E-Waste Management and Recovery of Valuable Metals

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I. Introduction:


It Is Estimated That The Usage Of Mobile Phone Increased From About 500 Million To 5000 Million In 1year (2010-2011) Worldwide [8], [9]. Now A Days, The Number Of Mobile Phone Users Is Exponentially Growing. Globally, More Than 7 Billion Mobile Phone Subscriptions Will Be There By The End Of 2015, With A Population-Wise Penetration Rate Of 97% Is Calculated Bythe International Telecommunication Union (ITU) [10]. Due Torapid Change Of Mobile Phone Models With Advanced Technology Forces The Consumer To Change Their Phones More Frequently. Therefore, The Service Life Of Mobile Phones Becomes Too Short And Thereby Generating Large Amount Of Waste Streams [11]-[13]. The Usage Period Of A Mobile Phone Is Less Than 3 Years In Developing Countries And Less Than 2 Years In Developed Countries, Thus It Can Be Predicted That Most Of The Mobile Phone Became Into Waste Stream May Still Have Performance Value. So These Can Be Recovered And Recycled[14].


It Was Observed That The Number Of Authorized Recyclers Is Very Few Compare To Un-Authorized Dealers. Few Authorized Dealers Managing E-Waste Are Tech-Logic, UPL Group And Various Municipal Bodies Of Big Cities. In Various Cities In India, Survey Reports Has Revealed That The Extent Of Electronic Waste Generated Is Of The Order Of 1000 Kg To 3000 Kg Per Month. An Awareness Programme Should Be Initiated With Major Waste Disposal Sector To Dispose E-Waste In Special Designed Bins Compare To General Bins. Special Drive Should Be Initiated Among School, College And Other Public Places To Control E-Waste Disposal And Conversion Of Waste Into Useful User. This Paper Represents An Overview Of E-Waste
Generation, Different Approaches For E-Waste Management And Finally Recovery Of Valuable Metals From E-Waste.

II. Generation Of E-Waste:
Changing Lifestyle And Urbanization Has Led To Higher Consumption Of Electronic Products. Huge Amounts Of Locally Generated And Internationally Imported Have Posed A Serious Threat To Human Health And The Environment. The Complexity Of The Issue Of E-Waste In India, Given Its Vast Geographical And Cultural Diversity And Economic Disparities, Makes Management Challenges In India Quite Unique. Fig 1 Shows The Summary Of The Generation Of E-Waste.

Several Researchers Have Focused On The Estimation Of Generation Of E-Waste. However, It Was Observed That The Most Of These Studies Pivoted On Their Local Waste Generation Statistics Only Rather Than A Global Representation. According To The Estimation By United Nation University That E-Waste Will Rise From The 41 Million Tonnes Currently Produced Each Year To 47 Million Tonnes In 2017 [8]. In The European Union (EU), E-Waste Is Growing At A Rate Of 3–5% Per Annum Which Is About Three Times Faster Than Other Individual Waste Streams In The Solid Waste Sector [22], [23]. It Is Estimated That In 2009 Around 5 Million Tonnes Of E-Waste Were In Storage And 2.37 Million Tonnes Of E-Waste Were Ready For Disposal, Which Represents An Increase Of Around 120% From 1999 Levels [24], [25].

Most Of The E-Waste Was Generated In Asia, 2016 Around 18.2 Mt, Or 4.2 Kg Per Inhabitant. Approximately 2.7 Mt Were Documented To Be Collected And Recycled Which Is Illustrated In Table 1. The Highest Quantity For Each Inhabitant 17.3 Kg/Inh Was Generated By Oceania. However, Oceania Generated The Lowest Quantity Of E-Waste In The World In 2016 At 0.7 Mt, And Could Only Document 6% Of Its E-Waste That Was Documented To Be Collected And Recycled (43 Kilotons (Kt)). Comparing To Oceania, The European Continent, Including Russia, Generated An Amount Of E-Waste Per Inhabitant (16.6 Kg/Inh). In Total, The E-Waste Generation For The Whole Region Is 12.3 Mt. Around4.3 Mt Of E-Waste Was Collected To Be Recycled In Europe, Showing The Highest Regional Collection Rate Of 35% Compared To E-Waste Generated. The Lowest Amount Of E-Waste Per Inhabitant Was Generated In Africa (1.9 Kg/Inh). The Whole Continent Generated 2.2 Mt Of E-Waste, And With Current Data, Only 4 Kt Were Documented As Collected And Recycled; This Is Less Than 1%. In 2016, The Americas Generated 11.3 Mt Of E-Waste 7 Mt For North America, 3 Mt For South America, 1.2 Mt For Central America. The Whole Continent Generated 11.6 Kg/Inh. Of E-Waste In 2016, And Approximately 1.9 Mt Of E-Waste Documented Was Collected And Recycled.

The Difference Of E-Waste Generated In Developed Versus Developing Countries Is Quite Large. The Richest Country In The World In 2016 Generated An Average Of 19.6 Kg/Inh, Whereas The Poorest Generated Only 0.6 Kg/Inh [8].

Table 1: E-Waste Generation And Collection Per Continent [8]

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Africa</th>
<th>Americas</th>
<th>Asia</th>
<th>Europe</th>
<th>Oceania</th>
</tr>
</thead>
<tbody>
<tr>
<td>Countries In Region</td>
<td>53</td>
<td>35</td>
<td>49</td>
<td>40</td>
<td>13</td>
</tr>
<tr>
<td>Population In Region (Millions)</td>
<td>1,174</td>
<td>977</td>
<td>4,364</td>
<td>738</td>
<td>39</td>
</tr>
<tr>
<td>WG (Kg/Inh)</td>
<td>1.9</td>
<td>11.6</td>
<td>4.2</td>
<td>16.6</td>
<td>17.3</td>
</tr>
<tr>
<td>Indication WG (Mt)</td>
<td>2.2</td>
<td>11.3</td>
<td>18.2</td>
<td>12.3</td>
<td>0.7</td>
</tr>
<tr>
<td>Documented To Be Collected And Recycled (Mt)</td>
<td>0.004</td>
<td>1.9</td>
<td>2.7</td>
<td>4.3</td>
<td>0.04</td>
</tr>
<tr>
<td>Collection Rate (In Region)</td>
<td>0%</td>
<td>17%</td>
<td>15%</td>
<td>35%</td>
<td>6%</td>
</tr>
</tbody>
</table>
Polák And Drápalová (2012) [26] Estimated The Generation Of Mobile Phone Waste In Czech Republic. They Used A Specific Method involving Calculation Of Life Span And Volume Of Distribution Of Mobile Phones To Estimate The Existing And Near Future Mobilephone Waste Quantity. They Calculated The Amount Of Discarded mobile phones And Reported The Quantity In Numbers That Is Only 45 Thousand In The Decade 1990–2000, While It Was 6.5 Million In The Next Decade, I.E., 2000–2010 And Projected Around 26 Million In The Current Decade (2010–2020). They Also Compared Their Values With Other Countries Such As Japan, China, US, UK And Korea. Babatunde Et Al. (2014) [27] Focused More On The Mobile Phone Used Battery Disposal Behaviour In Nigeria. They Made An Interesting Observation Regarding Life Cycle Of Mobile Phones And Observed That Approximately 40% Of The Inhabitants Used The Mobile Phone Only For One Year. They Also Studied The Trends In Battery Usage By The Residents. Rahmani Et Al. (2014) [28] Estimated The Past And Future Trends In Generation Of Obsolete Computers And Mobile Phones In Iran. They Achieved This Through Different Models Such As Time-Series Multiple Life Span Model And Simplified Logistic Function Model. They Calculated That About 39 Million Mobile Phones Entered The Waste Stream Until 2014 And Proposed That This Figure Would Reach 90 Million By 2035. They Also Projected That The Saturation Level For Mobile Phone Waste Would Be 21 Years From 2014. Li Et Al. (2015) [13] Compared Several Methods Such As Market Supply Method, Consumption And Use Approach And Sales And New Method. They Found A Great Differentiation In Results Depending Upon The Method Chosen. They Observed That 47.92 Million Mobile Phones Retired In 2002. And It Reached To 739.98 Million In China In 2012 Which Was The Result Of Applying The New & Sale Method. Therefore It Is Prior To Select The Proper And Most Appropriate Method To Get Accurate Values Of Mobile Phone Waste Generation.

### III. Management Of E-Waste:


The Major E-Waste Problem In Developing Countries Arises From The Importation Of E-Waste And Electronic Goods From Developed Countries. These Western Countries Export Their Older, Less Ecologically Friendly Equipment To The Developing Countries And Resulting 80% Of All E-Waste [29].


Jang And Kim (2010) [32] Gave A Detailed Review On Management Of Mobile Phone Waste In Korea. The Methodology Of Their Study Included Gathering Data Associated With Annual Domestic Demands Of Mobile Phones, Questionnaire Surveys, Site Visits, Interviews And Conversations, And Review Of Available Literature. They Discussed On Features And Effectiveness On The Legislative Measures Taken By The Korean Government For Proper Disposal Of Mobile Phone Waste. One Interesting Aspect Of Their Work Includes A Methodology Divided Into Four Stages As Generation, Collection, Reuse/Recycling And Treatment, Employed For Mobile Phone Recycling. They Indicated That Combined Efforts From Producers, Mobile Phone Companies, Consumers, And Governments Will Be Required To Solve The Increasing Mobile Phone Waste Issue.

The Ministry Of Environment In Norway Signed An Agreement To Set Up Take Back Companies With The Producers And Importers Of Electronic Waste As Early As 1998. It Was A Voluntary Agreement And Was Later Followed By An E-Waste Regulation In 1999. Like The Rules In India, Management Of E-Waste In Norway Is Also A Producer Responsibility And Producers Are Defined As Norwegian Manufacturers And Importers Of EEE.

India Plays An Important Role In The Domestic Generation Of E-Waste (2 Mt In 2016) Due To The Large Population, But The Country Also Imports From Developed Countries. India’s Electronics Industry Is One Of The Fastest Growing Industries In The World. The Formal E-Waste Recycling Sector In India Is Currently Being Developed In Major Cities. However, Informal Recycling Operations Have Been In Place For A Long Time, With Over 1 Million Poor People In India Involved In Manual Recycling Operations. Most Of These People Have Very Low Literacy Levels With Little Awareness Of The Dangers Of The Operations. Severe Health Impacts And Environmental Damage Are Widespread In India, Due To The Final Step Of The E-
Waste Processing By The Informal Sector. India Has Had The E-Waste Rules In Effect Since 2011. The Rule Mandates Producers To Be Responsible For The Collection And Financing Of Systems According To The Extended Producer Responsibility (EPR) Concept. Further Amendment To This Rule Came In 2015, Which Resulted In The E-Waste (Management) Rule In 2016. The Main Feature Of This Rule Is EPR. The Amended Rule Has Provisions For Producer Responsibility Organisations (Pros) And Deposit Refund Scheme Under EPR [8].

Sixty-Five Cities In India Generate More Than 60% Of The Total E-Waste Generated In India. Ten States Generate 70% Of The Total E-Waste Generated In India. Maharashtra Ranks First Followed By Tamil Nadu, Andhra Pradesh, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, Madhya Pradesh And Punjab In The List Of E-Waste Generating States In India. Among Top Ten Cities Generating E-Waste, Mumbai Ranks First Followed By Delhi, Bangalore, Chennai, Kolkata, Ahmadabad, Hyderabad, Pune, Surat And Nagpur. There Are Two Small E-Waste Dismantling Facilities Are Functioning In Chennai And Bangalore. There Is No Large Scale Organized E-Waste Recycling Facility In India And The Entire Recycling Exists In Unorganized Sector.


EPR Is The Most Defining Provision In The E-Waste Regulation Of Our Country. According To EPR, Manufacturers Are Responsible For The Post-Consumer Waste Of Their Respective EEE Products. The E-Waste Rules Were Notified In 2011 And Came Into Effect In 2012. It Has Been Three Years Since The Rules Were Notified And Two Years Since They Came Into Force But Only A Handful Of Companies Have Come Forward To Manage The End Of Life Cycle Of The Products That Have Been Put By Them In The Market. EPR Approaches To E-Waste Management At A National Scale Are Summarised In Table 2.

**Table 2: E-Waste Management Approaches To EPR[33]**

<table>
<thead>
<tr>
<th>Country</th>
<th>Policy</th>
<th>Target</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Netherlands</td>
<td>Take Back (Large Household Appliances And IT Equipment)</td>
<td>Recycling Rate 45–75% By Weight</td>
<td>[34]</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>Take Back (Electronic Appliances)</td>
<td>Recycle And Recovery 50–80%</td>
<td>[35], [36]</td>
</tr>
<tr>
<td>Germany</td>
<td>Take Back (Electronic Appliances)</td>
<td></td>
<td>[37]</td>
</tr>
<tr>
<td>Switzerland</td>
<td>Take Back (Electronic Appliances)</td>
<td></td>
<td>[38], [39], [40]</td>
</tr>
<tr>
<td>Japan</td>
<td>Take Back (Four Large Household Appliances: TV Sets, Refrigerators, P(Air Conditioners And Washing Machines) Product Re-Design (Lead Free Solders And Bromine Free Printed Circuit Boards))</td>
<td>Recycle Rate 50–60% By Weight</td>
<td>[39], [34]</td>
</tr>
<tr>
<td>United States</td>
<td>Take Back Household Appliances In Some States, Such As Maine (Take Back Only Televisions And Computer Monitors)</td>
<td></td>
<td>[41], [42]</td>
</tr>
<tr>
<td>Canada</td>
<td>Take Back Household Appliance In Some Provinces, Including Alberta And Ontario</td>
<td></td>
<td>[43]</td>
</tr>
<tr>
<td>India</td>
<td>Feasibility Study</td>
<td></td>
<td>[44]</td>
</tr>
<tr>
<td>Thailand</td>
<td>Developing Legal Framework</td>
<td>Collection And Recycling</td>
<td>[45]</td>
</tr>
</tbody>
</table>


So, Both The Government And Mobile Phone Manufacturer Has To Work Together With Recycling Industries To Develop A Proper Waste Recycling System.

IV. Metal Recovery From E-Waste:

Of Nickel And 80% Recovery Of Cobalt Were Achieved. They Also Noted That The Hydrochloric Acid Provided Best Recovery Efficiency At All Concentrations Than Other Acids. Hanafi Et Al. (2012) [54] Analyzed The Composition Of Waste Mobile Phone PcbS Using EDX (Energy Dispersive X-Ray Spectroscopy). The PCB Samples Were Disassembled, Pulverized And Density Separated Into Light And Heavy Fractions. The Compositions Of Each Class Were Identified By EDX. The Copper Was Extracted As Copper Sulfate Hydrate With 98.82% Purity.

V. Conclusion:

Management Of E-Waste Based On Collection And Take Back Of Household Electric Or Electronic Appliances And IT Equipments During Purchase Of The New One Than Recycling And Recovery Of Precious Metals From E-Waste. Developed Countries Like Netherlands, UK, Germany, Switzerland, Japan And USA Have Already Developed A System And Achieved Good Success With 45-75% Recycling And 50-80% Recovery Of The Metals. However, In Developing Countries Like India, This Management Is Still In The Nascent State. Proper Government Policies Like E-Waste Rule 2016 Along With Collaborative Work Of Govt., Electronic Goods Manufacturer And Recycling Industries Can Develop A Proper Waste Recycling System In India To Control The E-Waste Pollution.


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