Municipal solid management: an overview

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ABSTRACT: The quantity of waste produced worldwide is constantly increasing. Management of municipal solid waste (MSW) is getting increased attention from local authorities and agencies at national and international level. It is estimated that the municipal solid waste (MSW) produced globally exceeded 2 billion tons per year at the turn of the millennium, although there is controversy regarding the reliability and consistency of waste data. This increase is inherently connected to the world population, which continues to rise with projections, according to the United Nations Environment Programme (UNEP), nearing 7.2 billion by 2015 [1]. The management of the increasing masses of waste has become a specialised and complex activity that needs to be well organised. The focus of the present research is on MSW and an overview of the current situation on waste development and waste disposal options. The case of Greece will also be presented. The article will further examine waste management practices and models that are the current trends and limitations, and will briefly discuss the potential impacts of waste management activities on health.

INTRODUCTION

The quantity of waste produced in the world has increased considerably over the past decades, especially in wealthy countries. The connection between the national gross domestic product (GDP) and waste generation per capita further supports this argument [2][3]. It is estimated that the municipal solid waste (MSW) produced globally exceeded 2 billion tons per year at the turn of the millennium, although there is controversy regarding the reliability and consistency of waste data [4]. Naturally, the world population is inherently connected to this increase. The world's population is projected to reach approximately 7.2 billion by 2015 and, by 2025, it is estimated that two-thirds of the world's population will be living in cities [1]. Waste management was one of the issues at the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil in 1992. More specifically, it was agreed by 178 governments that there is need for more sustainable municipal solid waste management in both, developed and developing nations. Chapter 21 of Agenda 21, the Rio Declaration on Environment and Development, summarises the environmentally sound management of solid wastes, which includes among others, maximising waste re-use and recycling. Urban populations in developing countries grow by more than 150,000 people every day. Although in essence there is nothing against urbanisation, unsystematic and unplanned growth can result (as it has already) in environmental problems, such as air and water pollution and solid waste generation [5].

Medina has noted that when an increase in income is noted in a city, the consumption patterns of people change [6]. As a result the waste type and quantities change and produce an obstacle, which the municipalities have to overcome. Further to that, the characteristics of waste material evolve in line with changes in lifestyle, and the number of new chemical substances present in the various waste streams increase dramatically. According to Wang and Nie, municipal solid waste is the most complex form of solid waste – much more complicated than the waste derived from industrial or agricultural activities [7]. According to the European Environment Agency, municipal waste constitutes only around 15% of the total waste generated in 25 countries of the EU, but because of its complex character and its distribution among many waste generators, environmentally sound management of this waste is complicated. The management of the increasing masses of waste has become a specialised and complex activity that needs to be well organised, although the UNEP argues that if waste is considered as a resource, and it is managed properly, then the whole process can become less complicated [5].

Naturally, the volume of waste generated differs from country to country, and the collection of the pertinent data is a difficult task. In 2006, the 15 countries of the European Union (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Ireland, Luxembourg, Netherlands, Portugal, Spain, Sweden and UK) generated 219 million tons of MSW, or 560 kg/yr/capita [8][9]. In the USA in 2006, more than 228 million tons were produced of MSW, or 760 kg per capita [8-10]. The quantity of MSW generated in the OECD area in 2006 was more than 619 million tons, or 580 kg per inhabitant [8][9]. China and India are still lower (production per capita is less than 0.5 kg/day/capita in India and

less than 0.9 kg/day/capita in China compared to most OECD countries i.e. up to 2.1 kg/day/capita in the USA). The above observations are illustrated graphically in Figure 1 and Figure 2. However, as China and India become gradually more industrial, their populations will urbanise. More than 1 billion tons of industrial waste (about five times the amount of MSW) was produced in China in 2002, mostly mine tailings, coal ash, and slag, and by 2030 China is expected to generate approximately twice as much municipal waste as the USA, while India will overtake the USA [11]. Guisti argues that even in the case that a low waste generation scenario is assumed, the amount of MSW generated in 2030 would still be close to twice the waste predicted to be produced in the USA [12].

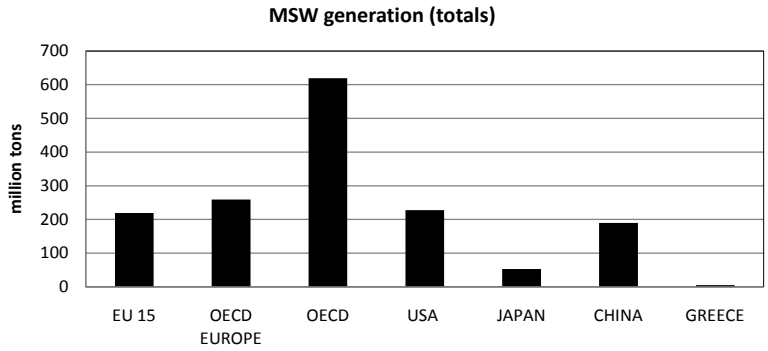

Figure 1: MSW generation in selected countries per year [8][9][11].

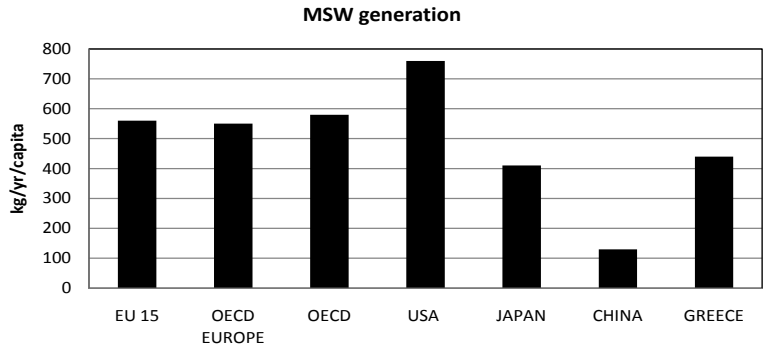

Figure 2: MSW generation in selected countries as kg/yr/capita [8][9][11].

WASTE MANAGEMENT PRACTICES

A number of guidelines have been introduced to deal with hazardous and unsustainable waste management operations. In a waste management hierarchy the most environmentally sound criteria are the following: waste reduction and re-use, waste re-use, recycling and composting (Figure 3). It is clear, however, that at present in many countries, a large percentage of waste cannot be re-used, re-cycled or composted, and in this case the main disposal methods end up being landfilling and incineration.

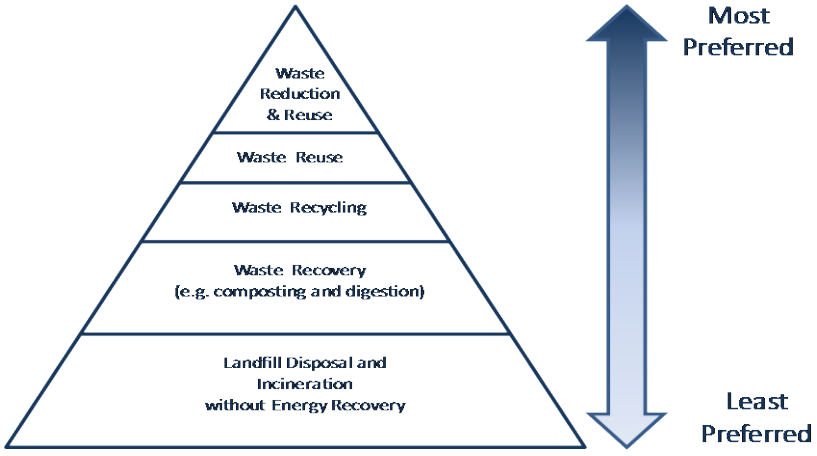

Figure 3: Waste management hierarchy.

In Europe, the main disposal method is landfilling. Recycling, however, is increasing overall in Western Europe and, according to the European Environment Agency, municipal waste contains many materials for which recycling is

environmentally beneficial. More specifically, the rate of MSW landfilling has been decreasing (1995, 67%; 1999, 57%) although it can be said that it still remains at high levels. In 2000, in Western Europe, incineration of MSW was approximately 18%, whereas recycling of MSW reached 25%. When Central and Eastern Europe are examined, then the data are far more encouraging, (1999, 83.7%) [13]. In Central and Eastern Europe incineration and recycling was 6% and 9%, respectively [14]. Figure 4 and Figure 5 illustrate the amount of MSW disposed of in certain countries and the waste management practices used respectively. Although the data used refer to slightly different years (see Table 1), comparisons can be achieved.

Table 1: Year of publication of MSW data.

USA	2005
Japan	2003
Grecee	2003
France	2005
Germany	2004
Italy	2005
UK	2005

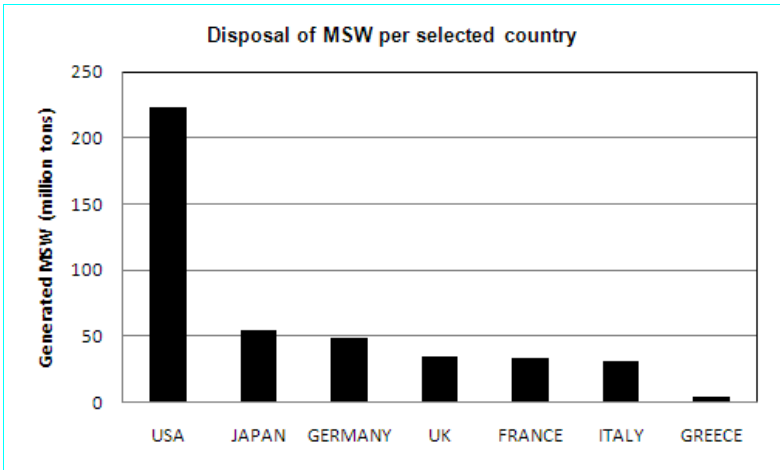

Figure 4: Disposal of MSW in selected countries [8][9].

The percentage of MSW disposed at landfills accounted for 3% in Japan, 18% in Germany, 36% in France, 54% in Italy and the USA and 64% in the UK. Besides the practical obstacles of landfilling, it is the legislation that makes it a less cheap option, forcing authorities to consider alternative solutions. For example, in the UK and Italy, there has been a significant reduction in the amount of waste landfilled [12]. In 1995, the UK landfilled 83% of MSW, whereas Italy landfilled 93%. Incineration on the contrary is quite popular in Japan with 73%, France 34% and Germany 25%, whereas in the USA it is not as common, with a rate of 14%. Composting is quite favoured in Italy with 33%, and less used in France, Germany, and even less used in the USA, Japan (8%, 6% respectively). Lastly, recycling is used in the USA at 24%, in Germany at 33%; it is not being used at all in Italy (or at least there is no available data of such use) and, it is being used in Japan and France (17%, 16% respectively). The results for Greece are discussed further below.

According to Troschinetz and Mihelcic, solid waste destined for landfills can be diverted to other practices, such as incineration with energy production, composting of organic wastes and material recovery through recycling [15]. According to Giusti, knowing the waste composition is of vital importance for the choice of waste treatment and disposal [12]. For example, in the case of organic material, incineration is not an option, due to its water content. Waste separation at source allows the removal of hazardous (flammable, toxic) items, better recycling and composting options, and a reduction of MSW to be disposed of. Methods such as incineration, composting and recycling potentially can be more sustainable in terms of MSW management, rather than the traditional landfill. The argument, however, that has been raised by Troschinetz and Mihelcic is that all these methods have disadvantages as well [15]. For example, incineration for energy recovery can be both, a costly method for many communities in the developing world and poses societal and environmental health risks, if misused (e.g. dangerous air pollution can be produced by burning toxic wastes). Alternatively, recycling can show a much more positive energy balance than incineration [16]. On the contrary, a recycling programme (compared to other solutions) may not be as economical, if the prices of recyclable materials are low.

Many communities and regulatory agencies respond to the arguments above by considering a v ariety of waste management strategies, including voluntary and mandatory recycling programmes, source reduction programmes and alternative waste processing options. The specific objectives of each group for implementing waste management plans depend on site-specific conditions and issues. Guisti, for example, argues that every country before adopting a waste management practice should examine both, economic factors and also technical means due to the type of waste to be handled [12]. A simple example is the following. Assume that a country uses coal burning for heating purposes, and

naturally, the coal ash generated can be disposed of with other urban waste. However, coal ash contains high concentrations of heavy metals and other potential contaminants that make composting difficult and, similarly, incineration becomes less efficient, when coal ash is within the waste. In this case, it may be worth considering a change of energy source, from coal to gas to improve the waste management options.

Solano et al discuss further that the most appropriate choice for managing municipal solid waste is not always clear [17]. For example, recycling, in general, aims to reduce consumption of natural resources and conserve some processing activities at manufacturing facilities. Whether these savings realistically compensate for the environmental burdens associated with the additional collection activities, as well as energy consumption at waste recovery facilities associated with recycling is still not clear. Typically, the net benefit, if any, of each waste management alternative with respect to environmental issues, is not well characterised, making it difficult to select an environmentally beneficial choice.

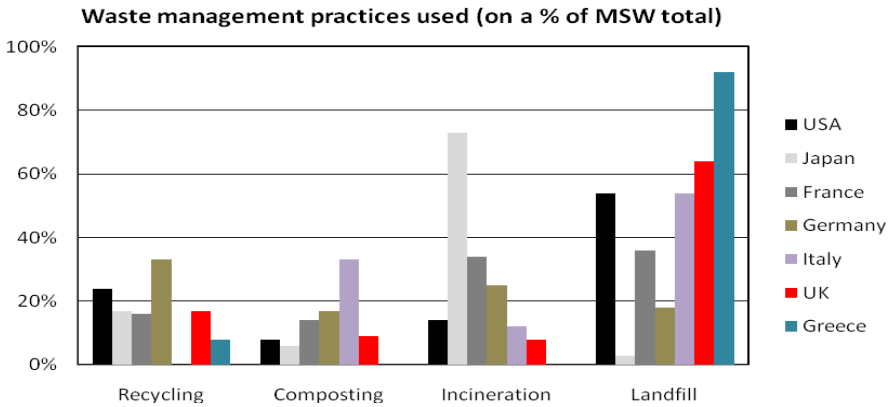

Figure 5: Waste management practices in selected countries [9].

Greece

In the case of Greece, the volume of waste generated, despite the population of the country, is comparable to other European countries of larger populations, as illustrated in Figure 2. The proportion of kg/year/capita based on the data available from OECD demonstrates that the Greek MSW generation is within the upper range of the EU [9]. Figures 6 and Figure 7 show a historic representation of the generation of waste starting in 1980 up until 2006, where it is clear that the weight of waste has increased, from 2.5 million tons to 4.9 million tons.

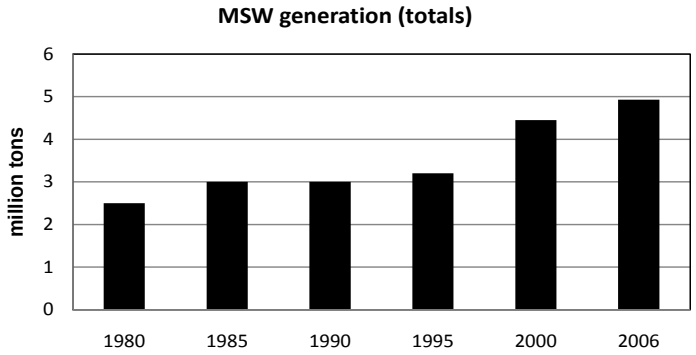

Figure 6: MSW generation in Greece for selected years [9].

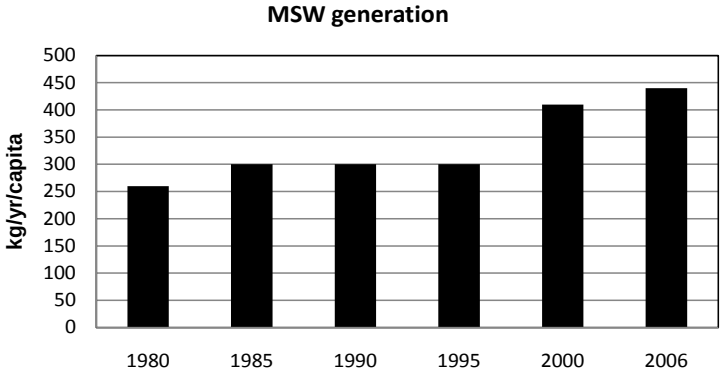

Figure 7: MSW generation in Greece as kg/yr/capita for selected years [9].

This is an increase of almost 100% in 26 years. Similarly, the generation of waste as kg/year/capita demonstrates an increase of 70% per capita in 26 years. Figure 5 shows the waste management practices used in Greece, where landfilling is by far the most commonly used practice approaching 92%, while the only other practice used is recycling at 8%. Practically, the practices of composting and incineration are not being applied, especially on a large scale.

MODELS AND LCA

A number of models have been developed over the years, which use a variety of methods and tools as part of a decision-making process, such as risk assessment, environmental impact assessment, cost benefit analysis, multicriteria decision making and life cycle analysis (LCA) [18]. In the 1990s, recycling and other waste management methods were included in models developed for the planning of municipal solid waste management (MSWM). More recently, the aim became the comprehensive assessment of the system's environmental impact, including all significant activities during its life cycle and, thus, the models now include the whole life cycle of products (see for example [19-21]). Research also demonstrated that until the 1990s, there was very little information with respect to costing information on integrated waste management systems. A waste management system, to be sustainable, needs to be environmentally effective, economically affordable and socially acceptable [22].

Waste management models adopt the same principles as any engineering project appraisal models, thus they can either use optimising methods or compromising methods. The optimisation models dealt with specific aspects of the problem examined, whereas the most recent models – which are compromising – focus on the principle of integrated waste management, with the concept of sustainability becoming fundamental. Solano et al discuss that lately the life-cycle methodology has been quite widely adopted to characterise environmental considerations, with respect to an array of pollutants [17]. During the life cycle analysis, environmental aspects and potential impacts throughout a product's life, from raw material acquisition through production, use and final disposal are being examined (i.e. from cradle to grave).

According to the European Environment Agency, a *life-cycle* approach in policy-making ensures that impacts are assessed from cradle to grave, and that environmental impacts are not simply hidden by moving them to different countries or different stages of production or consumption. In conclusion, many waste management models have been developed over the past decades. The models initially focused more on specific factors and, gradually, the focus shifted to the concept of sustainable waste management. It is recognised that for a model to satisfy the principles of sustainability, it should consider all environmental, economic and social aspects at the same time. According to Morissey and Browne, no model has achieved that [18]. In essence, all models have limitations, and there is no model yet that takes into consideration the complete waste management cycle, from the prevention of waste through to final disposal.

HEALTH

Although technology has greatly improved in the past few decades and the waste management legislation is much stricter, the public has not reached the stage of accepting without opposition the location and construction of new waste disposal and treatment facilities, due to the concern for potential adverse effects on the environment and human health. The number of direct and indirect health impacts of each waste management activity that have been discussed in the literature is vast. The present research highlights only a few of the health impacts, which are by no means exhaustive, such as inhalation (especially due to emissions from incinerators and landfills), consumption of water (in the case of water supplies contaminated with landfill leachate), the foodchain (especially consumption of food contaminated with bacteria and viruses from landspreading of sewage and manure, and food enriched with persistent organic chemicals that may be released from incinerators) [12].

Naturally, a number of indirect health effects can be linked to the waste disposal activities, such as the contribution to greenhouse gases, which cause rising temperatures due to climate change, and would affect old people with cardiovascular problems and also any people with respiratory problems, such as asthma [12]. Rising sea levels, flooding and extreme weather events are also likely to cause destruction and casualties. However, although there is justified concern, the 2000 and 2007 findings of the World Health Organization (WHO) [23][24] on the health effects of waste landfills and on the health effects of landfills and incineration respectively, demonstrated that the evidence that links waste landfills and incinerators to health endpoints (especially cancer, reproductive outcomes and mortality) is either inadequate or insufficient.

CONCLUSIONS

Environmental sustainability depends on a number of factors, one of which is waste prevention and minimisation. The amount of municipal waste generated has increased substantially during the past decades, and the projections show that the increase will continue, perhaps at a s lower rate. Although there is a clear strategy from governments and organisations to enhance the use of re-use and recycling, landfilling is still the most popular waste disposal method, although gradually decreasing. However, a number of waste management models have been developed over the years and, although the focus has now shifted to the concept of sustainability, there is still no model that satisfies all environmental, economic and social aspects at the same time. In many developing countries, the lack of resources and education, as well as illnesses due to bad sanitation and potable water, make waste management a low priority. In developed countries, on the contrary, the concern of the public has shifted to the location of landfills and incinerators

since they have been related to adverse effects on the environment and health. The overwhelming majority of epidemiological studies, however, have not managed to prove convincingly and unequivocally that excess risk of contracting specific illnesses is associated with waste management facilities. The existing epidemiological evidence linking waste management and human health is quite controversial.

The present research, besides the overview on the subject of municipal solid waste, has also identified the need for a more integrated methodology, adopted at a regional and or national level, which will look at the development, evaluation and implementation of a waste management strategy. Successful implementation of the strategy will not just be based on economic criteria, but also on the public participation, intergenerational equity and the satisfaction of social needs. Overall, beyond the development of any decision-making aid and waste strategy management strategies, the need for a more educated public is identified in terms of waste prevention, re-use and, generally, on the philosophy of sustainability.

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