

E-WASTE: ETHICAL IMPLICATIONS FOR EDUCATION AND RESEARCH

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ABSTRACT: “E-waste” is a popular, informal name for electronic products nearing the end of their “useful life”. This includes discarded computers, televisions, VCRs, stereos, copiers, fax machines, electric lamps, cell phones, audio equipment and batteries. E-wastes are considered dangerous, as certain components of some of these electronic products contain materials; such as lead; that are hazardous, depending on their condition and density. If improperly disposed, E-wastes can leach lead and other substances into soil and groundwater posing a threat to human health and environment. Many of these electronic products can be reused, refurbished, or recycled in an environmentally sound manner so that they are less harmful to the ecosystem. This paper highlights the types and hazards of E-wastes particularly the computers’ waste. The dimensions and ethicality of the problem in the third-world countries are reviewed. The needs for the appropriate management of E-waste and options that can be implemented are discussed. After reviewing the Islamic concepts for environmental protection, ethical implications for curriculum development as well research directions are highlighted. Elements for a course on e-waste as well as some across-the-curriculum topics are proposed. This is specially tailored to suit the Faculty of Engineering at the International Islamic University-Malaysia.

KEYWORDS: *E-Waste, Environment, Ethics and Education*

1. INTRODUCTION

The life span of computers used to be decades, then years, and now often months. Millions of computers, screens, and peripherals are being rendered obsolete after little more than a year of active use. Just a small percentage of these are reaching the solid waste stream. Most are stored in attics, garages, and warehouses because their owners are unwilling to throw away something they perceive to have so much value. Most consumers are unaware of the toxic materials in the products they rely on for word processing, data management, and access to the internet, as well as for electronic games. In general,

computer equipment is a complicated assembly of more than 1,000 materials, many of which are highly toxic, such as chlorinated and brominated substances, toxic gases, toxic metals, biologically active materials, acids, plastics and plastic additives [1].

There are two root computer and electronic waste (hereafter, E-waste) problems: (1) The volume of computers and related e-waste improperly disposed of in landfills and (2) The toxicity of both the computer chip manufacturing process and the computer or cathode ray tube monitor (CRT) itself as a waste product.

E-waste contains significant quantities of toxic materials [1]. Each computer or television display monitor contains an average of 4-8 pounds of lead. Monitor glass contains about 20% lead by weight. About 70% of the heavy metals (including mercury and cadmium) found in landfills come from electronic equipment discards. These heavy metals and other hazardous substances found in electronics can contaminate groundwater and pose other environmental and public health risks.

Three methods of disposal are currently applied [2]: (1) Incineration which generate and disperse contaminants and toxic substances, (2) Open burning which releases many pollutants into environment, and (3) Landfill where lead and mercury cause severe contamination in landfills besides these contaminations can spread to ground water resources. It is thus apparent that the environmental and health impacts are of serious concern. While computer waste is relatively valuable when delivered to a recycler, the high cost of transportation and handling generally makes it uneconomical. There is insufficient infrastructure to support increased recycling of CRT/computer waste and few economic incentives to create one.

What adds to the problem is that most developing nations lack awareness of the dangers posed by E-waste, as well as any E-waste collection and recycling or disposal systems or programs.

2. DIMENSION OF THE PROBLEM

The fundamental dynamism of computer manufacturing that has transformed life since the second half of the 20th century, leads to rapid product obsolescence. The average computer platform has a lifespan of less than two years, and hardware and software companies, especially Intel and Microsoft, constantly generate new programs that fuel the demand for more speed, memory and power. Today, it is frequently cheaper and more convenient to buy a new machine to accommodate the newer generations of technology than it is to upgrade the old. The dimension of this issue can be seen in the developing countries and the developed ones as explained below. Interested reader may refer to references [2] and [3] for more data on E-waste problems in various countries.

2.1 Developed Countries

Three quarters of all computers ever bought in the U.S. are sitting in people's attics and basements because they don't know what to do with them. Just to give an estimation of

the size of this issue, we will consider the following numbers in the U.S. as an example [4]. Americans are buying more computers than people in any other nation. Currently over 50% of U.S. households own a computer [4]. Because of advances in chip technology, the life span of a computer has been reduced from perhaps 4-5 years to approaching 2 years or less. Computer junking is also happening at a faster rate. The lifespan of computers is decreasing. In 1997 the average lifespan of a computer tower was 4-6 years and computer monitors 6-7 years. This has fallen to 2 years in 2005 [1, 5]. For the three years between 1997 and 1999, it is estimated that some 50 million U.S. computer towers had been dumped, burned, shipped abroad or stored to await eventual disposal [1]. A recent US study found that over 315 million computers became obsolete by the year 2004 [5]. Recycling of computer monitors is no better. Over 300 million computer monitors have been sold in the U.S. since 1980. Yet, in 1997 only about 1.7 million monitors in the US were "recycled," the majority of which - about 1 million monitors - was shipped abroad to countries such as China or India.

E-waste represents from two to five percent of the U.S. municipal solid waste stream. An estimated 300,000 tons of E-waste ended up in the U.S. landfills in 2000, and the problem is expected to grow four-fold in the near future. In 1998 only 6 percent of older computers were recycled compared to the numbers of new computers put on the market that year. In contrast, for major appliances such as washing machines, air conditioners, refrigerators, dryers, dishwashers and freezers, the proportion recycled in 1998 was about 70% of the number put on the market that year [5]. Of the small number of computers that are recycled, more than three-quarters come from large-scale users of the equipment. Individual users and small businesses contribute only a small fraction of the equipment that is recycled because no collection or recycling program is in place [5].

Currently the cheapest E-waste recycling option in the U.S. is to send E-waste overseas. However, how it is used or disposed of there is largely unknown [5]. The district of Guiyu in China, for example, has become an electronic trash junkyard, with PCs and peripherals forming mountains and overflowing into streets; with its people making a living stripping away PC parts with their bare hands. In the mean time, in the U.S., second hand dealers (Thrift shops, Salvation Army, Goodwill) and Waste Haulers or those in the recycling business are unsure about how to handle equipment they are receiving and what disposal options are legally available to them. Additionally, with no certainty about market volume, infrastructure investment is risky.

2.2 Developing Countries

In the developing countries, the dimension of the issue is not as drastic as it is in the developed countries. For example, Malaysia has been putting a lot of effort to eradicate this problem before it gets persistent and out of control. The "Recycle PC" campaign, spearheaded by the Association of the Computer and Multimedia Industry of Malaysia (Pikom) and waste management company Alam Flora Sdn Bhd [6], is picking up steam since its launch in March 2005. This campaign aims to create environmental awareness by encouraging the public and organizations to recycle PCs and their peripherals. Between the period of March 10 and April 30, 2005, Alam Flora has collected 816 computers and peripherals. This includes 194 computer monitors, 147 central processing units (CPUs) 428 printers, and 47 miscellaneous PC components [7].

Panasonic Malaysia Sdn Bhd was among the first corporations to answer the call to recycle when it handed over 60 used PCs and laptops to Alam Flora within a week from launching the PC recycling campaign [6]. The Japanese technology giant also pledged to donate more PCs to the Recycle PC campaign each time it embarks on a PC upgrading exercise. Alam Flora has assigned collection points and recycling centers all over the country for people to drop off their old PCs to be recycled.

In India however, the problem is worse. The developed countries use India as a drop point to dump their E-waste in. India has no PC recycling program or at least not a well-known one. Almost 50% of the PCs sold in India are products from the secondary market and are re-assembled on old components. The remaining market share is covered by multinational manufacturers (30%) and Indian brands (22%). PCs manufacturers are major contributors of E-waste. The waste consists of defective IC chips, motherboards, monitors and other peripheral items produced during the production process. Waste also includes defective PCs under guarantee procured from consumers as replacement items [8]. It is worth mentioning that in India, the import of E-waste is legally prohibited. Nevertheless, there are reports of E-waste imports from abroad. Analyses by the ministry of environment showed no results concerning import of E-waste, but the ministry admits that a 100% control of the borders is not possible [8]. What complicates the problem is that computer waste, which does not have any resale or reuse value, is openly burnt or disposed off in landfills.

In Africa, Nigeria is undergoing rapid and massive growth in cell phone and computer technology. The city of Lagos in Nigeria is believed to be representative of developments rapidly taking place in other port cities of Africa. While no official figures exist, it is apparent that a very significant portion of this growth is fueled by the importation of second-hand equipment from rich developed countries. Experts stated that 500 containers of used computers come into the port of Lagos each month imported primarily from Europe and North America [9]. Many of the exporters were identified by institutional asset tags left on the equipment. Additionally, private data from exported hard drive memory systems were extracted, raising questions about a new form of irresponsibility which is the privacy of information. While some of the imported material to Lagos is fully functional and is directly re-used, or can be repaired, there is nevertheless a significant quantity of the imported computer equipment or parts, estimated by local experts to be between 25-75% that is considered junk. It is unmarketable due to either its lack of computing effectiveness, or due to the fact that it is un-economic to repair. Local experts complain that of the estimated 500 40-foot containers shipped to Lagos each month, as much as 75% of the imports are “junk” and are not economically repairable or marketable. Consequently, this e-waste is being discarded and routinely burned in what the environmentalists call yet “another” cyber-age nightmare now landing on the shores of developing countries” [9].

Because most of the exports/imports are not pre-tested for functionality, it is not possible to know whether these exports are legally defined as hazardous waste (i.e. requiring disposal whole or in part, and being hazardous) under the Basel Convention. From a regulatory standpoint, diligent enforcement discretion would demand testing be performed prior to allowing export. The Basel Convention is an international treaty that sets up controls, enforcement mechanisms, and requirements that signatories agree to follow, including preventing and monitoring illegal traffic in hazardous waste, promoting

cleaner technologies and production, and focusing specifically on helping developing nations [10].

3. TECHNICAL ASPECTS AND SIDE EFFECTS OF DUMPING E-WASTE

To have an idea about the materials involved in the E-waste, the following table shows composition of a typical desktop PC weighing ~ 60 lbs [11]:

Name	Content (% of total weight)	Weight of material in computer (lbs.)	Use/Contents
Plastics	22.9907	13.8	includes organics, oxides other than silica
Lead	6.2988	3.8	metal joining, radiation shield/CRT, PWB
Aluminum	14.1723	8.5	structural, conductivity/housing, CRT, PWB, connectors
Germanium	0.0016	< 0.1	Semiconductor/PWB
Gallium	0.0013	< 0.1	Semiconductor/PWB
Iron	20.4712	12.3	structural, magnetivity/(steel) housing, CRT, PWB
Tin	1.0078	0.6	metal joining/PWB, CRT
Copper	6.9287	4.2	Conductivity/CRT, PWB, connectors
Barium	0.0315	< 0.1	in vacuum tube/CRT
Nickel	0.8503	0.51	structural, magnetivity/(steel) housing, CRT, PWB
Zinc	2.2046	1.32	battery, phosphor emitter/PWB, CRT
Tantalum	0.0157	< 0.1	Capacitors/PWB, power supply
Indium	0.0016	< 0.1	transistor, rectifiers/PWB
Vanadium	0.0002	< 0.1	red phosphor emitter/CRT
Beryllium	0.0157	< 0.1	thermal conductivity/PWB, connectors
Gold	0.0016	< 0.1	Connectivity, conductivity/PWB, connectors

Europium	0.0002	< 0.1	phosphor activator/PWB
Titanium	0.0157	< 0.1	pigment, alloying agent/(aluminum) housing
Ruthenium	0.0016	< 0.1	resistive circuit/PWB
Cobalt	0.0157	< 0.1	structural, magnetivity/(steel) housing, CRT, PWB
Palladium	0.0003	< 0.1	Connectivity, conductivity/PWB, connectors
Manganese	0.0315	< 0.1	structural, magnetivity/(steel) housing, CRT, PWB
Silver	0.0189	< 0.1	Conductivity/PWB, connectors
Antimony	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, hardener/(steel) housing
Cadmium	0.0094	< 0.1	battery, glu-green phosphor emitter/housing, PWB, CRT
Selenium	0.0016	0.00096	rectifiers/PWB
Niobium	0.0002	< 0.1	welding allow/housing
Yttrium	0.0002	< 0.1	red phosphor emitter/CRT
Mercury	0.0022	< 0.1	batteries, switches/housing, PWB
Arsenic	0.0013	< 0.1	doping agents in transistors/PWB
Silica	24.8803	15	glass, solid state devices/CRT,PWB

3.1 Risks Related to Some Toxic Substances in PCs

The following is a more detailed description of the hazards of E-waste based on the different material involved [11].

Lead:

Lead can cause damage to the central and peripheral nervous systems, blood system and kidneys in humans. Effects on the endocrine system have also been observed and its serious negative effects on children's brain development have been well documented. Lead accumulates in the environment and has high acute and chronic toxic effects on plants, animals and microorganisms [12].

Cadmium:

Cadmium compounds are classified as toxic with a possible risk of irreversible effects on human health. Cadmium and cadmium compounds accumulate in the human body, particularly in kidneys. Cadmium is absorbed through respiration but is also taken up with food.

Mercury:

When inorganic mercury spreads out in the water, it is transformed to methylated mercury in the bottom sediments. Methylated mercury easily accumulates in living organisms and concentrates through the food chain particularly via fish. Methylated mercury causes chronic damage to the brain.

Hexavalent Chromium:

Chromium VI can easily pass through membranes of cells and is easily absorbed producing various toxic effects within the cells. It causes strong allergic reactions even in small concentrations. Asthmatic bronchitis is another allergic reaction linked to chromium VI. Chromium VI may also cause DNA damage [12].

Plastics:

It is estimated that the largest volume of plastics used in electronics manufacturing (at 26%) was polyvinyl chloride (PVC), which creates more environmental and health hazards than most other type of plastic. PVC is a difficult plastic to recycle and it contaminates other plastics in the recycling process. Of more importance, however, the production and burning of PVC products generates dioxins and furans.

Brominated Flame Retardants:

Brominated flame-retardants are a class of brominated chemicals commonly used in electronic products as a means for reducing flammability. In computers, they are used mainly in four applications: in printed circuit boards, in components such as connectors, in plastic covers and in cables. They are also used in plastic covers of TV sets and in domestic kitchen appliances.

Various scientific observations indicate that Polybrominated Diphenylethers (PBDE) might act as endocrine disrupters. Research has revealed that levels of PBDEs in human breast milk are doubling every five years and this has prompted concern because of the effect of these chemicals in young animals [13]. Researchers in the US found exposure to Polybrominated Biphenyls (PBBs) may cause an increased risk of cancer of the digestive and lymph systems [14]. The presence of polybrominated flame-retardants in plastic makes recycling dangerous and difficult [15].

4. ISLAMIC ASPECTS OF ENVIRONMENTAL PROTECTION

Islam is considered a comprehensive way of life whose teachings cover, directly or indirectly, every possible human relationship including that with the environment. These

teachings are primarily available in the revealed knowledge which comprises the Qur'an and prophet Muhammad's tradition (*Sunnah*). Islam emphasizes strongly on preserving the environment. Basically, the relationship between human beings and the environment is of three categories [16]:

Vicegerency:

The human being in the Islamic world-view is considered a vicegerent. In her/his capacity as a vicegerent, the human being is perceived as the trustee of the earth. She/he is not supposed to cause corruption in any form on earth (i.e. the environment). Life on earth entails great responsibilities. It is a test with accountability. It is followed by either reward or punishment.

Subjection:

The earth is made available for human use, without abuse or misuse. The circle of things available for the benefit of humanity is much greater than that of the environment.

Inhabitation:

The Qur'an, moreover, makes it clear that the earth is our habitat and that we are required to dwell on it, work it out and establish a balanced way of life without excesses or deficiencies. The meaning of inhabitation (*I'mar*) includes spreading and settling all over the earth, inhabiting every livable quarters, building ...etc. In short, it includes every positive activity that would make life on earth prosperous. If an activity diverts humanity from the right path (i.e. against the *Shari'ah*), then it cannot be considered as *I'mar*. The *I'mar* of the earth should be in areas and projects that could benefit humanity and not harm it. This means that projects and activities that destroy the environment are excluded.

Protecting the Environment:

It should be known that Islam advocates the protection of the environment, though not in name, for the word 'environment' (*bi'ah*), along with its connotations, evolved in recent times [16]. The fact that to protect the environment is considered an act of worship does not mean that every component of the environment should be saved. In fact, it is sometimes to the contrary. The Prophet, peace and blessings be upon him, stated that a person who uprooted a tree [which formed an obstacle] in the path of people, ended up in heavens. The Islamic position forms a middle path between human behavior that has disregard to the environment and those who practically worship the environment. Islam prohibited the cutting or destruction of trees and plants, and encouraged people to protect and increase plants for the great reward associated with that.

In conclusion, protecting an environment is an essentiality in Islam. The aims of the *Shari'ah* are five: protection of religion, protection of life, protection of mind, protection of offspring, and protection of property. Though protection of the environment is not included in the aims of the *Shari'ah*, the environment encompasses all the other aims of the *Shari'ah*. For if the situation of the environment keeps deteriorating, there will ultimately be no life, no property and no religion. The destruction of the environment prevents the human being from fulfilling the concept of vicegerency on earth. Indeed, the

very existence of humanity is at stake here. Excessive pollution might lead to sterility, deformities, abortion and chronic diseases. As far as protecting the mind or reason, the highly polluted industrial cities might not see the sun for long days resulting in deep depressions which affects the person's ability to rationalize properly. Certain radiation might also destroy the brain. The attempt to protect the property will also be in vain in the context of a highly polluted environment. There are already many rivers and lakes that are considered dead with no marine life. This is a direct result of acid rain which destroys also forests.

It is worth mentioning that protecting the environment from an Islamic point of view is one of the topics that are well established and the above analysis is not meant to be conclusive. Interested reader may refer to other sources in the literature such as references [17] and [18].

5. RECOMMENDED ACTIONS

In this section, some actions that can be adopted are reviewed. Almost all of these actions have to be carried out simultaneously. Some of them are targeted to create a wider awareness amongst the end-users.

5.1 The 3R Initiative

One approach to dealing with the E-waste problem is the 3R Initiative which can be summarized as follows [19]:

- Reduce: attempt to reduce the amount of waste generated reduce/eliminate use of toxic substances like lead and mercury.
- Reuse: repeated use of items or parts of items which are still usable
- Recycle: use of waste itself as resource

However, it has to be stressed that success depends on [19]:

- Public recognition of hazards involved in E-waste
- Organized collection and transportation of E-waste

5.2 Binding Purchasing with Take-Back Product Responsibility

This is known as Extended Producer Responsibility (EPR). The aim of EPR is to encourage producers to prevent pollution and reduce resource and energy use in each stage of the product life cycle through changes in product design and process technology. In its widest sense, producer responsibility is the principle that producers bear a degree of responsibility for all the environmental impacts of their products. This includes upstream impacts arising from the choice of materials and from the manufacturing process as well as the downstream impacts, i.e. from the use and disposal of products. EPR focuses on the responsibility that producers are responsible for their products at the end of their useful

life (post-consumer stage). The model example of EPR is product take-back where a producer takes back a product at the end of its useful life (i.e., when discarded) either directly or through a third party. Other terms used are '*take-back*', '*product liability*' or '*life cycle product responsibility*'. This has been implemented by HP companies in the U.S. [20]. Hence, the producers have a great deal of responsibility to take back their products and recycle them at the end of the products' operational lives. It puts full financial responsibility on producers to set up collection, recycling and disposal systems.

5.3 Citizens' Responsibility

A great responsibility is placed on the citizen. The citizen has to feel responsible of whatever electronic gear that the end-user have at his or her house. The individual has to help the recycling organizations by giving them back the electronic devices after he or she is done with it. The end-user has to be aware of the dangers and risks that arise from dumping the electronic gears or storing them in their attics or backyards.

The end-user should contact the local or state government representatives, explain to them why he or she is concerned and ask them to get involved in developing solutions. They could ban the land filling and incineration of electronic junk. They can help to promote computer re-use and recycling infrastructure. They can support Extended Producer Responsibility (EPR) for computer manufacturers. Waste prevention is perhaps more preferred to any other waste management option including recycling. Donating electronics for reuse extends the lives of valuable products and keeps them out of the waste management system for a longer time. Reuse, in addition to being an environmentally preferable alternative, also benefits society. By donating used electronics, schools, non-profit organizations, and lower-income families can afford to use equipment that they otherwise could not afford. Care should be taken while donating such items, i.e., the items should be in working condition.

5.4 Encouraging Reuse

According to the Basel Action Network (BAN) [10], Developing countries need help to create environmentally sound waste management systems. Such efforts should not be part of continuing to stop exporting hazardous wastes to those countries, but rather as a necessity for any country that must deal with all kinds of wastes.

6. IMPLICATIONS FOR CURRICULUM DEVELOPMENT IN THE FACULTY OF ENGINEERING, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA (IIUM)

In the era of globalization, certain ethical, social, and global aspects of the graduate engineer need to be enhanced [21]. This has important implications for education and research [22]. As explained before, this needs to be stressed from an Islamic point of view. Another motive for such ethical consideration is that accreditation by recognized bodies necessitates taking into consideration the ethical contents of the engineering programs [23].

Academic Institutions have an important role in informing the students of the great environmental risks that could arise from the e-waste issue. Usually, computer engineering graduates know little information (if any) about the material or chemical contents of a PC. May be it is none of their concern from a career point of view but nowadays every individual and engineer in particular has to be updated of the environmental issues arising from the various electronic devices they use daily. As such, educational institutions in Muslim countries can play a role model in modifying their engineering curriculum to accommodate the e-waste problems.

There are many ways for the universities to spread the awareness amongst the students and staff of this issue. Workshops and seminars can be organized on a semester basis or at least annually. Courses could be added to the engineering curriculum on solid waste management in general and E-waste management specifically. Proposals for the faculty of engineering at the International Islamic University Malaysia regarding these issues are discussed below.

6.1 Designing a Course on E-Waste

A preliminary survey was done on universities syllabi for computer engineering programs. According to the authors' knowledge, no university offers a course for computer engineering students about the materials contained within a PC and its harm as e-waste.

In the Faculty of Engineering at International Islamic University Malaysia (IIUM), different courses could be added to the curriculum to help increase the awareness of this issue. As a start, a general course on solid waste management may be proposed. Such a course could be adapted in the Faculty of Engineering, in different programs especially in the Manufacturing and Materials Engineering Department.

For example, a course titled Solid Waste Management and Environmental Health (ENVH 445) is taught at the University of Washington (UW), in the U.S. The primary goal of this course is to provide students with a comprehensive understanding of solid waste management from an environmental/public health perspective. The learning objectives of the course aim at making the students able to: (1) Identify and discuss the public health, regulatory, planning, technical, and economic principles that influence the solid waste management system within Washington State, (2) Describe appropriate methods to minimize the impact to the public's health from solid waste related activities, (3) Analyze the importance of an integrated solid waste handling system including source reduction, recycling and reuse, composting, land filling and combustion and (4) Develop a more informed opinion on a variety of solid waste related issues. Some of the topics covered are: Public hazards and importance of laws and regulations, Solid waste characterization and planning, Source reduction/recycling in action, Solid Waste impact on global climate change, Land filling, Waste combustions, E-waste.

6.2 Including E-Waste Topics using Across-the-Curriculum Approach

Another approach is to include topics on waste management and E-wastes across the curriculum. For example, these topics may be included in the following courses:

Course	Department
MEC4131 - Advanced Materials Engineering	Manufacturing & Materials Engineering
BTE3610 - Waste Management and Utilization	Biotechnology Engineering

Since there is no such course in the Electrical and Computer Engineering program, selected topics could be covered using seminars or workshops. Another approach is to include elements of the E-waste problem in the course Computer Architecture and Design (ECE 3213).

In the mean time, waste and E-waste topics may be the topics of final year projects where the students may perform literature surveys on the technical aspects of the problem or even address one of the alternative solutions as explained in the following section. During industrial training, the students may be advised to be alert to the problem and try to assess its dimensions in the different fields. Finally, E-waste may be a good topic for a university outreach program undertaken by the students associations to educate the surrounding community on environmental issues.

7. IMPLICATIONS FOR RESEARCH AND REGULATIONS

E-waste processing in developing nations has only recently emerged as an important issue, thus relevant research remains scarce. The overarching issue of assessing and managing the environmental impacts of electronics, however, has a history of research and implementation, especially from the 1990's [2].

Specific areas that need science and technology inputs are [19]:

- Cleaner technologies such as those for waste minimization, recycling, recovery and treatment
- Environment friendly manufacturing processes (e.g. lead free soldering)
- Material flow analysis for benchmarking the performance review of industries
- Greening of supply chains of manufacturers of electronic components

Major events that have developed to service the research and implementation community are concerned with Green Electronics [2]. In the U.S., the flagship event is the "International Symposium on Electronics and the Environment", sponsored by IEEE, and has been held annually since 1993. International participation in previous years was mainly from Europe, but more recently presentations from Japan and other Asian countries have been on the increase. From 2003, a new annual event, "E-Scrap", has emerged as a new player in the field. It is more targeted towards industry and policymakers. In Europe, the main event in the field is "Electronics Goes Green", which has been held in 2000 and 2004 in Berlin. While there has been no regular event in Japan focuses on electronics and

the environment specifically, the “International Conference on Ecobalance”, held biannually since 1994, and “International Symposium on Environmentally Conscious Design and Inverse Manufacturing”, held biannually since 1999, include much content related to electronics.

7.1 Examining E-Waste Related Regulations

In its list of recommendations to combat illegal dumping of E-waste, The Basel Action Network (BAN) urges governments to pressure manufacturers to remove toxic chemicals from products as soon as possible. BAN also calls on strict enforcement of the Basel Convention [10] and lauds Australia for its efforts in that regard. Australia requires full testing of electronic waste to certify that it complies with the Basel Convention before it is exported. The BAN report on dumping in Lagos calls the U.S. "the worst actor" among developed countries that perpetuate dumping of hazardous waste in developing nations.

It is thus clear that there is a need to examine E-waste related regulations at the national level. Regardless of the fact that this issue has legal background, engineers can help in identifying the technical aspects of the problem to the legal experts.

7.2 Design of Toxic and Hazard Free Products

Many companies have shown they can design cleaner products. Industry is making some progress to design cleaner products but there is a need to move beyond these projects and ensure that all products are upgradeable and non-toxic

Some examples of alternatives are [24]:

(1) Hewlett-Packard Company has developed a safe cleaning method for chips using carbon dioxide cleaning as a substitute for hazardous solvents.

(2) Printed circuit boards can be redesigned to use a different base material, which is self-extinguishing, thereby eliminating the need for flame-retardants. Matsushita is accelerating efforts to eliminate toxic substances and develop more environmentally benign materials such as lead-free solder, non-halogenated lead wires and non-halogenated plastics. Matsushita also developed the first lead-free solder for flow soldering applications and have recently launched, in Japan, their first totally-recyclable television sets. Sony Corp has developed a lead-free solder alloy, which is usable in conventional soldering equipment. There is a range of lead-free solders now available. Obviously, substitutes need to be proven for safety.

(3) Pressures to eliminate halogenated flame-retardants and design products for recycling have led to the use of metal shielding in computer housings. In 1998 IBM introduced the first computer that uses 100% recycled resin (PC/ABS) in all major plastic parts for a total of 3.5 pounds of resin per product. Toshiba is working on a modular upgradeable and customizable computer to cut down on the amount of product obsolescence. They are also developing a cartridge which can be rewritten without exchanging parts or modules allowing the customer to upgrade at low cost.

It is thus worth mentioning that efforts are under way to propose safe alternate materials. More funding as well as directed research is still needed along these directions. As mentioned before, this is a golden chance for research institutions in Muslim countries to take the lead in relieving the environment from such problematic e-wastes.

8. CONCLUSIONS

While advances in technology continue to improve and enrich our lives, product lifecycles are getting shorter. This means an increasing stockpile of end-of-life equipment that needs to be managed. When discarded, much of this equipment ends up in landfills in developed countries or is exported to third world countries.

Electronic equipment contains harmful toxins which, when released into the environment, can contaminate water, land and air. While there are many ways to dispose of unwanted electronics, there are few guarantees that the resulting e-waste will be disposed of responsibly. This is a major issue, either in the developed countries due to the amounts generated or in developing countries due to lack of recycling systems.

It is clearly unethical for the developed countries to dump their E-waste in developing ones. Government control should be practiced to avoid such actions. Citizens have a responsibility in spreading the awareness on this issue. Engineers should be in the forefront since they master the technical background of the issue.

A preliminary survey indicated that E-waste is hardly covered in engineering faculties worldwide. As such, academic institutions in Muslim countries can play a role model in modifying their engineering curriculum to accommodate the E-waste problems.

The Islamic concepts of the need to protect the environment should be clearly spelled out in any course related to waste management in general and E-waste management specifically.

E-waste management can be introduced as separate courses. Related topics can be embedded in related courses, as well as as topics for final year projects. They can also be addressed during industrial training.

More funding as well as directed research is still needed to find alternate materials to tackle the E-waste problems. This is a golden chance for research institutions in Muslim countries to take the lead in relieving the environment from such hazards.

Technological issues that pose environmental threats need to be carefully examined. Implications for education and research due to these technological aspects need to be done on a systematic basis especially for universities in Muslim countries.

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