Application of decision tree algorithm in e-waste land filling

Saranya Mohanbaba[1]*, Shanthi V[2], Subhashini Mohanbaba[3]

[1]Ramco Systems, Adyar, Chennai-600 020, India
[2]Department of Economics, Chellammal women's College, Guindy, Chennai-600032, India
[3]State key Laboratory of Reproductive Biology, institute of Zoology, Chinese Academy of Sciences, Beijing 100101, China
[1]*saranya.muruga@gmail.com; [2]mohan.subhashini@gmail.com

Abstract

E-waste is the fastest growing source of municipal waste on earth. The 21st century witnesses novel environmental challenges due to the advent of electronic goods in our day-to-day life. The disposal of e-waste directly into landfill without prior treatment poses a threat for ground water contamination. The present investigation is to find out the best way of safe disposal of electronic wastes. For this purpose, we used the data in the existing literature on various soil properties and a decision tree algorithm, which was applied to the respective soil factors and bifurcated to find out suitable soil type/ conditions for dumping e-waste in landfill. In bifurcation with parameters *viz*. pH, specific gravity, electric conductivity, organic matter, clayey/ silt percent and permeability, it is found that clayey soil is much preferred to dump the e-waste chemicals because leaching is less besides its metal retention capacity. The study also suggests a pre-treatment prior to disposal in landfill area may further reduce the environmental threat caused by the heavy metal leachates from e-wastes.

***Keywords*:** e-Waste; Landfill; Decision tree algorithm; Soils; Safe disposal.

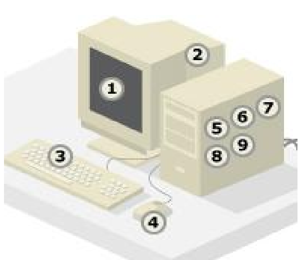
Introduction

E-waste encompasses ever growing range of obsolete electronic devices such as computers, servers, mainframes, monitors, TVs & display devices, telecommunication devices such as cellular phones & pagers, calculators, audio and video devices, printers, scanners, copiers and fax machines besides refrigerators, air conditioners, washing machines, and microwave ovens, e-waste also covers recording devices such as DVDs, CDs, floppies, tapes, printing cartridges, military electronic waste, automobile catalytic converters, electronic components such as chips, processors, mother boards, printed circuit boards, industrial electronics such as sensors, alarms, sirens, security devices, automobile electronic devices.

Toxic chemicals present in a personal computer

Fig.1 and Table 1 provides the hazardous chemicals used in manufacturing of computer parts.

Fig.1. Location of toxic chemicals (Recycle Old Computers, 2009)



1: Lead in cathode ray tube and solder
2: Arsenic in older cathode ray tubes
3: Selenium in circuit boards as power supply rectifier
4: Polybrominated flame retardants in plastic casings, cables and circuit boards
5: Antimony trioxide as flame retardant
6: Cadmium in circuit boards and semiconductors
7: Chromium in steel as corrosion protection
8: Cobalt in steel for structure and magnetism
9: Mercury in switches and housing

Table 1. Hazardous chemicals in the various computer parts (Oecd.org 2008)

Chemicals	**Location**	**MG (31.5 KG PC)**	**Diseases**
Lead acid Lead sulphate, Lead oxide	Cathode ray tube, solder, PCB's, PVC cable, wire sheating.	62370000mg	neurological poison and human carcinogen.
Cadmium, Cadmium Hydroxide Cadmium sulphide	Circuit boards, semi conductors, batteries, CRT coatings.	93271.5 mg	respiratory tract, kidney, liver, human carcinogen.
Beryllium, Beryllium copper.	Used in mother board in the form of copper beryllium alloy.	155610 mg	lung disorder, human carcinogen.
Cobalt	Steel for structure and magnetism.		lung irritation, human carcinogen.
Nickel hydroxide.	batteries.	315000 mg	neurological poison.
Mercury	Pcb's, batteries, LCD flat screens.	21829.5mg	brain, kidney damage and developmental defects in developing fetuses.
Arsenic	Older cathode ray tubes.	12899.25 mg	stomach and intestine irritation, decrease in red blood and white blood cell production, skin changes, lung irritation,dna damage.
Zinc oxide, Zinc sulphide.	Inside crt screen.	693000 mg.	zinc oxide causes decreased vital capacity, coughing, upper respiratory tract irritation and substernal pain, metal fume fever.
Copper	Mother board	22050 mg.	intestinal and respiratory irritation, high dose cause liver and kidney damage.
Hexavalent chromium (chromium iv)	Steel as corrosion protection.	62370 mg.	upset stomach and ulcers, skin rashes, weekened immune system, kidney, liver damage, alteration of genetic material, lung cancer and death.
Selenium	Circuit boards.		excess selenium causes deformities. lack of selenium in soil causes white muscle disease in mammals and strokes in human.
Aluminium	Computer cases, wires.	44730 mg.	eye, respiratory tract irritant, dementia, convulsion, speech disorders.
Iron		64575 mg.	eye, respiratory tract irritant, siderosis, gastro intestinal disturbances
Barium	Getter plate of electron gun of CRT's.	312480 mg	brain swelling, muscle weakness, heart, liver and spleen damage.
Antimony, Antimony trioxide, Sodium antimony.	Lead solder, crt screen, flame retardant, chip encapsulant, , melting agent in CRT.	2835000 mg	skin and eye effects, lung inflammation and irritation, cardiovascular effects.

E-waste estimation

The methods that are used in most of the countries to calculate the e-waste generated are WEEE Generation Method; 2) Material Flow Analysis and 3) Time Series Method.

Waste from Electrical and Electronic Equipment (WEEE) Method

A Computerized four-phase model has been developed by the European Tropic Center on Waste as the basis for the necessary analysis to show the emerging trends of WEEE in quantitative (Waste quantities) and qualitative (dangerous substances emitted) form.

Market Supply Method

Material Flow Analysis (MFA) is a quantitative procedure for determining the flow of materials and energy through the economy. It uses Input/output methodologies, including both material and economic information. It is an accounting system that captures the mass balances in an economy, where inputs (extractions + imports) equal outputs (consumptions + exports + accumulation + wastes).

Time-Series Method

Time-Series Methods make forecasts based on historical patterns in the data. Time-series methods use time as independent variable to produce demand. A first step in using time-series approach is to gather historical data. The historical data is the representative of the conditions expected in the future.

Using the Time-Series Method, the future outflow of e-waste that will be generated in the year 2025 is estimated based on the previous year sales data and taking consideration of the average weight of a PC as 31.5 kg. (Table 2) shows the PC sales data of the previous years and the estimated sales for the year 2010 are given below (Ruth David, 2008).

Table 2. Annual sales of Personal Computer

Year	PC Sales (million)
2005	40,40000
2006	49,00000
2007	54,00000
2008	77,63322
2009	81,89061
2010	89,60000

Expected sales for the predicted year 2025 will be 54, 58,586 and the E-waste generated is 171945459 million.

E-waste generation scenario

E-waste generation in USA accounts to 1-3% of total municipal waste generation. In Europe the total amount of e-waste generation ranges from 5 to 7 million tons per annum and is expected to grow at the rate of 3-5% per year (Envis Newsletter, 2008). According to the report “Recycling from e-waste to resources” china produces 2.3 million tons

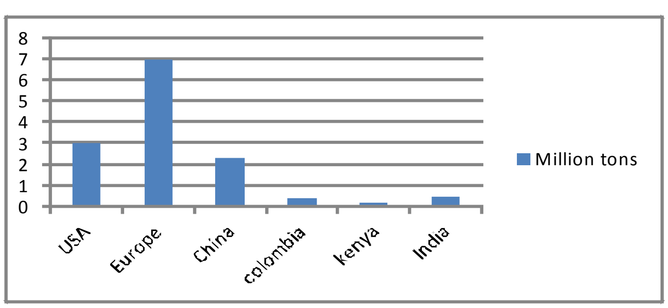


Fig.2. e-waste generation: world scenario

of e-waste. Fig.2 provides country wise details about e-waste generation (Science Daily, 2010).

Indian scenario

The total e-waste generation in India amounts to 1, 46,180 tons per year. This is due to the advent of information technology and modernization of lifestyle. Sixty-five cities in India generate more than 60% of total e-waste. Table 3 gives data about WEEE Generation in Top Ten Cities in India (Amit Jain, 2008).

Table 3. E-waste generation in major cities in India

City	WEEE* (Tonnes) per year
Mumbai	11017.1
Delhi	9790.3
Banglore	4648.4
Chennai	4132.2
Kolkata	4025.3
Ahmedabad	3287.5
Hyderabad	2833.5
Pune	2584.2
Surat	1836.5
Nagpur	1768.9
*Waste electrical & electronic equipments	

E-waste management policy

It is estimated that 75% of electronic junks are stored in houses, offices, warehouses etc and normally mixed with household wastes, which are finally disposed off in landfills. The Chennai Pollution Control Board (CPCB) ranks Chennai fourth among the top 10 e-waste generators in India. E-waste is also imported from U.S., the U.K. and Australia. Sixty percent of the e-waste in Chennai comprises desktop computers. The life span of most desktop computers in companies in Chennai is four years, which is very less than the average. Considering the severity of the program, it is necessary that certain E-waste management policies be adopted to handle the E- waste junks. Following are the some of the policies undertaken by the government, manufacturers and consumers:

- The e-waste (Management and handling) rule, producer responsibility for recycling and reducing e-waste in the country. The rules will come into effect from May 1, 2012. (Business Standard, 2011).
- IT companies plan to handle the issue by implementing Big Bridge, a project announced by NASSCOM recently, that aims to collect and

transport old computers to designated warehouses. Cognizant, HSBC, Nucleus Software, Bank of America, Microsoft, Socite Generale, Corelogic, Fidelity and recently Thompson Reutlers have joined hands with it (Hindu, 2011).

- HP's e-waste export policy contains the company's commitment to responsibly dispose of all e-waste generated by HP's global operations and take-back programs (News Release. 2010).
- TCS e-waste management policy looks for:
  * Buy computers from vendors who are ready to take back E-waste in future.
  * Extending the life of computers/hardware to 4-5 years.
  * Adhere to WEEE directives on E- waste handling.
  * Achieve 100% environmentally responsible disposal of E-waste.
  * Adhere to applicable country E-waste regulation.
  * Carry out E-waste disposal only through E-waste handlers / recyclers authorized by ministry of environment and forest /central or state pollution control boards in India or country specific regulatory agencies (pratik, 2008).
- Agencies handling E-waste must obtain environmental clearances and be authorized and registered by the PCBs even under the Hazardous Wastes (Hindu, 2011).
- Greenpeace campaign has resulted in International Market leaders like HP, Dell, LG Electronics, Samsung, Sony, Sony Ericsson and Nokia committing to eliminate some of the most hazardous chemicals from their products.
- HCL and Wipro, India's leading manufacturer have introduced full RoHS (Restriction of hazardous chemicals) -compliance of the new range of HCL laptops manufactured in India (Manu Sharma, 2008)
- The launch of pilot project by the government which help in setting up disposal bins especially for the disposal of electronic gadgets like compact disc ,mobile phones etc for the regular pick up and proper disposal of E-waste by the authorized recyclers . The bins are made of a special material to prevent thefts even as users dispose of the unwanted electronic gadgets (Hindu, 2011)
- Nokia India has introduced ' Take back' campaign where customers can drop their mobile phones and accessories in the recycle bin located near Nokia priority dealers and Nokia care centers and win gifts. Nokia Company will one by one plant a tree for every handset dropped into these bins (Live mint, 2008).
- DELL guarantee to provide free take back recycling services for all their products and support for producer take back recycling legislation (Texas Environment, 2011).
- Samsung in India has launched a new program called Samsung Take Back and Recycle Program (S.T.A.R program) which will allow the consumers to dispose the Samsung products across the Samsung service center network. It will allow the consumers to use 235 locations in 20 cities for disposal (Knowyourmobile, 2010).
- LG has involved in the process of 'Global Take back policy' but believes that existing Take back regulation is not enough. LG electronics supports the introduction of Individual Producer Responsibility (IPR) for potential wastes and promotes IPR through active participation in IPR related public forums held by digital technology association such as digital Europe. LG electronics is also in the process of becoming a member of IPR Works, a NGO and industry alliance dedicated to advancing IPR. LG electronics provides all users the access to information on take –back policy in various countries and regions on website (LG.com, 2009).

Disposal of e-waste

Electrical and electronic equipment are made up of a multitude of components, some containing toxic substances that can have an adverse impact on human health and the environment if not handled properly. Often, these hazards arise due to the improper recycling and disposal processes used. Nearly 20 percent of electronic waste is recycled nationwide and remaining 80 percent moves to landfill for disposal. Before discharging E-waste, a pre-landfill treatment is suggested which can reduce the mobility of toxic chemicals in the soil base on the leaching behavior in long time. This treatment is applicable to main pollutants like those that Pb, Cd, Sb and Mo, which is very well, present in E-waste. Prior to landfill disposal, a compacting process in S/S waste is studied to improve the mechanism controlling release on sustainable landfill for non-hazardous monolithic waste, which also includes E-waste.

The compaction process involves compacting products i.e metallic waste obtained through solidification of electric arc furnace dusts at industrial scale. Water content (2-8%) and pressure values (40-200 bars) are taken as input variables and mass density is analyzed in the monolithic as output variable. In this study three samples at 40, 120 and 200 bars have been considered. NEN7435 diffusion leaching test is performed to study the leaching of inorganic components from monolithic material at different compaction intensities. The pH, Electrical conductivity, redox potential and metal concentration of major pollutants in the solid waste like Cd, Pb, Mo, are analysed in the leachates. In all the cases, the mobility of sample at pressure equal to 120 is less compared to 40 and 120 bars. Therefore, a compaction process is recommended as treatment prior to land disposal for this kind of waste materials base on the leaching behaviour in a long time (Ruiz-Labrador *et al*., 2011).

Land filling

Landfills are the most preferred disposal of solid waste including electronic waste. Historically, landfills have been the most common methods of waste disposal and remain so in many places around the world. Some of the surface disposal designs recommended are *Low Land Burial* – The containers used for storing e-waste is steel or wood. E-waste containers are placed in trenches above water table. Sand, gravel, crushed stone is spread on the base of the trench in order to drain water and provide dry foundation for the waste containers. The space between E-waste containers is filled with sand or clay when the trenches are full, it is covered with compacted clay. *Concrete Canister Disposal*– E-waste containers are placed in large concrete containers and then piled one above the other in the trenches. *Granite Disposal*– The above canister concrete disposal can be replaced with granite, which is 4 x times stronger than concrete containers. *Augured hole* – It is another disposal option where a hole of about 10 feet in diameter and 120 feet deep is dug. The floor of the hole must be above the water table and the holes are lined with concrete or granite. The e-waste containers are placed inside the hole and the spaces between the holes are filled with sand or clay. Finally, the hole is closed using a cap made of concrete or clay. However, many a time, in absence of financial back-up or network and management system especially for e-wastes, the above approaches yet to find the practicality.

Leaching of e-waste into soil

Toxic chemicals like lead, arsenic, beryllium, copper, zinc, cadmium and mercury leaches into the soil from dumped e-waste thus polluting the underground water. Lead, arsenic, beryllium, copper, zinc, cadmium and mercury are some of the more toxic materials that can leach into the soil from dumped E-Waste (Greg Kelton, 2008). Mercury, for example, will leach when certain electronic devices such as circuit breakers are destroyed. Lead has been found to leach from broken lead-containing glass, such as the cone glass of cathode ray tubes from TVs and monitors. When brominated flame retarded plastics or plastics containing cadmium are land filled, both PBDE and cadmium may leach into soil and groundwater. In addition, landfills are also prone to uncontrolled fires, which can release toxic fumes

CRT monitors and TVs contain an average of 4 pounds of lead each. Excessive lead and other toxins pose a problem in landfills because they can leach into groundwater or, in the case of a lined landfill, force expensive leachate treatment. In combustors, the lead winds up on the ash residue, which in turn disposed of in landfills. Lead exposure ash been linked with learning disabilities, behavioral problems and at very high levels, seizures, coma and even death.

Soil plays a major role in leaching of hazardous chemicals from e-waste. The leaching pattern depends on the soil type and their properties. Soil can be characterized according to different parameters such as pH, electrical conductivity, cation exchange capacity, iron and aluminum oxides, mechanical composition, chlorides, sulphates, total nitrogen and total phosphorous. These parameters can be determined by standard analytical methods.

The soil properties that most influence the sorption and retention of Cu, Cd, and Pb are pH, specific gravity, and electrical conductivity, Organic matter and fine fractions of clay and silt. A soil's pH level is an indicator of its acid and alkaline content. Measures are based on a pH scale that runs from 0 to 14, according to NASA Soil Science Education (2011).

The soil pH of 7.5 and above in an unprotected e-waste landfill site clearly indicates that there is a possibility of the soil being polluted because of leaching of heavy metals. Since most of the chemicals present in the computer system such as aluminium, magnesium, zinc, copper and lead are alkaline in nature, the disposal of electronic waste in to the unprotected landfill will definitely increase the soil pH to some extent. The electrical conductivity of soils plays an important role in leaching of the chemical in to the soil. This may not be on higher side of alkali but over the time this definitely will increase the pH if there is a continuous dumping of E-Waste. The different soil types and their pH values as mentioned in the literature are tabulated in Table 4 (Kumar, 2006)

Table 4. Soil pH

Soil type	pH value
Peat soil	7.37
Clayey soil	8.46
Sandy soil	8.48
Red soil	7.20

A soil's conductivity level can help in identifying potential problems and serve as a gauge for future treatment applications. In most cases, a soil's pH level is directly related to its electrical conductivity level. Soils containing a high salt content have a high electrical conductivity level, according to “Ecosystem Restoration”.

Electrical conductivity actually takes place inside the pores that reside in between soil particles. As a result, conductivity levels can vary depending on soil density. Heavier densities like those found in clay like soils carry a high conductivity rate. Wet soils like sandy soil whose density is also moderately high can also be good conductors of electricity.

Soils containing high levels of organic matter like compost or fertilizer materials may tend to retain positively charged ions like Ca+, K+ and Mg+. High Ca concentrations usually decrease the soluble species of trace metals and form bridges between negatively charged soil particles and organic matter, thus decreasing its solubility (Temminghoff *et al*., 1998). Ca also competes with trace metals for binding sites on organic molecules. However, it has been shown that for high pH in sandy soil the DOM binding of Cu was the predominant factor for Cu mobility, rather than Ca competition with Cu (Temminghoff *et al*., 1998). These are naturally present in E-Waste. High cation content also raises electrical conductivity levels. Permeability is low when the soil contains high composition of fine fractions (i.e., silt plus clay). Clayey soil due to its high composition of fine fractions, the permeability is low. It has better adsorption capacity on heavy metals compared to other soils and results in less migration of heavy metals through the soil (Wang Zuhairi *et al*., 2008). The specific gravity, electrical conductivity, organic matter, clay and silt of different soil types are listed in Table 5 (kumar *et al*., 2005).

Table 5. Soil parameters

Soil type	Specific Gravity	Electrical conductivity (dS/m) (approximate)	Organic Matter	Clay and Silt (%)
Peat soil	2.20	120	9.51	3.6
Clayey soil	2.78	468	2.29	56
Sandy soil	2.55	330	0.9	5
Red soil	2.49	53	5.28	7.6

Yadong Li *et al*. (2009) prepared e-waste simulated landfill columns. In their experiment, column filled with mixture of municipal solid waste and CRT's monitored for toxic leachate for 2 years. It was found that Pb was not detected. However, such simulation work has limitation in understanding of the field behavior. For example, the soil factors influencing on the e-waste leaching are totally different as the field soil has many co-factors including micro-organisms, air contact and pH with climatic vagaries. Besides, microbial consortia greatly influence on soil pH and temperature, other soil parameters like moisture, pressure and depth factors add different effect. Hence, the simulation considering all the soil properties or influencing properties are the key approach for simulation experiment.

With this background we attempted to aggregate the soil parameters and developed suitable algorithm to find out a soil for considering dumping of the E-waste chemicals.

Possible approach

In the absence of appropriate management, e-waste is presently disposed of by Landfill, which may pollute the environment in particular the soil. Government should enact policies in consultation with PCB, Producers and Traders so that the e-wastes can be judiciously managed.

It should include buy-back policy of the producers (to recycle/ re-use the product); Extract the toxic component from the e-waste product; Invoke the Government subsidiary in collaboration with NGO's to meet that uneconomic final e-waste before dumping.

An unprotected landfill is still more dangerous. But in countries like India, China, Thailand, and Pakistan where the laws are not stringent it is always difficult to control the dumping of e-waste in an open land. In a broad spectrum it is always safe to project a site to dump the e-waste to minimize the danger to the environment. This paper addresses this problem and suggests the best site to dispose the E-Waste in an unprotected landfill site. The Decision Tree approach is the most useful in dealing such problems. This technique is used in this study for selecting the best soil for disposing in to an unprotected landfill. Soil containing high percentage of clay and silt is always preferred because of its retention capacity of heavy metals (Wan zuhairi *et al.*, 2008). Accordingly, the clayey soil and sandy soil may be preferred to dump the e-waste chemicals. Red and peat soil may be avoided. Fig.3 shows the decision tree approach that can be preferred to dump e-waste.

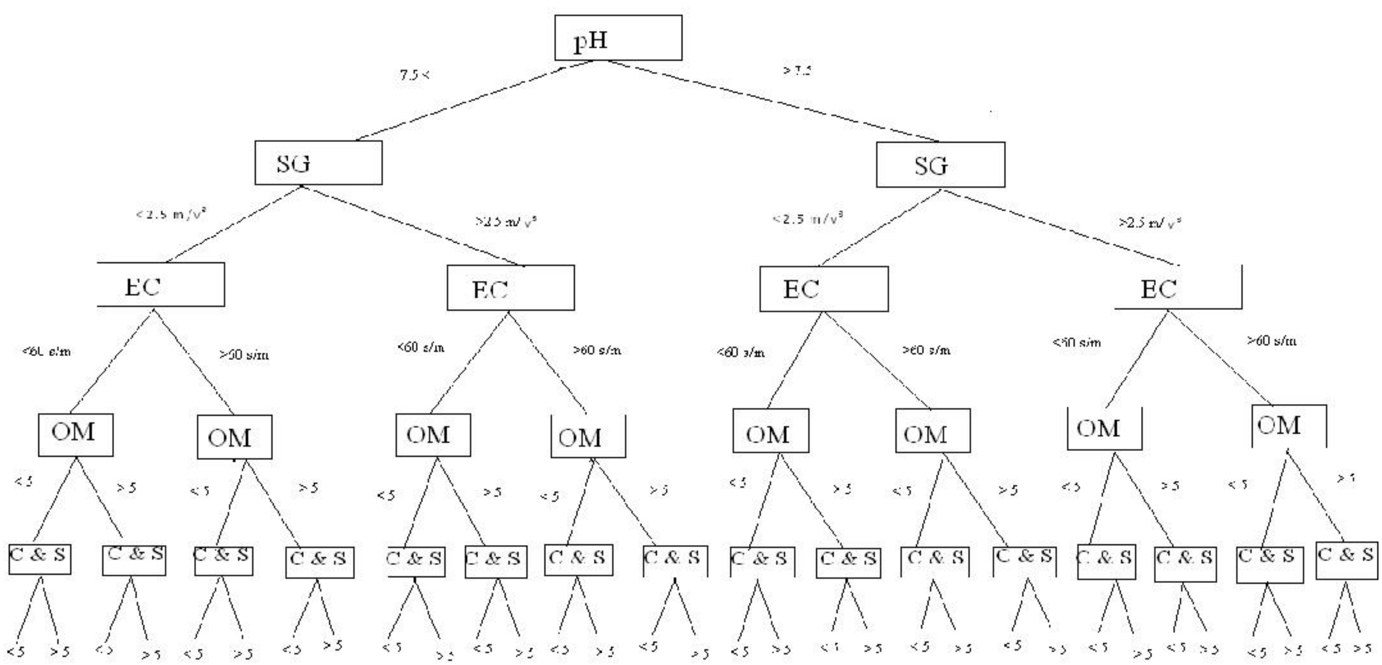


Fig.3. Decision tree algorithm displaying soil parameters ideal for e-waste dumping

Conclusion

From the decision tree algorithm applied to the soil parameters the following conclusion is drawn:

- When pH is low, EC is low, organic matter is low and clay and silt percentage is high.
- When pH high, EC is high, organic matter is low and clay and silt percentage is high. In this case permeability is low and it is concluded that the soil is more suitable for dumping e-waste. However,
- When pH is high, EC conductivity is high, Organic matter low and clay and silt percentage is low.
- When pH is high, EC is high, organic matter is high and clay and silt percentage is low. In this case permeability is high .So the e-waste disposal in the soil having such soil properties is less suitable.

The landfill emissions enter the ground water with time due to the long residence period in the landfill and soil. Since the heavy metals in soil will probably be released in the long run, may be decades, a method assessing the fate of heavy metals in soil is needed. This study does not include the effect of dumping other materials in the same E-Waste dump site. The effects may be higher depends upon the materials that are dumped near the unprotected landfill E-Waste site.

Acknowledgement

This work is based on the dissertation which was conducted at the Central Leather Research Institute, Adyar, Chennai in 2010 for partial completion of B.Tech Degree of the first author and she is grateful to the institute who provided an opportunity to complete her Dissertation. Also, she would like to acknowledge Prof. Natarajan Gajendran for his continued encouragement.

References

1) Envis Newsletter, (2008). Accessed from: http://envis.maharashtra.gov.in/envis_data/files/Ewastgeneration_scenario.html on 20th june 2011.
2) Business Standard, (2011). Accessed from:http://www.business-standard.com/india/news/india-gets-first-e-waste-management-rules/438474/on 30th june 2011.
3) Cdr.pratik deshpande, (2008). 15th july, TCS e-waste management policy, accessed from http://www.tcs.com/about/corp_responsibility/Documents/tcs_sustainability_ewaste_policy.pdf on 1st july 2011.
4) Renewing E-waste, (2011). Accessed from: http://www.thehindu.com/opinion/editorial/article2129505.ece. 30th June 2011.
5) News Release, (2010). Accessed from: http://www.hp.com/hpinfo/newsroom/press/2010/100211b.html on 30th june 2011
6) Manu Sharma, (2008). E-waste Computer manufacturers join hands with Greenpeace Global environmental organization to help IT behemoths tackle e-waste menace in India, accessed from: http://www.goinggreen.co.in/Network-Repository/Feature/Computer-manufacturers-join-hands-with-Greenpeace/141108112653/article.aspx on 15th july 2011.
7) TBC Recycler and Auctioneer, (2010). Accessed from: http://www.tbcrecycling.com/IT_Recycling_Overview.html on 15 july 2011.
8) Nokia launches e-waste management initiative, (2008). Accessed from: http://www.livemint.com/2008/12/31173330/Nokia-launches-ewaste-managem. html on 1st july 2011.
9) Texas Campaign for the Environment, (2011). Accessed from: http://www.texasenvironment.org/ewaste_dell.cfm on 16 july 2011.
10) Samsung introduces Samsung Take back and Recycle (STAR) Program in India, (2010). Accessed from:http://www.knowyourmobile.in/news/814852/samsung_introduces_samsung_takeback_and_recycle_star_program_in_india.html on 20 july 2011.
11) Take-back and recycling, (2009). Accessed from : http://www.lg.com/global/sustainability/environment/take-back-recycling.jsp on 1st August 2009
12) Jagdish Hiray, (2008). Time-Series methods of forecasting, accessed from: http://businessmanagement.wordpress.com/2008/02/21/time-series-methods-of-forecasting/ on 16 July 2011.
13) Chemicals present in a personal computer, (2011). accessed from: http://recycleoldcomputers.co.uk/page2.html on 1st june 2011.
14) Greg kelton, (2008). *Government Plans to ban E-waste at landfills ,accessed from:* http://www.adelaidenow.com.au/news/south-australia/push-to-ban-e-waste/story-e6frea83-1111117968572
15) Electronic Industries Alliance, (2000). The Evaluation of Materials used in Personal Computers accessed from: http://www.oecd.org/dataoecd/44/46/2741576.pdf
16) Government plans to ban e-waste at landfill, (2008). Accessed from http://www.adelaidenow.com.au/news/south-australia/push-to-ban-e-waste/story-e6frea83-1111117968572.
17) Temminghoff EJM, Van Der Zee SAETM, De Haan FAM. (1997). Copper Mobility in a copper-contaminated

sandy soil as affected by pH and solid and dissolved organic matter. *Environ Sci Technol*, 31, 1109-1115.
18) Wan zuhairi WY, Abdul Rahim Samsudin and Nurita Ridwan. (2008). The retention Characteristics of heavy metals in Natural Soils using Soil column Experiment India.
19) Mathava Kumar and Ligy Philip. (2005). Adsorption and desorption characteristics of hydrophobic pesticide endosulfan in four Indian soils.
20) Arno Kaschl, Volker Romheld and Yona Chen. (2001). The influence of soluble organic matter from municipal solid waste compost on trace metal leaching in calcareous soils Isreal.
21) Electrical conductivity of soils, (2011). Accessed from: http://www.ehow.com/about_6402059_electrical-conductivity-soils.html on 1st August 2011.
22) Bruce S. (2010). Seychelles Incinerator Sustainability Preliminary Study. Accessed from: www.s4seychelles.com/uploads/6/1/6/7/.../incinerator.eia_s4s.pdf.
23) Andeen W. Fentiman, Matthew E. Jorat, and Ronald J. Veley. What disposal methods are being considered for low-level radiowaste?,accessed from : http://ohioline.osu.edu/rer-fact/rer_42.html on 23rd October 2011.
24) P.K Narayanan, (2011). Near Surface disposal of Radio-active waste accessed from www-pub.iaea.org/MTCD/publications/PDF/P073_scr.pdf on 16 th October 2011.
25) ScienceDaily, (2011). Accessed from www.sciencedaily.com/releases/2010/02/100222081911.htm on 22nd february 2011.
26) Ruth David, (2008). India Computer Sales; it's getting personal. Accessed from http://www.forbes.com/2008/02/27/india-computer-sales-markets-equity-cx_rd_0227markets04.html on 18th October 2011.
27) Diwaskar Chettri, (2010). IDC: PC Sales in India Fall 10.25% QoQ To 1.97M accessed from http://www.medianama.com/2010/02/223-idc-pc-sales-in-india-fall-10-25-qoq-to-1-97m/on 18th October 2011.
28) Amit Jain, (2006). 3R South Asia Expert, accessed from: http://www.iges.or.jp/en/ltp/pdf/activity08/19_jain.pdf on 25th june 2011.
29) Arno Kaschl, Volker Romheld and Yona Chen. (2001). The influence of soluble organic matter from municipal solid waste compost on trace metal leaching in calcareous soils Isreal.
30) Larwik Engineering Consultant, (2011). Accessed from: http://www.larvik.co.in/materialflow-analysis.html
31) Ruiz-Labrador B, Coz A, Cifrián E, Galán B and Andrés A. (2011). Management of hazardous waste on sustainable landfills: Influence of the compaction of stabilised/solidified metallic waste on the leaching characteristics. Accessed from: http://www.iswa.org/uploads/tx_iswaknowledgebase/20-259paper_long.pdf