International Journal of Scientific & Engineering Research Volume 10, Issue 11, November-2019
ISSN 2229-5518

An Integrative Approach to develop E-Waste Management System for Developing Countries: A Review

Mahendra Garanayak[1],Satyananda Champatiray[2]

Associate Professor ,Subas Institute of Technology[1],Associate Head,Silicon Institute of Technology[2],Bhubaneswar.

ABSTRACT

E-waste (also known as waste electrical and electronic equipment) is one of the fastest-growing waste streams worldwide. Given this rapid growth, issues related to e-waste are a serious concern. Increasing amounts of e-waste pose detrimental effects to the environment and public health through improper recycling and disposal techniques. Such informal recycling practices are common in several developing countries, where recycling methods are rudimentary, and a significant proportion of e-waste components ends up in unsanitary (uncontrolled) landfill and open dump sites. To address these issues, this paper aims to introduce a systematic approach to e-waste management; a process termed integrated e-waste management (IEWM) is a theoretically viable technique in which municipal solid waste and e-waste management systems are managed. This is possible because both systems share common waste fractions and treatment and disposal technologies. Therefore, integrated e-waste management represents an advance in the controlled disposal of e-waste and improvements in local environments and public health in developing countries. This study employs a systematic approach that combines field trip work, systematic literature review, and quantitative data analysis to propose a solution that can bring benefits in the short, medium and long-term. The study proposes the hypothesis that an integrated approach can improve e-waste handling in developing countries by addressing region-specific issues simultaneously. This study considers the technical aspects of implementing an integrated approach and, by comparing these aspects against more traditional, widely practiced approaches.

Index Terms: e-waste, integrated waste management, developing countries, integrative thinking.

Introduction

E-waste Management Issues in Developing Countries

The production of electrical and electronic equipment (EEE) is growing rapidly worldwide. This growth is due to significant advances in the electronics and information and communications technology industries, changes in consumption patterns and consumers' lifestyles, short product life spans due to technological innovations, and economic development (Terazono et al., 2006; NSWMA, 2013; Needhidasan et al., 2014; Hossain M. et al., 2015). Several developing countries face huge challenges in managing e-waste, which is domestically generated or imported illegally as used products (Nnorom and Osibanjo, 2008a). In many developing countries, particularly low-income and middle-income countries, a significant proportion of e-waste components is disposed of in unsanitary (uncontrolled) landfill sites. Similarly, informal e-waste recycling is widely practiced. Wires are burned in open spaces to remove plastic and recover copper. Acid extraction is also practiced retrieving precious metals like gold, platinum, palladium, and silver from Printed Circuit Boards (PCBs). Such practices can be found in countries such as China, India, Pakistan, Vietnam, the Philippines, Nigeria, and Ghana, where e-waste is disassembled using rudimentary methods to recover valuable metals by people who lack the facilities to safeguard the environment and public health (Leung et al., 2006; SEPA, 2011). Figure 1 shows an example of improper e- waste handling practices in China, South Africa, and India. Another example can be seen in the developing Middle East and North Africa (MENA) region, where Seitz (2014) analyzed existing e-waste practices in 10 countries. Seitz concluded that e-waste is of rising concern in many of those countries, and the risks to human health and the environment from inappropriate e-waste management are not yet well known, and awareness remains low.

Objectives of This Paper and the Approach

To help prevent the improper handling of treatment and disposal of e-waste and to facilitate the development of e-waste management systems in developing countries, this paper aims to propose an approach to e-waste management for developing countries after reviewing the Integrated Waste Management (IWM) concept and by considering the findings of interviews and field visits. This approach takes into account the situation that portions or components of e-waste are mixed with municipal waste in many developing countries. This paper, therefore, proposes that to establish an effective e-waste management system, those developing countries can use the existing municipal waste treatment infrastructure, such as waste collection, landfill sites, and recycling facilities. This paper also proposes that the common fractions of the two waste streams of MSW and e-waste can be treated together and that residues can be disposed of in sanitary landfill sites in which such an approach can achieve an integrated e-waste management. The importance of this study is two-fold: firstly, it considers the key drivers of problematic waste management practices and safer, more acceptable alternatives; and secondly, it attempts to address them as a whole, rather than individually. By carrying out an in-depth, holistic study, and by considering the efforts of scholars for the individual approaches that are either problem-specific or approaches grounded in decision-making and stakeholder engagement, this research will provide a model for developing countries to improve their e-waste management. Thus, the implementation of any approaches proposed in this study should be considered theoretically possible. It should be noted that this paper focuses on the technical level of the e-waste problem, so political or stakeholder decision-making, which are themselves essential elements for implementing the proposed approach, are out of the scope of this study. Further, while e-waste might be considered a city-region issue in some countries, the literature survey indicates the existence of these issues at a national level, and therefore, both the discussion and the approach presented in this study aim to address the e-waste problem at this level. In addition to the literature survey presented in this study, the proposed approach was supported by three field trips that aimed to analyze the waste issues in two developing countries, Jordan and Vietnam, where interviews and discussions with local experts were conducted. The field trip to Vietnam centered on an observational study, while the two field trips to Jordan were part of a case study examining the potential implementation of the first sanitary landfill site in Jordan (a well- engineered landfill) with discussions with the waste management experts and officials.

This paper follows a literature, on-site investigations, and interviews based approach to

(1) Understand the existing e-waste management issues in developing countries,

(2) Investigate the IWM, and to integrative thinking in MSW and e-waste, and

(3) Propose a systematic approach to introducing integrated e-waste management to developing countries.This approach can be regarded as a systematic approach. The rationales of using a systematic approach are:

1. The complex nature of e-waste management in developing countries (e.g., open burning, open dumping, unsanitary land filling, and lack of knowledge on their environmental impacts and lack of awareness of its toxicity).
2. The complex composition of e-waste and associated varied environmental impacts.
3. The necessity of examining the environmental impacts and economic cost of waste management practices in developing countries.
4. The need to consider appropriate e-waste generation and construct a long-term plan for e-waste management systems.

Methods

The approach followed in this study consists of four stages:

(1) field work, (2) data analysis, (3) systematic literature review, and (4) Qualitative Data Analysis (QDA).

Results and Discussion

E-Waste Management

The waste management issues in developing countries are aggravated by the improper traditional waste management approaches due to rapid development (Deshmukh et al., 2002). Traditional waste management systems affect not only the local environment and public health but also the environment in neighboring areas (Murad and Siwar, 2007). Waste disposal is a significant hazard because improper disposal methods make waste a high risk for infectious diseases (Murad and Siwar, 2007). Waste problems are caused and exacerbated complexly by increasing population, rapid urbanization, industrial growth and changes in consumption patterns. The large amounts of waste generated and the availability of land at a low cost are other factors that support a traditional approach that depends mainly on landfills. For example, on average 90% of waste in MENA regions is disposed of in a landfill, and 10% is informally recycled (Bahor et al., 2009). The traditional approach should be replaced with alternative approaches that provide protection to human health, lessen environmental degradation, achieve social acceptability and optimize the economic cost of e-waste handling. These issues emphasize that IWM is necessary to implement waste recycling and save natural resources. shows example studies explored the e-waste management issues in some developing countries.

Integrated Waste Management

IWM has been discussed in the literature by several researchers, such as McDougall and Hruska(2000), McDougall et al. (2001), Shekdar (2009), Wilson et al. (2012), Ikhlayel et al. (2016), and Ikhlayel and Nguyen (2017). IWM is an integrative thinking concept in which the entire waste stream and current waste management practices are evaluated with all alternative and available options (McDougall et al., 2001). This approach aims to achieve proper waste management by reducing the environmental impact and associated costs and improving the social acceptability waste management. This can be achieved by looking at the existing system holistically, incorporating different waste processes including waste prevention, reduction, proper sorting, collection, and transportation (Ikhlayel and Nguyen, 2017). Waste processing technologies including recycling, composting, bio-gasification, incineration, and sanitary land filling are considered. Material reuse, energy recovery, and resource conservation are also considered. Through this approach, an appropriate management system can be established by combining environmental friendly and economically-viable alternatives.

Processes in IWM Systems for Municipal Solid Waste and E-waste

IWM should be harmonized with another important concept of waste management, waste hierarchy. Several processes should be included; these are listed below:

1. Waste sorting at the point of generation and/or at a Material Recycling Facility(MRF)
2. Waste collection schemes that consider the generation of waste quantities and their characterization.
3. Use of composting and bio gasification of the large amounts of organic waste produced in developing countries. For example, composting can produce fertilizers, and bio-gasification can produce energy.
4. Incineration technologies that reduce the volume of waste and recover energy from burnable materials. This can also be used to treat hazardous waste.
5. Sanitary landfill utilizing leachate collection and energy recovery to dispose of residues from recycling, incineration, bio-gasification, and composting and disposal of hazardous waste.
6. Materials and metals recycling in which all types of recyclable wastes are taken into consideration in a recycling scheme.The processes mentioned above should be included in an IWM system and examined environmentally and economically. This study by Ikhlayel (2017b), for example, aimed to evaluate the environmental impacts and benefits of advanced e-waste management technologies for the case of Jordan as a case study. The LCA method was employed to assess five state-of-the-art technologies for e-waste handling, including well-engineered land filling; proper recycling of metals, materials, and precious metals; and incineration of plastic and the hazardous portion of PCBs. The study considered six e-products for each scenario, which resulted in 30 total cases of e-waste management for the six products. The mentioned processes can be combined according to the waste management situation and economic conditions in a certain municipality. In the Municipal Solid Waste Management (MSWM) system, material recycling (paper and plastic), metal recycling (ferrous and

non-ferrous metals), thermal treatment (incineration), biological treatment (composting and bio-gasification), and sanitary landfill are major processes that are integrated with a structured waste sorting and collection systems. IWM for MSW can be depicted using the waste management hierarchy shown in Figure 2 (A), and IWM for e-waste management as depicted in Figure 2 (B). An integrated e-waste management system requires material recycling (paper and plastic), metal recycling (iron, steel, copper, and aluminum), precious metal recycling (including gold, platinum, palladium, and silver), thermal treatment, and sanitary landfill of residues. Several of these processes are common in both MSW management and e-waste management systems and are shown inFigure.

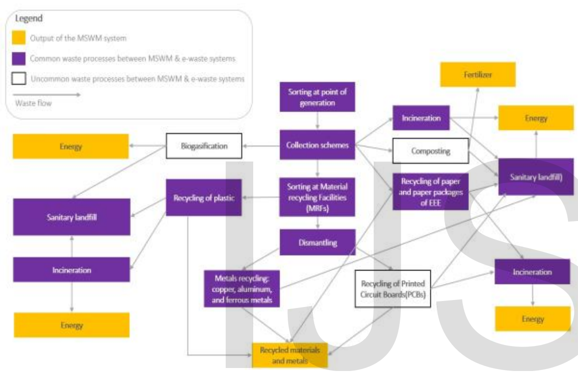

Figure: Common processes between MSWM and e-waste management system (the basic concept is formulated based on McDougall et al. (2001)

Planning for IWM and Estimation of Waste Generation

Planning for IWM requires consideration of various aspects of waste management including political, socio-cultural, economic, environmental, and stakeholder involvement (Schubeler, 1996). Memon (2010) identified seven essential steps towards integrated MSWM planning including data collection and analysis; gathering information on the current waste management system; setting targets; identifying local stakeholders' issues, financial, technical, environmental and social aspects; developing an integrated MSWM plan; developing an implementation strategy; and developing a monitoring and feedback system. From a technical viewpoint, planning an integrated MSWM system should begin with an analysis of the current waste management situation in a certain city or country. Data are required on waste composition, quantities, transportation, energy, and material flow (that is, the quantities that go to landfill, recycling, composting, and so on). The accuracy of these data depends on their collection: availability, reliability, range of data, and suitability for the estimation method (UNEP, 2007). Estimation of waste generation is the first step in planning cautiously for a future system, considering the capacities of existing waste treatment facilities (such as current landfill capacity). Estimating e-waste quantities is also crucial for planning an IWM. Reliable data should first be acquired to determine waste characterization (fractions of EEE). Estimating e-waste generation is a necessary step for selecting appropriate e-waste management treatment and disposal options.

Proposed Integrated Approach for the E-Waste Management

Based on the literature previously reviewed, and the three field trips work, this study proposes an integrated approach to managing e-waste in developing countries. This approach is referred to in this study as IEWM. The proposed IEWM approach aims to:

1. Optimize scenarios in which MSW and portion or components of e-waste streams are mixed;
2. Utilize the existing MSW infrastructure to process both waste streams; and
3. Achieve environmental and economic benefits.

The proposed IEWM approach is defined as "a systematic and holistic approach that utilizes and integrates existing municipal waste and e-waste management. It aims to mitigate the environmental and economic burdens of e-waste by following the IWM concept and utilizing the LCA method." This approach is regarded as holistic because it applies the waste management hierarchy. It is also regarded as systematic because it considers the integrity of waste management systems from production or import to EoL and by considering each stage and phase. The IEWM approach can be divided into two stages, as depicted in Figure. The first stage comprises three phases: sale of products, consumption of products, and waste generation (MSW and e-waste). The second stage is the EoL, which comprises two phases: collection, and treatment and disposal, that is, post-consumer stages.

Therefore, to establish an IEWM system, four major steps should be taken:

1. Determining the composition of municipal waste and e-waste;
2. Estimating the quantities of municipal waste and e-waste;
3. Environmental evaluation of the existing MSWM systems with alternative treatment and disposal technologies, and cost evaluation of the existing and the alternative systems; and
4. Environmental assessment of the present e-waste management practices, comparing and evaluating available state-of-the-art technologies.

At the first step, MSW is usually characterized by sampling and laboratory analysis of municipal waste. Examples of studies that followed this approach include Chang and Davila (2007;2008); Gomez et al. (2008); and, Younes et al. (2013). Estimation of MSW is less sophisticated than that of e-waste. MSW can be estimated by simply measuring the load of trucks that enter transfer stations or a landfill site. For example, Zeng et al. (2005) followed such an approach. At the second step, estimation of e-waste quantities is more complicated as it is not easy to analyze or measure the e-waste quantities. The composition of e-waste can be determined by conducting questionnaires, as seen in the studies by Tarawneh and Saidan (2012), Fraige et al. (2012), and Saidan and Tarawneh (2015).

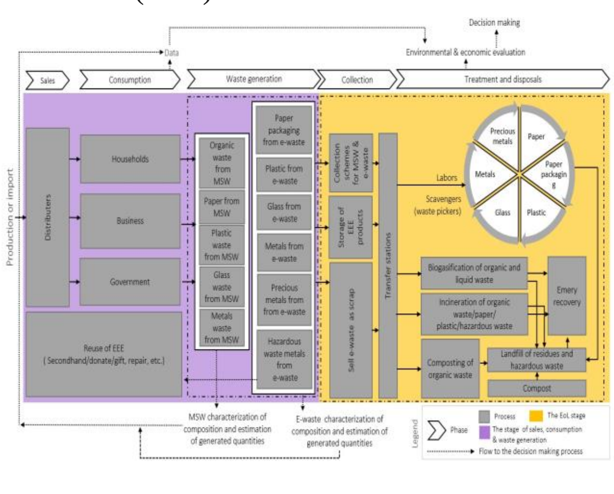

Figure: Proposed integrated e-waste management approach

Existing Approaches and Applications of the Proposed Approach

Existing e-waste management approaches to tackle e-waste issues in several developing countries consider the e-waste stream apart from MSW. These approaches, particularly focus on a certain topic of e-waste handling in those countries. Such problems include e-waste generation; informal and formal recycling; material flow (the fate of e-waste); legislation; etc. Wathetal. (2010) proposed a uniform national e-waste management system in India based on the current, social, economic, environmental system. The authors presented the approach based on a review and assessment of the e-waste management system of developed and developing countries with an emphasis on Switzerland experience. The proposed approach builds on the Extended Producer Responsibility (EPR) to achieve a reduction in e-waste amounts; reduce in e-waste disposed of; reduce hazardous constituents in the e-waste; decrease the use of virgin materials and metals; mitigate environmental pollution, and enhance the design for environment. The proposed approach also implements the consumer's tax when they purchase their electronic device required to cover the future recycling cost. The approach also focused on the legislation and their implementations. Nnorom and Osibanjo (2008b) aimed at reviewing e-waste management practices and legislations and their poor applications in the developing countries to find a midpoint for the carrying out of a form of EPR in the developing countries. The authors concluded it is necessary to establish legislations for effective e-waste management in the developing countries. The authors also concluded that the legislation should set the format of the two EU directives on WEEE and RoHS. Kiddee et al. (2013) discussed management strategies are used in some countries. The authors discussed some tools including LCA, MFA, Multi Criteria Analysis MCA and EPR developed to manage e-waste, especially in developed countries. The authors concluded that optimum e-waste management requires a combination of LCA, MFA, MCA, and EPR. The presented approach in this study introduced a different approach than those in existing literature and presented a practical implementation to IWM. However, still, consider similarities of other approaches to achieve proper handling of e-waste. Rather than looking to e-waste as an individual waste issue, it proposes a solution to both e-waste and MSW from a technical perspective. The presented approach looks at both waste streams as a single issue that can be mitigated from a technical viewpoint. Therefore, the societal aspects, for example, are excluded as well as the legislation and economic instruments. Based on the situation that portions of the components of e-waste are disposed of with the MSW waste and the existence of informal recycling for both common waste fractions of e-waste and MSW such as metals, and an existing infrastructure that can be utilized for mitigating the two wastes. Thus, this proposed approach provides a solution with some advantages for both waste types:

1. Mitigating the environmental and health impacts resulting from the poor collection and disposal in uncontrolled landfills, open dumping sites, and practices such as open burning and informal recycling.
2.Lower cost of handling both waste types when the common infrastructure is utilized.
3. Prevention of MSW and e-waste mixing.
4. Implementation an integrative approach to e-waste and MSW management.

The proposed approach has several applications for improper e-waste handling as seen in several developing countries. The approach is founded on the technical solutions and technical background of the waste issues. Therefore, it can be utilized for applications includes waste recycling of materials (paper, plastic, and glass) and metals including base metals (copper, aluminum, steel, etc.) and precious metals (gold, palladium, platinum, etc.). It also can be utilized for waste-to- energy utilization of common waste fractions between the two waste streams. With that explained, it is main application is providing a practical strategy for e-waste handling in several developing countries.

Conclusion

Waste management is an area in which integrative thinking could provide a useful basis for integrated solutions regarding integration and related elements in IWM. These should be investigated to address the challenges of waste management and how an integrated approach can solve such issues in modern societies. The situation that MSW and portion or components of e- waste or its components streams are mixed in several developing countries requires attention. The data, for example, of the seven countries of the MENA regions show high similarities regarding the waste management. Similarly, the overall situation in those countries also shares similarities and commonalities. Also, they can be seen as typical examples on how the traditional approach to waste management is practiced. The findings of the field trips revealed existing practices in which e-waste mixes with municipal waste. Some of the e-waste produced is often stored for a period of time due to difficulties of safely discarding it and the lack of proper recycling facilities. Further, the concerns of waste management officials, experts, practitioners and academics share similar concerns about the lack of (1) waste separation; (2) safe disposal of e-waste; (3) proper recycling; (4) technical support, to some extent; and (5) residents' awareness levels of the toxic nature of e- waste. The interviews emphasized the need to enforce e-waste regulation by to enabling proper handling of e-waste. This study discusses integrative thinking for MSWM and e-waste management combining different waste streams, treatment techniques, and disposal methods to provide solutions to e-waste management issues in various cities and countries. The aim of this concept is to prevent improper e-waste management in those developing countries where inadequate management are practiced by implementing integrated e-waste management systems in those countries. The IWM approach incorporates diverse MSWM processes to achieve environmental benefits and economic optimization. Both MSWM and e-waste management share common waste treatment and disposal processes. Therefore, it is theoretically possible to integrate both waste management systems. Introducing an integrated e-waste management system can take advantage of the existing infrastructure of MSWM. Therefore, it can be combined with e-waste management to achieve an IWM system. This paper proposed a systematic and holistic approach, IEWM, to meet the e-waste management challenges in several developing countries. This approach suggests focusing on the EoL of EEE products of which e-waste is improperly handled while considering the entire life cycle of e-waste from import or production of EEE to final disposal.

This study suggests the following:

1. The examination of e-waste issues holistically

and consideration of existing MSW management practices is the best means of identifying practical, region-specific solutions.

2. Achieving proper handling of e-waste should not stand alone from MSW management issues as both are interlinked and share similar complicities. Therefore, the study suggests that both should be considered in an integrative manner from the point of generation to final disposal.

3. Evaluation of the existing e-waste practices is fundamental, and it should lead to prioritizing actions that start by regulating the level of e-waste. This should include legislation of e-waste disposal and product imports.

4. Technically, implementation of any e-waste management plan starts with e-waste separation. This prevents mixing with MSW, separation of the differing forms of e-waste (each with their own impacts), and facilitates collection and recycling processes.

5. Long-term integrative e-waste management might be accomplished by addressing interlinking and complex social, cultural and economic factors, installing and maintaining proper infrastructure, and educating essential technical support. However, any integrated approach should aim to improve the present situation gradually. Implementing proper e- waste management is not only a practical and technical problem, a but a political and financial one, too. Decision-makers should align proposed improvements with regional priorities and with a mechanism for monitoring and evaluate changes to the management system.

6. The study suggests considering a trade-off between the issues resulting from improper waste management and the economic cost of improving it. Costs will always be a key determiner for implementation, so alternative technologies must be subjected to practical implementation analysis from an economic perspective.

7. This study considered, to a large extent, the technical aspects of e-waste for its aim and scope. However, the technical solutions do not stand alone. The economic viability of proposals, cultural norms and, and political and industrial planning must also be considered to ensure social and practical acceptance of proposals to e-waste management improvement.

References

1. Abduli, M.A., Naghib, A., Yonesi, M. & Akbari,A. 2011. Life cycle assessment (LCA) of solid waste management strategies in Tehran: landfill and composting plus landfill. Environment Assess, 178**,** 487-98.

2. Alavi, N.,Shirmardi, M.,Babaei,A., Takdastan,A. &Bagheri,N. 2015. Waste electrical and electronic equipment (WEEE) estimation: A case study of Ahvaz City, Iran. Journal of the Air & Waste Management Association,298-305.

3. Andarani, P. & Goto, N. 2013. Potential e-waste generated from households in Indonesia using material flow analysis. Journal of Material Cycles and Waste Management, 306-320.

4.Araujo, M.G., Magrini, A., Mahler, C.F. & Bilitewski, B. 2012. A model for estimation of potential generation of waste electrical and electronic equipment in Brazil. Waste Management,335-342.

5. Awasthi, A.K., Zeng, X. & Li, J. 2016. Relationship between e-waste recycling and human health risk in India: a critical review. Environ Sci Pollut Res Int**,** 11509-32.

6.Bahor, B., Van Brunt, M., Stovall, J. & Blue, K. 2009. Integrated waste management as a climate change stabilization wedge. Waste Management & Research**,** 839-849.

7.Bian, J., Bai, H., Li, W., Yin, J. & Xu, H. 2016. Comparative environmental life cycle assessment of waste mobile phone recycling in China. Journal of Cleaner Production**,** 209-218.

8. Buratti, C., Barbanera, M., Testarmata, F. & Fantozzi, F. 2015. Life Cycle Assessment of organic waste management strategies: an Italian case study. Journal of Cleaner Production**,** 125-136.

9. Buttol, P., Masoni, P., Bonoli, A., Goldoni, S., Belladonna, V. & Cavazzuti, C. 2007. LCA of integrated MSW management systems: case study of the Bologna District. Waste Manag**,** 1059-70.

10.Chang, N.B. & Davila, E. 2007. Minimax regret optimization analysis for a regional solid waste management system. Waste Management**,** 820-832.

11.Chang, N.B. & Davila, E. 2008. Municipal solid waste characterizations and management strategies for the Lower Rio Grande valley, Texas. Waste Management**,** 776-794.

12.Chen, L., Yu, C.N., Shen, C.F., Zhang, C.K., Liu, L., Shen, K.L., Tang, X.J. & Chen, Y.X. 2010. Study on adverse impact of e-waste disassembly on surface sediment in East China by chemical analysis and bioassays. Journal of Soils and Sediments, 359-367.

13.Clavreul, J., Baumeister, H., Christensen, T.H. &Damgaard, A. 2014.An environmental assessment system for environmental technologies. Environmental Modelling & Software,60, 18-30.

14.Crowe, M., Elser, A., Gopfert, B., Mertins, L., Meyer, T., Schmid, J., Spillner, A. & Strobel, R. 2003. Waste from Electrical and Electronic Equipment (WEEE) – Quantities, Dangerous Substances and Treatment Methods.

15.Dasgupta, D., Debsarkar, A., Hazra, T., Bala, B.K., Gangopadhyay, A. & Chatterjee, D. 2016. Scenario of future e-waste generation and recycle-reuse-landfill-based disposal pattern in India: a system dynamics approach. Environment, Development and Sustainability.

16.Dashti, M. & Doll, C.N. 2014. The Co-benefits Evaluation Tools for Municipal Solid Waste.de Souza, R.G., Climaco, J.C.N., Sant'Anna, A.P., Rocha, T.B., do Valle, R.D.B. & Quelhas, O.L.G. 2016. Sustainability assessment and prioritisation of e-waste management options in Brazil. Waste Management, 57, 46-56.

17. Deshmukh, S., Gupta, R. & Agrawal, V.S. 2002. Improving the solid waste management by developing the people's perception – a case study International Waste Management Biennial 161-175. Congress & Exhibition.

18.Duan, H., Eugster, M., Hischier, R., Streicher-Porte, M. & Li, J. 2009. Life cycle assessment study of a Chinese desktop personal computer. Sci Total Environ, 407, 1755-64.

19.Dwivedy, M. & Mittal, R.K. 2012. An investigation into e-waste flows in India. Journal of Cleaner Production, 37, 229-242.

20.EEA 2003. Waste from electrical and electronics equipment (WEEE)-quantities, dangerous substances and treatment methods. Copenhagen, Denmark.

21.Erses Yay, A.S. 2015. Application of life cycle assessment (LCA) for municipal solid waste management: a case study of Sakarya. Journal of Cleaner Production, 94, 284-293.

22.ESDO 2011. Illegal import and trade offof e-waste in Bangladesh. Bangladesh. Fei, F., Qu, L., Wen, Z., Xue, Y. & Zhang, H. 2016. How to integrate the informal recycling system into municipal solid waste management in developing countries: Based on a China's case in Suzhou urban area. Resources, Conservation and Recycling, 110, 74-86.

23.Fraige, F.Y., Al-khatib, L.A., Alnawafleh, H.M., Dweirj, M.K. & Langston, P.A. 2012. Waste electric and electronic equipment in Jordan: willingness and generation rates. Journal of environmental Planning and Management, 55,