Plastic waste and management methods environmental sciences essay

Abstract

This dissertation contributes new and unique evidence to the debates surrounding plastic waste management options and their effects on the environment. A recurring theme in the debates around plastic waste management system is the extent to that whether the plastic waste disposal options give genuine benefits to the environment. Often, criticizers of the strategy drive towards larger plastic recycling assert that the act of recycling could be in fact has less or no benefit to the environment, consuming extra energy in the collection and transportation of plastic waste to the recycling facilities than is saved by the procedure of recycling. In order to notify this debate in details, this dissertation commissioned a key international LCAs studies. By reviewing considerable international studies, and employing rigorous criteria to filter out those studies that have less robust methodology and assumptions, after the number of studies screened 11 state of the art LCAs were selected for methodical study, including disparate scenarios. The result is more objective oriented analysis of the environmental encounters of different waste management methods for Plastics waste than one single study can deliver. Through the use of past LCAs, it investigates both plastic waste disposal options and environmental effect of the activities of plastic waste management by using meta and statistical analytical methods. Research methodology also considered, setting up a framework to review and selection restricting criteria for LCA studies. In so doing it provides the waste management methods performances with regards to environmental indicators. Persuading plastic methods have been chosen to comparing options : Landfilling, recycling, incineration and pyrolysis performances with

regards to perusing environmental impact indicators: climate change, depletion of natural resources, energy demands and water consumption. This dissertation focuses on recycling, incineration, landfilling and pyrolysis that are plastic waste disposal methods and their performance concerning climate change, depletion of natural resources, energy demand, and water consumption that are environmental impacts indicators. By reviewing past LCAs, it investigates plastic waste management options and environmental effect of the activities involved. For selection of LCA studies restricting selection criteria are developed. Meta analytical methods were adapted to synthesize and codify the findings of LCAs. Codified data were statistically analysed to calculate mean size effect. It provides the best, intermediately and the worst option concerning environmental performances of plastic waste management methods. The results are clear that all of the studies prop the following conclusions:. after comparison between of recycling, land filling, incineration and pyrolysis of waste plastic, Recycling appears to be a preferable management option over alternatives. Whereas, pyrolysis method emerged as a promising option for plastic waste disposal.

INTRODUCTION

This study grew from a meeting of two interests – The author’s academic interest in the environment and development issues, and work experience in the field of Polyethylene (PET) plastic. The main objective of this dissertation is is to contribute to the debate concerning the causes of environmental impacts of plastic waste management methodsThe following section introduces the background and significance of choosing this study area and context of the study. It also outlines the aim and objectives of the

dissertation. Additionally, organisation of the whole study will be informed. Finally, justification of the undertakings the present study will be given. Plastics waste, need of a better waste management method and sustainability and plastic will be discussed.

1. 1 Plastic waste and management methods

Plastic is a durable, versatile material and relatively inexpensive. Plastic products have brought benefits to society in many ways such as quality of life, jobs, and economic activities. However, waste plastic also imposes environmental impacts. In view of the fact that plastic is non-biodegradable, it can remain in the atmosphere for a exceedingly long time and so plastic poses risks to the environment and human health, It is also difficult to reuse and/or recycle in practice (European Commission, 2013a). Many countries are trying to incorporate different strategies to increase plastic recycling rates. According to the Environmental agency (UK), statutory recycling targets have been given to all the local authorities in Wales (2012a). Whereas, in Scotland waste regulations operates without statutory recycling targets, and here funds are available for local authorities to help increase recycling rate(2012b). By making recycling mandatory or funding recycling a difference can be made to global environmental issue that exists because of waste. This dissertation focuses on recycling, incineration, landfilling and pyrolysis that are plastic waste disposal methods and their performance concerning climate change, depletion of natural resources, energy demand, and water consumption that are included as environmental impacts indicators. By using past LCAs findings, it investigates plastic waste disposal

options and environmental effect of the activities involved in plastic waste management.

1. 2 Aim and objectives of the study:

The aim of this research dissertation is to identify environmentally sustainable management options for waste plastics. There will be an attempt to achieve the aim of this study by undertaking following three objectives. Objective 1: By reviewing, the relevant literature to address environmental issues related to the recycling, landfilling, pyrolysis and incineration. In addition to environmental indicators that are included in the study: climate change, depletion of natural resources, energy demand, and water consumption evaluating international processes to recommend the best legislation, policies and practices. Objective 2: Objective two is to set up a framework for LCA selections. Once LCA studies are retained Meta analytical methods will be applied to synthesize the findings of selected LCAs. Further, use of Meta synthesis for the codification of the LCA findings. Finally, statistically analysed the data to calculate mean effect size using Microsoft excel tool. In order to assess the environmental viability of recycling, landfilling, pyrolysis and incineration for waste plastics through appraisal of included environmental indicators. Objective 3: The presentation of the codified data sample will take place in this objective. Codified data will be statistically analysed using Microsoft excels (2010). To present in the form of histograms and charts, four management options will be assessed under each environmental indicator based on the results of each selected LCA study. To find out which one of the four waste management methods

emerges as the best option regarding each or environmental indicator performances.

1. 3 Justification of the study:

Plastic waste management and its environmental implications are a majorly important issue and one of the major research topics of many governmental and environmental entities such as NAPCOR, DEFRA, WRAP, Recoup, Environmental Protection Agencies(EPAs) of majorities of countries and United Nation(UN). WRAP (2006) and Villanueva et al (2004). For instance, published a major preliminary environmental impact analysis of a different type of waste materials including plastic and comparison of recycling, incineration and land filling by reviewing international LCA's and the conclusion of that research is recycling offers more environmental benefits than alternatives. This research considered as high quality and information shared by UN and US EPA. However, there have been many waste management option emerged since WRAP report been published such as pyrolysis and gasification, Efw informs Jowit (2010). What is different in this study is the inclusion of pyrolysis, which as a new method was not included in WRAP (2006) and Villanueva et al (2004). Second gap that is addressed is the inclusion of one of the environmental indicators –water consumption in the impact studies, this indicator previously ignored by WRAP (2006) where the concentration is on Climate Change, Energy demand and Depletion of natural resources. To investigate and address these gaps the author will undertake past LCA studies. Findings of LCAs will present this in a new way. Additionally, the decision to use a meta- analysis approach originated from United Nations Development Program (UNDP) report on review of past LCA

using Meta analysis (2012). however, LCA selecting criteria were not used in UNDP research, which is otherwise adopted in this present study to ensure quality of the result. This study will also try to find out whether recycling is environmentally, sustainable option for plastic waste as claimed by past studies or will emerging technologies will prove to be a better option. This report will also attempt to identify data gap in the literature review and recommend if there is a need for further research in the specific area for future researchers.

1. 4 Organisation of the study:

The research structure includes four sections. Firstly, Literature review section that will review the existing literature that is related to four waste management options, continuously building towards the significance of environmental sustainability of plastic waste management methods. Additionally, to give broader understanding of included environmental indicators will be studied. Review of international policies, legislation and measures that are pertaining to plastic waste management methods and environmental indicators. The main purpose of this section is also to identify a data gap in the literature. Secondly, by reviewing waste management methods author will try to find out which is the acknowledged environmentally sustainable plastic waste disposal option. Secondly, methodology section will describe adapted methods for data collection where data will be collected for this study to illustrate the broader issues of preceding sections concerning environmental impacts of existing waste management options. This section will explain rigorous criteria applied for selection of data sample. Meta analytical method steps used for codification

will be outlined. Followed by systematic adaptation of statistical analysis using Microsoft excel to calculate mean effect size will be informed. Thirdly, presentation and interpretation of the results that are obtained from the analysis of data will take place. Based on the findings, discussion will take place in this section followed by recommendations to future researchers. Finally, the conclusion will employ findings of the dissertation and discussion as a reference in this section and research questions will be answered. More importantly, main aim and all the objectives in connection with the findings of this dissertation will be addressed in the conclusion section.

Summary

This section provides information that undertaken study area is vital and problematic. Justifications have been given for undertakings of this study along with the gap in existing knowledge have been addressed where evidence has been given of previous studies further role of this dissertation findings was informed. Organisation of this study has been informed. This section also informed the significance sustainability to justify inclusion of environmentally sustainability in this study area. Following section will review the known literature in accordance with existing plastic waste management methods and identify its environmental implications. It will also assess proposed policies, proven strategies those are originally introduced to help enhance present environmental conditions; summarisation of real life case studies and learned examples will be noted in the following section by introducing and reviewing items of previous research in the area.

LiTeRATURE REVIEW

This section is an attempt to achieve the objective one. The following section divided into three parts, First section addresses plastic waste management methods: landfilling, recycling, pyrolysis and incineration. Secondly, environmental indicators: climate Change, depletion of natural resources, energy demands and water consumptions that are used in the study as a benchmarking to compare each waste management method performances. Finally, provides an overview of the international strategies and policies applied in practice. Key sources used for this study are reports of Government Agencies: WRAP, DEFRA and EU and internationally United Nations Environment Programme (UNEP) along with published international scientific databases and journals from Springer, International Journal of Life Cycle Assessment and ScienceDirect. This represents a combination of sources including Governmental Agencies and academic authors. In addition, the webpage of the European Commission was searched for studies commissioned as input to EU policies.

2. 3 Environmental Impacts Indicators

The following table explains each of indicators that are included in this study; it also critically analyse policies and measures taken to prevent environmental impact.

Indicator

Description of Environmental Indictor

Description, impact and related worldwide policies

Climate Change

Climate change is also addressed as globe warming. Globe warming is the rise in the average temperature of the earth surface, due to a possible rise in the greenhouse impacts, provoked by anthropogenic emissions of greenhouse gases. Research published in the journal PLoS Medicine (2012) informs according to a group of European public health experts that climate change could alter patterns of food availability, physical activity and in some cases might bring direct physical harm. Friends of Earth (2007) reported that waste prevention is the most beneficial option from a climate point of view, followed by reuse and recycling; Warhorse and Watson confirm (2006) landfill and incineration are the worse options (p. 6)The United Nations Framework Convention on Climate Change (UNFCC, 2013) an international treaty joined by 195 countries, except America. To follow up from Kyoto protocol green house gas emission is seen as the most crucial issue within the field of climate change policies. BBC informed back in 2009 that The America accounts for almost 25% of the world’s total CO2 emission and have received a large amount of criticism for its stance on climate change.

Depletion of natural resources

Resource depletion described as the cutting potential of all natural resources. The resources believed in this study are mineral and fossil resources. Plastics are made from oil, coal and gas, which are limited natural resources (Australia EPA, 2013). majority of plastic bags are made from

polyethylene, made up of natural gas, and Plastic is not biodegradable, so all the plastic that has ever been made is stilexist around us today. Most of it is in landfills, if not then floating in the sea. University of Cambridge’s report on plastic recycling informed that the production of 1 kg of polyethylene (PET or LDPE), requires the equivalent of 2 kg of oil for energy and raw material. Although plastics only consume around 4% of the world’s oil, supplies are becoming depleted. Once depleted these resources cannot be replaced. The depletion of natural resources is becoming a key focus(Karen, 2008) This is evident in the UN's Agenda 21 Section 2 which provides the necessary steps to be taken by all countries to sustain their natural resources (2002) Schilling & chiang confirms the depletion of natural resources is a sustainable development issue (2011). furthermore, Salvati and Marco (2008) noted in regards to natural resources, depletion is of concern for sustainability as it poses the ability to degrade current environments(p. 218) and potential to impact the needs of future generations(p. 523)

Energy demand

Primary energy is obtainable raw energy in nature and is separated into renewable and non- renewable primary energies. The non renewable are: atomic energy, usual gas, coal, and oil, Renewable is wind energy, solar, biomass and hydraulic. UK department of Energy and Climate Change (2012) informed that the UK has developed Pathways analysis and calculator tool which will help policy makers. Gervet (2007) in his captivating report on the use of crude oil in plastic making contributing to the global warming pointed out that energy consumption in total worldwide plastic production from 1939 till 2004 is 0. 59 10 14 kWh (p. 5). Plastics Europe informed in order to

produce plastic products, energy resources are consumed(2013). Currently energy resources are majorly obtained from non-renewable sources, and when used; greenhouse gas (GHG) emissions are produced. Nevertheless, it was established in a study undertaken by GUA/denkstatt in 2004/2005 even more energy would be consumed along with more GHG emission, if plastic products were to be substituted by alternative materials. [Pilz et al., 2005].

Water consumption

Water consumption symbolizes to the removal of water from the various origins (rivers, seas, and groundwater) for use by humans. This water is not returned to the origins and sources. According to the UN World Development Report, up to 500 Million Tons of wastes accumulate each year from Industry; most of it goes into the fresh water supply. Also informed some of the developing countries dump 70 % of industrial waste into untreated waters where drinking water gets polluted (2013). Professor Grossman noted back in 2004 that Industrial water use is about 22 %. According to Centre for Science and environment- India, countries all over the world set standards and target for water consumption for industries. China, For instance government push companies to save as much as 6 billion cubic meters of water per year informed in China water conservation Agency report in 2005. Proposed and implemented governmental strategies and policies targeting plastic waste will be discussed in details in the following part of this chapter.

2. 4 Policies on plastic waste

Plastic waste management goes across a numerous policy fields: along with sustainable management of resources and habitat protection, climate change, agriculture, soil protection and energy, biodiversity. Purpose of this

section is to provide an overview of measures taken by Government agencies and environmental protection bodies to reduce the environmental impacts of plastic waste. According to Science for environmental policies , European commission, (2011) Municipal waste collection and separation is a vital part in all waste management methods, for countries such as Germany, Austria and Sweden where waste management systems are more advanced, and source separated collection rates are already high(Waste Management World, 2013 b). waste management world (2013) reported European Union as the most advanced waste management system. The European exports of plastic waste rose by 250%, reaching 2. 27 million tonnes approximately 5 million tonnes are annually recycled in Europe. Some selected counters, policies and measures related to the waste management are discussed in following table

Country and Government Agency

Introduced, Implemented Policies, Legislation and measures

Netherlands

Dutch Waste Management Association (DWMA)The Netherland recycle no less than 64% of its waste and the remainder are incinerated with generation of electricity, and a small percentage ends up in landfill. This is a country that is practically unique when consider recycling. Separating waste is the popular environmental measure activity among Dutch people that account for more than 90% of Dutch people involved in this sort of activities. Source: http://www. dwma. eu

United State of America

National Solid Wastes Management Association (NSWMA)According to a recent study by NSMWA Privatised, waste services signifies cost savings and lower financial risks for municipalities than public sector counterparts dExperiment of using fly ash(recycling toxic)as an additive to produce light weight composite that can be used in the automotive industry is taking place in the New York university. The university researchers claim that it has the potential to keep tons of toxic waste out of landfills while lowering the cost of some of the expensive raw materials. Source: www. environmentalistseveryday. org

Qatar

Ministry of Environment(MOE)An integrated solid waste treatment in the Qatar, that is the first of its kind in the Middle East. This facility centre has a capacity of treating 2300 tonnes of solid waste per day, along with 5000 tonnes of C&D waste. Source: www. moe. gov. qa

United Kingdom

Department for Environment, Food and Rural Affairs (DEFRA)UK is home to the world’s largest plastics recycling plant. The £15 million venture by Coca-Cola, WRAP and ethical plastic bottle recycle, ECO Plastics is going to be the world’s largest plastics reprocessing facility. The plant will save about 33, 5000 tonnes of carbon dioxide per Annum that is the equivalent of taking 15, 715 cars off the road. Source: www. defra. gov. uk

Taiwan

EPATaiwan is planning to excavate about 400 landfills for energy and material recovery, additionally, add bio-energy capacity to its incineration facilities. Environmental Protection administration (EPA)TaiwanSource: www. epa. gov. tw

Australia

Department of Sustainability, Environment, Water, Population and Communities

Stewardship Bill have been introduced by the Australian government and of the aim of helping to manage the environmental, and human health. This will demand manufacturers and importers of computers, and TVs to fund and implement national collection and recycling of these products. Source: www. environment. gov. auExample of failure of advanced waste management systems: The increasingly recognized problem of plastic floating landfills. A closer view of the possible land-based resources includes Japan and the USA that considered being advanced waste management areas compared to the vast majority of the world. In According to the Waste Management World (2012), the down turn of recycling programs due to the global recession is proof of the market’s incapability when it comes to sustaining recycling, recovery activities, and additionally suggested a need of another type of global cooperation with strong environmental governance to provide a different framework for market-driven actions.

Summary

To summarise this section, the chapter has attempted to cover objective one by reviewing related literature to identify environmental issues that relate to

the waste management of plastic. These were using options of landfill, Incineration, Pyrolysis and Recycling. It seems clear from review that a major drawback to landfills, considering a sustainability aspect is that the material resources used for production of the plastic is recovered, and the flow is linear rather than cyclic. Incineration reduces the need for plastics waste landfilling; however, hazardous substances may be released into the atmosphere in the incineration process. Furthermore, review helped to identify the gap in the available literature on pyrolysis. On the balance, evidence suggests that one of the main benefits of recycling of plastics is to reduce the production and requirement of virgin plastic . Importance of issue around environmental impacts: climate change, depletion of natural resources, energy consumption and water demand was explained. Also identified the unique policies, measures and levy that are being implemented, used internationally. It is certain that, there is increment in public awareness for sustainable production and consumption is a vital issue. Local authorities should be encouraged to organize the collection of recyclables and encourage manufacturers to develop products with recycled content. Finally, need to identify environmentally sustainable plastic waste management method was noted. Further chapter will discuss adapted methods for this study and its significance and limitations in details in order to cover objective two.

Methodology

Following on from the literature review this section explains how there will be analysis taking place in this section. Methodology for this dissertation is explained bellow covering objective two to compare plastic waste

management methods to find environmentally better option for waste plastic. To do this, the methods used by a number of key researchers and organisations dated 2004 and 2006 by Villanueva et al in an analytical review of existing LCA studies, with Technical University of Denmark and Danish Topic Centre on Waste. European Commission and the Intergovernmental Panel on Climate Change (IPCC) research report (2012 & 2011), United Nations (2010) report on Waste and Climate Change. WRAP (2006) followed the same methods in an international review of life cycle comparisons for key materials in the UK recycling sector to find whether recycling is environmentally beneficial as compared to alternative waste disposal options by reviewing existing international LCA studies for plastic waste. The guidance for the selection criteria of existing studies for this dissertation based on WRAP (2006) research report. In Literature review, the importance of the policies by organisation like UNEP, US EPA was mentioned, and these are informed by a number of LCA studies confirming that information is shared.

Research questions in connection with aim and objectives

A primary research question was developed to discover the best probable plastic waste management method. What is the environmentally sustainable method for plastic waste disposal? Author has adapted an approach to reviews of previous LCA studies to find the answer to research question. Restricting selection and review criteria for existing LCA have been developed. On retention of LCAs, the Meta- analytical methodology is used to synthesize LCAs results and to compare and/or combine outcomes of different LCAs with similar characteristics. Meta analytical method helped

identify the data sample and allocate the same in category system that allowed all of the data to be categorized systematically. Once sample was codified and categorized, statistical analysis was used to derive mean from the data sample. The decision to use a meta- analysis approach originated from United Nations Development Program (UNDP) report on review of past LCA using Meta analysis (2012). however, LCA selecting criteria were not set in UNDP research. It is also explored in an issue of Journal of industrial Ecology (2012). this issue includes 12 high quality meta analyses and critical review of LCAs furnish understanding of environmental impacts of various technologies.

Meta Analysis:

The applications of meta-analytical methods are used to synthesize results from a body of previous researched LCA. Meta-analysis, a term coined in 1976 by Gene V. Glass, an American statistician (Lifset, 2012), Met analytical method refers to techniques used to combine and synthesize the results of multiple studies and widely used in sophisticated statistical methods of combining evidence in the studies such as biomedical, psychological, and educational research. Greenland and O'Rourke (2012) noted that this method focuses on combining and contrasting results from various studies, sources of disagreement among those results, or other intriguing relationships that may become known in the context of multiple studies (p. 652). The research design of this study followed the steps for qualitative research meta synthesisOutlined by Moody (1990) (a) delineate the domain of study. (b) Define admissible studies; (c) locate studies.(d) Code and classify study variables.(e) Determine a common scale or metric. (f) Analyze

across studies. (g) Interpret and report results. (h) Explicate theory and research outcomes. (i) Inform and project future research trends. Meta synthesis outlined steps as follows (a) delineate the domain of study, (b) define admissible studies, and (c) locate studies are covered in the following part where LCA selection criteria are discussed in details.

Framework for the selection and assessment of LCA studies

Process fall in to two main categories and explained: 3. 1. The criteria used to select the LCA studies3. 2. The criteria used to review the selected LCA studiesFollowing section explains each criterion that is used to select the LCA studies:

3. 1. The criteria used to select the studies

3. 1. 1 The research had to be an LCA

LCA believed as the most reliable method for analysing the environmental impacts of services and products (UNEP, 2012). It was difficult to locate adequate number of studies due to this restricting criteria. In accordance with the standard ISO 14040, the LCA contains four interrelated phases as gave in the figure 3. 2 below. All selected LCAs fall in to this framework. Goal and Scope DefinitionDInventory AnalysisImpact AssessmentInterpretationFigure: 3. 2 LCA Framework and applications according to ISO 14040

3. 1. 2 The LCA should include a comparison between waste management options.

The original purpose of a comparative LCA is to reflect the environmental impacts of choosing one option over another. This criterion was conditional

one, effect of which some of the studies with high qualities and interest had to be disqualified from the selected LCA studies list. However, it also ensured the overall quality of the study.

3. 1. 3 No ambiguity in the method encounters are assigned to selected material type

Present study is based on plastic waste; therefore it was necessary to select studies evaluate plastic as a waste material rather whole MSW result of which high quality studies comparing the end of life options for whole MSW had to excluded.

3. 1. 4 Reasonability of the waste management options

Plastic waste management options concealed by the scope of this research are those commonly used in the UK: Recycling, Landfilling, Incineration additionally Pyrolysis, which is relatively new method even for UK. The following section explains each of criteria that are used to review the selected data sample.

3. 2. The criteria used to review the selected studies

3. 2. 1 Transparency in the assumptions made and functional unit

Every study has different assumption made in it, hence variability in result Assumed ratio of recycled plastic with virgin plastic; generally, assumed ratios are 1: 1 or 1: 0. 5. European Union (2012) in science for environmental policy confirmed that it is extremely common for LCA studies using the same kind of system but leading to disparate conclusions due to different assumed ratio. It is essential to understand the key parameters that can explain

variation in conclusions from one LCA to another and the transparency of the assumptions made was therefore believed as immensely significant aspect in the process of selection of the data sample. At the time of review author, addressed the lack of transparencies in assumption made in many existing LCA research and lead to the elimination for those studies from the present research. The transparency of the assumptions made was therefore believed a crucial aspect in the process of selection of the data sample. Across the selected LCAs, the assumptions found to be most critical to the conclusion were those that connected to the interdependency among waste handling and the energy arrangement of the encircling techno sphere including. The kind of energy utilized for the production of previous materials; the kind of energy utilized for the production of secondary product from reprocessed and recycled Materials; the kind of recycling technology applied. Table 3. 1: Key system boundary issues in the LCAs (In terms of Plastic)

Material production

Virgin Plastic Production

Marginal. Specific / Average? Electricity: which? Coal, gas, oil, other? Steam: which? Biomass, coal, gas, oil, other? Dealing with Co-products? Allocation?

Secondary material

Marginal. Specific / Average? Electricity: which? Coal, gas, oil, otherSteam: which? Biomass, coal, gas, oil, other? Dealing with Co-products? If the answer is yes: allowance? By expanding the scope of the system?

Material recovery

Product dependent material recovery included. Yes/noProduct type depends on the recovery of materials

Material disposal

Disposal method compared to e. g.: recycling vs. incinerationLandfill Discharge Considered. Whether heat substituted from Energy recovered from incineration? Used electricity is substituted from Energy generated from incineration. Considered? Alternative use of incineration included? Considered ? Used ratio between recycled material and virgin material? (1: 1 or 1: 0. 5 or other)Source: Wrap, 2010

3. 2. 2 Reasonability of environmental impact indicators categories.

Priorities given to LCA's assessing–Climate Change, Depletion of natural resources and Energy Demand; they were assessed in WRAP's original research; however, Water consumption is added in the present research. Whereas As Climate Change is of the highest interest, this impact category is given specific attention.

3. 2. 3 Data age and quality

It was necessary to choose LCAs studies published in the period from 2001 to 2012. It was not until the mid 1990's that the very first methodological articles explaining key issues in material recycling LCAs were published Amato et al., 1996, or Ekvall, 1996 for instance. The LCA methodology has been uniform by the International Standards Organization (ISO). ISO produced a series of standards in 1997/98, revised in 2006– ISO 14040: 2006

outlining LCA principles and framework– ISO 14044: 2006 for requirements and guidelines in addition to use the ISO standards LCAs should be critically reviewed by LCA experts to technically and scientifically validate used methods and conclusions before they are disclosed to the public. Therefore ISO standards guarantee the transparency and quality and selected studies meet all above mentions criteria and employed publication strictly choose LCA studies with ISO standard, Except for some studies published by recognised organisations such as US EPA, for example. The fulfilment of the ISO 14040-series was required for the LCA selection. It is most likely that the results of the studies published before 1997/98 did not consider key methodological questions involved in recycling LCA, and therefore their quality of results are questionable.

3. 2. 4 Types of Publications

In order to select suitable publications and relevant for assessment, a catalogue of selection criteria was established. Search of LCAs was carried out by employing following origins of publications and information centres and International scientific databases and journals: Springer, Science Direct and International Journal of Life Cycle Assessment. Publications by relevant worldwide organisations in the life cycle assessment and waste management: WRAP, Bio Intelligence Services (BIOIS) own databases and National Environment Protection Agencies. The broad internet search was performed using search engines, such as Google, Google Scholar, AltaVista and Cardiff Metropolitan Universities electronic library. In parallel, homepages of environmental institutions were searched in this step, especially EPAs in North America, Australia and Europe. EPAs were searched

specifically because many of their publications are not accessible via Internet search machines. At the same time, researcher experienced that national EPAs are potential commissioners of large LCA studies. Having considered each of selection criteria and their apprehension, they were then applied in the selection of LCA process result of which total sum of 11 LCAs were retained. The following table represents selected LCA studies along with their title, author, year of publication and country name. Table 3. 2 Presentation of the selected studiesIt can be perceived from the above table that the analyzed LCAs studies enclosed various countries. 8 out of the 11 studies have been published after 2006. The two studies from 2000 and 2001 have been encompassed even though their period as they were meeting all the restricted criteria. Sidman (1960) in Tactics of Scientific Research noted that good data can always be separable, regarding to their scientific importance and the purposes for which they are acquired (p. 428). upon selection of LCAs next step was to codify and categorize the data sample. The following part explains (d) Coding and classification (e) determine a common scale or metric, (f) analyzes across studies and discussed in details.

3. 3 Coding and Classifying Study Variables

The next step in the meta-analysis process was to identify those variables that were of potential interest and to code these variables in a manner that allowed for statistical analysis. Stock (1994) informed importance of items for selection of codes based on substantive as well as methodological considerations. However, many of these considerations only become apparent as a study progresses and as the Author becomes increasingly

familiar with the domain of inquiry and the statistical challenges that need to be addressed. In the present study developing a codebook is an iterative process that develops throughout the data collection phase of the study design. Results of previous studies are grouped together in a database, according to differentiating characteristics. Each LCA has been given numbers such as N01, N0 2 etc, The types of plastics assessed are PE, HDPE, LDPE, PET, PP, PS, PVC and a mix of plastics types [MIX] in overall selected studies. If study number 3 assesses PET and PVC plastic types, then the cases will be represented as follow study NO [assessed plastic type] e. g. 3[PET] and 3[PVC]. Finally, 27 cases were retained. Using cases data scenarios table have been formed, where cases have been categorised with respective of waste management methods. Sums of 65 scenarios were retained. The following part explains (f) analyzes across studies ; (g) interpret and report results; (h) explicate theory and research outcomes, and (i) project future research trends discussed in details.

3. 4 Statistical Analysis of data

On retention of 65 scenarios estimates are assumed a function of these scenarios and their effects are assessed by the mean of specific statistical methods using Microsoft excel 2010. Statistic is the study of data. In statistic descriptive data, method is applied to interpret data. In this study, results will be presented in the histogram and graph form using. The outcome of that statistical analysis provides mean effect size. Throughout the statistical analysis section, comparisons between all waste management methods have been taken place under each environmental impact indicator; Climate Change, for example, 1) Scenarios that compared recycling to incineration,

landfilling, pyrolysis2) Scenarios that compared landfill to recycling, incineration pyrolysis3) Scenarios that compared incineration to recycling, landfilling, pyrolysis4) Scenarios that compared pyrolysis recycling, landfilling, incinerationSimilarly, calculations have been performed for depletion of natural resources, energy demand and water consumption.

3. 5 The limitations of the study

Access to the information for pyrolysis was limited, The reason being that pyrolysis is a relatively new method. Author also noticed water consumption environmental indicator was ignored by researchers despite it is one of the significant environmental impact categories. It was extremely difficult to codify the findings of each LCA in order to bifurcate each waste management method in best, intermediary or worst option. Author experienced limitation related to qualitative study concerning reliability and testability because casual references cannot be made since author cannot rule out alternative explanations as Wiersma (2000) noted that it is difficult to replicate studies (p. 211). Every effort has been made to search the content on overall research processes and especially meta-analysis procedure. However, the author is aware as Strauss and Corbin (1990; 1998) pointed out that as a novice, mistakes can be made.

Summary

This section attempts to cover objective two by setting up a research framework. Research questions link with aim and objectives were furnished. Explained and justified the qualitative approach and Meta analysis research design, including the adapted criteria for selection and review of the LCAs, following by list of selected eleven LCAs table were presented. Meta analysis

background and significance of adapting Meta analytical methods were informed. LCA classification, codification process and categorized variables explained in details followed by the data analysis components of the study. Significance of adaptation of secondary data in this study was explained. The role of the author was informed. Finally, the author articulated and discussed the limitations of this study. The following section will use above set methodology to analyze the data sample which will lead to the formation of findings and conclusion of this research.

Data Analysis

The following part presents coding and classifying of study variables. Table 4. 1 bellow provides an overview of the waste management alternatives compared within each study forming different number of cases. This table only shows the bifurcation within the assessed plastic types and relative ranking of the waste management solutions forming cases. Table 4. 1 Overview of the waste management alternatives compared within each study case for plastics

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In 4. 1, table, 27 cases have been discovered along with indication of each waste management method that are evaluated with 11 LCAs. When particular method that is not studied or taken in to a specific number of study is indicated as N/A. Additionally, cases denoted by (*) feed stock recycling are that studies were feedstock recycling(instead mechanical) were compared with alternative waste management methods. This table is not final codification but helped towards forming and bifurcating variables for data research. Table 4. 2 bellow compares the ranking of disposal options

within each environmental indicator. It shows the relative ranking of the different waste management within a given case study. Landfilling, for instance, have emerged as the best option in study number 5, it is denoted with +++, and if the study number 5 have also assessed recycling and incineration, result shows intermediary and worst option respectively it is denoted as Recycling ++ and + respectively with respect to a particular case. Table 4. 2 compares the ranking of disposal options within each scenario for different plastics types. The overall 65 scenarios derived from 11 studies. Several studies were oriented from assessment of mixed plastic types with various environmental effects. The climate change and energy demand indicators were the most assessed indicators among the selected studies, and almost all analysed LCAs included these two indicators. However, Depletion of natural resources was also included relatively often; however, the water consumption indicator was included in only two LCAsStatistical analysis performed by using the above table no 4. 2 and the results are presented in histograms and pie chart form for each environmental indicator assessing each waste management method. In Graph, ‘ X’ axis represents the number of assessed scenarios whereas ‘ Y’ axis represents each method’s performance with respect to that indicator. A pie chart shows each waste management methods performances with respect to accessed environmental indicator. Following part presents results of compared four waste management methods under the heading of four environmental indicators. Interpretation of the results will take place now in the following part where histograms and pie charts will be analysed alongside any parameters that are affecting the results will be informed.

4. 2 Interpretation of analysed data

Results of comparison between four waste management methods carried under each environmental indicator is explained. This section analyses and interprets the results. Additionally, informs which one of the method has emerged as a better option in assessed indicator. More importantly, informs factors that might have affected the end results.

4. 2. 1 Climate Change:

Recycling shows obvious benefits over alternative methods. It emerged as the best option within 25 out of 29 scenarios. Fewer benefits for recycling in the case 3[MIX] as compared to pyrolysis purely because it is almost impossible to recycle plastic mixed types, whereas it is accepted in pyrolysis process. 86 % of scenarios elected recycling as the best option. When compared with the incineration the less recycling benefits for case 11[PVC] because the fact it is hard to recycle comparing other plastics types. When recycling compared with landfill, recycling is 100% better as showed in about 89% of the cases (16 out of 18 cases). Comparison between recycling and pyrolysis concludes that recycling is better for Climate change indicator. It concluded that incineration proves to be worse option, and landfill is better than incineration in 67% (i. e. 10 out of 15 cases). For climate change, Recycling has emerged as the best option whereas pyrolysis is intermediary option. However, landfilling performs better than incineration because of plastic’s characteristics of slow degradability.

4. 2. 2 Depletion of natural resources

In this indicator, recycling performs 100 % better than the alternatives. Pyrolysis shows fewer advantages when compared with recycling. Landfilling emerges as the worst option in all the scenarios. Difference is the highest for Landfilling while the benefits of recycling over pyrolysis are lower. When comparing incineration with other alternatives. Four cases pyrolysis appear more advantageous than incineration. However, in the study N0 11, landfill presents more benefits than incineration. Reason being lower heating value of PVC and PET, where as it is higher in other types of plastic that are analysed in study N0. 11 for PE, PP and PS. For depletion of natural resources, recycling elected as the best option. Expectedly, landfilling emerged as the worst option when compared with alternatives. Yet again pyrolysis has come up as an intermediary option followed by incineration.

4. 2. 3 Energy Demand

The majority of analysed scenarios are in favour of recycling, three cases accredit benefits to incineration. In the comparison between incineration and recycling, though the most of analysed scenario elected recycling as the best option, three cases assign an advantage to incineration. Reason being technology used for sorting and recycling required extra energy. Results categorically shows that, why incineration performs better than landfill . however Pyrolysis performs better than incineration. Though, Landfill has low energy demand receives fewer credits for avoided production. For Energy demand indicator, recycling is the best option. Pyrolysis and incineration are intermediary option. Again landfilling has emerged as the worst option.

4. 2. 4 Water Consumption

This indicator is assessed by only two LCA that are N0 9 and 10. Whereas, N0 9 showed the comparison of recycling with all the alternatives; however, it only assesses plastic Mix type. The overall result of N0 9 represents recycling as the best option. Incineration and pyrolysis are intermediary. It signifies that recycling and pyrolysis consume less water. Whereas N0 10 compares of recycling with landfilling only, however it assesses three types of plastics The study N0 10 conclusion fluctuates depending on the plastic types. Recycling is better for 10[PVC], not for 10[PET], and 10[PE] reason being contamination is high in both the plastic types. In the recycling of PET and PE, use of water is high, due to washing of contamination in collected plastics, due to this reason water use is higher in recycling than the use of water in avoided virgin plastic production. Whereas PVC requires more quantity of water for production. For water consumption indicator, surprisingly, landfilling emerged the best option. Pyrolysis and incineration are intermediary option and recycling is emerged as worst option. Following table shows the best and worst option within all the reviewed LCAs under each studied indictor. 4. 3 Overview of the best and worst option for managing plastic waste based on the results of the LCA studies. Above table evidently shows the maximum number of reviewed LCA in studies support recycling as the best option and landfilling is the worst option for three environmental indicators that are climate change, depletion of natural recourses and energy demand. However, landfilling elected as the best option and recycling as worst option for water consumption.