An Overview of Solid Waste Management and Plastic Recycling in Qatar

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ORIGINAL PAPER

An Overview of Solid Waste Management and Plastic Recycling in Qatar

M. Al-Maaded · N. K. Madi · Ramazan Kahraman · A. Hodzic · N. G. Ozerkan

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Abstract Municipal solid waste management (MSWM) constitutes one of the most crucial health and environmental problems facing authorities in the Arabian Gulf. Recent literature on current solid waste management (SWM) in Qatar has been reviewed in this paper, and a focused study has been carried out to provide a review on the total amount of municipal solid waste generated, stored, collected, disposed as well as the constituents of the waste. The analysis showed that Qatar produced around 2,000,000 tons of solid municipal waste annually, corresponding to a daily generation rate per capita of about 2.5 kg. About 60% of MSW is organic material and about 300 kg is composed daily. Landfill and composting is considered the most appropriate waste disposal techniques in Qatar. Um-Al-Afai landfill has nearly 80% of MSW. Because of the increased migration in Qatar, there is a sharp rise in the volume and also in the variety of solid waste. It is important to alleviate societal concerns over the increased rate of resource consumption and waste production; thus, policy makers have encouraged recycling and reuse strategies to reduce the demand for raw materials and to decrease the quantity of waste going to landfill. An example of the benefit of mechanical recycling of plastics compared to land filling and composting was conducted by GaBi 4 life cycle analysis tool which showed the benefits to the global warming and human toxicity. Recycling is the favored solution for plastic waste management, because it has a lower environmental impact on the defined impact categories, from Global Warming Potential (GWP) and Human Toxicity Potentials (HTP) indicators.

Keywords Waste- polymer recycling · Gulf cooperation council (GCC)-Qatar · Life cycle assessments

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Introduction

Municipal solid waste management (MSWM) is defined as the discipline associated with the control of generation, storage, collection, transportation, processing and disposal of municipal solid waste (MSW), in a way that is governed by the best principals of public health and economic, engineering, aesthetic and other environmental considerations. MSW should be properly disposed in order to help protect environmental quality and human health, as well as to preserve natural resources [1, 2]. Solid wastes have both direct and indirect effects on environment and human welfare. Direct effects range from the damage of materials and loss of aesthetic importance to the impairment of human health, thus creating significant socioeconomic impacts. Indirect effects are mainly long-term effects which range from change in ecosystem structure and behavior to the climate change, which in turn will affect socio-economy and the sustainability of the region [3–5]. Aside from a technical issue, SWM is strongly influenced

by political, legal, social, cultural, environmental, economical factors and available sources. All these issues need to be addressed to reach a sustainable SWM action. It must be stressed that the lack of environmental legislations itself is not the heart of the problem. Rather, it is the lack of enforcement and/or the availability of viable alternatives. Recently, Arab Gulf States, for example, dealt positively with the problem by adopting a uniform system across the region, as well as a refined strategy for waste management. Most legislations and strategies adopted for waste management are based on the universally accepted scientific approach for integrated waste management hierarchy. However, the hurdle lies in effective implementation.

With the rapid socio-economic development, the contradiction between increasing waste-generation rates and decreasing waste-disposal capacities is very import. In response to this concern, development of effective MSW management strategies with satisfactory economic and environmental efficiencies are highly desired.

The earlier per capita waste generation rate among Gulf Cooperation Council (GCC) was recorded as low as 300 g/capita/day [6]. However, the discovery of oil in the early thirties has resulted in the fast development of the cultural, constructional and industrial aspects of the nations in the region. Also there was an increase in immigration to the region, which increased the pressure on the existing infrastructure quite rapidly. The generation of urban solid waste is therefore rising continuously [6, 7]. It is estimated that 120 million tons of waste is produced per year in GCC states, of which little is recycled or even managed; 60% is from Saudi Arabia, 20% from the United Arab Emirates (UAE) and the rest is from Kuwait, Qatar, Oman and Bahrain. This increase in solid waste generation not only results in the environmental pollution but also involves huge loss of natural resources, which remains unaccounted for [8]. Financial cost of the MSW should be considered, as Asian countries alone spent about US$25 billion on solid waste management per year in the early 1990s; the figure is expected to rise to around US$50 billion by 2025 [9].

Land disposal is the most common method adopted. In developed countries, well managed landfills are governed by local councils that provide regular construction and maintenance [10]. On the other hand, the waste in less legislated regions is disposed of in open dumps, which not only leads to severe environmental degradation but also results in loss of natural resources. This paper will provide a comprehensive review of Solid Waste Management practices in urban areas of the state of Qatar in order to analyse the problem, assess the environment and to recommend suitable measures for improvements in this area.

The rapid socio-economic global development have accelerated the generation rate of MSW and the management process poses a grave challenge even in the modern societies [11]. In the gulf region, including Qatar, where most countries have the highest per capita waste generation across the world [12], the scale of the challenge faced by civic authorities is even bigger. Fast-paced industrial growth, recent construction boom, increased population and urbanization, and vastly improved life style and unsustainable consumption pattern have all contributed to this burgeoning waste problem. It is estimated that the total volume of solid waste generated in the GCC region is around 120 million tons per year of which little is recycled or even managed [13]. Sixty Percents is from Saudi Arabia, 20% from UAE and the rest is from Kuwait, Qatar, Oman and Bahrain. A huge proportion of this waste is expected to be generated from the construction and demolition activities. Municipal solid waste is the second largest waste category by source. Waste in the Gulf states are mostly organic materials which also contain a valuable part of recyclables, e.g. glass, papers, metals and plastics. However, the method of waste disposal by landfill is still practiced widely. In country such as Qatar, with an area that does not exceed 11,000 km^2, landfills do not seem to be the most prudent areas. In the last few years, municipality affairs and agriculture authority in Qatar have awarded contract to the private sector, Domestic Solid Waste Management (DSWM), for setting up and operating integrated waste management facilities or waste recycling units. Designed to treat an initial capacity of more than 1,550 tons of wastes a day, the DSWMC will comprise waste sorting and recycling facilities, landfills, and composting plants.

The objective of this study is to assess the current state of Qatar's solid waste management. There is a lack in information about the solid waste management in this important region of the world. The available technique(s) and several recommendations for system improvements will be discussed in this paper. Life cycle assessment will be used to study the scenarios of different end of life of recycled polymers. The effect on the environment will be discussed.

Methodology

To carry out such investigations, several questionnaires were prepared and provided to Solid Waste Program operators. The questionnaires aimed to collect the information about the locality type, MSW quantities collected, collection service availability, collection equipment and vehicles, collection fees, final disposal methods, location/type of dumping sites, and problems faced with the current management system.

All the data collected and used from the questionnaire were based on the interviews and meetings with decision

makers and workers in this field. Meeting with the general managers of the following were conducted in the period from October 2009 to May 2010, Qatar Municipality Organization, Qatar Statistical Authority, Qatar Petrochemical Company (QAPCO), Qatar Plastic Product Company (QPPC), Doha Plastic for Polymer Recycling and Sold Waste Management Facilities in Umsaaid.

Current Scenario of Waste Management in Qatar

Environmental management in Qatar can be traced back to the establishment in 1981 of the Permanent Environment Protection Committee (PEPC) whose main objective was to provide a forum to discuss environment-related legislations and regulations. In 2000, the PEPC was superseded by the establishment of the Supreme Council for Environment and Natural Reserves (SCENR), and in 2008, the SCENR was superseded by the establishment of the Ministry of Environment (MoE). Its responsibilities include developing and implementing plans to protect the environment, monitoring and documenting pollution scenarios, developing and setting-up emergency response plans, implementing measures to mitigate pollution impacts, evaluating and approving environmental impact assessment studies for government or private sector projects, enforcing environmental laws and standards, and implementing environmental awareness programmes [14].

Waste management can be defined as the judicious use of means to achieve an end. "An end" is the removal of the rejected material from the material flow pattern. Any integrated SWM system should establish a hierarchy based on a sound pyramid of source reduction and waste minimization, reuse, recycle, incineration and land filling. These elements collectively provide the basis for a sound management strategy of solid waste; nonetheless, specific conditions and capabilities must be stressed in putting more emphasis on some versus the others. However, the integrated management system of waste should be unchangeable holistically for lack of resources, emphases on proper collection and transportation. However, in developing countries such as Qatar properly designed and maintained landfills are seldom found. The waste is disposed of in open dumps, which does not only lead to severe environmental degradation but also results in loss of natural resources [13].

According to 2009 census, of 1.6 million people living in Qatar, more than 90% live in urban areas, while 10% live in rural areas [15]. Furthermore, out of those 90% living in the urban areas, 85% of them live in three major cities of Qatar. (a) Doha, on the east cost, is Qatar's largest city and commercial center and contains about half of the emirate's population, (b) Al-Rayyan, just northwest of Doha, is the second major urban area. Doha and Rayyan are the most populated areas accounting for 83% population of country. The average household size in these two cities is nearly 7.3. (c) The main oil port and industrial center is Umm Sa'id which is the south of Doha on the eastern coast (2%). These three cities are generating high amounts of solid waste which is increasing annually with the respective population growth.

MSW Generation and Characteristics

The characterization of solid waste streams and the estimation of solid waste generation rates are critical data required to propose any sustainable management system and to find the most appropriate and viable alternative solutions to MSWM [16]. The generation of domestic waste increased from 450,000 tons in 2006 to reach approximately 3,000,000 tons in 2008 years are presented [15, 17], this is due to the increase in the population in Qatar from 1,041.733 in 2006 to 1,448,449 in 2008 as well as the increase in construction and demoltion waste in 2008 [15], see Fig. 1. According to Qatar MSW organization, Qatar reached 1,000,000 tons of solid municipal waste annually corresponding to a daily solid waste of about 3,000 tons/day. Commercial and industrial waste amount is 2,500 tons/day, and construction and demolition waste amount is 20,000 tons/day. However, only 4,600 tons of this waste is discharged to be recycled. Population increase, economic progress, expansion in urban areas, rapid industrial development, and rising standards of living all contributes to rise in solid waste generation [18]. A quick estimation of the amount of waste to be produced in Qatar in year 2020 predicts that this figure may exceed tens of million tons per year. Table 1 provides an overview of the solid waste generation rate in Qatar and other states of GCC in comparison to USA [13].

It is important to consider that waste largely fluctuates from month-to-month: usually high during the working months of the year and, especially, during major holidays

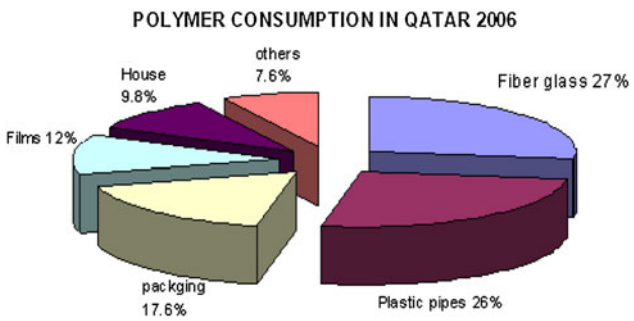

Fig. 1 Major end-uses of produced plastics during 2006

Table 1 Municipal solid waste generation rate in the GCC and USA. Rates and quantities of municipal solid waste in some Arab countries "2006" [13]

Country	Population -2006 (approximately) (×1,000)	Generation kg/per capita/day
Kuwait	3,052	1.40
Saudi Arabia	23,678	1.4
Bahrain	746	2.7
Qatar	838	1.3
United Arab Emirates	4,229	1.2
Oman	2,577	0.7
USA*	308	2.1

* American Journal of Applied Sciences 4(6):354–356, 2007

(Ramadan, 'Id al-Fitr, 'Id al-Adha, Christmas, etc.), and lower during summer months, when many expatriate and Qatar households travel to vacation destination outside the state.

Physical Composition of the Waste in Qatar

In Qatar, the total waste is classified into four principal categories; domestic, industrial solid waste, hazardous, and medical. Each category is monitored by the Municipality, Ministry of Environment, and Health Organizations. In this study, the municipal solid waste is investigated.

The categorization of the solid waste (SW) in Qatar, GCC countries USA and UK are presented in Table 2 [17–19]. In GCC countries, households are considered to be the major source of MSW rather than commercial or industrial sources. One can notice that 80% of the total municipal solid wastes in Qatar are decomposable and recyclable, and the remainder is inert matter. On average, 57% of municipal solid wastes is organic. This situation is nearly observed in most of the GCC countries. Evidently, GCC's urban solid waste differs considerably from USA and UK. This may be because, the GCC's member states have distinctive cultural traditions and habits that differ greatly from others and which consequently affect the waste generation and compositions [20].

Table 2 Solid waste generation and composition in the Arabian Gulf countries compared to USA and UK

Country	Organic (%)	Paper (%)	Plastic (%)	Glass (%)	Metals (%)
Qatar	57	11	14	4	9
Bahrain	59.1	12.8	7.4	3.4	2.1
Kuwait	51	19	13	4.5	5
Oman	60	8	12	10	9
UAE (Dubai)	42	6	10	3	3
Abu Dhabi	49	6	12	9	6
USA	11.2	37.4	11	6	8
UK	20	4	7	10	10

As shown in Table 2, polymers account for about 14% of the total waste volume (5% by weight) produced by the municipal sector. Only 1–2% of this is being recycled, while the amount of polymers waste is expected to increase to 50% by the year 2020 from 2009 waste tonnage figure of 1,900 tons [17].

Waste Handling and Separation

The method of handling, storage and processing of solid wastes at the sources plays an important role in public health; aesthetics and efficiency of the MSW system [21]. Separation of the wastes at source will not only bring economic benefits, but will also make the recycling of other components more efficient [22]. Unfortunately, the situation in Qatar is completely different. Most Qatari people use plastic bags and these bags contain mixed garbage, and they are thrown in medium-sized containers, which are located near houses. This makes the separation process difficult. Therefore, the separation process is achieved after disposal to landfill. There is no treatment for the disposed waste at landfill except the separation of the valuable components of MSW, such as paper, plastics (PET, PP, PE, etc.), glass, and metal sand collection by scavengers in the city, as well as at the dumpsite and selling of the recovered materials to private recycling centers. At present, there will be no landfill regulations or standards that provide a basis for compliance and monitoring, but national guidelines for these landfill standards are being prepared by Domestic Solid Waste Management (DSWM) centre, near Um-Said.

Collection, Transport and Transfer of Solid Wastes

In Qatar, municipalities led by Qatar General Cleaning Project (QGCP) are responsible for waste collection both directly, using their own infrastructure, and indirectly through private sector contract. Waste collection and transport in Qatar is carried out by 700 oil-fuelled trucks that collect MSW from 54,000 collecting points, households or roadsides. The waste is discharged in an open dump used as a transfer station, approximately 6–7 km from the city centre. This site contains two big containers each of capacity 15–20 tonnes where the waste is stored for few days before being transferred to the landfill. The waste is not separated prior to dumping. After that this waste is transferred directly to landfill by trailers of different sizes.

The capacity of a small size trailer is about 7 tons. Each trailer makes 2–3 rounds to landfill. The domestic solid waste is sorted at the landfill according to its components, namely organic, plastic, glass, metals and paper.

Final Disposal: Landfill/Composting

Landfill and composting are considered the most appropriate waste disposal methods. There are three landfills in Qatar; namely, Umm Al-Afai for bulky and domestic waste, Rawda Rashed for construction and delimitation waste, and Al-Krana for general sewage wastes.

The Umm-Al-Afai landfill is located northwest of Doha and it was constructed 30 years ago. The landfill was separated into different cells by the native rock soil, the area of each landfill cell is about 0.3 km^2 and the total area of the landfill is 2 km^2. Refuse is disposed in individual landfill cells with the filling height of 4–6 m. Around 2,000 tons of refuse is placed in the landfill daily. Um-Al-Afai is properly designed to mitigate the risk of leachate generation. It is constructed on geologically impermeable soil and it has, also, a basal leachate collection layer made of concrete clay of thickness 3 m. The second layer is domestic waste damped in the ground, and finally the green house emissions are released through collection pipes of height about 12 m above the ground.

The domestic waste is almost organic, (nearly, 60%) corresponding to a daily organic waste of about 300 ton/day. This high content of organic matters in municipal waste triggered the interest in composting; thus, in eighties a large composting plants have been established in Doha-Qatar, currently producing around 170 ton/day of compost-fertilizing materials and soil conditioners.

Needs for Plastic Recycling in Qatar

Plastics are composed mainly of the non-renewable resources, petroleum or natural gas. So the more petroleum we burn to make new plastic products, the more harmful gases we release to the environment. Recycling old plastic products will therefore use much less energy than manufacturing it from new. Moreover, recycling plastics helps the environment by reducing the amount of space used in a landfill for plastic products.

Plastics have special importance because they are chemically stable since they are non-biodegradable materials. This means that plastic waste will be visible for months or years, and waste will sit in landfill sites for years without degrading. Furthermore, they take years to break down, and when it does break down, it leaks chemicals into the ground, and eventually into the ocean, which not only depletes natural resources, but may also cause harm to the ocean life. Scientists have recently discovered that some plastics breakdown quickly in the ocean, releasing toxic chemicals during their decomposition process. The chemicals released as plastic breaks down are dangerous to ocean life and people [23–25]. Recycling plastics will also indirectly reduce such harms to the environment.

During the past decade, Qatar became one of the largest producers of polymers in the region, and the plastic industry is of valuable contribution to the Qatar economy. Table 3 gives the detailed information about the progress in plastic processors in Qatar and Fig. 1 shows the different end uses of produced plastics during 2006 [26]. Despite of this great activity in producing and consumption of plastics, polymer processors in Qatar have not adopted recycling as means to solve the plastic waste disposal problem. Only 1,900 tons/year of plastic are discharged to be recycled in small recycling plants scattered in the industrial area that are mainly operated by the private sector.

As shown in Fig. 1, half the polymer waste stream (by volume) consists of packaging and pipes waste. The vast majority of packing and pipes material is polyethylene (PE) and it contributes heavily to the waste stream, and showing a strong need for a solution that would reduce its contribution. Mechanical recycling of polymer waste is the motivation for the recycling program that has been recently developed in Qatar.

Life Cycle Assessment of Recycled Plastics

The increased awareness of the importance of the environmental protection has increased interest in the development of methods to better understand and address these impacts. One of the techniques being developed for this

Table 3 Progress in plastic processing and trade in Qatar by weight (Kg)

	2004	2005	2006	2007	2008
Import	64,560,927	97,758,745	135,394,901	179,222,170	192,018,026
Export	385,475,572	563,821,320	923,224,622	957,492,318	961,950,199
Net import	320,914,645	466,062,575	787,829,721	778,270,149	769,932,173

purpose is life cycle analysis (LCA) which is a primary analytical tool of industrial ecology, and constitutes of the systematic view of local, regional and global uses and flows associated with products, processes and industrial and economic sectors. LCA allows for a comprehensive analysis of the environmental consequences of a product system over its entire life, i.e. from resource extraction to ultimate disposal [27, 28].

LCA addresses the environmental aspects and potential environmental impacts throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal.

Within the scope of this study, three end-of-life scenarios for plastic waste management were compared by performing LCA Using GaBi 4 LCA tool. Three end-of-life scenarios were selected, namely: mechanical recycling, landfilling and thermal treatment (direct incineration with energy recovery). Since in LCA for waste management the functional unit must be defined in terms of system's input, i.e. the waste, in this study, the functional unit was chosen as 10 kg of plastic mix waste. For inventory analysis, the data regarding the manufacturing of HDPE, injection molding and service life of HDPE come from EcoInvent (Netherland) database, also included in GaBi 4 impact assessment and modified for Qatar. In all these scenarios, manufacturing processes of plastics, injection molding and service life of plastic wastes were kept constant. Moreover, in each scenario, transportation was also taken into consideration. The impact assessment methodology used for global impact categories was CML 2 baseline 2001. For environmental impact categories, global warming (GWP), human toxicity (HTP), abiotic depletion (ADP) and acidification potential (AP) were taken into consideration during LCA. The comparison of the end-of-life scenarios according to the defined impact categories is given in Figs. 2 and 3, respectively. As seen from both figures, recycling is the favored solution for plastic waste management, because it has a lower environmental impact on the defined impact categories, from Global Warming Potential (GWP) and Human Toxicity Potentials (HTP) indicators. Moreover, when abiotic depletion, due to non-renewable resource consumption for waste management, and acidification, which has direct and indirect damaging effects such as nutrients being washed out of soils or an increased solubility of metals into soils, are compared for three end-of-life scenarios, the results are obtained as shown in Figs. 4 and 5. It can be seen from these figures that abiotic depletion and acidification potential vary with the end-of-life scenarios, and from both ADP and AP perspectives, recycling is the best solution for the waste management. These results will encourage the decision makers to initiate policies of incorporating recycling of plastic wastes as one of the waste management methods in Qatar.

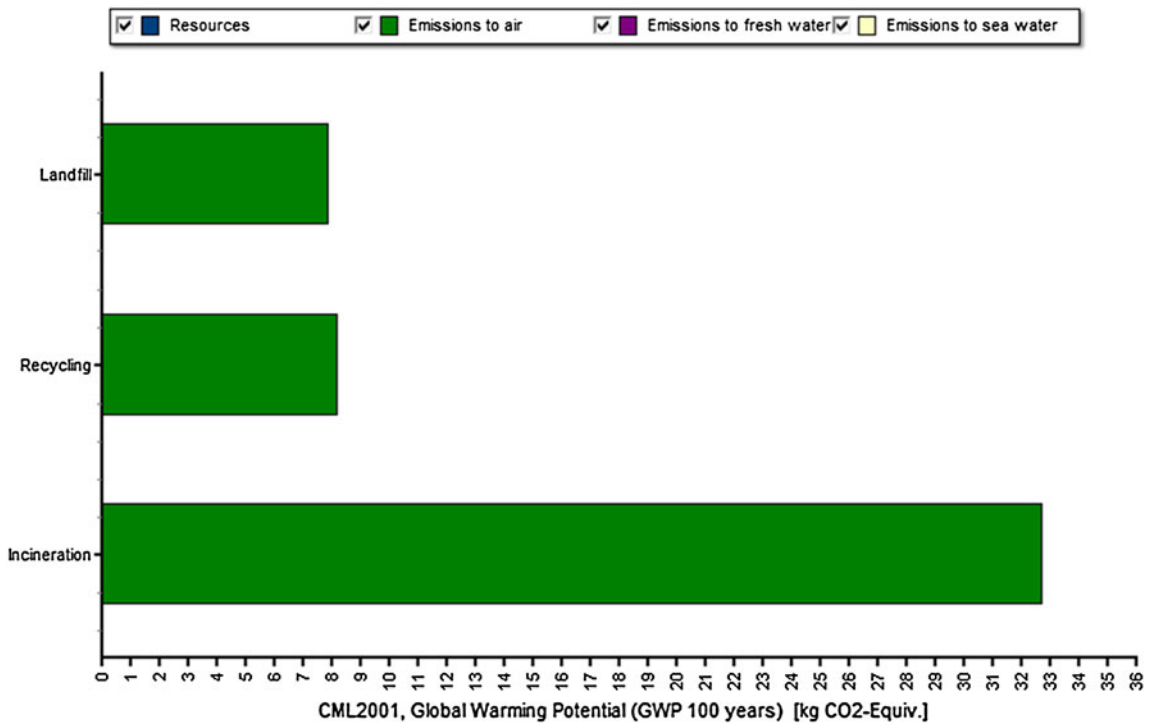

Fig. 2 Comparisons of global warming potential indicators

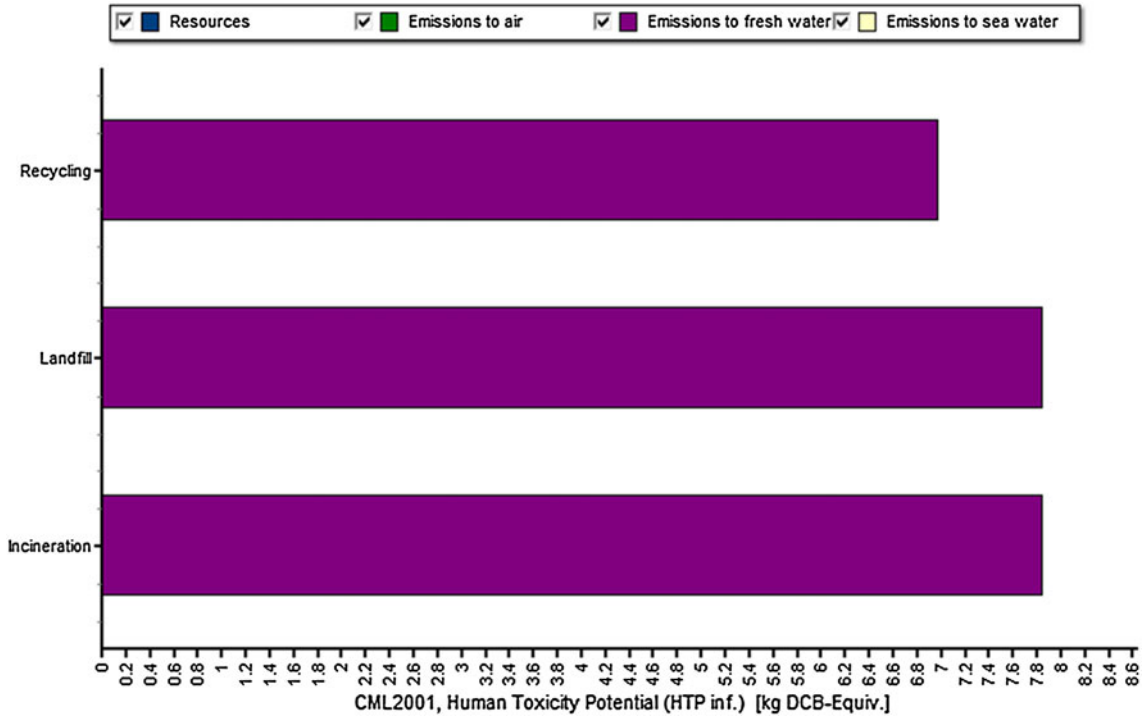

Fig. 3 Comparisons of human toxicity potential indicators

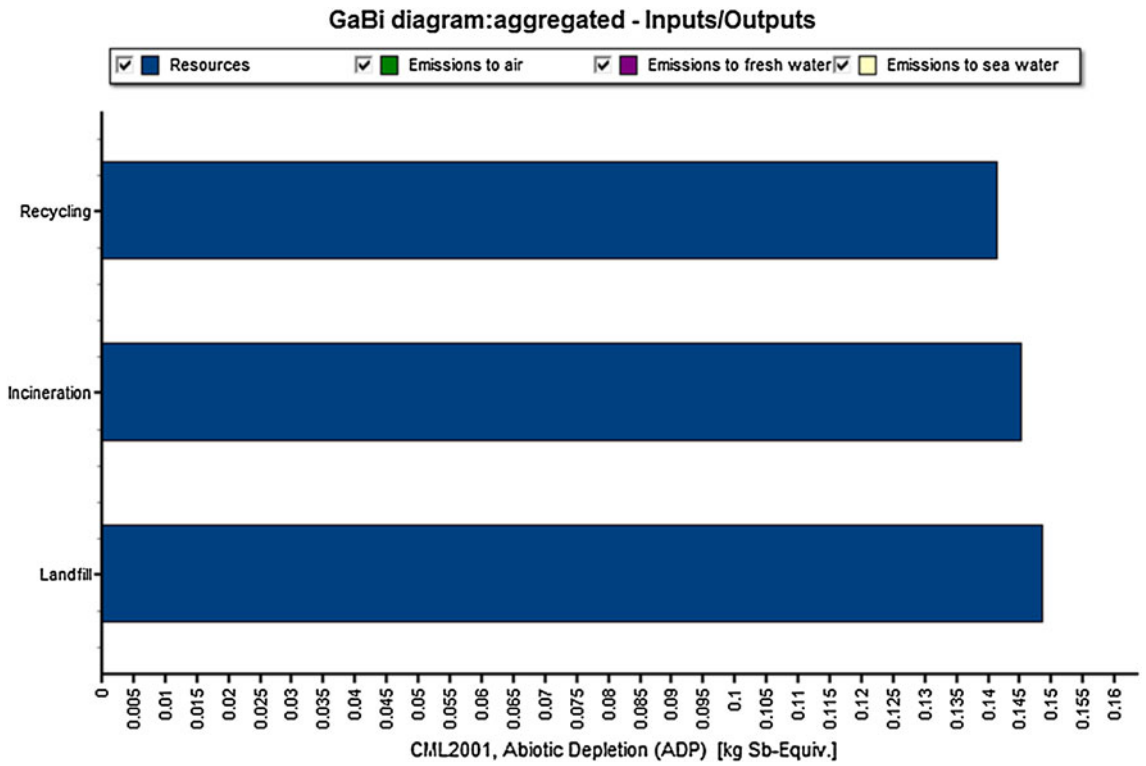

Fig. 4 Comparisons of abiotic depletion potential indicators

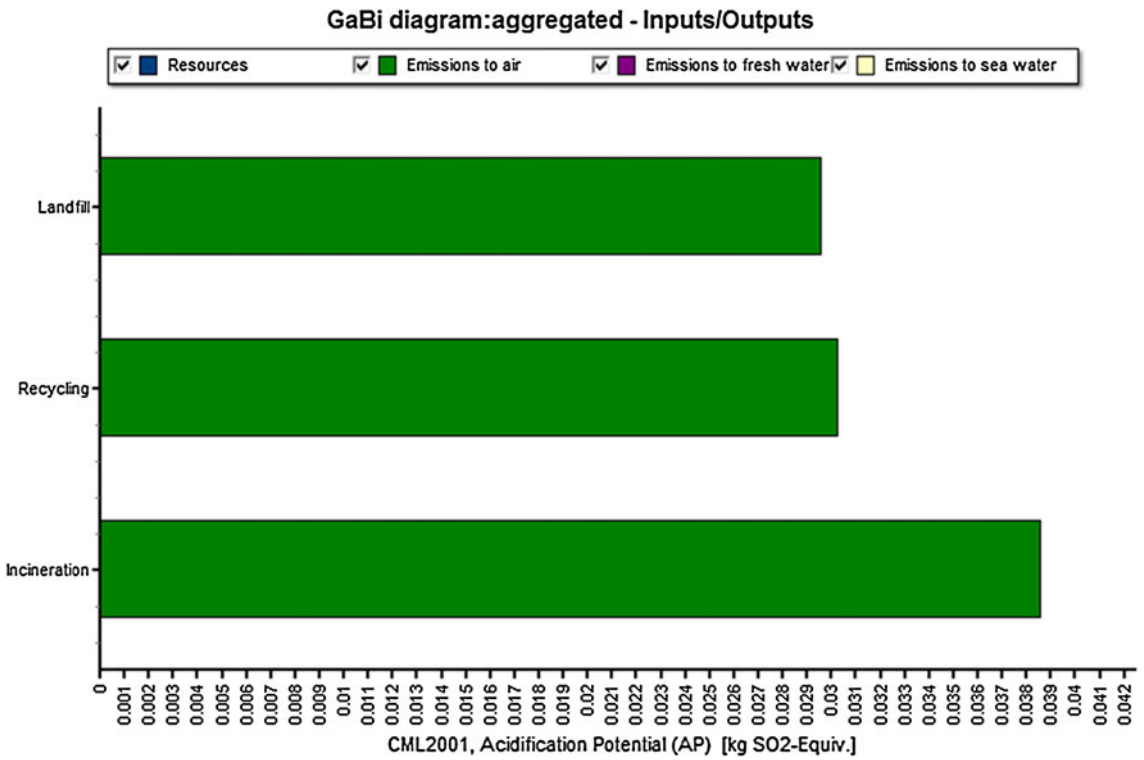

Fig. 5 Comparisons of acidification potential indicators

Conclusion

Qatar is a small country, with the second income level per capita and a population that reached 1.6 million in 2010. Qatar is having new challenges in the waste management system, as the main component is the organic waste that has reached 60% of the total waste. The government created a composting waste management area which concentrated on solving of this problem alone. As its main component, a new Domestic Solid Waste Center is aimed to start operating at the end of 2010. There are other important components in the waste system that could be used in a more efficient way, and in more environmentally friendly way. The municipalities in Qatar are still faced with serious challenges emanating from the vast expansion in urban developments, the increasingly unsustainable life style and consumption patterns. In 2009, more than 80% of all waste generated nationally ended up in landfills. The low price and high quality of recycled products will encourage the industry, especially construction, to use recycled products, with a specific focus towards the second major waste component, the plastic waste.

More regulations and initiatives for recycling from the ministry of the Environment will ensure that this will be adopted by the industry and society in Qatar. LCA results showed that the recycling of plastic wastes is the best solution for the plastic waste management system, because it has the lowest environmental impact. Recycling is the favored solution for plastic waste management, because it has a lower environmental impact on the defined impact categories, from Global Warming Potential (GWP) and Human Toxicity Potentials (HTP) indicators.

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