# AN EVALUATION OF SOLID WASTE MANAGEMENT PRACTICE IN JAPAN

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***Abstract*—***This paper presents an evaluation of the current solid waste management practice in Japan. Because of limited space, the siting and construction of a new solid waste management (SWM) facility is a big challenge in Japan. A SWM facility should be socially accepted as well as environmentally and economically sound. So it is considered to be one of the most serious environmental problems confronting urban areas both in developed and developing countries. From the physical characteristics analysis of solid waste in Japan it is shown that about 68% of the total waste is inorganic which has good recycle value. Now-a-days, about 55% of total paper, 78-83% of metal cans and 22.8% of polyethylene terephthalate (PET) bottles are recycled in Japan. At present 20.3% of total solid waste is land filled, including ash from incineration. Approximately 75% of the gross amount of municipal solid waste that Japan generates annually is incinerated providing an estimated 2.5 million Kilowatts of electricity is generated. The "waste management hierarchy" (minimization, recovery, transformation and disposal) has been adopted by Japan in recent times as the menu for developing solid waste management strategies.*

***Keywords*—***Incineration, landfill, recycle, reduce, reuse, solid waste.*

## 1. Introduction

Solid waste management has become a major environmental problem confronting urban areas all over the world [9]. Inadequate collection and uncontrolled disposal of solid waste cause a serious health hazard to inhabitants and environment [4]. At all levels of activity human beings produce waste. In fact, waste is an essential by products or the necessary evil of every human living [8]. A solid waste management system is an interrelated system of appropriate technologies and mechanisms involved in the generation, collection, storage, processing, transfer or transport and disposal of solid waste designed to reduce waste at the lowest possible cost [8]. This should also minimize risk to the health of the people and the environment as a whole. Today, Japan's archipelago covers 145,882 square miles (377,835 sq. km) inhabited by 127.4 millions of people (2005); thus one of the highest population densities of the world, 873 persons per squared mile, higher than the same value in India, for example. So the problem of solid waste is particularly acute in Japan, where the combination of dense population, a productive economy and a limited landfill spaces exacerbate the situation. Incineration of solid waste is a known source of dioxins contributes to air pollution in Japan. Citizen protests and referendums opposing landfill sites have made it difficult to find the endpoints for disposal. Meanwhile Japanese society continues to produce large amounts of solid waste. The 3R principles, i.e. reuse, reduce and recycle activities reduce the volume of waste but cannot eliminate it. Therefore, there is still a need for appropriate disposal methods for residual waste. Limited siting space is a major challenge when constructing a new facility and social acceptance by neighbors is another. Some experts have seen that locating facility in the near ability is a predominant acceptance problem [6]. To be accepted, an SWM facility should be environmental friendly, economically sound and socially acceptable [3]. A SWM facility that is not accepted may be opposed [2].Especially in Japan, where SWM facilities are usually located near residential areas, the opposition of residents is a vitally important issue in solid waste management. Japan was the second most productive society after the Second World War and enjoying the most equitable income distribution, highest life expectancy (82 years), highest level of education (99%) and one of the highest per capita incomes of the world. The consequences on the environment of such economic growth based on heavy industrialization processes, were converting the country into one of the most polluted countries in the world too at that time [12]. But during the last few decades the SWM practice in Japan has got the institutional shape. In this paper, the recent solid waste management practice by Japan is evaluated.

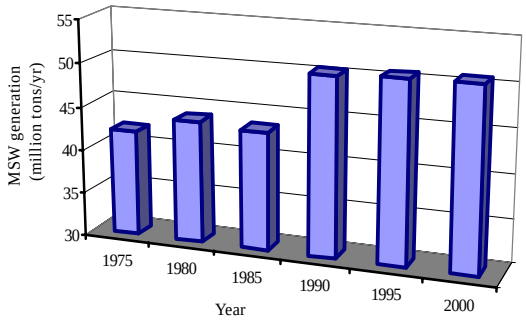


Figure 1. VARIATION of the MSW generation during last 3 decades in Japan (MOE,2000)

## 2. Solid Waste Generation and Characteristics

Solid waste in Japan is broadly classified into three main categories [12]: Domestic refuse (solid waste generated by households, markets, food centers and commercial premises such as hotels, restaurants, shops etc.); industrial refuse (from different industries not including toxic and hazardous waste that requires special handling, treatment and disposal); institutional refuse (solid waste from various government and big installations, hospitals, schools, recreational facilities and public development projects). Figure 1 shows the actual amount of solid waste disposed of last few decades in Japan. Japan generated 50.20 million tons of MSW on 1992. Though Japan's population has stabilized and is slightly decreasing, the amount of solid waste generated per capita is still increasing. The food habit and the purchasing capacity of the people also affect the generation of total solid waste from place to place. The management of municipal solid waste (MSW) is the responsibility of the citizen, local government and private business. The main problem that Japan faces on solid waste management is the concentration of waste sources in urban areas where available spaces for treatment or disposal facilities is already scarce. The average percentage of different types of solid waste is shown in figure 2. From the characteristics analysis of solid waste it is found that in Japan the major portion of the total solid waste is inorganic with a high calorific values and low moisture contents which is very useful for incineration and recover energy from solid waste [10]. Normally, the different types of solid wastes are separated from the individual house holds and kept in specific color bags in the road sides for the collection and final disposal. At present, Japan's approach to deal with solid waste are: First, pollution prevention, which seeks to redesign industrial processes in order to decrease the volume and / or the toxicity of the waste generated. Second, reuse or recycle strategies seek the use of waste material generated by any given activity as the raw material for another one. And third, the environmentally sound waste final disposal. Table 1 shows the physical composition of MSW in different cities in Japan. It is shown that even in the same country in different cities the quantity of the different physical compositions of solid waste is different. It is probably due to different food habits and living standards of the people and also the different weather condition in different cities.

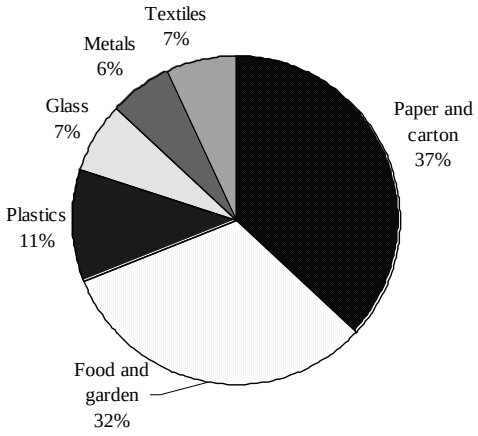


Figure 2: PHYSICAL characteristics of solid waste in Japan.

## 3. Methods of Recent SWM Practice

### 3.1. Sanitary Landfills

For landfills, even the best engineered projects of disposal sites don't address the main problem of solid waste: its initial generation. Besides, landfills face inevitable problems in future, for example, potential leaching and pollution of ground water, methane generation (due to anaerobic decomposition of organic waste, methane is also a green house gas) and space shortage when landfills compete with urban, industrial or agricultural land development projects. In a country with some of the world's highest land prices per unit of area, landfills are becoming economically unattractive.

Figure 3: TYPICAL picture of landfill in Japan.

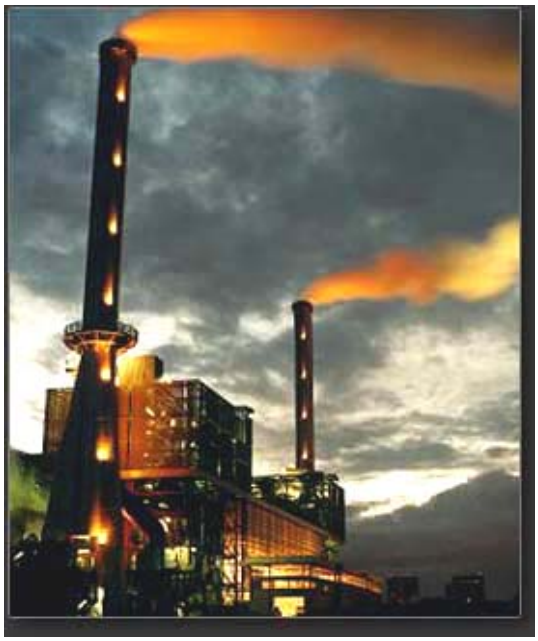

Figure 4: TYPICAL picture of incineration plant in Japan.

Due to the scarcity of landfill spaces and attention to the environmental problems associated with MSW disposal, there has been strong support for MSW management by citizens and government at all levels. At present only 20.3 % of the total solid waste is land filled, including ash from incineration.

### 3.2. Solid Waste Incineration

Japan's waste incineration with controlled air pollution is one of the most important ways of getting rid of MSW and is an important part of the electric generation of the country; waste incineration facilities are common all around the country. Approximately 75 % of the gross amount of MSW that Japan generates annually is incinerated providing an estimated 2.5 million Kilowatts of electricity with an aimed 4 million Kilowatts expected for generation in 2010.The most efficient plants achieve complete conversion of waste materials in a closed-loop process based on high temperature gasification with an extended residence time for process gases that eliminates any hazardous organic compound and recovers any hazardous materials for a posterior treatment. The result is approximately 6 million tons per year of residues which are then landfilled, with leachate control. In Netherlands, more than 90% of the annual bottom ash from waste incineration is utilized in embankments and road base applications and fly ash is also utilized as admixture in the preparation of ashphalt filler [14]. In Germany, 60% of the bottom ash from the municipal solid waste incineration is utilized in road construction [15]. Incineration bottom ash is also used in the USA as an aggregate substitute in road construction and in ashphalt pavement [1]. In Japan recent research has shown that incineration ashes may be used as a partial substitute for cement in the manufacture of concrete products, such as paving blocks. More research is needed to provide information on the long-term effects of these reusing programs as well as the post reuse effect.

### 3.3 Organic Waste Composting

Composting is the biological process in which the bacteria decompose the organic fraction of the waste to stable end product compost. Compost can be used as a good soil conditioner as well as a good fertilizer in the agricultural applications. In Japan, the total amount of the organic waste is 21.98 million tons/year: 12.41 from home, 5.52 from restaurants and 4.05 from food industries. Recycling ratio as compost is only 1% from home, 8% from restaurant and 22% from food industries.

## 4. Re-Use and Recycling

Waste minimization has been placed at the top of solid waste management hierarchy. Waste minimization consists of two basic operations: source reduction and recycling [5].Source reduction is most desirable to avoid waste generation, while recycling is useful to conserve resources and to prevent materials from entering the waste stream [11]. Recycling is very successful in Japan with regard to some materials: In 2004, an estimated

Table 1: PHYSICAL composition of MSW (%) in Japan in some major cities (Source: Sakai, 1996).

| Name of the City | Paper | Kitchen Waste | Textile | Wood | Plastics | Metal | Glass | Others |
|---|---|---|---|---|---|---|---|---|
| Tokyo | 44.5 | 31.3 | 3.9 | 6.1 | 7.8 | 1.4 | 1.11 | 3.8 |
| Yokohama | 40.0 | 9.8 | 4.2 | 5.8 | 14.8 | 5.7 | 13.4 | 6.5 |
| Osaka | 35.7 | 6.5 | 5.9 | 5.2 | 20.3 | 5.3 | 7.1 | 2.7 |
| Sapporo | 25.2 | 46.6 | 2.4 | 1.7 | 12.5 | 3.7 | 7.1 | 0.8 |

**Table 2: NAME of the law and implementing year related to SWM in Japan**

| Year | Name of the Law |
|---|---|
| 1954 | Public cleansing law |
| 1970 | Waste disposal and public cleansing law |
| 1991 | Promotion of resource reuse and recycling law |
| 1998 | Home electric appliance recycling law |
| 2004 | 3R initiative |

55% of the paper, 78-83% of metal cans, and 22.8% of PET bottles were recycled. As of April 2001, air-conditioners, television sets, washing machines and refrigerators are required to be recycled by the user, at a certain fee. The target is to close the material loop. The volumes of recycled materials are recorded by each company and industry. The following sections discuss the recycling of papers, metals including steel cans and aluminums cans, glass, plastics, and polyethylene terephthalate (PET) containers.

### 4.1. Recycling of Papers

In 1992, Japan was the second largest producer of paper and plate paper (for corrugated cardboard) with 28.31 million produced tons. Japan was also the second world consumer of paper products (228 kg/person/year) after the U.S.A. The rates of recycling (51.3%) and reusing used paper (25% for normal paper and 86% for cardboard) were maybe the highest of these rates under any world standard by 1996. One of Japan's main problems to deal with paper was those with low reuse/recycle rates such as fine-quality or printing in information papers (photocopies, computer forms, ledgers and slits). Another problem was the confidential nature of some papers and the lack of available space for storing and/or an adequate collection enterprise. To address the first issue the involvement of private industry was a must. Printers that accept recycled paper and high quality recycled paper are common in the Japanese market now. Here is where the role of government became essential by taxation of the technologies targeted for replacement and incentive for the purchase and implementation of products and processes that will replace them. The enactment of an appropriate set of laws written in collaboration with all the stakeholders involved was the most important task. Minimization of bureaucracy and paper work and an efficient digitalization process of the already existing information can potentially reduce the amount of waste generated; these are usual processes these days in Japan. Reduction of packaging paper and card board package was also necessary. A 100% rate for recycled paper use has been achieved in Japan since 2001.

### 4.2. Recycling of Metals

Aluminum recycling presents a great advantage. Today, only 3% of the energy required to process raw aluminum (21000 kWh/ton) is required to produce the same unit of volume by recycling (590 kWh/ton) and still the main problem to achieve 100% recycling is the collection/separation systems. Once this first step is accomplished and sorted high quality material is delivered to the related industry, the recycling process in fact reduces costs. The main problems that steel recycle faces are the technical requirements to be met in order to recycle this material efficiently (impurities elimination, dimensions of the compressed material, etc.). This raised the economical cost of this processes when compared with the utilization of virgin and often imported material. In Japan, there are two types of metal can, steel (54% of total) and aluminum (46%). The recycling rate of steel cans has been estimated at 82.9% and of aluminums at 78.5% [16]. Steel cans are used as drink containers in E.U., Japan and South Korea but not in the USA. At present aluminums cans are the popular containers for drinks all over the world.

### 4.3. Recycling of Glass

By 1999 the recycling rate for beer bottles reached a stable 95%. The Asahi Beer Company in Tokyo, for example, recycled 98.5% of its raw materials in 1999 and Suntory, a top Japanese producer of Western-style alcohols, started during the same year using "ecology bottles", exclusively in domestic wine production, made 100% from recycled green glass. The recycling of broken glass, after removing impurities and sorting the class by color, had a rate of 55.5% in 1993, in clear increase compared with the 48% in 1990 even when recycled bottles are more expensive and heavier than others made of virgin materials. Since 2001 Japan maintains a 100% rate of recycled glass use [13].

### 4.4. Recycling of Plastics

The global use of polyethylene terephthalate (PET) containers has been growing steadily, due to their lightness, convenience of use, and recyclables. PET usage is expected to grow at 10% per year. The per

capita annual consumption of PET containers in Japan is 2.9 Kg. The recycling rate of plastic reached 44% in Japan in 2002, positioning the country as the first world-wide plastic recycler. Most of the plastic bottles that are collected and reused end up being turned into fiber. For example, led by middle schools in the Tohoku area, new students at some 800 elementary and middle schools carry school bags that have been woven from the fiber produced by recycling ten 1.5 liter plastic bottles. While these bags cost the same as previous school bags, between ¥5,000 and ¥8,000 (between $46 and $75), the fiber is stronger than nylon, so they can last up to five or six years. According to the Japan Containers and Packaging Recycling Association, 362,000 tons of plastic bottles were produced in Japan in fiscal 2000, 125,000 tons of which were recycled, so the recycling unit costs (yen/kg) are constantly decreasing since 2001 [17].

## 5. Waste-To-Energy in Japan

As noted earlier, Japan has tried to reduce waste generation and re-use or recycle as much as possible of the MSW generated. Due to land limitation, the first priority in Japan has been to reduce the amount of landfilled waste. As a result of this long-standing policy, presently 74.5 % of the waste goes to combustion plants. Thus only 6.3 % of the MSW is directly landfilled. There are 1717 combustion plants in Japan of total capacity of 193, 00 tons per day; of these, 1130 plants (64.2%) are Waste-to-Energy (WTE) plants and 215 plants (12.5%) generate a total of 1060 MW [7].

## 6. Industrial Waste Management

Japan also is a pioneer in the control of air emissions that culminated in the country's initiative to enact the Kyoto Protocol of 1992. The objective of the Kyoto Protocol is to regulate and control the emission to the atmosphere of sulfur oxides, soot and dust; and harmful substances that include: cadmium, cadmium compounds, chlorine, hydrogen chloride, fluorine, hydrogen fluoride, lead, lead compounds, nitrogen oxides, asbestos, ammonia, carbon monoxide, methanol, benzene, trichloroethylene, tetrachloroethylene, dioxins among others. The disposal of industrial wastes depends on their physical and chemical properties. Ashes, product of incineration processes are sent to landfills, wastes classified by their hydrophobicity; acid/bases are neutralized and active sludges dehydrated. Japanese environmental laws evolved from mutual agreements on local basis to worldwide regulations of Japanese industry and pollution movement. Table 2 shows the Japanese law and implementing year for solid waste management. The 3R initiative has four main objectives in order to be implemented: reduction of barriers to the international flow, cooperation among stakeholders (communities, private sector, NGOs and central and local governments), promotion of science and technology and cooperation with developing countries. The steps to follow to address any environmental concern through the 3R initiative are: identify and target specific problems, involve and describe the role of all the stakeholders, raise aware of the potential consequences of the problem and develop a project to deal with it. The most interesting aspect of this Japanese initiative is the extent toward which this project is directed, aware that environmental pollution doesn't respect any political boundaries, Japan looks for international collaboration in order to lower the impacts of human activities and eventually achieve a new sustainable economic model.

## 7. Conclusions

Rapid industrialization and economic development has caused tremendous increase of solid waste generation in Japan. Because of the very limited landfill capacity for waste disposal and the need to conserve this limited capacity for future, land filling of solid waste in Japan has been opted as the least desirable disposal methods. Solid waste incineration, although much more expensive, has been given top priority over all other waste transformation methods. It has been planned to incinerate all incinerable solid waste and to allow only non-incinerable solid waste and incineration ashes for landfills. Also, Japan landfills only 20.3% of its MSW, including the WTE ash, plants and combusts 74.5 % of its MSW in costly waste-to-energy facilities that convert solid wastes to electric energy and heat. The "waste management hierarchy" (minimization, recovery, transformation and disposal) has been adopted by Japan in recent times as the menu for developing solid waste management strategies which makes Japan as one of the cleanest countries in the world.

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