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Household Solid Waste Composition and Management in Jeddah City, Saudi Arabia: A planning model

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Abstract

Recently, the states of Gulf Cooperation Council especially Saudi Arabia have a significant increasing urbanization, developing and population that created huge amount of household solid waste (HSW). These wastes have a considerable impact on both human health and the environment. The HSW in Jeddah City was dominated by organics, paper, plastics and other small components. Generally, the production of solid waste has a direct relationship with density of population and economical developments. The charge of safety collecting and disposing of these wastes can be minimized and used in management of these wastes. The inhabitants themselves must be jointed in re-sorting processes of these household wasters in pre-transferring from houses. These wastes can be minimized by changing some of social and traditional feeding habits. The management of household solid waste can be created al lot of jobs and money thought reuse, recycle and recovery of these wastes.

Keywords: Household solid waste, composition, management, waste hierarchy, Jeddah, Saudi Arabia.

Introduction

Virtually all production and consumption activities that humans engage in create byproducts, or waste materials, that are socially costly to handle[1]. Development does not come without environmental burdens and generation of waste is one among them. Waste in recent times has become a topic of extensive attention in academic and popular literature[2]. Waste is conventionally defined as unwanted material at the point of generation which does not have immediate use. Problems due to waste exist where there is a human inhabitants[3]. As the name suggests, the term solid waste is used for waste which is solid. When governments took the responsibility of solid waste management originally, they bothered only about the waste generated from household and commercial activities. However, anthropogenic activities produce waste materials that are frequently discarded as they are considered useless[4].

The generation of urban solid waste is therefore rising continuously[5,6]. Development does not come without environmental burdens and generation of waste is one among them. Waste in recent times has become a topic of extensive attention in academic and popular literature[2]. Waste is conventionally defined as unwanted material at the point of generation that does not have immediate use. Problems due to waste exist where there is a human inhabitants[3]. In the context of rapid urbanization, developing countries are largely unable to deal with increasing amounts of waste generated in cities. Governments responsible for this task struggle with the collection, treatment and disposal with significant impacts on human health and the environment[8]. Rapid development and urbanization not only lowers the accessibility of compostable urban waste but also its quality, with rising percentages of non-compostable matter due to greater use of plastics by urban households and chemical pollutants[9].

Household solid waste (HSW) is considered as a type of municipal solid waste (MSW) and consists mainly of plastics, paper, glass, metals, organics, wood and others. These wastes must be predisposed accurately to assist keep environmental quality and human health, as well as to preserve natural resources[10,11]. Household solid waste (HSW) has 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[12,13,14].

Saudi Arabia Kingdom (KSA) is one of the promising economies of Arab world and its population is almost 29.4 million according by 2012. Conventionally, the municipal authorities and waste collection companies are responsible for waste management in KSA. But, due to the urbanization, waste management problem has become severe, especially in main cities (Riyadh, Dammam and Jeddah) and it is one of the significant challenges for the municipal authorities[15].

Recently, Saudi Arabia Government, contract really with the problem by approving a standardized system across the region, as well as a developed strategy for waste management. Most

legislations and strategies allowed for waste management are based on the universally accepted scientific approach for integrated waste management hierarchy. However, the problem lies in successful performance. At last few decades, Jeddah City has a remarkable rapid socio-economic development, so that deny between rising waste-generation rates and decreasing waste-disposal capacities is very significance. This increasing in solid waste generation not only results in the environmental pollution but also involves huge loss of natural resources, which remains unaccounted for Parikh and Parikh, 1997[16]. Also, Jeddah has witnessed a remarkable increase in population in the past few decades. Jeddah's population grew rapidly (from 147900 in 1964 to 3430697 in 2010). Also, the total urban mass has expanded radically from 18315 hectare in 1964 to 54175 hectare in 2007[17]. The dynamics of urban growth in Jeddah has changed as the city expanded, and hence, the city expanded through the emergence of both formal and informal settlements[18].

The waste management is generally applied in order to reduce negative effect of wastes on human health, the environment or aesthetics aspects in nature[19]. Waste management relates to all activities on recovering resources from wastes. Waste management refers to managing solid, liquid, gaseous non-hazardous or hazardous wastes substances with minimum negative side effects. Waste management includes the prevention of waste production, the reduction of the quantity of waste and its negative impact on the environment, the reduction of the volume or harmful nature of the waste[19]. This work is a close up trial dealing with composition and management of household solid waste in Jeddah City, Saudi Arabia to shed more light on its dreadful and harmful environmental impact.

Overview: The discovering of oil in the states of Gulf Cooperation Council (GCC) 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[20]. The rapid socio-economic global development have accelerated the generation rate of municipal solid waste (MSW) and the management process poses a grave challenge even in the modern societies[21].

Conventional solid waste management planningusually focuses on economic optimization, in which therelated environmental impacts or risks are rarely considered[22]. Solid waste management is a big challenge for the government and local authorities in the Kingdom of Saudi Arabia. The country generates more than 15 million tons of municipal waste each year with vast majority diverted to landfills and dumpsites. Recycling, reuse and energy recovery is still at an early stage, although they are getting increased attention. Recycling rate ranges from 10-15%, mainly due to the existence of the informal sector which extracts recyclables from municipal waste stream. Accumulation of unmanaged wastes, especially in developing countries, is the cause of environmental concerns. Such concerns can be partially addressed by recycling of such wastes[23]. Problems found in waste management systems, among others, include limited areas for landfill, waste disposal costs, the emission of greenhouse gases and dioxins and concern over health and environmental quality, all of which can be solved more easily in combination rather than individually[24].

The waste hierarchy ranks the different ways in which we can treat and dispose of our waste in order of sustainability, or relative environmental benefits. From an economic point of view, applying the waste hierarchy on the collected wastes[25]. Under conventional circumstances, waste disposal has become the base of a waste management hierarchy with energy recovery, recycling, reusing and reducing being implemented at the minimum. Final disposal being inevitable, landfill has become the largest component in the waste management pyramid. In addition, due to its simple and low cost technology, landfill is highly preferred consumption in most developing nations[24]. The waste hierarchy must be used as a basis of waste management strategies, focuses to minimize and reduce the pre-landfill quantity of wastes. Rasmussen and Vigsø, (2005) stated that, the waste hierarchy is a simplified list of priorities that help some waste management options over others (reuse over recycling, recycling and disposal).

Figure-1
Waste hierarchy

Waste Reduce: It is clear that more needs to be done to reduce the environmental impacts of our lifestyles. It would be overly simplistic to say that consumers must be encouraged to rein in their consumption, as the purchasing patterns which members of the general public display are now ingrained within the fabric of society. However, there is scope for providing consumers with more information about the sustainability of the products they purchase, so that they can make more informed decisions. Household wastes were anticipated to steadily rise due to an increase in population and economic growth. But policies for controlling waste generation have led to a gradual reduction in

the amount of waste generated. In order to manage of household wastes effectively, it is important to reduce waste generation and recycle waste as much as possible[24].

Waste Reuse: Recently, under effect of the increasing consumption and the consequently decreasing of available natural resources it is very important to use alternative ways to reuse several types of household solid waste materials. The reusing of household waste is the next best option in the waste hierarchy. This option is an even better than recycling, because a substantial amount of energy is being saved in not re-manufacturing the product. Despite increasing attention to the more integrated notion of wastes as resources, problems persist in analysis and implementation. Although material by-products have been reused since prehistoric times, modern technological societies have dramatically increased both the quantity and complexity of what constitutes today's discard streams, exacerbating the management challenges of how to determine which streams are wastes and which are resources. Considering the lack of evaluative tools to support and ground the efforts toward waste reuse[26]. Under the resource-based paradigm, waste materials are considered potential resources set to take advantage of unexploited opportunities for reuse unless or until proven otherwise[27]. The end-of-waste criteria help to alleviate prejudice related to waste labeling, and increase confidence of users, thus encouraging reuse by defining technical and environmental requirements[28]. The reuse potential indicator provides information about the technical feasibility of reuse even before market conditions are assessed by addressing how development of a new technology alters the usefulness of waste materials[26].

The reuse of demolition waste has the lowest overall impact, followed by a combination of reuse and recycling, with landfill the least desirable option, as long as primary materials are displaced. Also, the reuse of metallic wastes, the life cycle assessment methods applied to mineral waste reuse do not radically diverge from the ones commonly used in the practice and referring to well established approaches[29]. By reusing biodegradable waste the environmental impact of waste disposal sites can be significantly reduced: in cities in developing countries this reduction potentially ranges between 50% and 90%[30]. In addition, reuse practices have contributed to the management of waste while supporting the livelihoods of many[9].

Waste Recycle: In Saudi Arabia, waste sorting and recycling rate ranges from 10% to 15% that driven by an active informal sector which extracts paper, metals and plastics from the waste. Recycling, reuse and energy recovery is still at an early stage, although they are getting increased attention[15].

Waste Recovery: Households were informed that biogas produced from separately collected food waste is used as renewable fuel in vehicles and that remaining bio-solids can be recovered and used as fertilizers on farmland[31]. International Energy Agency[32] statistical data shows that the traditional biomass energy constitutes 80% of the total renewable energy consumed mainly in developing countries. In Saudi Arabia, King Abdullah research centre for atomic and renewable energy is planning to get 16 GW from PV, 25 GW from 17 GW nuclear, 9 GW from wind, 3 GW from waste to energy and 1GW from geothermal by the year 2032[33].

With fossil energy sources eventually dwindling and becoming increasingly more expensive, waste-to-energy routes are gaining future attraction[34]. Cities account for approximately two-thirds of the world's primary energy consumption and 71% of global fossil fuel related direct greenhouse gas emissions[35]. To ensure that cities maintain their vital social and economic functions, there is a need to develop urban energy systems that are more efficient and emit less. Biomass is an interesting renewable energy source for several reasons. The main reason is that bio-energy can contribute to sustainable development[36].

Waste Landfill: To conserve resources, reduce reliance on landfills, and combat environmental problems associated with traditional waste handling methods, nations have turned to aggressive pursuit of recycling and other waste reduction policies[1]. Some of the waste substances can be reused and can be a resource for an industry. Indeed waste management is one of the most important problems of our time as development and subsequent use of materials generates enormous quantity of wastes[4].

Problems found in waste management systems, among others, include limited areas for landfill, waste disposal costs, the emission of greenhouse gases and dioxins and concern over health and environmental quality, all of which can be solved more easily in combination rather than individually. The 3Rs (reduce, reuse and recycle) campaign was initiated to reduce the waste quantity and reuse plus recycle based on an increasing awareness of the linkage between waste generation and resource consumption[24].

Municipal solid waste especially household 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[20]. Arab countries are presently faced with problems such as increasing urbanization and demands for more food and shelter to sustain a standard life pattern. Currently the organizations for the waste management in the kingdom are working for the safe disposal of the waste only, and not for the energy recovery from it. The Saudi government is aware of the critical demand for waste management solutions, and is investing heavily in solving this problem and efforts are underway to deploy waste-to-energy technologies in the Kingdom[15].

It is closely related to human comfort and security as existing landfills, which are rapidly filled, pressure the waste managers

to identify new landfill sites[37]. Over-flowing landfills and improper waste management systems pose risks to human wellbeing and public health[38].

Need for the study: Saudi Arabia is a developing country and waste management is currently in its early stages. The mean way of solid household waste treatment is the disposal of waste into landfill. The country is looking into other possible more green and environmentally sustainable options such as the recycling, composting and Energy from Waste (EFW) treatments. However, before any alternative could be practically considered, the different types and quantities of waste need to be determined by city basis. Therefore, this study aims to address this issue in order to lay a foundation for decision makers to choose suitable treatment options based on the actual types and amounts of waste. Jeddah city was selected as the study area because it is the second largest city in the country with a population of about 4 million and is currently running out of landfill space.

Methodology

Because of differences in density population, life-style and economic level, Jeddah City was divided into four sampling zones (north sampling zone (N); central north sampling zone (CN); central south sampling zone (CS) and south sampling zone (S), figure-2). To determine the quantity and composition of household solid waste over 400 sample household wastes samples were randomly collected from over 60 distrusted dump sites. These samples were segregated and sorted manual then and weighted and tabulated. The collected samples were classified and sorted according to Serdarevic[39] (figure-3) then the household wastes separated into different subtypes. The studied household waste samples were comprised of seven categories of wastes (plastics, paper, glass, metals, organics, wood and others).

Results and Discussion

The solid waste is not always the same throughout the year. It often changes from place to place and time to time. Organic materials represent the huge amount of municipal solid waste (MSW) including food waste, paper and wood waste. Fruit and vegetable waste is generated in large quantities with their high biodegradability, in the main cities of the kingdom. Solid waste generation from food (meat, fruit, and vegetables etc) in the central sharing market of three largest Saudi cities (Riyadh, Jeddah and Dammam) exceeds 6 million tons per annum[40]. Municipal solid waste generation has increased from 12.1 million ton per year to 15.2 million ton in five years since 2007. It is clearly found that, the compared increasing population ratio with the amount of generated waste is much higher, and hence the per capita rate per day was raised from 1.4 in the year 2007, to 1.75 by the year 2012[15].

The states of Gulf Cooperation Council (GCC) have the highest per capita waste generation across the world[41]. Owing to 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 Gulf Cooperation Council (GCC) region is around 120 million tons per year of which little is recycled or even managed. Sixty Percents (72 million tons per year) is from Saudi Arabia[42].

The quantities and characteristics of waste generated in any region are functions of the lifestyle and living standards of the region's citizens and the type of the region's natural resources. Excessive quantities of waste are generated from a society from inefficient production processes, and low durability of goods as well as unsustainable consumption of resources[43]. According to the estimated results the household solid wastes (HSW) in Jeddah City varied from zone to another in both quantity and quality. Analysis of household solid waste type in Jeddah City shows that these wastes are composed mainly of organics, paper, plastics, others, metals, glass and wood respectively in a decreasing order of abundance (figure-4). The composition of household solid waste provides a description of the constituents of the waste and it differs widely from place to place[44].

It was found that, the organic materials are the most abundant component in the household solid wastes in all over the studied four zones especially in the south sampling zone and decreasing northwards where concentrated the high income inhabitants. Also, it was found that there an inverse relationship between organic wastes and paper, plastics and metals (figure-4). This really reflects the northward difference in consumption pattern, cultural and educational differences. The most striking difference is the difference in organic content which is much higher in the low income areas than the high income, while the paper and plastic content is much higher in high income areas than low income areas.

This reflects the difference in consumption pattern, cultural and educational differences. Northwards, in higher income areas disposable material and packaged food are used in higher quantities while southwards (in the case of lower income areas), the usage of fresh vegetables to packaged food is much higher. Plastics and metals were increased northwards, this owing to wastes from industries which located within northern areas of Jeddah. These results agreed with many researchers[45-47].

The planning Model: Management alternatives are sequentially evaluated byadding several environmental risk control constraintsstepwise in an attempt to improve the managementstrategies and reduce the risk impacts in the long run.Statistics associated with those risk control mechanisms arepresented as well. Sitting, routing, and financial decisionmaking in such solid waste management systems can alsobe achieved with respect to various resource limitations anddisposal requirements[22].

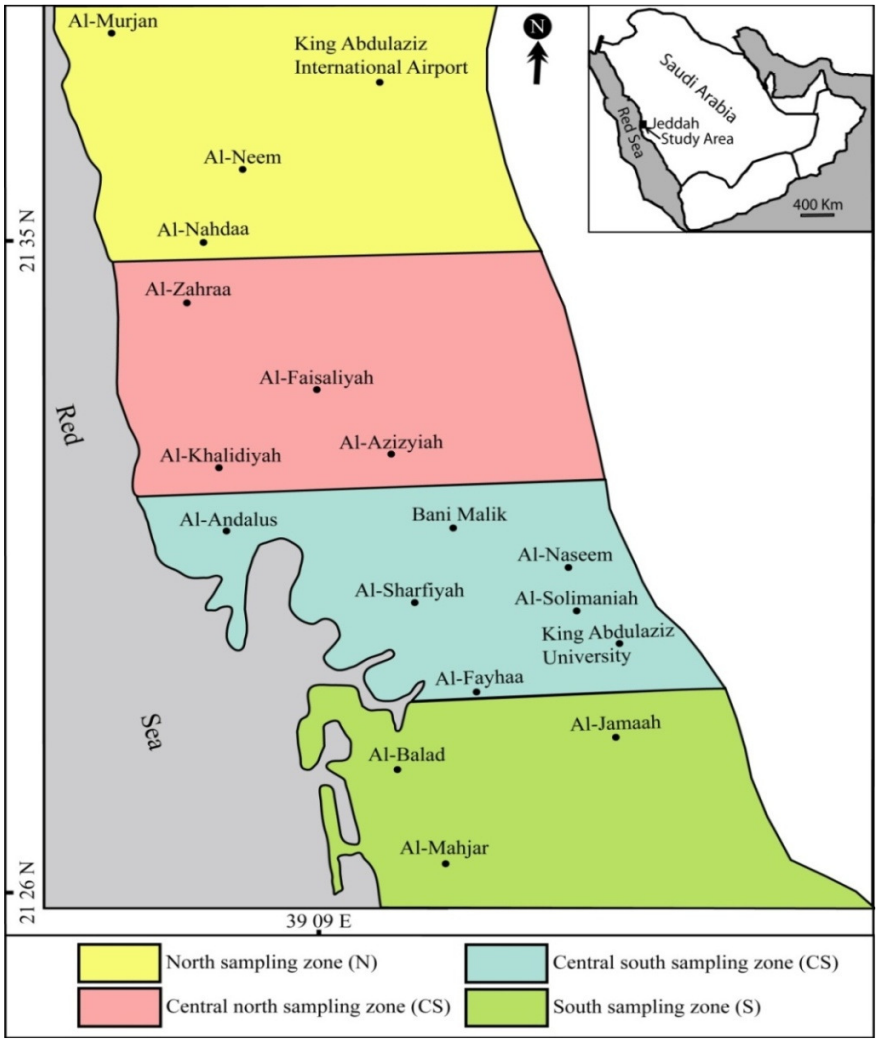

Figure-2
Location map and sampling zones

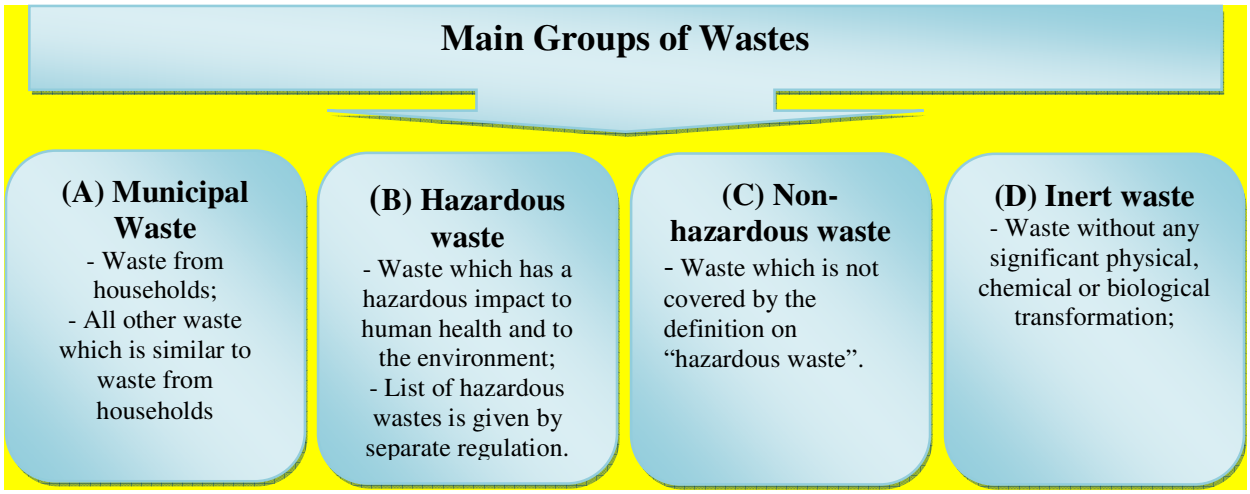

Figure-3

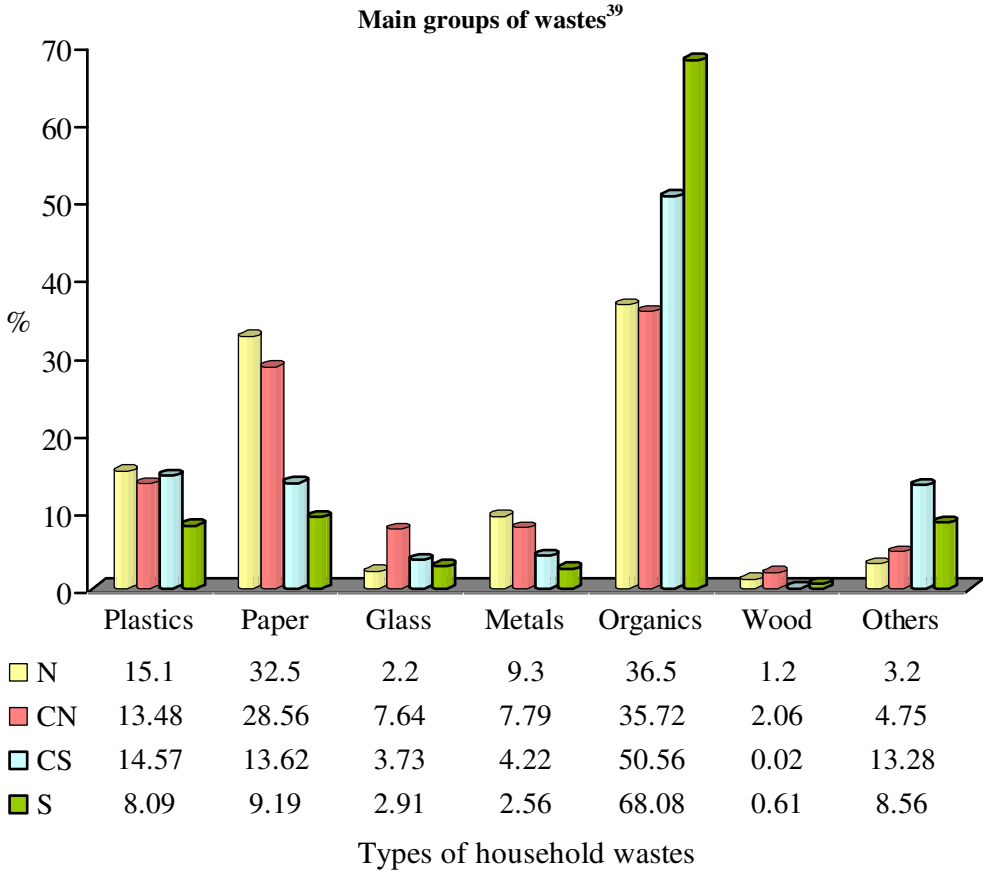

Figure-4
Abundances of household solid wastes for four studied zones (average values)

Waste Collection, Separation and Sorting: Initially, it is must be seen that, the household solid waste management starts from the production sites in houses where these wastes should be sorted and separated into colored bins according to heir types (organics, paper, plastics, metals and others). This step is very important which should be done on order to help and reduce financial costs of waste management. The practice of separating waste into a number of bins (typically recyclables and general waste) requires time and effort on the part of the householder, and as such it imposes nonmonetary costs on them. However, recycling systems that allow householders to place a variety of recyclable materials into one bin rather than having to separate the recyclables into paper, plastic, glass and metals, tend to have much higher total yields of recyclables[48].

In most urban areas, solid waste has not been sorted at its source. Only a few households sort solid waste in order to sell certain waste such as bottles, jars, metal and paper to scrap collectors. According to the survey it was revealed that household waste management is seen as the responsibility of the wife (about 54 %), the husband (23 %), and female adult (20 %). The remaining respondents stated that it is the responsibility of male adults and male children. It was important that the waste storage points were accessible by those responsible for household waste management, primarily women[24].

Bolzonella et al.[49] stated that food waste disposers can cause an increased organic load in the biological step at the wastewater treatment plant and thereby increase the energy demand for aeration in the wastewater treatment. Food waste disposers have been suggested as a practical way to establish on-site separation of household food waste without increasing transportation, odor, or need for more waste bins amongst others[50].

Sorting and segregation of biodegradable and non-biodegradable wastes are done at the household level and all other sources. It is also mandated that wastes segregation shall primarily be conducted at the source, to include household, institutional, industrial, commercial and agricultural sources. Solid waste sorting at source is a relatively new activity, which has not yet become a common practice and has been only experimented on household garbage in some big cities including[24]. As above mentioned, organic waste constitutes the dominance component of household solid waste in Jeddah City (figure-4). This organic waste mismanagement is one of the main reasons for environmental deprivation[51].

Benefits of 4Rs (Reduce, Reuse, Recycle and Recovery) of

Household Solid Waste of Jeddah City: This close up study of household solid waste considered as a planning model in management of this type of solid waste. Also, by applying this model the desirable effects of these wastes on both human health and environment will be minimized. The sustainability of solid waste management programs hinges on the structural and functional integration of education and community participation, policy and regulatory intervention, waste reduction, reuse and recycling, healthcare, electronics and household hazardous waste, landfill management, dumpsite rehabilitation, composting, waste to energy and financing, economicanalysis and public private partnership[52]. Some craft villages which recycle paper, plastic and metal, etc. have been effectively developed and contributed to job creation, poverty reduction and improved people's income and lives[24].

Really, the quantity and quality of household waste can be reduced to an acceptable limit by pursuing food systems and changing some of social customs and traditions. This requires raising awareness through educational systems and through publication of this culture through special integrated long-term programs through various media.

It was stated that, the organic materials are the most abundant household waste (figure-5), these wastes can be sorted primarily and separated in houses and saved and reused as food bank in poorer urban communities, this will build helpful community (people band together and build communities around common causes, issues, and advocacies)[53]. Also, some species which represent higher ratio of household solid waste in Jeddah City, can be sorted and reused (bottles, jars, metal and paper, figure-5) this will create a lot of jobs and help build a strong economy[24,53].

In Saudi Arabia, municipal solid waste (MSW) is collected from individual or community bins and disposed off in landfills or dumpsites. MSW consists mainly of food waste, yard waste, plastic bags, furniture scrap, used tires, home appliances, and waste paper. In KSA, currently only 10-15% of this waste is recycled while the remaining goes to landfill[54]. Waste recycling is a process a series of activities that include: the collection and sorting of waste materials, the processing of these materials to produce brand new products, and the purchase and use of these new products by consumers[53].

Recycling helps protect the environment, helps conserve limited resources, promotes energy efficiency, helps build a strong economy and builds community[53]. Recycling plays a critical role in reducing waste quantities, returning resources back to use, and minimizing the financial and environmental burden of MSW management. An extensive partially tiered system exists for waste recycling within each city/province comprising scavengers, small household/commercial recyclers, larger recyclers and manufacturers to produce recycled products[24].

It was stated that, the organic materials are the most abundant household waste (figure-5), these wastes can be recycled and used as natural fertilizers for reclamation the neighborhood new desert lands. This will reduce greatly coasts of import of the fruits and vegetables from other countries. Also, these natural organic fertilizers can be used for planting trees in order product furniture woods. In addition, the recycling organic household waste will reduce greenhouse gas emissions from waste. Papery wastes represent the second common household solid waste of Jeddah City (figure-5), these huge amount of waste paper can be recycled and used as source of packing papers mills. Recycle paper with virgin pulp to produce mainly packing paper[55].

Organic waste materials from domestic sources of Jeddah City can be converted to useful energy forms such as bio-hydrogen, biogas, and bio-alcohols through waste-to-energy routes for global sustainable growth. Biomass energy can play an important role in reducing green house gas emissions. The use of biomass for energy offsets fossil fuel greenhouse gas emissions[56]. It has been estimated that the total biomass energy potential of KSA is 3.0 (mtoe)[57].

In the Saudi Arabia and many other countries, waste Landfill maintains to be the most important method of municipal solid waste (MSW) disposal. A large number of new waste treatment facilities have been commissioned in recent years and the role of mechanical–biological pretreatment in waste management is expected to become more popular in the short term. Pretreatment will have major implications for the nature of the waste that is disposed of to landfills and hence for the way in which the landfills should be managed. Mechanical–biological pre-treatment normally involves sorting to remove recyclables, mechanical particle size reduction and partial biodegradation which may be achieved through either anaerobic digestion and/or aerobic composting processes. The long term behaviour of mechanically biologically treated waste in landfills will be different from that of unprocessed municipal solid waste owing to the removal and reduction of certain waste fractions during the mechanical[58].

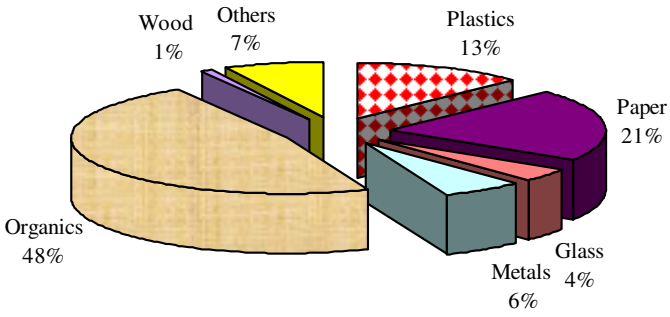

Figure-5
Abundances of household solid wastes in Jeddah City (average value of 400 samples)

Municipal solid wastes are mainly disposed into a landfill because it is the simplest, cheapest and low cost-effective

method of waste disposal[59]. Between different fractions the organic ones constituted the major component of municipal solid waste that because of its biodegradation in landfill under anaerobic condition represents, also, the major fraction affecting waste pollution in landfill.

Conclusion

From above mentioned result, the following main conclusions: This study can be used as an abdicable planning model of household solid waste management. As a result of developing and human utilization activities solid waste materials create which are costly handled. The rapidly acceleration of social and economic Saudi development have reflected on the generation rate of household solid waste (HSW) in both quality and quantity. In Jeddah City, organic materials represent the largest ones of household solid waste which concentrated in the southern metropolitan where lower income inhabitants. On the contrary, in northern richer ones paper and plastics wastes were recorded with highest ratios. The sorting and separation of household solid waste must start in houses pre-waste management. The quantity and quality of household waste can be reduced by raising awareness through educational systems and integrated long-term programs through various media. The organic materials of HSW can be used as natural fertilizers and in biogas generation. The papery wastes of Jeddah City (represent the second common household solid waste) can be used as source of packing papers mills.

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