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ENVIRONMENTAL MODELS FOR PORTABLE BATTERY WASTE MANAGEMENT

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ABSTRACT

Alkaline batteries share more than 60 percent of total volume throughout the world and these wastes are disposed along with municipal solid waste. This is not an eco-friendly practice and criticized in this paper. Models suggested by the researches to quantify the wastes have been explored and applicability has been critically analyzed. Based on these critical reviews, environmental instruments that can have the potential for higher collection and recycling rates have been investigated through this paper.

Key words: Environmental instruments; Collection modules; Tack-back policy; Incentives; Portable waste battery.

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1. INTRODUCTION

Per capita demand of portable, industrial, and automotive batteries in Europe is approximately about 218 gm, 259 gm, and 1.091 kg. This production accounts nearly 160,000 tons of portable, 190,000 tons of industrial, and 800,000 tons of automotive batteries (Meller, 2006). European community shares only about 12% of the world population and therefore it accounts for a global mass production from everyday work of household, offices, transport, and industry for continuous power supply in equipments and machineries. Recycling of any spent battery is influenced by its type (*i.e.* household, industrial or automotive battery) and chemistry including, lead-acid, nickel-cadmium, nickel-metal-hydride, lithium-ion, alkaline, zinc-carbon, sliveroxide, aluminum oxide, and mercury-button (Gaines, 2014). Batteries containing lead, mercury, cadmium, nickel and rechargeable household batteries renowned as hazardous waste, collected separately and transported to recycling site for environmentally safe disposal.

Manufacturing of alkaline batteries without mercury has been posing the dilemma to many battery working groups and researchers on separate collection and recycling from Municipal Solid Waste (MSW) for its recycling and safe disposal mainly due to uneconomical recycling technology available till date against environmental impacts and amount of energy consumed (BAJ, 2012; Olivetti et al., 2011). Most of the countries around the world including, United States, Japan, Brazil, and few European countries do not have mandatory practice of collection and recycling of primary alkaline batteries and these are going to landfills after end-of-life. However, states of European Unions and Canada consider all spent batteries as hazardous and do not permit the disposal of any household batteries including alkaline in household trash and establish a mandatory collection target to all portable batteries as 45% till September 26, 2016 (Commission, 2006).

However, Alkaline batteries made of zinc carbon do not pose much impact on environment but its disposal in household trash pose wrong practice and affect the collection of other rechargeable household batteries that have hazards chemistry like, nickel-metal-hydride, lithium-ion, nickel-zinc, and button-cell. Disposal of spent batteries along MSW in landfills containing heavy metals like, zinc, manganese, nickel, lithium, aluminum, copper, and silver cannot be environmentally sound practice and amalgamation of heavy metals with leachate can pose the threat in surface and ground water resources. It is reported that lithium-ion batteries can has the potential to pose 27.5% of heavy metals and 5% of toxic electrolyte (Ordoñez et al., 2016). Order of human toxicity of different battery chemistry ranges from highest to lead-acid to nickel-cadmium to lithium-ion to nickel-metal-hydride and least to sodium-sulphur (McManus, 2012; SCU, 2012). Many researchers, international forums, working groups, and life-cycle-assessment studies recommended recycling and recovery of materials instead of landfills and they had demonstrated that retrieval of materials even from portable spent batteries could be a dominating environmental foot print (Fisher et al., 2006; Masanet and Horvath, 2012).

Broad dispersion and small size of individual battery makes the logistic of battery collection challenging and it requires a framework of responsibility among the stakeholders (Chryssos, 2015; Cueto and Manteca, 2012). Study conducted by EPBA (European Portable Battery Association) on collection of portable batteries in thirty signatory countries of European Economic Area (EEA) indicated the achieved average collection rate 31.35%, 34.86% and 38.48% of batteries put-on-market (POM) in three consecutive years 2010, 2012 and 2013, respectively (EPBA, 2014). Lower collection rate of any country among them was vindicated by inattention, unawareness at consumer level along with flexible regulation by the authorities and it creates the need of amendments in existing drivers of policies that can able to turn up more batteries into recycling units (Commission, 2014).

Decision based modeling for e-waste management has been used by the researchers to find the driving factors against higher collection and recycling rate for the framework of stakeholders under EPR policy (Kiddee et al., 2013; UNIDO, 2015; Xavier and Díaz, 2015). In India, major part of portable household primary batteries including rechargeable units except from lead-acid batteries are being dispose off in landfills due to the flexible legislation of Batteries (Management and Handling) Rules, 2001 and its respective amendment on 2010 (GOI, 2001, 2010). Both Rules, 2001 and 2010 provide the guidelines to the manufacturer, dealer, retailer, importer, vendor for handling of especially lead-acid batteries that result low attention of stakeholders on the collection and recycling of portable batteries. It reflects the need of further amendment in existing policy of Battery Rules so that all concerned stakeholders may come forward to address the portable waste battery management in a compliance system against minimization of improper disposal.

Study explores the framework of models to achieve higher collection targets especially to portable types of battery wastes. Worldwide many models had been implemented to develop the policies for the collection modules. These models have been used to discover the environmental instruments. Such instruments can be directly useful to the responsible authorities of OEMs to decide the key-regulating policy for environmentally sound and safe disposal of their particular hazard product.

2. METHODOLOGY

Environmental models assist to deal the situation among the scientists, working groups, OEMs, consumers, and the decision makers. It helps to formulate the environmental policies on the best available resources, especially when the process has negative economic values. Efficiency of the these models are reflected directly from the adaptability of the outcome in the form of policy by the stakeholders and it depends upon the environmental instruments taken in a particular framework (Huhtinen, 2009; Xavier and Díaz, 2015). These instruments range from administrative (bans mandated by laws, environmentally sound standards, limitation on use of natural resources, utilization mandates, landfill restriction, product-policy, collection and recycling targets, and producer responsibility) to economical (material/product taxes, upstream-combined taxes, recycling fee, grants-subsidy, deposit-refund system, tradable recycling credits, and public procurement policy) to informative (communication among authorities, eco-leveling, consultation with local government about collection network, awareness programs, and environmental education) and to voluntary *i.e.* self-motivated OEM's decisions (Bell, 2003; Bragadóttir et al., 2014; Smith, 2005).

Many models have been suggested by the researches to quantify the waste generated by these batteries (Blumberga et al., 2015; Garlapati, 2016; Kaushal et al., 2015; Lin and Chiu, 2015; Terazono et al., 2015). Few models among them are reviewed in this paper for their possible implementation in specific area of location. Based on these critical reviews, environmental instruments that can have the potential for higher collection and recycling rates have been highlighted.

3. RESULT AND DISCUSSION

Assessment of environmental policy in Nordic countries for 'prevention of waste' gave strong support on economic over the administrative instruments and voluntary was suggested as the supplement to others instruments (Bragadóttir et al., 2014). Obligations of the Producer *i.e.* Producer Responsibility (PR) aims to develop environmentally sound practices for the collection-treatment-recycling system of waste batteries and it had been found worldwide as a suitable and effective policy under the administrative instrument (Gupt and Sahay, 2015). This PR system in real sense will not have any effective outcome unless it has the collective roles of all stakeholders involved in the life-cycle of the product including OEMs, retailer, consumer, municipality, recycler and consumers (Akenji et al., 2011). This extension of responsibility over PR system creates a network within a framework known as Extended Producer Responsibility (EPR) for Design of Environment (DfE) and it as defined as "an environmental policy approach in which a Producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle" (OECD, 2001). All stakeholders under EPR policy are connected through a chain of roles and responsibilities in a suitable framework known as product-stewardship from mandatory to voluntary role of local action groups intended to achieve better recycling rate of spent batteries (Akenji and Bengtsson, 2010; Walls, 2003).

EPR legislation depends upon nation's economy (*i.e.* industrialized, emerging or least) and its implementation in actual practice is challenging especially to emerging economic nations like, People's Republic of China, India, Indonesia, Vietnam, Malaysia, and Thailand for many reasons like, difficulties in identification of the producer, competition with the informal waste management sectors, poor infrastructure for waste collection-treatment-recycling, and perceptions about waste (Akenji et al., 2011). Many of these nations have prepared the EPR draft for DfE and they are operating it to some extent also, but many challenges remains for the improvement through proper cost sharing among the stakeholders in terms of physical and financial responsibilities (Chotichanathawewong and Thongplew, 2009; Jain, 2009; Manomaivibool et al., 2009; Xuejun and Peiry, 2009). Many EPR models including product-stewardship, take-back, and voluntary-co-regulatory schemes have been suggested by the researchers but the record of achieved collection and recycling target indicates the further need of present hour to develop more efficient market-based framework that can integrate all the stakeholders in a system particularly for the nations with emerging economy (Akenji et al., 2011; Kaushal and Nema, 2013a).

Asian countries with industrialized economy like, Japan, the Republic of Korea, and Taiwan have strong state institutions and capacity of implementation of their own comprehensive EPR legislations, and they are practicing it since 1990s even for a wide range of products like, e-waste, automobile, packaging and container waste (Chung et al., 2009). In Japan, Waste Management and public cleansing law for the promotion of effective utilization of resource had started a movement in 2001 to recycle all rechargeable batteries governed by Battery Association of Japan (BAJ) followed by establishment of Japan Portable Rechargeable Battery Recycling Center (JBRC) in 2004 along with approximately 310 OEMs and importers as members with 33000 collection sites nationwide (Nakajima, 2015). But, the collection, treatment and recycling of primary batteries is vested in the jurisdiction of municipality and this practice causes the unintentional disposal of other portable batteries in regular trash for those recycling are mandated particularly by those people who are unaware regarding environmental consequences and ecolabelling mark (Chong et al., 2009; Claro et al., 2013; Lee and Na, 2010). Most of the countries even industrialize economic states around the world are also not bothering for mandatory practice of collection, treatment and recycling of portable batteries but very few states among them, including, Belgium(59%), Sweden(55%), Austria(44%), Germany(39%), Netherlands(32%), and France(16%) are putting their effort consistently since 2002; numeric value written in bracket represents the corresponding collection rate achieved in 2002 (BBC, 2006).

To ensure higher level of environmental protection and material recovery throughout the community, on September 26, 2006, European Union (EU) directive on batteries and accumulators established the mandatory rules to all 29 EEA member states. These rules includes registration and financing; ban on marketing of batteries containing mercury or cadmium; minimum collection target for all portable batteries as 25% in 2012 and 45% in 2016; recycling target as 65% for lead-acid batteries, 75% for nickel-cadmium batteries, and 50% for others; ecolabelling; and minimum rules for PR system against the sustainable approach of metals utilization (EPBA, 2014). Cyprus, Malta and Romania were only the 3 EEA states who missed the scheduled collection target of 2012 and further, 10 EEA states including Bulgaria, the Czech Republic, Latvia, Lithuania, Hungary, Malta, Poland, Romania, Slovakia and Slovenia are expected to miss the target of 2016 and hence, WEEE Directive 2012/19/EU sets lower interim of 40% (rather than 45%) only to these states. It indicates the need of reformation of the present policy to achieve higher collection rates (EPBA, 2014).

Recycling and recovery of metals from the portable batteries needs a lot of infrastructure and technology which causes extra financial burden and poses a big challenge to develop such recycling facility in all the country of the world (BAJ, 2012). Portugal is found one among them and outsource recycling was used from Austria, France, and Spain for their waste portable battery and further, life cycle study conducted by researchers on this initiative showed noticeable advantages only if recovery of materials and energy is taken account otherwise landfill was found as the best option (Xará et al., 2014). Policy intervention is essential in the separate scheme of collection, treatment and recycling of waste portable batteries due to the fact that it has negative economic value which causes conflicts among stakeholders (Xavier and Díaz, 2015).

EEA countries are implementing EPR based compliance system under any of three basic principal models, namely, state fund, single-organization, or competing-organization (EPBA, 2014). 'State Fund Model' ponders Producer as only financially responsible and monetization of fund is made by the payment of product-fee/eco-contribution/eco-tax to either single or multi tasking waste management authority designated by Government. 'Single Organization Model' works under environmental agreement among the government and the entire industry sector within a framework of well defined nationwide collection system towards self-propelling waste battery management. 'Competing Organization Model' dispenses take-back obligations of Producer among all stakeholders under mandatory or involuntary action for nationwide coverage of waste battery collection in a coordinated manner of system. Statistics of achieved target within EEA member states suggested that any of the aforesaid scheme model can facilitate to high collection rates and its efficiency depends upon the performance drivers of stakeholders like, awareness creation, nationwide collection points and coordination network, alternative existing collection schemes, take-back obligation on municipality and retailer, interim collection targets, and fiscal instruments like, eco-taxes, fees (EPBA, 2014).

South Korea, in 2003 launched PR system on Producers to develop either their own recycling system or search a outsource job from commercial recycling company or simply join the 'Producer Responsibility Organization' by paying the deposit fee (Lee and Na, 2010). It results the establishment of Producer-built recycling plant by Samsung, LG, Daewoo and many more commercial recycling companies within the country. PR system has the priority on increasing recycling amount rather than promoting DfE and consumer is free to deposit his/her waste to either at producers, municipalities, recycling agencies or exporters (Chong et al., 2009). However, conflicts on deposit rate, higher recycling fee, lack of physical monitoring of improper recycling of hazard wastes, and illegal export to East Asian countries are the policy challenges of the present PR system (Smith, 2005). Taiwan introduced a Recycling Fund Management Committee (RFMC) in 1998 to regulate and impose only economical responsibility to OEMs by depositing annual fee approved by 'Rate Review Committee' for recycling process of hazardous waste (Chung et al., 2009). Collected waste at the collection centers are transported to the recycling sites where it is to be purchased by the recycling units and now both firms (collection as well as recycling enterprise) are entitled to claim the subsidy from RFMC for their participation. However, proper recycling is not guaranteed in this policy because recycling plants may be outside from the system if they do not opt for subsidy. Producers are also not incentivized for any action of environmentally safe manufacturing which shows that system has weak influence on DfE.

Worldwide, present scenario of framework for collection, treatment and recycling of waste battery practice consist of different battery compliance organizations having varying obligations of stakeholders with many challenges to implement DfE and therefore it requires amendment through proper cost sharing among Producer, Consumers, Recyclers, and Regulatory body. Application of Game theory for accounting the role of stakeholders under conflict situation in willingness to pay has been found a better framework of modeling (Casey et al., 2007; Kaushal and Nema, 2012; Wang et al., 2010; Zhang and Jin, 2011). Researchers are using it as a mathematical tool to analyze the critical review of the problems of multi-stakeholders' structured organizations within a framework of uncertainties while implementing of their own decisions (Borocz and Fldesi, 2008; Kaushal et al., 2015; Mingang and Yanting, 2009). In the present study, such potential of Game theory is used to quantify the driving parameters responsible to propel the system of collection, treatment and recycling by computing the Nash-equilibrium points of the game which causes win-win situation among all the set of all possible strategic planning for a problem. These equilibrium points simulate all possible aspects of the conflicts with numerical values of corresponding stakeholders' payoff and outcomes are optimal payoff that make the results closer the practice which are normally ignored in other optimization methods of decision making problems (Kaushal and Nema, 2012; Kaushal and Nema, 2013b).

4. CONCLUSION

Certain instruments can have the potential to form the environmentally sound practices for higher collection as well as recycling rates. Implementation of such practices through legislation can pose a strong barrier on land disposal of portable batteries after its end-of-life.

- Policy of Green-tax can serve a milestone for creating the environmental awareness among the societies as well as financial fund to implement the legislation.
- Outsource recycling fee and subsidy can pose the stability on recycling plants in the market and it can also attract the interest of private investors to develop more recycling units.
- Incentive for environmentally safe manufacturing can be a policy of communication of recycling performance to respective OEMs.
- Imposition of penalty on Producer for lower recycling rate can be a tool to increase the efficiency in working model of collection system.

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