AN ASSESSMENT OF FLOW PROCESS OF SECOND-HAND DESKTOP COMPUTERS FROM IMPORT TO E-WASTE IN LAHORE

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ABSTRACT

An assessment of flow process of second-hand desktop computers in Lahore from import to E-waste management is presented. Lahore is a hub of import, reuse, recycling and export of dismantled second-hand desktop computers.

There are twenty main importers of second-hand desktop computers in Lahore and three centers of storage, sale of second-hand computers, dismantling and repair namely Walton Road, Hall Road and Hafeez Center. A total of 50,000 second-hand desktop computers are imported in Lahore per month.

The second-hand computer systems are sold for Rs. 10,000 each. The average life of a second-hand desktop computer is about six months. Then it may be used after repair for another couple of years. These computers are used by lower middle class individuals, NGOs, lower middle class educational institutions and private offices since they can't afford to buy new computers.

There is informal system of hawkers and junk shops for E-waste from households and institutions. The main business centers namely Hafeez Center and Hall Road generate substantial quantities of E-waste which is sold to recyclers.

A large amount of this E-waste is recycled in small units close to Bund Road and Shahdarrah. Steel and plastic is recovered from the body of computers while precious metals i.e. gold and silver and heavy metals like lead (Pb) and copper (Cu) are recovered from the printed circuit boards. The recycling facilities are highly polluted and hazardous. Acid fumes, dioxins, lead and cadmium vapors and other heavy toxic metals like copper are released in effluents. The workers of these recycling units are exposed to dioxins, heavy metals and acid fumes. In addition they are exposed to heat stress and injuries

while operating unguarded risky machines. Plastic granules manufactured in recycling units are exported to China.

Mother boards, plastic and RAM are also exported to China for recycling. Dubai imports only mother boards for recycling.

Dedication

I dedicate this thesis to Almighty Allah and His Holy Prophet

Muhammad (PBUH)

and

to my beloved parents, Muhammad Inayat Khan and Musarrat Inayat.

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*With the name of **Allah**, the Most Beneficent and Merciful, the source of knowledge and wisdom to mankind, who has blessed me with the requisite potential and ability to complete this task in limited time period successfully. All respect to our last **Prophet Hazrat Muhammad (P.B.U.H)** who knew the new ways of learning, knowledge and wisdom for all humanity.*

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Sidrah Inayat Khan

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List of Symbols

As	Arsenic
Au	Gold
Ba	Barium
BAN	Basel Action Network
Be	Beryllium
BFRs	Brominated flame retardants
BLLs	Blood Lead Levels
Cd	Cadmium
CD	Compact Disk
CFER	Centre de Formation en Enterprise et Récupération
CNS	Central Nervous System
CPU	Central Processing Unit
Cr[VI]	Hexavalent Chromium
CRT	Cathode Ray Tube
Cu	Copper
EPA	Environmental Protection Agency (USA)
EPR	Extended Producer Responsibility
ESTs	Environmentally sound technologies
ETBC	Electronics Take Back Coalition
EU	European Union
E-waste	Electronic Waste

Hg	Mercury
ISWM	Integrated Solid Waste Management
KEDA	Karachi Electronic Dealers Association
Kg	Kilogram
LCD	Liquid crystal display
MSW	Municipal Solid Waste
OECD	Organization for Economic Co-operation and Development
P	Phosphorus
Pb	Lead
PBDE	Polybrominated Diphenyl Ether
PCBs	Polychlorinated biphenyls
PCs	Personal Computers
PEPA	Pakistan Environmental Protection Act
PEPC	Pakistan Environmental Protection Council
PWB	Printed Wiring Board
Sb	Antimony
SEPA	Swedish Environmental Protection Agency
Sn	Tin
UN	United Nations
UNEP	United Nation Environmental Programme
US	United State
WR3A	World Reuse, Repair and Recycling Association
$	American dollar

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1. Introduction

1.1 Background of the Study

E-waste is a mounting worldwide threat. The growth of E-waste has been increasing rapidly for the last few decades due to the technological advancements. Another aspect of the problem is the diminishing of average life of computers. E-waste is one of the major environmental issues in the industrial countries and has become rapidly a problem in the developing countries. The very obvious and important reason for this problem is mainly illegal export of E-waste to the developing countries like Pakistan, India and China etc. as final disposal sites. There is no management system in developing countries like Pakistan to handle E-waste. The study takes an overview of the flow of second-hand desktop computers to Lahore, Pakistan. The requisite information was gathered through interviews with the stakeholders and visits to the field areas, where waste is handled.

1.2 Definitions of E-waste

There is no agreed definition of E-waste. The reason is that after meeting its end of life at one place electronic waste still has valuable use at other place. In the following are given some definitions based on literature review:

"E-waste encompasses a broad and growing range of electronic devices ranging from large household devices such as refrigerators, air conditioners, cell phones, personal stereos, and consumer electronics to computers which have been discarded by their users." (Puckett et al, 2002)

"Any appliance that uses electric power and has reached its end of life-cycle limit." (OECD, 2001)

"Some of the second-hand products that are extremely old are commonly referred to as E-waste." (Schluep, et al., 2008)

Nnorom and Odjango (2007) suggest that E-waste is "internally generated or imported illegally as used goods in an attempt to bridge the so-called digital divide".

E-waste contains more than 1000 different substances. Most of these contain heavy metals which are dangerous to environment and human health (Gaulon et al 2005).

This study covered mainly Desktop Computers consisting of Central Processing Units (CPUs) and monitors.

1.3 E-waste at Global Level

The rapid growth in the field of electronics in industrialized countries has posed serious and dangerous environmental challenges due to uncontrolled handling of E-waste. Over a few decades, the personal computers as obsolete electronics have become a major problem. According to the European Commission, "E-waste is the fastest growing component of municipal trash by a factor of three" (Schmidt 2002). Due to rapid change in technology and reduced life span of the desktop computers redundancy is increasing. The average life of a computer has been reduced from four to five years to two years. The amount of E-waste is increasing day by day due to intended obsolescence in a designed system that serves corporations (Pucket et al. 2002). The rapid piling up of redundant goods and end of life electronic products is accumulating huge quantities of electronic

waste. This waste is being exported to developing countries. Due to forced redundancies the consumers abandon their computers rapidly (Tong & Wang 2007).Urbanization is also a major factor for the increased growth and consumption based market in the developing countries. The amount of electronic waste that is discarded every year in developed countries continues to grow rapidly. In 1994, it was estimated that approximately 20 million PCs, became obsolete every year. By 2004, this figure was to increase to over 100 million PCs. This fast growing waste stream is accelerating because the global market for PCs is far from saturation and the average life span of a PC is decreasing rapidly, for instance for CPUs from 4 to 6 years in 1997 to 2 years in 2005. The UN estimates that 20-50 million tons of E-waste is produced globally every year (UNEP, 2006). The EPA US estimates that 29.9 million desktops and 12 million laptops were discarded in 2007. That's over 112,000 computers discarded per day. In 2008, 3.16 million tons of e-waste was generated in the U.S. Of this amount, only 430,000 tons or 13.6 % was recycled (EPA). The rest were shipped to the developing countries where they were dumped particularly into poor rural communities. These products come into the system from the developed countries and may cause the problem of handling them as waste. Pakistan has been receiving over 500,000 second-hand computers per year (China Daily, 2012). Developing countries are expected to triple their output of E-waste by 2010.

E-waste is one of the major environmental issues in the developed countries and has become rapidly a problem in the developing countries. The very obvious and important reason for this problem is illegal export of E-waste to the developing countries like Pakistan, India and China etc. as final disposal sites. Large quantities of used computers are exported to the developing countries. It is claimed that all this waste is sent to the

developing countries for the purpose of reuse, repair, refurbishment and recycling. The recycling process in the developed countries is not feasible economically due to stringent environmental restrictions (Luther, 2010). The developed countries therefore ship this waste to developing countries for getting rid of their E-waste in the garb of trade. The serious issue of handling E-waste is rapidly growing. The handling of a large number of obsolete computers and continuous illegal import into Pakistan from other countries is of great concern**.** Since this is basically an urban problem there is an urgent need for proper management of E-waste particularly in the larger cities of Pakistan**.**

E-waste accumulation in developing countries is prompted due to its resale to consumers for recycling as well as flexible legislation. In the US, approximately 50 to 80 percent E-waste produced, is not handled locally but exported to the third world for the purpose of recycling and dumping in deprived rural communities (ETBC 2008). E-waste export to the countries like China, India and Pakistan are extremely harmful due to open burning of E-waste to get different valuable metals like gold, use of acid baths and extensive dumping (Puckett et al. 2002).

1.4 E-waste in Pakistan

The agents of some Western companies involved in computer dumping are working in Pakistan as well as other third world countries. These second-hand imported computers work for very short duration and become a waste. The rapid growth of E-waste stream is accelerating because the global market for PCs is expanding and the average life of a PC is decreasing rapidly (Culver, 2005). The UN estimates that 20-50 million tons of E-waste is produced globally every year (UNEP, 2006). These products come into the

system from the developed countries and may cause the problem of handling them as waste. Pakistan has been receiving over 500,000 second-hand computers per year (China Daily, 2012). In Lahore, the demand for used computers is high in educational institutions, government offices and NGOs. The consumption at household level of second-hand computers is also rising fast.

In Lahore and its suburbs, in the name of recycling, there is an active and continuous process of burning of different parts of E-waste to extract precious metals like gold and silver as well as copper etc. by those people who are unaware of their toxic effects. Plastics and steel of desktop computers get recycled and meet different forms of uses. Many of the parts of computers comprise organic compounds and heavy metals which are harmful to health and even carcinogenic and cause other diseases relating to nervous and reproductive systems (SEPA, 2011). The remains of the E-waste are further treated with municipal waste because of absence of specific management system to deal with E-waste. In the US, "the Department of Toxic Substances Control has determined that most electronic devices are toxic" (Earth tones 2006). Toxic chemicals such as beryllium (Be) and cadmium (Cd) in motherboards and semiconductors respectively cause cancer. Many substances in E-waste, such as lead (Pb), tin (Sn), copper (Cu), antimony (Sb), cadmium (Cd), mercury (Hg), hexavalent chromium (Cr[VI]), plastics, brominated, chlorinated and phosphorous-based flame retardants, polychlorinated biphenyls (PCBs), barium (Ba), beryllium (Be), toners, phosphorus (P), arsenic (As), and additives, are toxic to the human health and environment (Puckett et al. 2002, Meinhardt 2001, Earth Tones 2006, Worldwatch Institute 2005, Brigden et al. 2005, Environment Victoria 2005).

Computer monitors contain lead, which is a toxic heavy metal. The exposure to lead can cause damage to the central nervous system (CNS), cause hypertension and mental retardation. Alkaline batteries contain mercury and floppy disks have chromium which poses serious public health risk. Plastics that are used in the computers contain brominated flame-retardants (BFRs) which are not recycled very easily. When this hazardous waste is disposed, toxic substances can seep into the soil and contaminate ground water which may adversely impact human health and environment.

In Lahore, Pakistan the main stakeholders in E-waste management system are importers, repairers, waste treaters, recyclers and informal recyclers like Kabariyas (junkshop dealers). The main objective of involvement by formal and non formal sector in E-waste management is to make lucrative business. Non formal sector is interested just to get profit by extracting the valuable metals from different parts of computers. Vendors dismantle used computers to sell to the repairing shops so that the different parts of the computer can be reused. In this way refurbishers have also important contribution to the system followed by the recyclers. Many such businesses are actively working in Lahore city around Hafeez Centre, Hall Road and particularly in the suburbs of Lahore. Acids and other hazardous chemicals are used to dissolve the waste**.** All these processes are carried out in open spaces, particularly in suburbs without any safety measures. Furthermore the E-waste residues are finally dumped. The effluents from these processes are released in waterways.

Pakistan has not organized any management system for handling E-waste. It is a difficult job to get the statistical data on E-waste relating to all sectors like imports and exports, distribution, and the processes of handling. Lack of specific policy framework for E-

waste has resulted in the increased imports of E-waste into the country. Pakistan is a member of Basel Convention but has done nothing to control and regulate imports of second-hand computers. There are no regulations on burning E-waste in open spaces.

1.5 Legislation and Regulatory Framework on E-waste in Pakistan

E-waste has been become a major problem globally but it has become one of the biggest problems for health and environment in this century. This risky situation needs laws specific to the E-waste, yet to be enacted in the country. "Proper legislation and its implementation is the need of the hour to control this menace" (Daily Times**,** 2012).

Ministry of environment is responsible for National Environment Policy, Planning and International Environment Condition. The policy and decision making on environment under Constitution is the responsibility of Pakistan Environmental Protection Council (PEPC) presided by the Prime Minister of Pakistan. Environment Protection Agencies are established at both federal and provincial level. Section 13 and Section 14 of Pakistan Environmental Protection Act (PEPA) (1997), prohibit any imports of hazardous materials to the country. However the Act does not cover E-waste specifically nor does it cover its treatment and safe disposal.

According to Basel Convention Trans-Boundary Movements of Hazardous materials are banned. Although Pakistan is a member of Basel Convention on the Trans-Boundary Movement of Hazardous Waste and its Disposal, yet one finds no such ban in practice.

1.6 Objective

The overall objectives of the study were;

- To study in detail the import process of second-hand desktop computers.
- To assess the factors involved in trans-boundary movements of these products.
- To identify the process of entrance of second-hand computers into the city.
- To understand the flow of second-hand desktop computers in the Lahore city from a qualitative life cycle assessment point of view.
- To describe the marketing process of second-hand computers in the city.
- To assess the demand of consumption depending on the consumer.
- To assess different strategies of treatment of E-waste and different impacts associated with them in the Lahore city and its surroundings.
- To identify relevant stakeholders involved at each step.
- To identify the end of life of E-waste in Lahore
- To describe health and environmental impacts of E-waste flow in the city based on the literature review.

1.7 Research Question

- What is the flow process of second-hand desktop computers and its impacts during handling and recycling in Lahore?

1.8 Why is E-waste a Problem?

The amount of E-waste in Pakistan has been increasing due to enhanced use of internet technology. Urban area of Lahore is expanding fast. The consumption patterns and life style are rapidly changing. Computers have entered all walks of life i.e. offices,

educational institutions, business and domestic sector etc. The problem of handling E-waste has not yet reached a critical stage but situation is getting worse. There is no system to check and manage the flow of E-waste in Lahore city.

Import of second-hand computers by the developing countries enables them to use information technology. However, developed countries are finding a way to dispose their second-hand computers in lands of developing countries. Pakistan has been receiving 500,000 second-hand computers per year.

Desktop computers contain hazardous materials, toxic substances and other chemicals. These toxic substances include heavy metals such as lead, copper, arsenic and brominated flame retardants. These substances cause adverse effects on human health as well as on environment when handled at their end of life.

E-waste is the most rapidly growing waste problem in the world. The production of electronic devices is the fastest growing manufacturing sector in industrialized countries (UNEP, 2007). Another aspect of the problem is the diminishing of average life of personal computers. The amount of electronic waste that is discarded every year in developed countries continues to grow rapidly. In 1994, it was estimated that approximately 20 million PCs became obsolete. By 2004, this figure was to increase to over 100 million PCs (Widmer et al, 2005). This fast growing waste stream is accelerating because the global market for PCs is far from saturation and currently the average life span of a PC is decreasing rapidly, for instance for CPUs from 4 to 6 years in 1997 to 2 years in 2005 (Culver, 2005).

These second-hand computers meet their end of life in developing countries. It is very difficult to handle obsolete computers. Due to the absence of specific management system for E-waste in Lahore, discarded computers are managed poorly. After winning metals, the remains are disposed with municipal waste in open dumps and pollute ground and surface water. The main dumping site for such waste is Mehmood Booti.

The mother board and plastics of computers are also exported to China and Dubai.

1.9 Composition of E-waste

E-waste contains many different toxic substances and chemicals which cause adverse effects on human health as well as on environment. E-waste contains more than 1000 different substances including heavy metals which are dangerous to human health and environment. E-waste contains a wide range of substances and also mixtures of them that makes E-waste more complicated and hazardous in nature when treated for its disposal (Brigden et al, 2008).

Desktop computers came into the market in early 1980's, and were used for communication and networking in office buildings in addition to their use as personal computers. A desktop computer mainly consists of the following components along with CPU and monitor:

- Printers
- Keyboards
- Scanners
- Modems
- Routers
- Others

CPU works as main internal operation system of a desktop computer. It consists of mother boards, other adapter boards containing network cards etc. hard drive, power supply, microprocessors, some other drives like CD drive, fan and wiring.

Monitor of a desktop computer consists of plastic casing, a cathode ray tube (CRT), a printed circuit board, a yoke and wiring.

Table 1.1: Composition of a Desktop Personal Computer Based on a typical desktop computer, weighing ~27 kg

Material name	**Content (% of total weight)**	**Weight of material in computer (kg)**	**Use**	**Location**
Plastics	22.9907	6.26	Insulation	Cable, Housing
Lead	6.2988	1.72	Metal joining	Funnel glass in CRTs, PWB
Aluminum	14.1723	3.86	Structural, Conductivity	Housing, CRT, PWB, connectors
Germanium	0.0016	< 0.1	Semiconductor	PWBs
Gallium	0.0013	< 0.1	Semiconductor	PWBs
Iron	20.4712	5.58	Structural, Magnetivity	Housing,CRTs, PWBs
Tin	1.0078	0.27	Metal joining	PWBs, CRTs

Copper	6.9287	1.91	Conductivity	CRTs, PWBs, connectors
Barium	0.0315	< 0.1		Panel glass in CRTs
Nickel	0.8503	0.23	Structural, Magnetivity	Housing, CRT, PWB
Zinc	2.2046	0.6	Battery, Phosphor emitter	PWB, CRT
Tantalum	0.0157	< 0.1	Capacitor	Capacitors/PWB, power supply
Indium	0.0016	< 0.1	Transistor, rectifier	PWB
Vanadium	0.0002	< 0.1	Red Phosphor emitter	CRT
Terbium			Green phosphor activator, dopant	CRT, PWB
Beryllium	0.0157	< 0.1	Thermal Conductivity	PWB, connectors
Gold	0.0016	< 0.1	Connectivity, Conductivity	Connectivity, conductivity/PWB, connectors
Europium	0.0002	< 0.1	Phosphor activator	PWB
Titanium	0.0157	< 0.1	Pigment, alloying agent	Housing
Ruthenium	0.0016	< 0.1	Resistive circuit	PWB

Cobalt	0.0157	< 0.1	Structural, Magnetivity	Housing, CRT, PWB
Palladium	0.0003	< 0.1	Connectivity, Conductivity	PWB, connectors
Manganese	0.0315	< 0.1	Structural, Magnetivity	Housing, CRT, PWB
Silver	0.0189	< 0.1	Conductivity	Conductivity/PWB, connectors
Antinomy	0.0094	< 0.1	Diodes	Housing, PWB, CRT
Bismuth	0.0063	< 0.1	Wetting agent in thick film	PWB
Chromium	0.0063	< 0.1	Decorative, Hardner	Housing
Cadmium	0.0094	< 0.1	Battery, blue-green Phosphor emitter	Housing, PWB, CRT
Selenium	0.0016	0.00044	Rectifiers	rectifiers/PWB
Niobium	0.0002	< 0.1	Welding	Housing
Yttrium	0.0002	< 0.1	Red Phosphor emitter	CRT
Rhodium			Thick film conductor	PWB
Platinum			Thick film conductor	PWB
Mercury	0.0022	< 0.1	Batteries, switches	Housing, PWB

Arsenic	0.0013	< 0.1	Doping agent in transistors	PWB
Silica	24.8803	6.8	Glass, solid state devices	CRT,PWB

Source: *Microelectronics and Computer Technology Corporation (MCC) 1996.*

Manufacturing of computers requires a lot of natural resources and energies. "A UN (2005) study found that the manufacturing of a computer and its screen takes at least 240 kg (530 pounds) of fossil fuels, 22 kg (48 pounds) of chemicals and 1.5 tones of water - more than the weight of a rhinoceros or a car" (Kuehr and Williams, 2003). By having an overview of a desktop computer's life cycle, it is observed that 81% energy of a desktop computer is used in manufacturing that is more than that energy consumed during its usage.

The desktop computers are composed of both hazardous and valuable constituents.

Printed circuit boards become the main sources for the valuable metals like gold, copper etc. "A ton of circuit boards yields approximately 10 ounces of gold" (Broughton 1996 cited in Biddle, 2000).

Table 1.2: Precious Metals in E-waste.

Precious Metals	Gold (Au)
	Copper (Cu)
	Silver (Ag)
	Iron (Fe)
	Aluminum (Al)
	Palladium (Pd)
	Platinum (Pt)

E-waste contains hazardous materials which are unsafe and dangerous to the human health and environment during improper treatment. Following table represents poisonous materials of E-waste.

Table 1.3: Hazardous material in E-waste

Halogenated Compounds	PCB
	TBBA (Fire retardants for Plastics)
	PVC
Toxic Metals	Arsenic
	Barium
	Beryllium
	Cadmium
	Chromium VI
	Lead
	Mercury
	Nickel
	Zinc

Source: *Microelectronics and Computer Technology Corporation (MCC). 1996.*

1.9.1 Types of E-waste in Pakistan

E-waste can be divided into many categories. EU Directive (2002) provided following 10 categories for E-waste**:**

Table 1.4: E-waste categories pursuant to the EU Directive 2002

No	Category
1	Large household appliances
2	Small household appliances
3	IT and telecommunications equipment
4	Consumer equipment
5	Lighting equipment
6	Electrical and electronic tools (with the exception of large-scale stationary industrial tools)
7	Toys, leisure and sports equipment
8	Medical devices
9	Monitoring & control instruments
10	Automatic Dispensers

According to the Ministry of Environment Pakistan, E-waste can be divided into the following sub groups in Pakistan:

Table 1.5: Sub groups of E-waste

1	Electrical Switches	Switches, Relays, Connectors and related Scrap materials
2	Telecommunication Wastes	Mobile phone, Telephones, Telephone exchanges, Wireless Equipment cables and related scrap material
3	Electronic Waste	Electronic-metal waste, Printed circuit boards, Electronic equipment and machinery, IC, Socket Connectors
4	Cable Waste	PVC, Pre Insulated Copper and Aluminum Cable waste
5	Chemical waste	Chemical sludge and residue

2. Literature Review

Rudimentary activities of informal E-waste treatment in Ghana investigated the consequences of damage of resource, adverse health impacts and environmental destruction (Oteng-Ababio, 2012).

To set up a comparatively protective and environmental friendly management system for E-waste, it is necessary to deal with informal recycling sectors that create serious health and environmental issues through primitive methods of treatment. Lack of environmental awareness is the main reason for flourishing informal recycling. According to Chi, et al (2011) 1.7 million tons of E-waste produced in China that is equal to 1.7 kg of E-waste per capita in the year of 2006.

Many of the parts of computers comprise organic compounds and heavy metals which are harmful to health and even carcinogenic and cause other diseases relating to nervous and reproductive systems. Uncontrolled recycling process of E-waste particularly in developing countries is connected with emissions of hazardous compounds (e.g. lead, cadmium, mercury and PBDEs). Toxic emissions from E-waste loaded with organic compounds (including other BFRs, PCBs, PCNs, and chlorinated and brominated benzenes and phenols), PAHs, oganophosphorous compounds, non poylphenol and phthalate esters and metals like cadmium, mercury, tin, antimony, nickel, barium, chromium, zinc, beryllium and copper pose a serious problem. Report concludes that there is no entirely protected and environmental friendly method of treatment for E-waste (SEPA, 2011).

Prakash, (2011) conducted a detailed study of the social life cycle assessment on the waste management.

Production of E-waste from different electronic products depends on their mass, quantity in market, consumption and average life cycle. Computers have very short life span, this is the reason why these are contributing major part in the E-waste stream compared to the other electronic items. Author describes future trends that could increase E-waste due to advancement in technologies which could increase consumption and consequently the waste. Export of E-waste to developing countries poses serious threat to environment and human health due to treatment of E-waste in slack environment (Gaidajis et al, 2010).

Ogungbuyi, (2010) reveals that about 100,000 tonnes of imported E-waste entered Nigeria illegally in 2010, out of which approximately 30% was found non-functioning. Inventory showed that in Nigeria recycling activities include dismantling of E-waste, uncontrolled open dumping and burning of cables and wires.

An assessment review, (2010) evaluates different aspects of life relating to the imported second-hand products with particular emphasis on second-hand computers. These imports created more negative impacts compared to the positive ones. The study concludes that such imports produce serious environmental problems due to their complicated and hazardous composition (Chanthy & Nitivattananon, 2010).

Guidelines for E-waste management in Kenya, (2010) suggested policy development as the most effective guideline for the E-waste management system in Kenya to reduce the harmful impacts on the environment.

A study by Alam (2010) in Malaysia reveals that out of 48% storage and 37% sale of second-hand equipment only a fraction (22%) of electronic waste gets recycled. The reason is lack of awareness and absence of take-back system.

"A study on electronic waste (E-waste) in higher educational institution" proves that open burning of E-waste for the extraction of precious metals like copper is hazardous for human health as well as environment. This was observed in the 27 square kilometers area of Delhi (Khalid, 2010).

Goosey et al, (2009) discuss the unsustainable production, consumption and management of the electronic products. They also analyze the worldwide legislation on E-waste and the problem of handling particularly establishment of different ways to identification of the plastics used in the electronic products and their additives such as flame retardants. The rapidly emerging technology may also cause the reduction of the lifespan of these products and result in the increase of the volume of the E-waste. It gives a detailed review of the E-waste system in respect to the comparison of the responsibilities of individual producer and collective producer.

The issue of illegal export of E-waste to the developing countries for recycling has its adverse impact on human health as well as environment. In areas where handling of E-waste was being carried out, lead was observed in children's blood. Soil and water was also found contaminated with heavy metals (Luther, 2009).

Chatterjee and Kumar, (2009) proposed that the equal participation of formal and informal sectors must be encouraged for E-waste management system to make it a profitable business.

E-Waste is becoming an uncontrolled tsunami globally due to short life span of electronic equipments, hazardous composition, and export to third world with cheap labor and weak health, safety and environmental regulations. Developed countries act as 'waste traders' for the developing countries, although exporting E-waste is illegal like in US. Toxic compounds like mercury, lead, cadmium, brominated flame retardants (BFRs), plastics, beryllium cause risks for neuro developmental defects in new borne babies, brain damage in children, kidney damage, found in breast milk of women, cause harm to immune and reproductive system and cancer causing respectively (ETBC, 2009).

An estimated 20-25 million tonnes E-waste is being produced per year at global level. Developed countries of Europe, the United States and Australia are producing most E-waste. Rich countries are adopting an illegal way under Basel Convention to export E-waste to the poor developing countries due to toxic composition and its hazardous effects on human health as well as environment (Robinson, 2009).

Strict laws and regulations and their implementation are one of the important ways to control illegal imports and dumping of E-waste in the developing countries. Developed countries find recycling more expensive compared to export to the developing countries. Asian as well as African developing countries like India, Pakistan and Nigeria are all facing problem of E-waste handling and its worse effects on environment, ecology and human health due to hazardous and toxic composition of E-waste. In Guiyu, 80 percent

families found PBDEs (a kind of BFR) in their blood at a dangerous level at workplace while handling E-waste or dismantling. (Ni & Zeng, 2009)

"Electronic Waste Recycling in the Bay Area, California: What Do People Really Know?" written by Lee, (2009) shows that about 50-80% of US E-waste is shipped to the developing countries. The writer believes that education and awareness creates positive effects on the attitude towards recycling.

Cheap labor and competition for technical advancements are the main drivers while major barriers which become hurdle to manage E-waste in Philippines are lack of environmental awareness, weak laws and policy and illegal imports of second-hand computers. (Crisma, 2009)

In Uganda, approximately 2000 tons of E-waste consisting of desktop computers and CRT screens, that include 80 and 400 tons of printed circuit boards and plastics respectively where generated in 2005. Report suggests that more than 80,000 useless personal computers might still be in stockpile. (Wasswa, et al, 2008)

Recycling process consists of disassembly and open burning to extract valuable metals in a very rudimentary way. In Ghana children and women are involved in carrying out most of the work with no health and safety measures. Ground water and soil samples were found polluted with contaminated ash of burnt E-waste containing toxic heavy metals like lead. Organic compounds and toxic metals such as cadmium and antimony are also found. (Brigden et al, 2008)

A study by Gupta (2008), conducted by Ministry of Environment & Forests Central Pollution Control Board Delhi reveals that approximately 1, 46,180 tones E-waste was produced in the year 2005. The study suggests that Extended Producer Responsibility (EPR) should be included as policy framework. Other guidelines suggest that informal sector must be upgraded according to the main stream system and license system should be established for all concerned stakeholders.

Kuper and Hoksik, (2008) while considering and analyzing the Electronic Waste in Ghana revealed that E-waste exported to the developing countries for reuse is useless. They also believe that recycling poses a human and environmental problem. This report investigates the illegal export of E-waste to the third world countries like Ghana. Samples taken from different dumping sites have different toxic materials.

A life cycle assessment study of Desktop PC Systems was conducted to describe the composition of E-waste and its adverse effects on the environment. (Eugster, 2008)

The United Nation Environmental Programme has done extensive work on the Integrated Solid Waste Management (ISWM) including E-waste handling based on environmentally sound technologies (ESTs).(UNEP 2007)

A study in Guiyo revealed that children working with E-waste treatment were found with high blood lead levels (BLLs). The main cause was primitive recycling methods and dumping of E-waste remains in open fields, workshops, and waterways. Primitive methods included dismantling of old electronic equipments, acid baths and open burning to extract valuable materials. (Huo et al, 2007)

A descriptive overview of flow of E-waste in South Africa showed a critical observation on the current situation of growing waste stream. Author proposed a Green E-waste Channel to introduce the processes of reuse and recycling by involving main stakeholders. **(**Anahide, 2007)

National inventory for Thailand, (2007) revealed that after every half a year, 15% computers are discarded by the users.

BAN has been trying to get US ratification for Basel Convention as to control flow of illegal exports of E-waste to developing countries. Robin Ingenthron, president of the "World Reuse, Repair and Recycling Association (WR3A)", said that local importers intentionally mention scrap instead of complete systems since they want to pay minimum taxes. It, therefore, makes sense to gather correct data of imports of E-waste. Approximately 100,000 computers or 44,000 television sets enter Lagos in Africa per month through 500 containers. (Schmidt, C. W., 2006)

Basic information on E-waste, legislation and initiatives anticipated for the management of the growing volumes of E-waste are being discussed at global level. It is reported that E-waste is 8% constituent of municipal waste and is increasing rapidly. The authors describe hazardous process of extracting valuable metals from different parts of the computers. (Widmer et al, 2005)

Williams (2005) describes the current situation of the E-waste at global level. The issue is investigated in more detail in developed countries where the electronic products are manufactured. The article describes the management of E-waste carried out through the environment friendly techniques.

Puckett et al, (2002) gives an overview of the current situation of E-waste exported by the United States to Asia. The article describes as to how the first world is getting rid of their waste in the Asian lands. The study reveals that the Asian countries like India, Pakistan and China are not paying a serious attention to the illegal export of E-waste. He believes that trade is wrapped by the evergreen word "recycling". The crude recycling is very harmful for the human health and environment due to open burning and acid baths. Other major reasons for this state of affairs are lack of effective legislation and poverty.

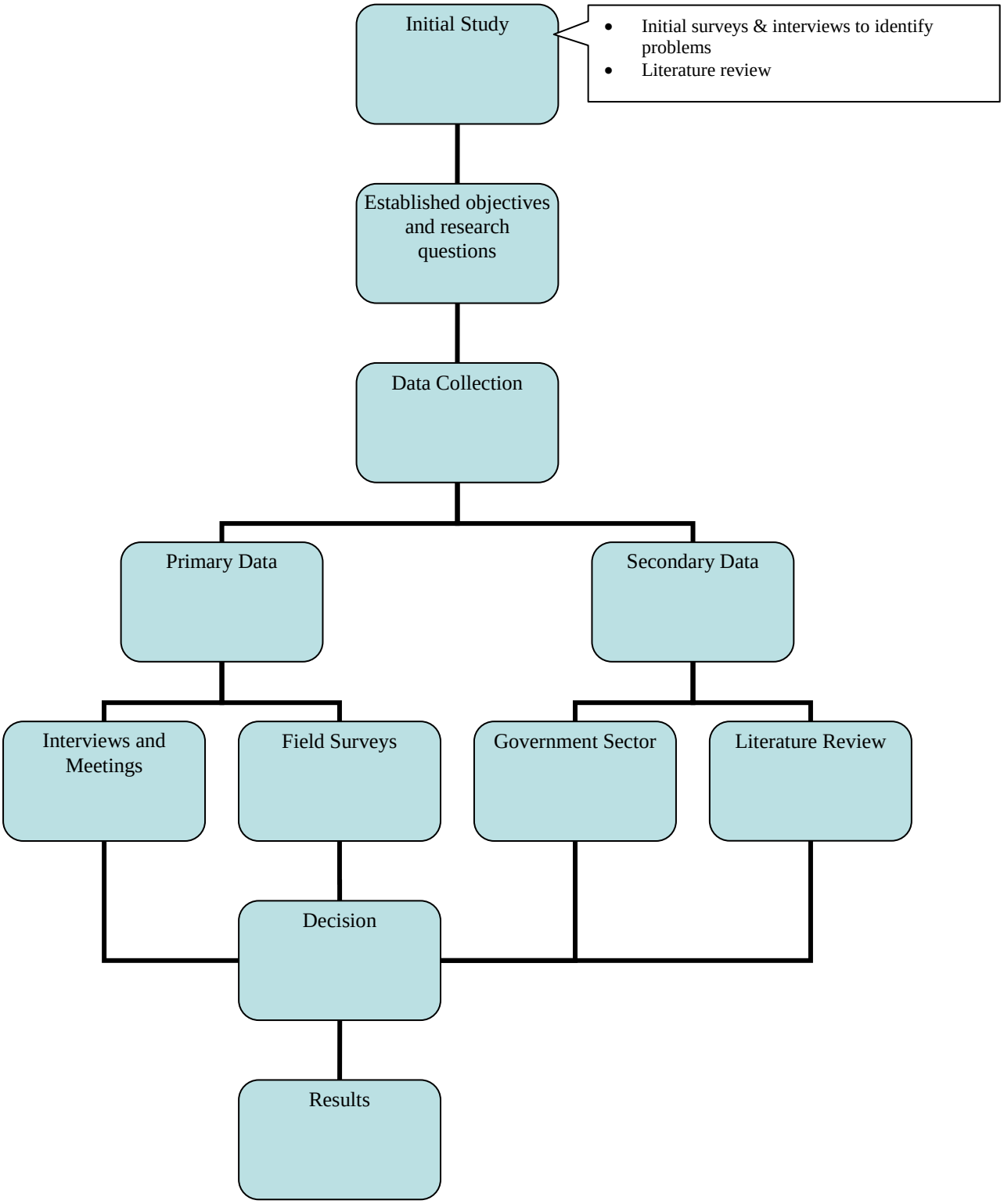
Scanlon, (2001) in his book expresses his serious concerns on growing volumes of the hazardous E-waste problem in California. According to an estimate more than 6000 computers are becoming obsolete per day in California out of which only 5% to 15% are recycled excluding recycling of individual household and office computers. On the other side 2.2 million latest computers are coming into the system per year. E-waste contains lead and other toxic materials that can cause harm to human as well as environment particularly during recycling when burned. The Cathode Ray Tubes in computers and TVs contain toxic heavy metals like lead. He suggests market-based solution to minimize the waste by increasing the producer responsibility.

About 250,000 metric tons of E-waste is entering only five African countries each year out of which 30 percent is useless and the remaining can be reused with repairs. The author warns that complete ban on imports of second-hand electronic products could create another problem, such as flourishing of market of low quality products causing worse environmental issues of handling. (Lubick, N.)

3. Methodology

This study is focused on the flow and qualitative life cycle assessment of desktop computers and their E-waste in Lahore. The study is based on collection and analysis of secondary as well as primary data. The primary data were collected through open ended interviews, looking at records and extensive field visits. The field observations included areas like dry ports, storage depots, retail and whole sale outlets, E-waste storage areas, repairing facilities, metal recovery areas, plastic granulation units, plastic roping units, plastic rope utilization units and processing for export units. Health impacts of E-waste recycling and processing were also considered.

3.1: Methodology Flow Chart



3.1 Initial Study

An initial study conducted was helpful to define objectives and scope of the study. It included interviews and observations based on random surveys at different sites. The information collected from the interviewees helped plan and execute the study.

3.2 Meetings and Interviews

Meetings and semi structured interviews were conducted through pre planned and discussed questions with the stakeholders. For every stakeholder category interview questions were selected.

The following stakeholders were interviewed:

- Importers (see appendix E)
- Retailers (see appendix E)
- Collectors (see appendix E-1)
- Dismantlers (see appendix E-2)
- Repairers (see appendix E-3)
- Junk shop dealers (Kabariyas) (see appendix E-4)

Interviews were conducted with the stakeholders in the government sector for gathering useful information on used computers flow and waste management. The Custom Department was contacted for gathering information on import volumes and their procedures. Telephonic interviews were also conducted for data collection.

3.3 Survey

Exploratory surveys were conducted to identify collection, dismantling and recycling sites. Collectors and junk shop dealers were the important sources of information.

3.4 Data collection

Both primary and secondary data was collected. Identified sites were visited to get as much information as possible.

3.4.1 Primary data

Acquisition of primary data for research was the main part of the study. Primary data collection was also important because this is the first study of its type in Lahore.

Primary data was collected through surveys and semi structured interviews with stakeholders (importers, retailers, dismantlers, repairers, Kabariyas) from different sites falling in the study area. Random surveys were conducted for identification of sites where wastes of used computers are being handled.

3.4.2 Secondary Data

Secondary data was collected from published books, articles, reports, miscellaneous publications, journals, websites and print media. The secondary data was taken from different government sectors involved in regulating E-waste trade. These materials were analyzed.

3.5 Study Area

Lahore, the second largest city of Pakistan is an important hub for the business of new and second-hand computers. This city is also an important center for E-waste dismantling, recycling and export. Two main dry ports are actively working in Lahore for imports of these products. Lahore supplies new and used desktop computers to most cities of Punjab.

3.6 Limitations

- Limited number of stakeholders could be persuaded for interviews.
- Most of the recycling and quite a volume of imports are illegal; therefore the entities and stakeholders involved are not willing to share data.
- The illegal recycling activities are dispersed and their locations are kept secret.
- It was extremely difficult to access the recyclers. They were not willing to share reviews.
- The recyclers and their workers did not know anything about environmental impacts of their activities and were unable or unwilling to share health and safety issues.

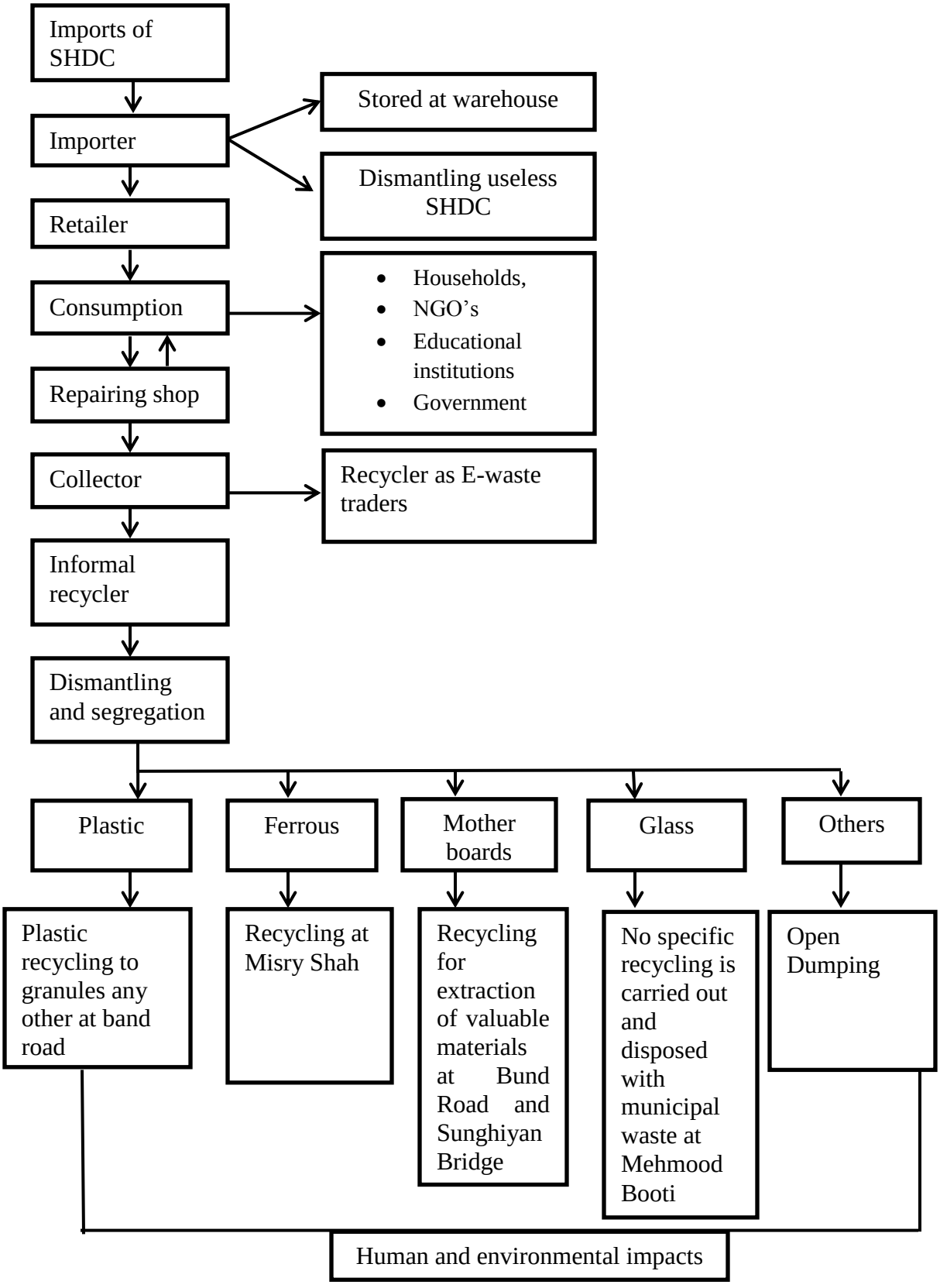
4. RESULTS & DISCUSSION

4.1 E-Waste Management Practices Common in Lahore

This is the first qualitative life cycle assessment study of second-hand desktop computers in Lahore. This study becomes all the more important since second-hand desktop computers and their E-waste also flows out of Lahore to various cities of Punjab and to some extent to Khyber Pakhtoon Khwa. Lahore with its two dry ports is considered as the electronic hub of the Punjab Province. There is a very well-articulated outflow network of second-hand desktop computers from this hub.

The flow diagram constructed is presented as figure 4-1. It will be elaborated, explained and discussed in this chapter.

4.1: Qualitative Life Cycle Flow Sheet



4.2 Imports

E-waste is one of the major environmental issues in the developed countries and has become rapidly a problem in the developing countries. The very obvious and important reason for this problem is illegal export of E-waste to the developing countries like Pakistan, India and China etc. as final disposal sites (Pucket et al. 2002). Large quantities of used computers are exported to the developing countries. It is claimed that all this waste is sent to the developing countries for the purpose of reuse, repair, refurbishment and recycling. The recycling process in the developed countries is not feasible economically due to stringent environmental restrictions (Luther, 2010). The developed countries therefore ship this waste to developing countries for getting rid of their E-waste in the garb of trade (Pucket et al. 2002). The problem of handling E-waste is rapidly growing. The handling of a large number of obsolete computers and continuous illegal import into Pakistan from other countries is of great concern**.** This is basically an urban problem and there is an urgent need for proper management of E-waste particularly in the larger cities of Pakistan like Lahore. Karachi is the main city for the second-hand desktop computers scrap imports. Karachi port is mainly used for shipment of second-hand computers including a big portion of scrap from different developed countries (Pucket et al. 2002). All kinds of E-waste is not only imported but also smuggled in by sea and land**.**

The agents of some Western companies involved in computer dumping are working in Pakistan as well as other third world countries. According to the legislation in developed countries electronics become obsolete to their defined end of life that has already been fixed. Local users drop off their electronics to the recycling companies to recycle properly. The process of recycling of used desktop computers in developed countries is

very expensive due to high cost of labor and strict environmental laws. Agents of Pakistani importers work hand in glove with E-waste exporters from developed countries.

New computers are imported through corporate sectors. There are multinational companies Intel, Hp, Dell that are involved in selling their brand new products. These computers ultimately join the waste stream.

The second-hand imported computers work only for very short duration and become a waste. These second-hand computers cost approximately rupees 10,000 each with no warranty and often have a short life span of less than 6 months (Daily Times, 2009). Pakistan has been receiving over 500,000 second-hand computers per year (China Daily, 2012). However at present only one city of Pakistan namely Lahore imports more than 50,000 used computers per month.

Countries which are actively involved in exporting second-hand desktop computers to developing countries including Pakistan are America, Canada, Australia, UK, Japan, Korea, and Germany. Major exporting countries to Pakistan are UK, US, Australia, Japan and Canada. Dubai and Singapore are important links for imports from Europe and South Asia. Pakistani importers obtain electronic scrap using UAE as safe medium from where they ship this waste to Karachi sea port.

Unfortunately Pakistan has no policy on E-waste imports. This is the basic reason for constant unchecked imports of used computers into the country out of which a significant number is useless (Pucket et al. 2002). Institutions reveal that full tax on these computers is hardly ever paid. The tax evasion makes this business even more attractive.

The responding importers claim that they are providing this technology to people at an affordable price therefore they are doing a wonderful job. They want unrestricted flow of second-hand computers at zero tax.

The shipped containers of second-hand computers reach Karachi port where different products are charged custom duties according to their price and value. Under invoicing is very common which makes this business quite lucrative. Institutions show that importers sometimes use subterfuges like fake auctions in collaboration with official entities for further tax evasion. Traders are unwilling to share information or records of the prices of imported products. More than 200 agents handle the proceedings. The containers once released are brought to the ware houses. These ware houses at Karachi often prove an open market for buyers of second-hand computers. The ware houses are owned either by the importers or transporters. However most of the second-hand computers destined for Lahore land at dry ports.

4.2.1 Custom Duties

The breakdown of taxes paid is as follows:

Sales tax = 16 %

Additional tax (handling charges) = 2%

Income tax = 6%

4.3 Afghan Transit Trade

According to the Afghanistan – Pakistan Transit Trade Agreement, 2010 "the governments of both the Islamic Republic of Afghanistan and Islamic Republic of Pakistan agree to facilitate the movement of goods between and through their respective territories and provide all possible facilities in accordance with the provisions of the agreement". A significant part of imports is carried out through Afghan Trade Transit 2010. There is no statistical data on the movements of second-hand computers through this transit.

4.4 E-Waste Management Activities in Lahore

After paying custom duties the containers move through freight forwarder or importers arrange trucking to Lahore. These containers reach ware houses located at different places. Different importers own ware houses at different locations. This study shows that ware houses are located at Hafiz Center, Hall Road, Walton Road and Waris Road.

Figure 4.2: Ware house at Hall Road

4.4.1 Dry Ports Lahore:

There are two dry ports working in Lahore for imports:

- Dry port Mughalpura
- NLC Multan Road

4.4.1.1 Dry Port Mughalpura

Dry port in Lahore at Mughalpura is used for imports. This port at Mughalpura is managed by Pakistan Railways since 1973. Imports are carried by trains. However, this port has not been used for imports for the last one year. The reason is the general decay of Railways in Pakistan.

4.4.1.2 NLC Multan Road

Dry port in Lahore at Multan Road is another port used for imports. NLC is working under army. It has its own transport to move the imported containers. It is being used for imports.

4.5 Percentage of Functioning Second-hand Computers

A study carried out in Karachi claims that only 2% second-hand computers can be reused while the rest is E-waste for reuse after repair or recycling (Pucket et al. 2002). However, this study shows that more than 75 percent second-hand desktop computers can be reused directly or after repairs. These second-hand computers cost approximately rupees 10,000 with no warranty and have a short span of less than 6 months (Daily Times, 2009). The

reused computers after their useful life are collected by hawkers and sold to junkshops from where they reach recyclers.

Figure 4.3: Advertisement by Hawkers of E-waste at Public Places

After containers of second-hand computers reach Lahore, irreparable computers are sent to Walton Road for dismantling. Parts of these computers cannot be repaired.

4.6 Distribution

In Lahore, there are two main sites to receive second-hand desktop computers for marketing:

- Hafeez Center
- Hall Road

These are the main centers which supply used electronics to the other cities of Punjab. Only Hafeez Center receives more than 40,000 second-hand computers per month. This is the main market in Lahore that is hub of second-hand computers from where not only

other cities of Pakistan but also markets of other developing countries like Afghanistan get benefited. Thirty to forty percent used computers are dispatched from Hafiz Center throughout Punjab.

Hafeez Center also specializes in providing the best quality used computers to special consumers. 10-20% dealing of second-hand computers is carried out as bulk dealing. Local buyers or shopkeepers from nearby cities such as Shiekhupura called 'walking dealers' buy second-hand computers in bulk from importers. Second hand computers are being moved from here to the big trading centers of other cities.

Hall Road is also an active center in selling used computers at individual level. This center provides the best bargain.

During 2001 to 2002, there were only 5 to 7 main importers in Lahore. This number now stands at twenty. The number of small importers is now on the rise. Increasing number of large and small importers clearly shows the increasing demand on the part of consumers as well as recyclers. The importers have the license issued from local business market to deal in the used computers with the local buyers as well as other traders at Punjab level.

After coming into the market second-hand computers are used at consumer level. It is difficult to estimate average life of second-hand computers during household use, because there is no statistical data but a short span of less than six months is more likely (Daily Times, 2009). The second-hand electronics are distributed not only in the Lahore city but throughout Punjab. This study shows the main consumers are lower middle class persons, education departments and NGO's.

There are different categories of second-hand desktop computers which are imported such as Pentium1, Pentium4 etc. A complete system CPU and monitor can be imported but import of monitors is banned since the monitors can be used as television. Different spare parts of the computers are nevertheless imported. They include:

- LCD
- Monitor
- CPU
- Keyboard
- RAM
- HARD Devices

4.7 Purchasing Prices of Scrap

A forty ft. container generally accommodates 800 to 1200 used computers which include both monitors and CPUs. The same container can accommodate almost 1600 pieces of monitors and 2000 to 2200 pieces of CPU. Price of a forty ft. container including every additional charge on the average is Rs. 5,000,000 to 6,000,000.

Following are the average purchasing prices for different parts of second-hand desktop computers brought to Pakistan as scrap:

P4 CPU = 35 $

= (35) (96)

= Rs. 3360 per system

Table 4.1: Purchasing prices of E-Scrap in dollars

Name	Price in dollar
15 inch LCD with CPU	35 $
17 inch LCD with CPU	45 $
19 inch LCD with CPU	55 $
Keyboard	1.5 $
Mouse	1.5 $

It has been estimated that 50 containers of imported second-hand computers land at Hafeez Center per month for further distribution through retailers. Only 3 to 5 containers reach Hall Road for one importer owning business at a large scale. The import of second-hand computers also depends on the demand from consumers which is on the increase.

4.7.1 Prices of Second-hand Desktop Computers and Spare parts

The marketing and distribution of second-hand desktop computers is carried out through retailers at Hafeez Center as well as at the Hall Road. A single computer usually sells at

Rs. 10000 to 12000. Many non-functioning parts are replaced from other second-hand computers.

4.7.2 Prices of Individual items Recovered from Computer Scrap in Lahore

Following are the average prices of scrap in Lahore:

Table 4.2: Prices of E-scrap in Lahore in Rupees

Name	Price (per kg)
Monitor	400
CPU	700
CPU casing	40 to 50
Ram	2900
Mother board	700
Plastic	35 to 40
LCD without tube	40
LCD along with tube	60
Others (key board, mouse, cables etc.)	10

4.8 Treatment of E-waste

There is no manufacturing unit in Pakistan for computers. Even cables not are being manufactured. Efforts have been made to manufacture and market cables. Due to poor quality the cables could not be successfully marketed. The cables were also banned due to their low heat bearing capacity. Networking cables are now being considered for manufacturing. The entire existing system is based on the imported second-hand computers which get obsolete and meet their end of life in the country after being used in developed countries in a suitable working condition.

Many of the imported second-hand computers are non-functioning and are dismantled at Walton in specified ware houses.

Figure 4.4: Useless Second-hand Computers

After coming into the market second-hand computers are used at consumer level. It is difficult to estimate average life of second-hand computers during household use, because there is no statistical data. However based on a preliminary survey it is estimated that this life span is no more than six months. This duration could be increased up to more than one year but with repairs. These units require repair and replacement of non-functioning parts. There are 600 repair shops at Hafeez Center and another 600-700 repair shops throughout the city for repairing computers.

Up till 2010 most of the out of use second-hand computers were stored by the consumers. However since then an informal network of hawkers and E-waste junkshops have come into existence. This has facilitated the flow of end of life computers at consumer level in Lahore to E-waste dismantlers and recyclers.

Figure 4.5: E-waste at Mixed Waste Dealing Junk Shop

There is also a donation system in which obsolete working systems are donated to those who may benefit.

There are six collectors who collect E-waste from Hafeez Center. This waste is produced during repairs. They are registered with the market and are issued identity cards. They collect approximately 200-300kg E-waste per week.

Figure 4.6: Junk Shop, dealing E-waste Near Hafeez Center

Following are the most recyclable parts of desktop computers:

Table 4.3: Recyclable parts of desktop computers in Lahore

Recyclable materials	Plastics
	Ferrous Materials
	Mother boards
	Glass

These parts are not only recycled in Lahore but also exported to the other countries. The main importer of these parts is China. RAM and HARD drives are also exported to China. Mother boards are often exported to Dubai.

Most of the recycling activities in Lahore were carried out along and very close to the Bund Road. The highly polluting activity of incineration and acid bathing of mother boards to win precious metals along with copper and lead results in pungent smells, acid fumes and heavy metal pollution. Heavy metals like lead (Pb) and cadmium (Cd) pollute the air and are very dangerous. Dioxins are another serious problem.

People working and living close to these recycling units protested and relevant authorities took notice. As a consequence the recyclers shifted their units to undisclosed spots close to very small nearby villages or hamlets. The recyclers were able to win the support of the residents by offering them jobs.

4.8.1 Plastics

The most abundant component of E-waste of a typical desktop computer consists of 23% plastics containing Brominated flame-retardants (BFRs) which are difficult to recycle. Cables are burnt to recover copper. The burning of the plastic cable covers produces 100 times more dioxins than municipal solid waste. Dioxins are known carcinogenic agents. Dioxins also produce skin disorders.

Plastic parts of the computers particularly housing of monitors and of other parts of computers are sent to the suburbs of Lahore where plastics are recycled to make plastics rope.

Figure 4.7: Making Ropes; A New Product

Plastic rope is in turn converted to granules of various sizes which are used as a raw material for manufacturing a wide variety of plastic items. Plastic ropes are being produced close to Bund Road opposite Sabza Zar Scheme. Some of the plastic casings of obsolete computers are exported to China.

Figure 4.8: Plastic Housing of Computers

Figure 4.9: Shredded Plastic

Figure 4.10: Pulverized Computer Plastic

4.3.2 Ferrous Metal

A desktop computer is composed of approximately 20 percent of ferrous metal**.** Steel and iron parts of obsolete computers are collected in the same way as plastics by collectors. The steel casings are compressed with a heavy weight tool called Damoosa, in the local language, by the local mixed waste dealers. They receive approximately 40-50 kg steel casings per month. These compacted casings are sold by the dealers for recycling in Misry Shah.

Figure 4.11: Steel casing of CPU at Junk Shop

4.8.3 Printed Circuit Boards

Hardware printed circuit boards work as base and are present in all categories of E-waste and supply electrical connections to the electronic equipments. Printed circuit boards are the main source for the valuable metals like silver, copper, gold etc. “A ton of circuit boards yields approximately 10 ounces of gold” (Broughton 1996 cited in Biddle 2000, p.

22). Mother boards from Hafeez center reach E-waste dealers. E-waste dealers receive approximately 200 kg mother boards per week.

Figure 4.12: Mother Boards at Junk Shop

Earning of one collector from Hafeez Center is Rs. 5000 per week. Mother boards are also purchased from E-waste dealers at Hall Road. The mother boards are either exported to China or sent to recyclers. These highly polluting activities are carried in cottage industries. Around Sunghiyan Bridge near Shahdarrah furnaces have been installed for incineration of mother boards. This is an environmental hot spot around Bund Road and Shahdarrah where acid baths are used and incineration is carried out to win valuable metals.

A cluster of hotspots has already emerged near River Ravi Bank Shahdarrah, Batti Chowk, Shahdarrah Mor, across Railway line near Shahdarrah power station and

Wandala Dayal Shah. This area has also become a repository of waste from municipal sources and other industries like iron and steel units and flour mills.

The E-waste recycling units and their activities are illegal and highly polluting. The leftovers from E-waste e.g. screen glass, dust and useless chunks of E-waste are disposed along with MSW in open dumps. The dumpsite scavengers recover these very low value items for further recycling.

4.9 Workplace Health and Safety

As discussed earlier that recycling in developing countries is based on processes that cause human health as well as environmental problems. It includes shredding, burning, melting of plastics and using acid and chemicals to recover metals from E-waste. The pitiable thing is that the workers exposed to serious hazards are not aware of risks to their health and their surroundings.

At the workplace where dismantling of used electronic equipment is carried out to separate reusable and recyclable parts can cause injuries because all the work is done manually.

During the processes of recycling of the plastic products containing brominated flame retardants, workers without any safety measures are exposed to dust and toxic chemicals.

Figure 4.13: Unguarded Machine Used to Crush Plastic

The recycling activities are carried out in a closed hall with poor ventilation. There are no proper separate sections for cutting, melting and washing the end products of plastic recycling. The closed working rooms are connected to other sections like maintenance, offices and sitting rooms. In other words, all the people working in recycling are exposed to the impacts of different chemicals used in recycling of plastics, noise and heat. In addition the workers are exposed to dioxins. Ventilation was the major problem.

Figure 4.14: Process of Recycling of Plastics, Making Ropes

In the working area, workers were exposed to some hazards related to slip and trips. The factors that contribute to these hazards are

- Uneven surface
- Obstructions
- People unaware of the dangers
- The task- carrying loads, space to work
- Unsuitable footwear

Most of the workers work on unsafe and unguarded machines and are exposed to external injuries like cuts, bruises, abrasions, and crush injuries. They also suffer from internal injuries like strains and tears.

Figure 4.15: Low Illumination at Workplace

Workers were not provided gloves and goggles. Due to poor ventilation, illumination and high noise level the workers experience considerable stress and discomfort and may fall ill. Workers who melt plastics were exposed to thermal stress.

Figure 4.16: Worker working on a Machine without any Safety Measures

The problem of heat stress is exacerbated during summer at workplaces which are closed and without proper ventilation.

Figure 4.17: Recycling Plastic into new products

To recover desired valuable materials from printed circuit boards are being shredded, cut, heated and acid and chemicals are used for dissolving E-waste components.

E-waste treatment releases toxic chemicals and gases into the atmosphere. The most commonly identified pollutants at workplace causing adverse effects to human health and environment are lead, cadmium, copper, iron, beryllium and chromium etc. (CFER)**.**

5. Conclusion

Developed countries are dumping their E-waste in Pakistan. About fifty thousand second-hand desktop computers are imported into Lahore each month. Most of these computers are used either directly or after repairs by lower middle class persons, educational institutions, offices and NGO's. The imported second-hand desktop computers enter the waste stream after about a couple of years. This E-waste is collected by hawkers and junk shops, is recycled for recovering steel, plastic, precious and heavy metals. The recycling industries provide jobs to people but are highly polluting and extremely harmful to the workers and the environment.

6. Recommendations

- Second-hand E-waste trade should be regulated under Basel Convention on Trans-Boundary Movements of Hazardous materials.
- Detailed data on E-waste imports and flow should be gathered and maintained.
- An E-waste management plan should be developed and introduced.
- E-waste management rules should be enacted and introduced.
- All E-waste recycling units should be registered and brought under the control EPA.
- Factories Act 1934 should be made applicable, after due amendments, to E-waste recycling units. The labor department should monitor health and safety conditions of workers.
- Training and financial help should be provided to E-waste recyclers to carry out environmentally acceptable recycling.
- Research should be carried out to develop cheap and environment friendly recycling of E-waste.

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APPENDICES

APPENDIX A:

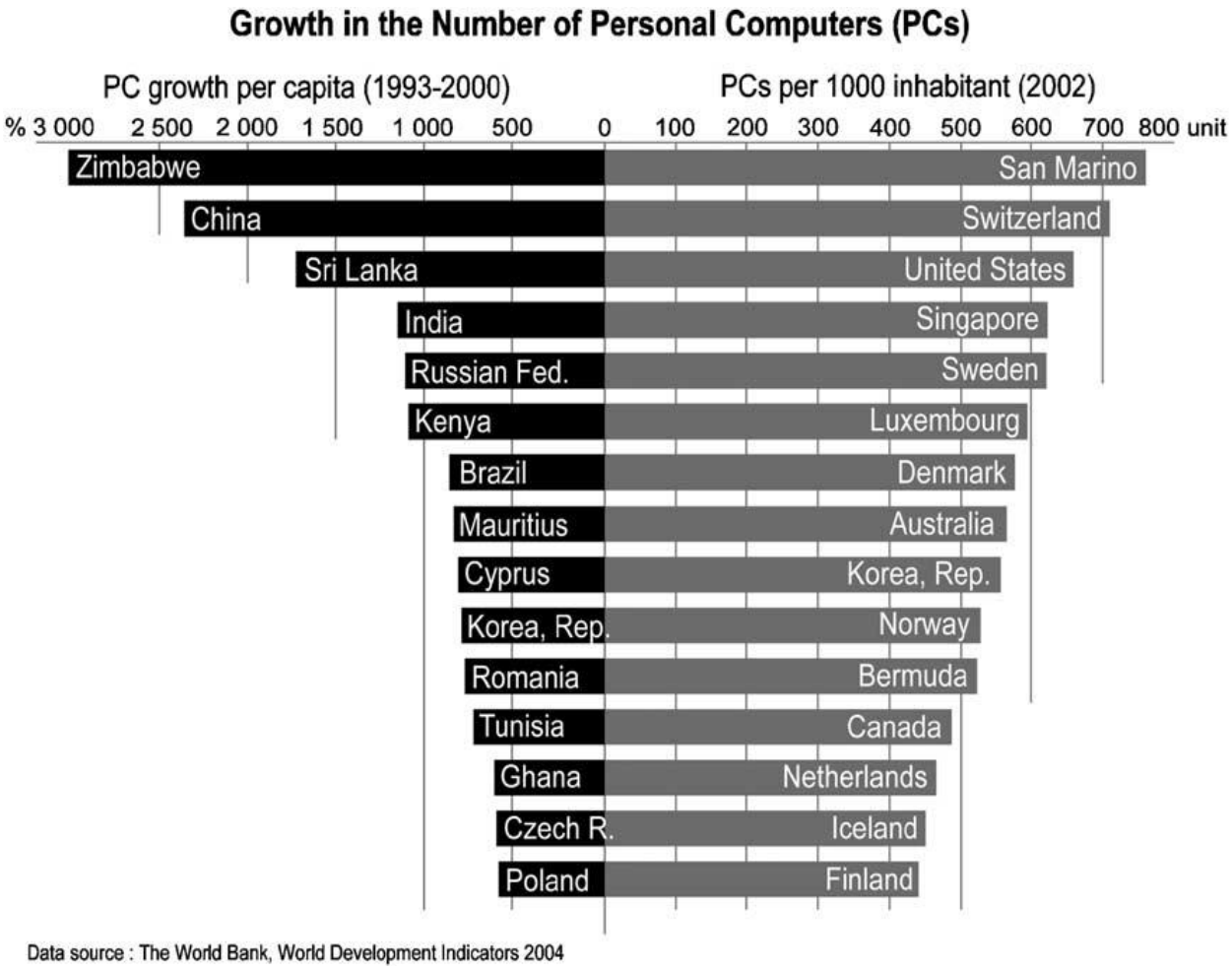
Some developing and industrializing countries import considerable quantities of e-waste, even though the Basel Convention restricts transboundary trade of it. Figure indicates the main E-waste traffic routes in Asia. There are, however, no confirmed figures available on how substantial these transboundary E-waste streams are. From non ratifying countries, such as the USA, estimates have been made that 50–80% of the collected domestic e-waste is not recycled domestically but rather shipped to destinations such as China (Puckett and Smith, 2002).

Asian E-Waste Traffic

Source: *Schwarzeret al., 2005.*

APPENDIX B:

Top scoring countries in PC growth rates (cumulated 1993 – 2000) and market saturation (2002) (Schwerzer et al., 2005).



This graphic shows a classification of the top 15 countries in the growth of the number of personal computers per capita (on the left). By comparison, the countries' number of PCs per 1000 inhabitants is shown on the right. Presently, e-waste is mainly generated in countries of the Organization for Economic Cooperation and Development (OECD), which have highly saturated markets for Electrical and Electronic Equipment (EEE), as

figure shows for the example of PCs. Comparatively, the market penetration of EEE in industrializing countries is not very high. However, these countries show the fastest growing consumption rates for EEE, and thus large quantities of domestically generated E-waste will become part of the waste stream in them as well in the near future.

APPENDIX C:

Some initiatives that have been taken to tackle the global e-waste problem.

(Widmer et al 200)

Initiative	Description
The Basel Convention on the Control of Transboundary movements of Hazardous Wastes and their Disposal. -came into force in 1992-	The most comprehensive global environmental agreement regulating movements of hazardous wastes, including WEEE, between nations, and specifically to prevent transfer of hazardous waste from developed to less developed countries.
The Basel Ban Amendment -not yet into force-	An amendment to the Basel Convention that completely prohibits the export of hazardous waste from a list of developed (mostly OECD) countries to developing countries. The Basel Ban Amendment has, however, not yet come into force.
The Mobile Phone Partnership Initiative (MPPI)	A partnership initiative between the Basel Convention, 12 mobile phone manufacturers and other stakeholders, to develop and promote the environmentally sound management of end-

Initiative	Description
-launched in 2002-	of-life mobile phones
The Nairobi declaration -signed in 2006-	An agreement by the parties to the Basel Convention to accelerate the efforts to solve the global e-waste problems.
Partnership for Action on Computing Equipment (PACE) -approved in March 2009-	A multi-stakeholder partnership under the Basel Convention aiming to tackle the environmentally sound management of end-of-life computing equipment.
The StEP initiative (Solving the E-waste problem) -initiated in 2004-	A UN-led initiative started at the 'Electronic Goes Green' Conference in Berlin to build an international platform to exchange and develop knowledge on WEEE systems among countries to enhance and coordinate various efforts around the world

Initiative	Description
	on the reverse supply chain.
Silicon Valley Toxic Coalition (SVTC) and computer take back campaign -formed in 1982-	A diverse organization engaged in research, advocacy and grassroots organizing to promote human health and environmental justice in response to the rapid growth of the high-tech industry.
The Electronics TakeBack Coalition (ETBC) -formed in 2001-	A coalition of non- governmental organizations in the US working together to urge the electronics industry to launch take back programs for their products, according to the extended producer responsibility (EPR).
WEEE forum -founded in 2002-	Founded in 2002, the WEEE forum is a group of representatives of voluntary collective WEEE take-back systems in Europe, taking care of individual producers' responsibility in Europe.
National Electronics Product Stewardship	A multi-stakeholder dialogue to develop the framework of a national WEEE management

Initiative	Description
Initiative (NEPSI) -created in 2001-	system in the USA. The NEPSI dialogue includes representatives from electronics manufacturers, retailers, state and local governments, recyclers, environmental groups, and others.
Electronic Product Stewardship Canada (EPS Canada)	EPS Canada was created to work with both industry and government to develop a flexible and workable Canadian solution. An industry-led organization. Founded by 16 leading electronics manufacturers.
European Recycling Platform (ERP) -Initiated in 2002-	Set up at the end of 2002 by Hewlett Packard, Sony, Braun and Electrolux to enable the producers to comply with the WEEE directive. It aims to evaluate, plan and operate a pan European platform for recycling and waste management services.
Seco/Empa e-waste programme (Swiss State Secretariat for Economic Affairs, Seco) (Swiss Federal Laboratories for Materials Testing and	A project set up by Seco and implemented by Empa in cooperation with a number of local partners and authorities, to assess and improve WEEE recycling systems in different parts of

Initiative	Description
Research, Empa)	the world by analyzing the systems and by exchanging knowledge on recycling techniques and frameworks.

APPENDIX D:

Environmental and Occupational Impacts in Asia

Computer / E-Waste Component	Process Witnessed in Guiyu, China	Potential Occupational Hazard	Potential Environmental Hazard
Cathode ray tubes (CRTs)	Breaking, removal of copper yoke, and dumping	- Silicosis - Cuts from CRT glass in case of implosion - Inhalation or contact with phosphor containing cadmium or other metals	Lead, barium and other heavy metals leaching into groundwater, release of toxic phosphor
Printed circuit Boards	De-soldering and removing computer chips	- Tin and lead inhalation - Possible brominated dioxin, beryllium, cadmium, mercury inhalation	Air emission of same substances
Dismantled printed circuit board	Open burning of waste boards that have had chips removed to	- Toxicity to workers and nearby residents from tin, lead, brominated dioxin, beryllium, cadmium, and	- Tin and lead contamination of immediate environment including surface and groundwater. Brominated dioxins, beryllium,

Computer / E-Waste Component	Process Witnessed in Guiyu, China	Potential Occupational Hazard	Potential Environmental Hazard
processing	remove final metals	mercury inhalation - Respiratory irritation	cadmium, and mercury emissions
Chips and other gold plated components	Chemical stripping using nitric and hydrochloric acid along riverbanks	- Acid contact with eyes, skin may result in permanent injury - Inhalation of mists and fumes of acids, chlorine and sulphur dioxide gases can cause respiratory irritation to severe effects including pulmonary edema, circulatory failure, and death.	- Hydrocarbons, heavy metals, brominated substances, etc. discharged directly into river and banks. - Acidifies the river destroying fish and flora
Plastics from computer and peripherals, e.g. printers,	Shredding and low temperature melting to be reutilized in poor	Probable hydrocarbon, brominated dioxin, and heavy metal exposures	Emissions of brominated dioxins and heavy metals and hydrocarbons

Computer / E-Waste Component	Process Witnessed in Guiyu, China	Potential Occupational Hazard	Potential Environmental Hazard
keyboards, etc.	grade plastics		
Computer wires	Open burning to recover copper	Brominated and chlorinated dioxin, polycyclic aromatic hydrocarbons (PAH) (carcinogenic) exposure to workers living in the burning works area.	Hydrocarbon ashes including PAH's discharged to air, water, and soil
Miscellaneous computer parts encased in rubber or plastic, e.g. steel rollers	Open burning to recover steel and other metals	Hydrocarbon including PAHs and potential dioxin exposure	Hydrocarbon ashes including PAH's discharged to air, water, and soil
Toner cartridges	Use of paintbrushes to recover toner without any protection	- Respiratory tract irritation - Carbon black possible human carcinogen - Cyan, yellow, and magenta	Cyan, yellow, and magenta toners unknown toxicity

Computer / E-Waste Component	Process Witnessed in Guiyu, China	Potential Occupational Hazard	Potential Environmental Hazard
		toners unknown toxicity	
Secondary steel or copper and precious metal smelting	Furnace recovers steel or copper from waste including organics	Exposure to dioxins and heavy metals	Emission of dioxins and heavy metals

APPENDIX E:

Questionnaires for different stakeholders

Questionnaire for importers/ traders

Information about the Company/Institution

Name of Company/Institution:

- Are you working in a company? Or at individual level?

What is your position in this cycle?

- Importer/exporter/trader/distributer

Year of Establishment:

- When did you start to work in this field? What was very first phase in business you started? Did you start this job as your business; if not then when did you feel that it could be started as a profitable business?

Do you have any contract with others? (Any institutions; educational entities, NGO's etc.)

To import second hand computers do you have any license from government?

Stock and Generation of E-waste

How much electronic equipment do you possess?

- Which types of electronic equipment do you import?
- What type of electronic equipment do you deal in; monitors, CPUs, complete systems, spare parts of old computers?
- What is the number of imported computers? (per month on average?)

- What percentage of your imported or assembled equipment is 2nd hand?
- If spare parts? Quantity?
- Any other electronics you import?
- Are only second-hand computers imported into the country or this import also includes scrap that can be used for recycling?

Origin of E-waste

How the electronic wastes come into the country?

- How do you import the computers?
- Which country do they come from?
- Please list major countries?

Export of Used EEE

Which electronics do you export?

- Complete computers or spare parts for recycling?
- What is the average quantity exported per month?
- What is the Average increasing/decreasing rate of export during the last few years?
- Which countries do they go to? Please list the major countries.

Distribution /Retail Profile

How do you distribute your computer equipment?

How many PCs were provided/ sold to clients in the last few years?

- Do you have any idea about your sale in the Lahore city?

What is the distribution per sector?

- Government (including schools)
- Private sector
- Residential

How are the imported] computers going to be utilized? Please indicate the ratio of the units by destination.

- Second-hand shops (selling at the market without repair)
- Repair shops (mainly for repair for selling at the market)
- Dismantlers (mainly for recovering reusable parts and recyclable materials)

End of Life Management:

Do the consumers get back to you for their waste? Or do you have some idea what they do?

- Store, sell, throw them away with general waste, Give them to a recycler, Donate them to schools, employees, friends, Give them back to the person who sold them; Other..?

Do you have waste collectors in your area?

Do you pay anything to kabaria?

APPENDIX E-1:

QUESTIONNAIRE FOR COLLECTORS

Enlist the particular parts of computers you collect?

- Mention all possible sources of collection?
- How much average quantity do you collect per month?
- Where do they come from? Please indicate the ratio (%) of the units.
    - Charity Drives
    - Household
    - Office
    - Educational institutions

What are the collection routes of used computers from original dischargers such as households and offices?

What percentage of collected used computers is going to repair shops, second-hand shops, dismantlers or exporters?

- Ratio (%) of used computers collected
- Repair shop (repair used computers)
- Second-hand shop (sell used computers without repair)
- Exporter

Do you link with other steps of this second-hand computers flow in Lahore city?

- Second-hand shops
- Repair shops
- Exporters

APPENDIX E-2:

QUESTIONNAIRE FOR DISMANTLERS

Which type of second-hand electronics do you dismantle?

How much average quantity do you dismantle? (kg)

Describe all the sources of used computers you dismantle?

Where do they come from? Ratio (%)

- Importer
- Domestic collector
- Directly from household/office

Please describe dismantling process and required technology/equipment for the process.

- **How many kilograms of reusable parts do you recover, which you can sell?**
- **Recyclable materials, those you can sell?** (kg)
- **Residues you cannot sell?** (kg)

Provide information about the persons who buy reusable parts and recyclables.

What and how much residues do you generate from dismantling process?

Type of Residue;

- Plastics
- Metals
- Glass
- Other
- Quantity (kg/month)

APPENDIX E-3:

QUESTIONNAIRE FOR REPAIR SHOPS

Enlist the particular parts of computers you get for repair?

- Mention all possible sources through which you receive the second hand computers?
- How much average quantity do you get per month?
- How much does one unit weigh? (kg/unit)
- Where do they come from? Please indicate the ratio (%) of the units.
    - Imports
    - Domestic collectors
    - Directly from discharger
    - Charity Drive
    - Household
    - Office
    - Educational institutions

Do you link with other steps of this second hand computers flow in Lahore city; importers, domestic collectors?

Please describe repair process and required technology/equipment for the process?

What is the ratio (%) of used computers sold at your shops?

- Imported
- Domestically collected

How old are the majority of used computers sold at your shops?

How many kilograms of reusable parts, recyclable materials and residues are generated per final products (repaired computer);

- Reusable parts (kg)
- Recyclable materials (metals, plastics, glass etc.) (kg)
- Residues

Who buy final products (repaired computers), reusable parts and recyclable materials?

What and how much residues do you generate from repair process per month?

Type of Residue;

- Plastics
- Metals
- Glass

APPENDIX E-4:

Questionnaires for Informal E-waste Recyclers

What volume of electric equipment do you process per week, month or year?

- Number:
- Weight (tons)

What kind of materials do you extract from the Computers?

- Glass
- Battery
- Copper wires
- Plastics

What method do you use to dismantle the computers?

Where do you sell the extracted materials?

What do you do with the waste?

How many similar dealers are present in this area?

Workplace description

- Describe the area (room / hall / backyard) where the business operations are conducted.
- Include information on lighting and ventilation.
- Indicate the ownership of the workplace

Production processes & technologies

- Give a description of the applied technologies and processes used in the enterprise.
- Also describe the type of tools and machines used for these processes.

– Include information on implemented health protection measures.

Health and Safety issues

– List and describe obvious health and safety risks from the operations carried out.

What is the number of computer repair shops in Lahore city?

Information on upstream sectors:

Where does the enterprise get the used equipment for repair or scrap? Are there many dealers in the area? Do they deal with other products as well?

Information on downstream sector:

Where is the repaired equipment or processed scrap sold?

APPENDIX E-5:

Questions as a whole

- How does the E-waste management take place in the Lahore city?
- Which parties are involved in the process?
- Do you know as to which authorities are responsible for managing the electronic waste in Pakistan?
- How many retail outlets sell your computer equipment in Lahore?
- What in your view is the proportion of the second hand market for computer equipment in Lahore?
- How much material is imported daily into Lahore?
- Where do you store the imported second-hand computers? (physical location)
- Are there any government programs or initiatives that have been put in place regarding E-waste (e.g. recycler responsibility; supplier take-back initiatives)?
- If yes, please specify this program.
- What is the country's recycling policy on electronics specifically about second hand computers?
- What are the government's considerations for E-waste management planning?
- Are you aware of any company that collects discarded E-waste for recycling?
- Do you know the companies in other e waste business in this street? In what business do they work?

  Provide brief background on the current issues about shipment of E-waste to foreign Countries? What is major reason of second-hand computers imports in Pakistan?