Estimation of Wastes Generated from Obsolete Personal Computers in India

Pamela Chawla, Neelu Jain

Abstract: - The objective of this paper is to characterize future trends in obsolete computer generation in India in the next fifteen years using logistic model based approach. The amount of various toxic and non-toxic components generated from these computers as well as precious metals recoverable from the obsolete computers by 2025 is also estimated. In this model, the historical sales data and an assumed first lifespan distribution of desktop and laptop computers are used to estimate future computer penetration rate and subsequently obsolete PCs to be generated in India. The estimation carried out in this study will serve as a guideline for government & planning bodies to setup collection, recycling and disposal facilities for the different types of toxic and non-toxic waste generated from obsolete computers in the next 15 years. This would also help regulatory authorities in formulating policies to mitigate impacts of informal recycling.

Index Terms: - End-of-life computers, First life span, Penetration rate, Toxic waste, Hazardous waste, Obsolete computers, Recycling

1 Introduction

Electronic waste or e-waste is the collective name for discarded electronic devices that enter the waste stream from various sources. E-waste includes household electronic appliances, toys, electrical and electronic tools, medical devices, mobile phones, monitoring and control instruments, automatic dispensers, information telecomunication and telecom equipment and consumer electronic items. Because of huge population and the changing consumption patterns, India is generating huge volumes of e-waste, which moves into the informal waste trade and recycling processes. The recycling of e-waste is proving to be a highly lucrative business as valuable metals like gold, silver, copper and lead are recovered from this waste. Apart from these, e-waste contains significant concentration of substances that are highly toxic and are hazardous to human health and the environment. Management of e-waste has become critical issue for almost all major cities in India. According to the latest annual report of the Union Ministry of Environment and Forest (MoEF), by the end of 2012, India would have generated a whopping eight lakh tones of e-waste which is up eight times in the past seven years. Environmentalists point out that an additional 50,000 tonnes is imported from developed countries despite a ban,as in [1].

Computer waste is the most significant of all the e-waste categories owing to the large volume generated and the fast rate at which it is generated. This can be attributed to a number of factors. The rapid growth of technology has led to reduction in lifespan of PC/Desktop as it is more economical and convenient to buy a new PC vis-à-vis its upgradation. Computers that cannot be upgraded increasingly become waste, of which a part is recycled and a large proportion ends up in landfills.

A personal computer contains different types of elements, including valuable components (gold, silver, platinum, etc.) as well as hazardous materials (cadmium, mercury, lead, brominated flame-retardants, plastics etc.). Due to high content of precious metals and high demand for used machines in developing countries like India, obsolete PCs are attractive to informal recyclers. The recycling of computers in an environmentally sound manner requires sophisticated technology and processes, which are not only very expensive, but also need specific skills and training for the operation. Most of the recyclers currently engaged in recycling activities do not have this expensive technology to handle the waste. When computer waste is landfilled or incinerated, it poses significant contamination problems. Landfills leach toxins into groundwater and incinerators emit dioxins which are toxic air pollutants. Even with all toxics removed recycling will cause impacts due to emissions while extracting valuable materials [2].

The objective of this study is to characterize long-term trends in generation of obsolete computers in India as it will provide a roadmap to both government and private setups in developing an appropriate formal recycling infrastructure. We estimate the volume of obsolete PCs mainly desktops and notebooks and quantities of the toxic and non-toxic components likely to be generated from them.

Table 1 & Table 2 give the composition of desktop and notebook PCs respectively in terms of toxic and non-toxic components/metals recoverable from an obsolete personal computer.

2 Approach

The objective of this paper is to estimate long term future trends of various hazardous and non-hazardous components generated from computer waste in India. For this purpose logistic function based model proposed by Yang and Williams [3], [4] has been used. This model uses data on historical stock and historical sales to forecast PC sales and generation of obsolete PCs over next fifteen years.

The logistic function growth curve displays an S-shaped behavior and has been found to empirically describe technology diffusion processes like computer adoption or penetration rate and at the same time display their typical phases of growth, inflection and saturation. Frank [5] used the logistic model to forecast diffusion in wireless communication in Finland. Research papers by [3], [4], [6], [7] address and translate this technology diffusion into WEEE prediction. Combining the logistic model with material flow analysis(MFA)

TABLE 1
COMPOSITION OF DESKTOP COMPUTERS

(Average weight: 27.2 kg)

Description	Content %age of total weight	Weight of material
Toxic Components		
Plastic	22.99 %	7.24 kg
Lead	6.2988 %	1.98 kg
Mercury	0.022 %	0.693 gm.
Arsenic	0.0013 %	0.4095g m.
Cadmium	0.0094%	2.961 gm.
Chromium	0.0063 %	1.98 gm.
Barium	0.0315%	9.92 gm.
Beryllium	0.0157%	4.92 gm.
Non-toxic Components		
Aluminum	14.1723	3.86 kg.
Iron	20.4712	5.58 kg.
Copper	6.9287	1.91 kg.
Gold	0.0016	<0.1 kg.
Silver	0.0189	<0.1 kg.

Source: http://svtc.igc.org/hightech_prod/desktop.html

TABLE 2
COMPOSITION OF NOTEBOOK COMPUTERS

(Average weight 2.85 Kg.)

Description	Content %age of total weight	Weightof material (kg)
Toxic Components		
Glass	134.4	0.382
PCB	15.8	0.450
Battery/Transformer/ Capacitors	9.58	0.273
Plastic parts	26.66	0.760
Non-Toxic Component		
Metals	34.49	0.983

Source: AEA Technology (WEEE & Hazardous waste Part 2) for DEFRA.

enables estimation of discarded / obsolete devices [4].

The general logistic equation for computer penetration rate which has been modeled by [3], [4] is expressed in conventional logistic form as:

$$dN/dt = r N(1-N/K) \qquad (1)$$

where N represents number of computers owned per capita (penetration rate of PCs), r is the intrinsic growth rate or adoption rate which is constant for a logistic model, K represents the carrying capacity or average number of PCs a person is likely to posses. The rate of adoption 'r' is a constant for logistic model.

The solution of (1) at time t is given as

$$Nt= K/ [1+e-(rt+c)] \qquad (2)$$

At time t=0, initial penetration rate is denoted by N_0.

$$N_0= K/ 1+ e^{-c} \qquad (3)$$

$$\therefore c =\ln(N_0/K-N_0) \qquad (4)$$

Yang and Williams [4] proposed the bounding approach to determine the maximum and minimum possible values of K should be worked out from statistical fits of historical time-series penetration rates, but for case of PCs this data set is yet in initial stages. In the context of India also, the approach proposed by [4] in which instead of using historical computer penetration rate data, a time-series of computer penetration rates are recreated based on estimates of stock, historical sales and assumptions on lifespan.

A lifespan is defined as the time between initial purchase of a computer and the time it is ready for End of Life (EoL) management. It generally includes three stages: First usage, storage and possible second usage. EoL disposition options are recycling, incineration and depositing into a landfill. Since the storage time-span for a computer before next use stage varies a lot from case to case [8]), the approach given by [9] using initial lifetime or first span lifespan of computer is used for our study. Some researches assume an average 3 year use of new computers for both business users and home users [10] whereas some other studies assume a 4 year use [11]. Accuracy of any computer waste forecasting model depends on accuracy of lifespan estimation [12]. Instead of using a uniform lifespan [13] have proposed multiple lifespan for estimation of obsolete PCs. In our study, the assumed lifespan probability distributions are shown in Table 3.

TABLE 3
ASSUMED LIFE SPAN DISTRIBUTION OF COMPUTERS.

	Average life span in years	Years in use 5	4	3	2
Upper line					
Desktop	4	25%	50%	25%	
Notebook	3.5	20%	20%	50%	10%
Base line					
Desktop	3.5	20%	20%	50%	10%
Notebook	3.0		20%	50%	30%
Lower line					
Desktop	3.0		25%	50%	25%
Notebook	2.5			50%	50%

Due to lack of data in used computer market, reused computers are not included in this study.

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The procedure followed was to assume a lifespan distribution Lj where 'j' represents the year after which the computer becomes obsolete and using the historical sales S_i we estimate the annual obsolete quantities (O_i) for a given year 'i' from the expression:

$$O_i = \sum [\text{Sales in the year (i-j)*Percentage of computers that become obsolete after 'j' years}] = \sum S_{i-j} L_j \quad (5)$$

Assuming that computers enter the national stock after being purchased, we estimate the possession amount or stocks in use (Sti) in year 'i' is estimated as:

$$St_i = \text{Stocks in use in year (i -1)+ Sales in year i'- Obsolete stock in year i'} = S_{t\,i-1} + S_i - O_i \quad (6)$$

The penetration rate Ni in year 'i' is computed from the relationship:

$$N_i = St_i / Q_i \quad (7)$$

where Qi is the population in year 'i'.

Statistical fits are performed on the generated time-series historical penetration rate in order to identify the parameter values r and N_0 of the logistic model. The approach here was to separately identify these parameters for both the upper and lower bound carrying capacity.

The computer penetration rates from the logistic curve are translated to their corresponding sales using (7). The forecasted sales figures of notebook and desktops coupled with their respective first lifespan distribution are utilized to generate forecasted obsolete numbers of computers and subsequently the weight to each toxic component and metals etc to be generated.

3 Results And Discussion

The present study has been done using actual population data of India for years 2001 and 2011 given by Census of India 2001 & 2011 survey and projected population data from Census of India 2011[14]. Historical sales data of desktop and notebook computers for India are from the annual report of MAIT (Manufacturing Association of IT) [15].

Our analysis gives desktop penetration rate for year 2006 to be 0.012, 0.013, 0.015 for lower line, base line and upper line respectively. The assumptions of first lifespan distribution used to calculate computer penetration rate in years 1996 to 2010 are corroborated by report by [16], according to which penetration rate of computers is 0.012 in year 2006. This empirical data is same for lower line case of our study. For baseline and upper line case the reasons for higher values of penetration rate could be due to unavailability of sales data before 1996 as market for personal computers was in its infancy hence penetration rate was unavailable. Fig.1 and Fig. 2, shows these plots.

For this study, value of lower bound carrying capacity is assumed as 0.0336 and upper bound carrying capacity estimation to be of 1.027 computers per capita [16]. A lower bound on carrying capacity is set by assuming that in commercial sector all IT employees' posses a computer at their workplace and from domestic sector it is assumed that all wealthy Indians families posses a computer. For the upper bound parameter estimation it is assumed that all employed persons own a computer at work and every person aged 15 to 64 years has a computer at home. Table 4 gives estimated computer penetration rate in year 2025. Fig. 3 to Fig. 8 give plots of forecasted penetration rates for desktop and notebook computers

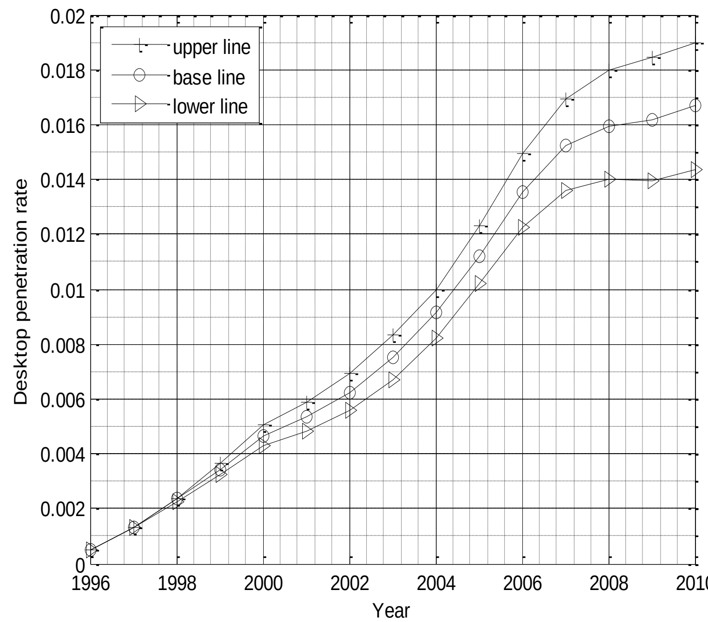

Fig. 1 Historical Desktop Penetration Rate

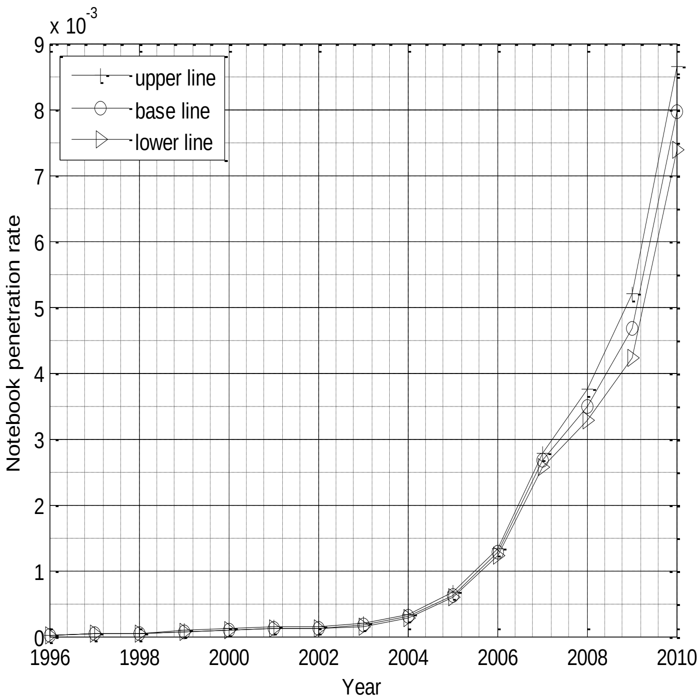

Fig. 2 Historical Notebook Penetration Rate

For the case of lower line, the estimated desktop penetration rate in the year 2025 will be 0.04 & 0.12 per capita for lower bound & upper bound cases respectively & the estimated notebook penetration rate in year 2025 will be 0.04 & 0.86 for lower bound and upper bound cases respectively.

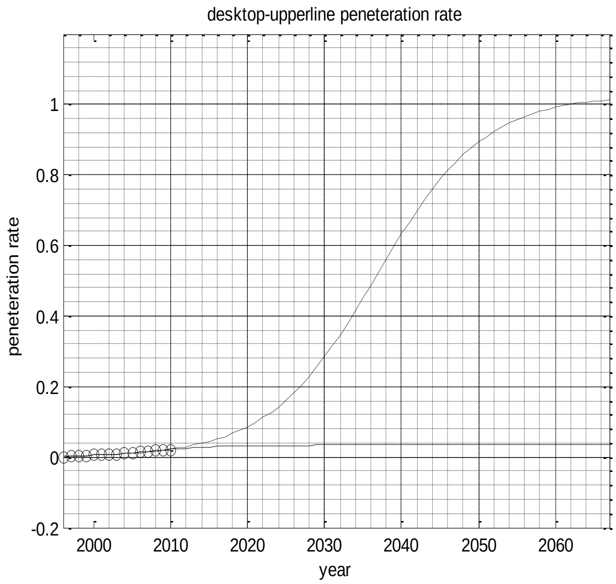

Fig. 3 Desktop Upper Line Penetration Rate Forecast

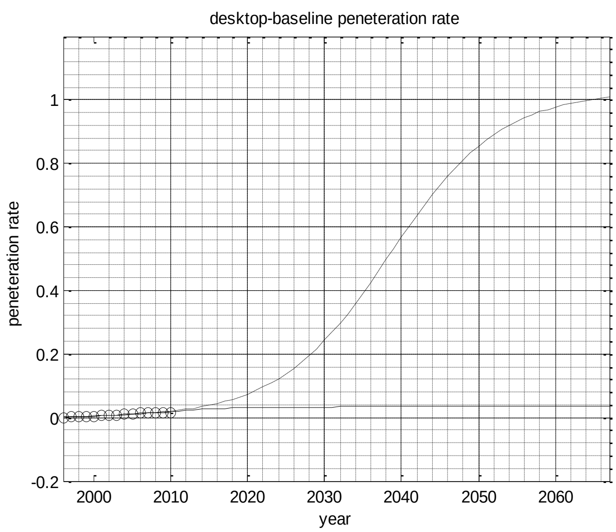

Fig. 4 Desktop Baseline Penetration Rate Forecast

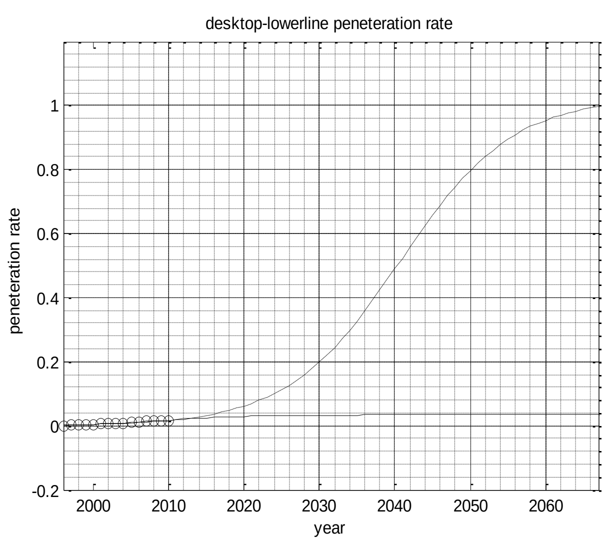

Fig. 5 Desktop Lower line Penetration Rate Forecast

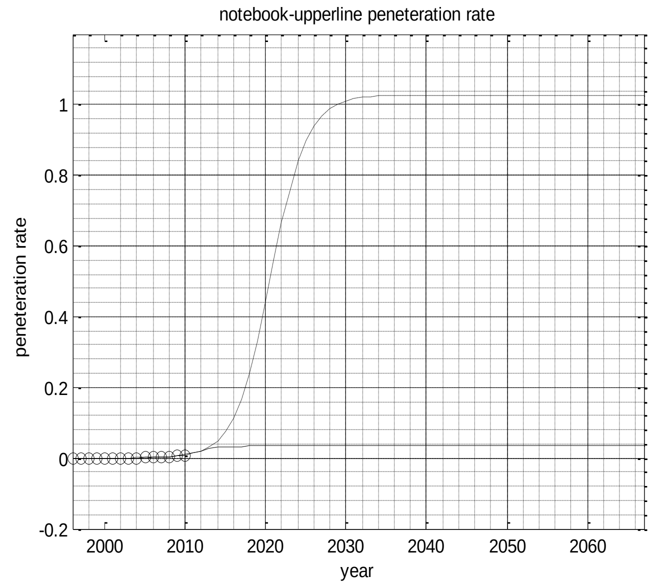

Fig. 6 Notebook Upper Line Penetration Rate Forecast

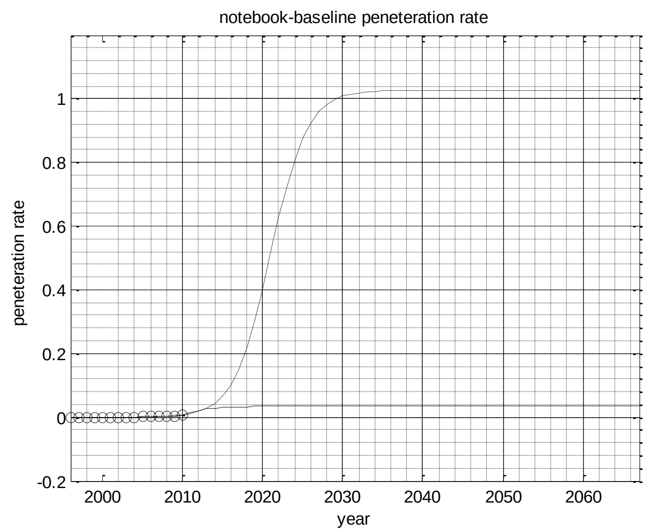

Fig. 7 Notebook Baseline Penetration Rate Forecast

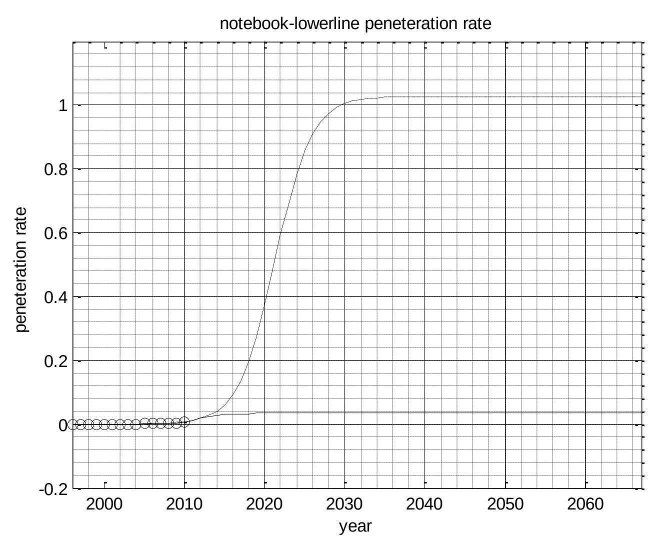

Fig. 8 Notebook Lower Line Penetration Rate Forecast

TABLE 4
ESTIMATED COMPUTER PENETRATION RATE (YEAR 2025)

	Desktop		Notebook	
	Upper bound	Lower bound	Upper bound	Lower bound
Upper line	0.16	0.04	0.90	0.04
Baseline	0.14	0.04	0.88	0.04
Lower line	0.12	0.04	0.86	0.04

TABLE 5
ESTIMATED VOLUME OF OBSOLETE DESKTOP AND NOTEBOOK COMPUTERS (YEAR 2025) IN MILLIONS

	Upper bound (K=1.027)		Lower bound (K=0.0336)	
Lifespan	Desktop (million)	Notebook (million)	Desktop	Notebook
Upper line	138	860	45	50
Baseline	126	900	44	50
Lower line	112	920	43	50

TABLE 6
ESTIMATES OF TOXIC AND NON-TOXIC MATERIAL GENERATED FROM OBSOLETE DESKTOP COMPUTERS.

	Upper line (Metric Tonnes)			Baseline (Metric Tonnes)			Lower line (Metric Tonnes)		
Toxics/ Year	**2015**	**2020**	**2025**	**2015**	**2020**	**2025**	**2015**	**2020**	**2025**
Plastic	223	481	1006	212	448	922	196	405	816
Lead	61	131	275	58	122	252	53	110	223
Mercury	0.021	0.046	0.096	0.020	0.040	0.088	0.018	0.038	0.078
Arsenic	0.012	0.027	0.056	0.012	0.025	0.052	0.011	0.022	0.046
Cadmium	0.091	0.196	0.411	0.086	0.183	0.377	0.080	0.165	0.333
Chromium	0.061	0.131	0.275	0.058	0.122	0.252	0.053	0.110	0.223
Barium	0.305	0.659	1.379	0.290	0.614	1	0.269	0.555	1.118
Beryllium	0.151	0.326	0.684	0.144	0.304	0.627	0.133	0.275	0.554
Non Toxic									
Aluminum	118	256	536	113	239	491	104	216	435
Iron	171	370	775	163	345	711	151	312	629
Copper	58.8	126	265	55	118	243	518	106	215.
Gold	0.011	0.025	0.052	0.011	0.023	0.048	0.010	0.021	0.042
Silver	0.135	0.292	0.611	0.128	0.272	0.560	0.119	0.246	0.496

TABLE 7
ESTIMATES OF TOXIC AND NON-TOXIC MATERIAL GENERATED FROM OBSOLETE NOTEBOOK COMPUTERS

	Upper line (Metric Tonnes)			Baseline (Metric Tonnes)			Lower line (Metric Tonnes)		
Toxics/Year	**2015**	**2020**	**2025**	**2015**	**2020**	**2025**	**2015**	**2020**	**2025**
Glass	8.46	73.75	329.94	2.76	5.94	12.6	10.4	85	354E+03
PCB	9.96	86.89	388.67	3.25	6.99	14.9	12.2	100	417 E+03
Battery/Transformer/Capacitor	6.04	52.70	235.79	1.97	4.24	9.02	7.42	60.7	253 E+03
Plastic parts	16.8	146.72	656.42	5.49	11.8	25.1	20.6	169	704 E+03
Non Toxic									
Metal	21	189	849	7.11	15.3	32.5	26.7	219	911E+03

Long term equilibrium on penetration rate can be achieved sometime in year 2044 i.e from 32 years from now giving a penetration rate of 1.0269. Yu. *et al.* [6] have also reported that Asia pacific region will reach a long-term equilibrium in penetration rate in 30-60 years, which is confirmed by our results. The eleventh Five year plan (2007-2012) report prepared by Department of Information Technology, Government of India cites a penetration rate of 0.0325 computers per capita which is very close to the value predicted by our analysis of 0.0244 computers per capita.

Our results summarized in Table 4 & Table 5 estimate that obsolete desktop generation at end of 2025 to be 44 million units for lower bound and 126 million units for upper bound values of carrying capacity. Obsolete notebook computers generation at the end of 2025 is estimated to be 50 million units for lower bound and 900 million units for upper bound values of carrying capacity. Fig. 9 to Fig. 14 show plots for above results.

Table 6 & Table 7 estimate the weight (in metric tonnes) of various toxic and non-toxic materials generated from the obsolete computers. Results indicate that the amount of waste material generated is increasing at an alarming rate i.e. doubles every five years for desktop PCs, whereas for notebook PCs, the increase is eightfold.

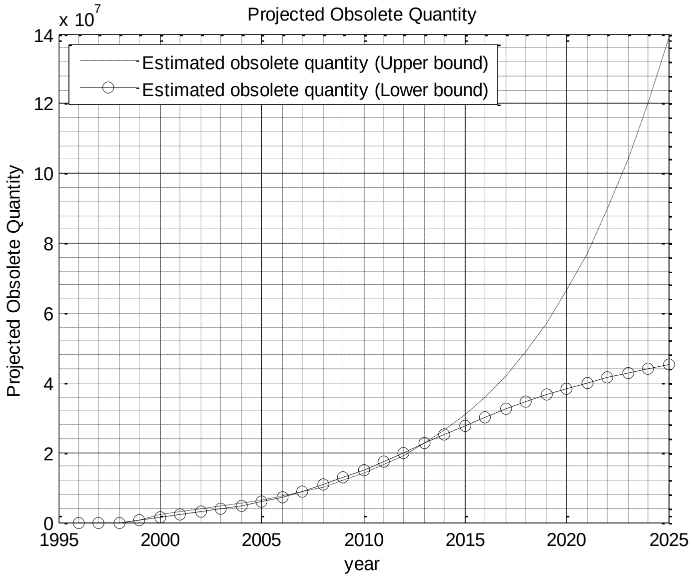

Fig. 9 Desktop Projected obsolete Volume (Upper Line)

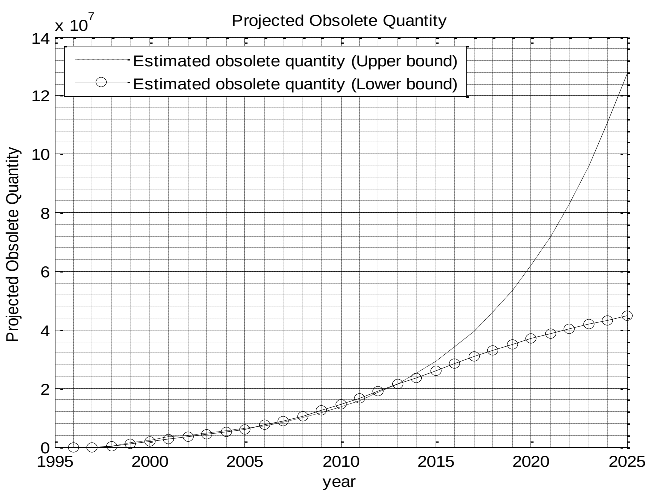

Fig. 10 Desktop Projected obsolete Volume (Baseline)

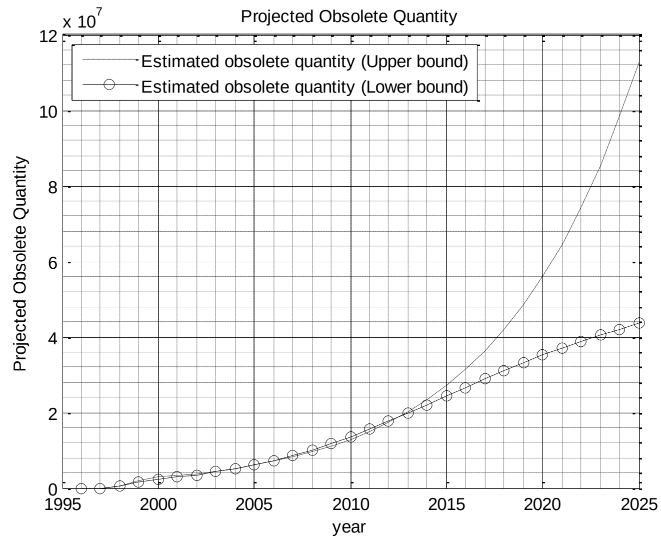

Fig. 11 Desktop Projected obsolete Volume (Lower Line)

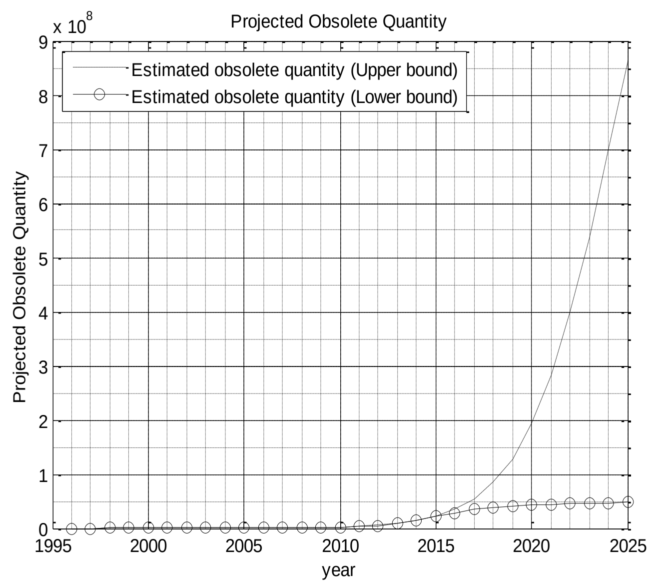

Fig. 12 Notebook Projected obsolete Volume (Upper Line)

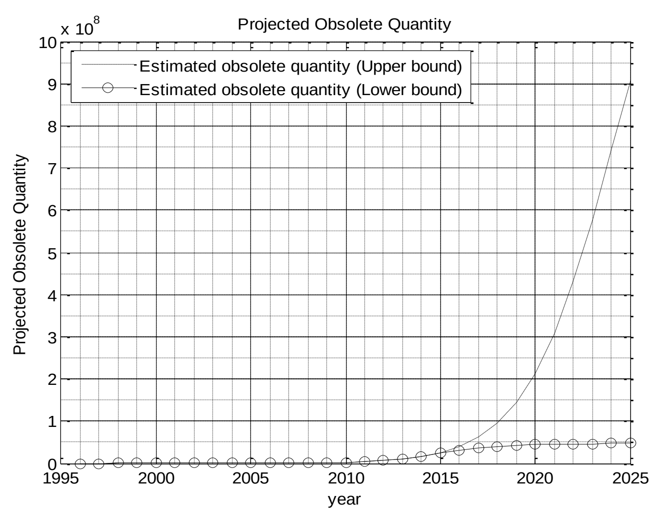

Fig.13 Notebook Projected obsolete Volume (BaseLine)

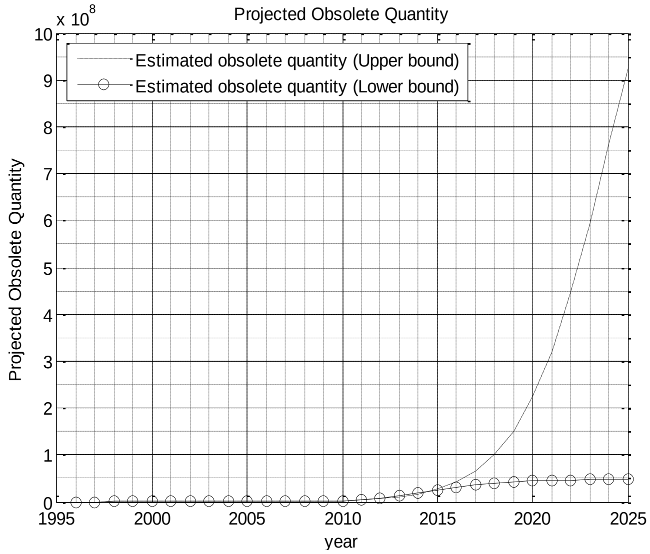

Fig. 14 Notebook Projected obsolete Volume (Lower Line)

4 CONCLUSION

This paper presents an approach to estimate the number of obsolete desktop and notebook computers and the amount of various toxic and non-toxic components generated from these computers in India. The results of the study indicate that the obsolete PCs will continue to increase exponentially with time on account to large population trend in India, better social-economic conditions and increased technology awareness in both rural and urban India. With favorable government policies, it may take 30 years more to achieve a penetration rate of 1 computer per capita.

Management of e-waste is a global concern and has to be tackled by using a holistic approach. Effective collection and recycling programs have to be developed once the necessary legal and regulatory instruments are in place. The estimation carried out in this study will serve as a guideline to government authorizes to setup collection, recycling and disposal facilities for the different types of toxic waste and also the recoverable metals or non-toxic waste generated from these obsolete computers in the coming 15 years.

These are preliminary results and within the context of our modeling framework. Our analysis covers only first life of computers. The period for which computers are stored in reuse and recycling systems affects their handling, this needs to be considered in future work.

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