Journal of Cleaner Production 124 (2016) 41–50

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

A comprehensive study of the environmental and economic benefits of resource recovery from global waste management systems

Atiq Uz Zaman

School of Built Environment, Curtin University, Australia

A R T I C L E I N F O

Article history:
Received 2 December 2015
Received in revised form
18 February 2016
Accepted 18 February 2016
Available online 26 February 2016

Keywords:
Municipal solid waste
Global waste management
Environmental benefits
Economic benefits
Resource recovery
Zero waste index

A B S T R A C T

This study analyses the municipal solid waste management system of 172 countries from all over the globe with a population of 3.37 billion. This study indicates that we generate around 1.47 billion tonnes (436 kg/cap/year) of municipal solid waste each year and waste generation is increasing over time. This study also found that there is a positive correlation ($r = 0.539$, $p < 0.05$) between per capita income gross domestic product(GDP/capita/year) and per capita waste generation (kg/capita/year) and a similar correlation is also observed ($r = 0.653$, $p < 0.05$) between per capita income (GDP/year) and per capita resource recovery (kg/year). The findings of this study show that globally, about 84% of the waste is collected and only 15% of the waste is recycled and most of the global waste was still managed by landfills. This study tries to measure the environmental benefits of global waste management systems by applying a tool called the Zero Waste Index (ZWI). The ZWI measures the waste management performance by accounting for the potential amount of virgin material that can be offset by recovering resources from waste. In addition, the ZWI tool also considers the energy, greenhouse gas (GHG) and water savings by offsetting virgin materials and recovering energy from waste. The ZWI of the world in this study is measured to be 0.12, which means that the current waste management system potentially offsets only 12% of the total virgin material substitution potential from waste. Annually, an average person saves around 219 kWh of energy, emits about 48 kg of GHG and saves around 38 l of water. The global municipal solid waste management systems potentially contributed around $201.5 billion or around $60 per person of economic benefits annually.

1. Introduction

The history of waste management system is not new, on the contrary, it has begun during the early time period of human civilization (UNEP/GRID-Arendal, 2006; Zaman, 2015). Over time, various social innovations as well as technological innovations took place. Despite of the advancement in technological development for waste treatment and management, we still fall far behind in achieving the very fundamental sustainable waste management goals: avoidance and reduction of waste generation (King et al., 2006). Global waste generation rate is constantly increasing and it is projected that the generation of waste will continue to increase until its global peak as far off 2100, unless any aggressive sustainability measures are implemented (Hoornweg et al., 2014).

According to a study, the 'end-of-life' solid waste contributes only 5% of a product's overall environmental impacts (Hoornweg and Thomas, 1991). However, the overall environmental impact would be greater if the considerations of the environmental impacts during the resource extraction are taken into account. It is estimated that around 71 tonnes of 'upstream' materials are used for every tonne of municipal solid waste (MSW) (Liss and Christopher, 2012). Therefore, material recovery from waste significantly offsets the 'upstream' environmental burdens. This benefit was recognized by Frosch and Gallopoulos and they emphasized the importance of a new industrial system that would eliminate and reduce waste production (Frosch and Gallopoulos, 1989 cited in Hoornweg et al., 2014). The idea of elimination of waste from the production process has been developed, practised and evolved over time and is currently known as zero waste philosophy.

Zero waste (ZW) is one of the most studied topics in the past decade and at the same time it is also one of the most debated and controversial areas of discussion amongst recent developments in waste management. In spite of some strident critique, the concept continues to be embraced by individuals, families, communities,

E-mail address: atiq.zaman@curtin.edu.au.

http://dx.doi.org/10.1016/j.jclepro.2016.02.086

businesses and local governments in many cities and countries around the globe. Currently, many zero waste programs, policies and strategies are implemented in many places around the globe.

The concept of 'zero waste', as defined by the Zero Waste International Alliance (ZWIA), is 'designing and managing products and processes systematically to eliminate the waste and materials, conserve and recover all resources and not burn or bury them' (ZWIA, 2013). It is understandable that the zero waste concept recognizes the core problems of waste which is a 'design and system' problem rather than a management problem. Thus, it advocates prevention of waste rather than its treatment. Zero waste does not see 'waste' as a material that must be disposed of or incinerated, but considers waste as a resource that should be used again (Glavič and Lukman, 2007). Therefore, the zero waste concept directly challenges the common assumption of waste as a valueless and unavoidable by-product that is created at the end of product's life phase.

Zero waste differs with the concept of waste as an 'end of life' product, instead, it extends the understanding of 'waste' as a 'resource' which produces during the intermediate phases of production and consumption activities, and thus, it should be recirculated to production processes through reuse, recycle, reassemble, resell, redesign or reprocess. This implies that zero waste – as a concept – is a target for transforming waste management systems towards a 'circular economy', where extraction, production and consumption become increasingly waste free. Zero waste is an aspiration, a goal and a target to transform our common understanding on waste and achieve the holistic sustainable waste management goals. It means that waste produced in a 'zero waste society' would be treated as a 'resource in transition' which will be returned back to the production and ecological systems. As a result, there will be no waste for landfills or littering. According to the waste hierarchy, waste avoidance and reduction is the best waste management policy at up-cycling stage. At 'down-cycling' stage, resource recovery from waste through recycling and advanced waste treatment technologies is the key issues in sustainable waste management. Resource recovery in the form of material, energy or fuel from waste, not only contributes directly to fulfilling and offsetting the resource demand of our society, but also saves energy, water and avoids greenhouse gas (GHG) emissions. In addition, these resources have economic benefits. Therefore, it is important to understand and measure the environmental benefits as well as economic benefits of the waste management systems.

Given the current waste management scenario, this study intends to analyse waste management performance on a global scale. The aim of this study, is to evaluate the environmental and economic benefits of resource recovery from the municipal solid waste management systems. The study applies an evaluation tool called the Zero Waste Index (ZWI), developed by Zaman and Lehmann (2013) to measure the global waste management performance. The waste data of 172 countries (urban waste data in some cases) are analysed to evaluate the global waste management performance by considering the potential material recovery and resulting the energy, water and greenhouse gas savings from waste. In addition, the study also considers the economic benefits of the global waste management system. Therefore, the aim of this study is to analyse and assess the global municipal solid waste management systems with specific focus on environmental performances and economic benefits.

2. Previous studies

The literature review of this study is conducted by focussing on two research aspects (i) global waste management performance in the context of waste collection and treatment methods in a global context, and (ii) global waste management performance in terms of resource recovery and environmental benefits. The following sections analyse findings from a number of previous studies.

2.1. Global collection and management of waste

Studies on municipal solid waste collection and treatment in a global context are limited as there is a lack of accurate and reliable data on municipal solid waste management systems. Waste data often possess poor reliability and accuracy as the definition of municipal solid waste varies in different countries and thus the data on waste management systems would also vary in terms of homogeneity. The data on waste management systems in the developing countries are very limited and often only refers to the waste management systems in capital cities. Waste management systems mostly rely on informal waste management systems in the developing countries; however, there are no accurate data on how much waste is managed by the informal sector except educated guesses. The waste data in the developed countries are available but still lacks accuracy in terms of homogeneity. Therefore, global initiatives on accurate waste data collection and analysis are urgent in terms of better understating waste management systems in a global context.

A study conducted by the UNHABITAT in 2010 on waste management systems in 22 cities around the globe found that an average person in reference cities produced around 343 kg/year, which was equal to around 2.2 billion tonnes of municipal solid waste each year globally (UN-Habitat, 2010, p.13). The study also forecasted that if waste is generated at the average OECD (the Organisation for Economic Co-operation and Development) rate (580 kg/cap/year) the world would produce 3.8 billion tonnes of municipal solid waste. Waste management performance in the global cities was analysed by considering eight different indicators such as collection coverage, controlled disposal, waste captured by the system, material prevented and recovered, provider inclusivity, user inclusivity, financial sustainability and institutional coherence (UN-Habitat, 2010, p42).

A comprehensive study of global waste management systems conducted by the World Bank in 2012 showed that globally about 1.3 billion tonnes of municipal waste is generated in urban areas and it will increase to 2.2 billion tonnes by 2025 (Hoornweg and Bhada-Tata, 2012). About 145 countries were considered in the analysis of waste management systems. Countries were categorized in this study according to four different income levels (gross domestic product-GDP) (shown in Table 1): high-income country (HIC, GDP = more than $12275/cap), upper middle-income country (UMIC, GDP = $3976–$12275/cap), lower middle-income country (LMIC, GDP = $1006–$3975) and low-income country (LIC, GDP = less than $1005).

The World Bank's study also found that the waste composition varied amongst different income groups. The proportion of organic waste is significantly high, around 64% in low income countries and comparatively low (28%) in high income countries. Table 2 shows the composition of municipal solid waste in different countries based on their income level.

Countries from the low and lower middle-income groups were mostly dependent on the unsanitary waste management systems such as open dumping and landfills. High-income countries mostly rely on sanitary landfill and incineration. Formal waste recycling services are only available in the high-income countries with a recycling rate of 22% and very low recycling rates (less than 3%) for countries from other income groups. Table 3 presents the average waste management methods in different countries.

A recent study conducted by Hoornweg et al. (2014) on forecasting the 'global waste peak' suggested that the peak waste