters, an oxygenated derivative of triphenyl phosphate (TPP) and a chlorinated nitrophenol, again of unknown origin. Concentrations of metals were again expectedly high, including 31.8 mg/l antimony, 12.2 mg/l cadmium, 774 mg/l copper, 153 mg/l nickel and 85.5 mg/l tin.

triphenyl phosphate (TPP) is one of several organophosphorus flame-retardants used in electronic equipment, for example in the casings of computer monitors. TPP is acutely toxic to aquatic life and a strong inhibitor of a key enzyme system in human blood. It is also known to cause contact dermatitis in some individuals and is a possible endocrine disruptor.

Comparison of a sample of sediment collected from the river upstream from the acid works with a similar sample collected downstream gives a clear indication of the nature and extent of contamination resulting from the activities taking place within these facilities. Concentrations in the downstream sample, as compared to the upstream sample, were more than 20 times higher for antimony, mercury and nickel, around 10 times higher for cadmium and copper and between 3 and 6 times higher for lead, tin and zinc. Moreover, whereas the upstream sample (pH 6) contained only 15 extractable organic compounds, dominated by non-halogenated hydrocarbons, the downstream sample (pH 4, i.e more acidic) contained more than 70 compounds, including the phthalate DEHP and 24 separate PBDE congeners. The acidification of the water and sediments, as well as making toxic metals more mobile and, therefore, more likely to have toxic effects, may in itself be expected to have substantial impacts on aquatic life.

Phthalate esters and PBDEs were also among the organic contaminants detected in river sediments adjacent to two other acid working facilities, located close to the Guiyu to Nanyang road. Acidic solid wastes collected from the "overflow" area adjacent to the larger of these two facilities contained high levels of copper, lead, tin and antimony, as expected, as well as elevated levels if nickel and silver. These wastes also contained PBDEs, PCBs and chlorinated benzenes, as well as a chlorinated and a propylated naphthalene derivative and, in one of the two samples, the phthalate ester DEHP. The adjacent river sediments were highly acidic and contained a similar range of metal contaminants along with the phthalate esters and PBDEs. A control sample collected from the same river some distance from the facility contained little in the way of organic contamination. Concentrations of many metals in this control sample were also tens to hundreds of times lower.

DELHI, INDIA - 11 AUGUST 2005 - COMPUTER MOTHERBOARDS BEING MELTED OVER OPEN FIRES IN A ELECTRONICS WASTE RECYCLING YARD IN DELHI.

DELHI, INDIA - 11 AUGUST 2005 - A MAN TAKES A BREAK IN THIS WORKSHOP-LIVING QUARTERS, SURROUNDED BY HEAPS OF ELECTRONIC SCRAP.

polychlorinated naphthalenes (PCNs) were the precursors to the PCBs, once used extensively in capacitors and as insulating compounds in wiring (among many other uses). They also share many properties with the PCBs, including environmental persistence and toxicity to wildlife and possibly humans. Impacts on the skin, liver, nervous system and reproductive system have been reported in animals.

Samples collected at an acid processing/leaching facility in New Delhi, located in a small workshop in the Mandoli Industrial Area, focused on materials and wastes at different stages in the leaching process. As expected, heavy metals detectable in the original ground plastic waste appear to be concentrated to very high levels in the final spent acid wastes (e.g. 68 mg/l antimony, 240 mg/l copper, 20 mg/l lead, 478 mg/l nickel, 340 mg/l tin and 2710 mg/l zinc). Residues of phthalate esters and chlorophenols were also detectable in these acid wastes.

Additionally, several samples collected in association with the acid processing facilities contained a number of so-far unidentified compounds showing fragmentation patterns characteristic for polyhalogented (probably polybrominated) organic compounds. Further research would be necessary in order to identify these.

Aside from the obvious health and safety concerns which arise from the handling of concentrated acid solutions in these workshops, indications from workers that the contaminated spent acid wastes are simply disposed of to land also raises substantial environmental concerns.

open burning Analysis of several (five) samples of ashes and partially burned electronic wastes collected from a dumpsite in the Longgang village of Guiyu (China) revealed both the extent and degree of variability of contamination of such wastes. Levels of each specific contaminant in these wastes almost certainly depend on the precise nature of the components burned as well as the techniques used. Cadmium, copper, lead and zinc were abundant in most samples. Levels of antimony were notably high, with concentrations in four of the five samples at or above 1000 mg/kg and in one of these reaching 15200 mg/kg.

This latter sample also contained the greatest number and diversity of hazardous organic contaminants, including a range of chlorinated and mixed chlorinated/brominated benzenes, 2-bromophenol, tetrabromodiphenyl ether (a PBDE), 3,4-dibromostyrene, 1,3-dibromobutane and three isomers of tribromotoluene. Some or all of these may arise from their specific use as flame retardant additives in certain plastics though the possibility that some have been formed as products of incomplete combustion of electronic goods cannot be ruled out. Among the many other organic compounds identified were numerous polycyclic aromatic hydrocarbons (PAHs, typical products of incomplete combustion) and chlorinated biphenyls (PCBs), as well as more than 10 additional compounds suspected to be halogenated but which could not be identified to any degree of reliability. A possible positive result for the most toxic dioxin congener, namely 2,3,7,8-tetrachlorodibenzo-p--dioxin (TCDD) was subsequently confirmed by an external laboratory accredited for dioxin analysis. It was not possible to analyse the other samples for presence of chlorinated dioxins, nor any of the samples for brominated dioxins (though their presence may well be anticipated).

High levels of cadmium, copper, lead and zinc were also characteristic of ashes collected from two waste burning operations in New Delhi (India), at Ibrahimpur and Shashtri Park. PCBs, chlorinated benzenes and PAHs were also in evidence here.

mercury (Hg) is still used in some batteries and lighting components for flat screen electronic displays, and was formerly used also in switches and relays. Mercury and its compounds are highly toxic, causing damage to the central nervous system and kidneys. Once in the environment, mercury can be converted to its organic methylated form by bacterial activity, a form, which is highly bioaccumulative, as well as being toxic.

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storage of wastes for processing Soil and dust samples collected from two locations in New Delhi (Kantinagar and Brijgang) used to store cathode ray tubes (CRTs), from televisions or computer monitors, demonstrated the potential for contamination of these materials with heavy metals from the tubes. Cadmium, zinc and yttrium sulphides have been used in the “phosphor” coatings inside CRTs while lead oxide occurs in the glass itself. Levels of all these metals were elevated in the dusts and soils collected in the CRT storage areas.

DELHI, INDIA - 11 AUGUST 2005 - OLD CATHODE RAY TUBES ARE GIVEN A NEW LEASEOF LIFE AS THIS WORKER INSERTS NEW FILAMENTS, SEALING IT OFF WITH A RUDIMENTARY BLOW TORCH.

GUIYU, CHINA - 8 MARCH 2005 - A MIGRANT WORKER STRIPS WIRES FROM E-TRASH IN A JUNK YARD IN GUIYU IN GUANGZHOU PROVINCE.

DELHI, INDIA - 11 AUGUST 2005 - A WORKER IN AN ELECTRONICS WASTE RECYCLING YARD IN DELHI.

GUIYU, CHINA - 9 MARCH 2005 - A STACK OF OLD KEYBOARDS AND OTHER E-WASTE IN NANYANG, CHINA.

conclusions Although clearly not an exhaustive study of "e-waste" recycling facilities in either country, the results summarised above do provide an illustration of the breadth and scale of health and environmental concerns arising from this industrial sector. Both wastes and hazardous chemicals used in the processing are commonly handled with little regard for the health and safety of the workforce or surrounding communities and with no regard for the environment. Overall, the result is severe contamination of the workplace and adjacent environment with a range of toxic metals and persistent organic contaminants.

Clearly, it is not possible from the results of this study to evaluate the damage likely to be caused to human health from these widespread practices. Nor was it possible to conduct a comprehensive survey of the full extent of environmental impacts arising from each facility, or from the sector as a whole, in either country. Nevertheless, the results do indicate that exposure to hazardous chemicals arising from the waste-stream can be locally severe. Further research would be necessary in order to identify and quantify the full impact of this industrial sector, including studies on the health of workers and of residents in adjacent communities.

In the mean time, however, the data available do provide a compelling case for immediate action in both countries to address workplace health and safety and waste management.

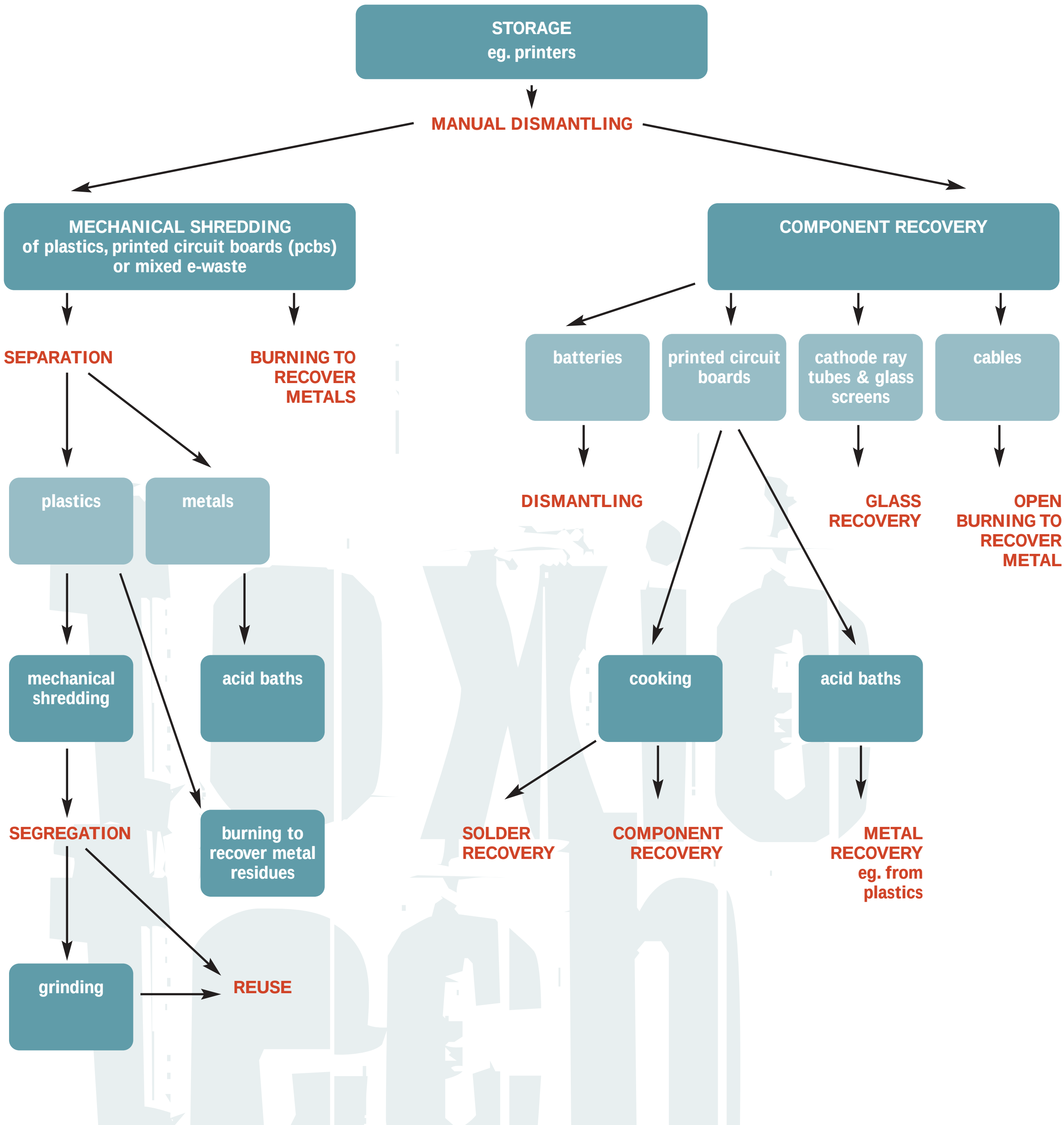
The problems identified are greatly exacerbated by the poor working practices and lack of responsible waste management in the areas sampled in this study. However, the fact that wastes generated by every stage of the recycling process are contaminated with a range of toxic heavy metals and persistent organic pollutants is a direct result of the use of these hazardous materials in electronic goods at the manufacturing stage. Therefore, as well as bringing to light some of the many unseen impacts of the vast and growing electronics waste stream, and the need for much tighter controls both on the transboundary movement of such wastes and the manner in which they are recycled, this study also adds weight to the need to redesign and reformulate all new electronic goods in order:-

- to facilitate proper dismantling and component separation and
- to avoid the use of hazardous chemical components at source.

The European Directive on Waste Electrical and Electronic Equipment (WEEE) and the related Restrictions on Hazardous Substances (RoHS) go some way towards addressing the problem, though applying only regionally and covering only a fraction of all the hazardous substances used in electronics manufacturing.

In short, this study provides a further illustration of the urgent need for manufacturers of electronic goods to take responsibility for their products from production through to the end of their lives. As a major contribution towards addressing these problems, manufacturers must develop and design clean products with longer life-spans, that are safe and easy to repair, upgrade and recycle and will not expose workers and the environment to hazardous chemicals.

DIAGRAM 1: DIFFERENT STAGES OF E-WASTE RECYCLING PROCESSES SAMPLED IN INDIA AND CHINA



NB: Different processes are used to recover materials from the same components. Not all the processes shown here are used in all cases and there is no set sequence which applies to all locations or all types of electronic equipment.

DELHI, INDIA - 11 AUGUST 2005 -
YOUNG WORKERS AT AN E-WASTE RECYCLING YARD IN DELHI.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greenpeace international
Ottho Heldringstraat 5, 1066 AZ Amsterdam, Netherlands
t +31 20 718 2000 f +31 20 514 8151
www.greenpeace.org