CHANGES IN BARRIER SYSTEMS AND LEACHATE TREATMENT TECHNOLOGIES FOR LANDFILLS IN JAPAN

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ABSTRACT

As a part of research activities by "The Landfill Systems & Technologies Research Association of Japan, NPO (LSA, NPO)", a series of studies on the history of landfill system technologies in Japan has been carried out to clarify how the technologies should be and to contribute to the progress of them. In these studies, changes in laws and regulations on the waste management, landfill structure, etc. and social backgrounds of applying the related technologies are put in order from a historical viewpoint. In this paper, changes in the law, the social problems, the barrier systems and leachate treatment technologies for landfills in Japan are reported. In consequence of the comparison between social backgrounds and history of adopting landfill system technologies, it has been cleared that the changes in barrier systems and leachate treatment technologies were closely related to the occurrence of social problems on landfill structure.

Keywords: history of landfill system, barrier, leachate treatment technology, laws and ordinances, social conditions

INTRODUCTION

It is not too much to say that the history of landfill system technologies in Japan was first made by Dr. Hanashima (Professor Emeritus of Fukuoka University, Japan) who started a research on the landfill disposal of waste in the middle of 1960's. Dr. Hanashima paid his attention to an environmental pollution problem derived from waste landfills and started the research and development of landfill technology to reduce pollutive level of leachate by utilizing microorganisms for decomposition of organic wastes in landfills effectively. Through the field experiments for aerobic landfill, Dr. Hanashima developed the semi-aerobic landfill structure peculiar to Japan and the results of his studies led Japanese landfill systems and technologies to be established.

As a matter of course, such studies have been pushed forward based on social requests, and the technology has progressed as a result of them. However, there are few reviews which reported the technical progress systematically with a social background of the time. Therefore, on the basis of conventional results of

research and a social trend, a series of studies, which review the changes in laws and regulations pertaining to final disposal sites, in landfill technologies and in social background related to them, has been carried out by the research group of the LSA, NPO.

This paper reports a part of the results of these studies. The changes in laws and regulations for final disposal sites in Japan and social conditions and problems, that were thought to have provided the occasion for the change, are described here. The change in hydraulic barrier playing an important role in landfill systems is also reviewed, and from the result of the investigation by questionnaires to the members of the LSA, NPO, the first cases where various barrier systems were used for landfills in Japan are reported including social problems related to them.

The studies on the leachate treatment technologies were also initiated in the middle of 1960's. And the basic technologies for leachate treatment that combines the biological and physiochemical treatments were established before the time when the Joint Order was issued in 1977. After that, various advanced treatment technologies are added with change of waste and it has continued up to now. The details of these matters are also reported in this paper.

CHANGES IN LAWS, ORDINANCES AND SOCIAL CONDITIONS RELATED TO FINAL DISPOSAL SITE AFTER THE WORLD WAR 2

"Public Cleansing Law" was promulgated in 1954 after about 50 years since "Filth Cleansing Law" that was the first law relating to waste disposal in Japan was established. This law provided that hygienic disposal of filth was placed under the responsibility of cities, towns and villages from the viewpoint of public sanitation maintenance.

In 1956, it was declared in a White Paper on Japanese Economy that the postwar revival was over and the times when Japanese economy accomplished a big change began. The Metropolitan Expressway, Tomei Expressway and the Tokaido Shinkansen were constructed to be ready for the Tokyo Olympics held in 1964, and Japanese population rose above 100,000,000 in 1966. On the other hand, the outbreak of a rare disease in Minamata in 1956 and the intensification of the Yokkaichi pollution that began with increase of an asthmatic of 1960 became big social problems. Also, the pollution caused by insanitary waste landfills started attracting public attention.

In such a high economic growth and the pollution issue that occurred thereby, a study on an aerobic landfill structure that aimed at improvement of insanitary landfills was started in 1966 by the research group led by Associate Prof. Hanashima of Fukuoka University (presently Professor Emeritus), and "a study on aerobic landfill disposal technology" was performed as a research sponsored by the Ministry of Health and Welfare in 1973. In this study, it was confirmed that the pollutive level of leachate was improved as a result of natural aeration promoted by the large-diameter drainage pipe. This was an opening of a Japanese original semi-aerobic landfill structure, and based on these results of the research, a final waste disposal site with the semi-aerobic landfill structure was completed first in Fukuoka City in 1975.

Reflecting such a tendency of the times, "Waste Management and Public Cleansing Law" (hereinafter called as "Waste Management Law") which took place by radically amending "Public Cleansing Law" was enacted in the Diet of 1970 when 14 pollution related laws were established and/or revised, and a standard for final disposal site was prescribed by the Cabinet Order and the Regulations of "Waste Management Law" in the following years.

In 1972, “Japanese Islands Remodeling Idea”, that was going to solve depopulation and congestion and a pollution issue at the same time by linking the Japanese Islands in a high-speed transportation network and promoting industrialization of a district, was announced by Mr. Tanaka, the then Minister of International Trade and Industry, but the first oil crisis happened in the next year, and the Japanese economic growth suddenly slowed down thereby. On the other hand, Vietnam War terminated in 1975, and it was the time when the light and the shade were divided clearly.

In such tides of the times, Japan gradually changed from the age of high economic growth into the age of environmental protection, and the Waste Management Law was partially amended in 1976 in order to advance the measures preventing environmental pollution induced by waste disposal and treatment facilities. In accordance with this amendment, “Order Determining Engineering Standards Pertaining to Final Disposal Site for Municipal Solid Wastes and Final Disposal Site for Industrial Wastes” (here in after called as “Joint Order”) by the Prime Minister's office / the Ministry of Health and Welfare was promulgated in the next year, and it was required to install barrier system and leachate treatment facility. In addition, “Landfill Guidelines” was incorporated in “Commentary on Waste Treatment Facility Structure Guidelines” of publication in 1978 and established alone in the next year.

However, with the news on the polluted water outflow accident caused by the damage of geomembrane liner in Tobuki landfill site of Hachioji City in 1986, “Landfill Guidelines” was revised in 1988 to aim at advance of leachate treatment facilities, substantiality of barrier systems and a thorough landfill management, and “Commentary on Landfill Guidelines” was published in 1989.

In the 1990’s, with the news that the leakage of leachate might occur by the damage of geomembrane liner in regional solid waste disposal site of Yatozawa in Hinode Town, the strong opposition movements by residents broke out against the construction of a new landfill site in each place of Japan. Furthermore, the illegal dumping of industrial waste represented by the one at Teshima Island in Kagawa Prefecture became a big social problem, so that distrust of inhabitants for landfills spread out in all over Japan.

In response to those series of problems, the Waste Management Law and the Joint Order were amended drastically in 1997 and 1998, respectively. By these amendments, reinforcement of lining systems and clarification of technical standard for landfill structure were performed, including the obligation to apply the double liner systems for the controlled type landfill. Furthermore, “Guidelines for the functions of landfill” was established in 2000 instead of the conventional guidelines in which the structural system of landfill had been mainly prescribed.

CHANGES IN BARRIER SYSTEM

The structures of double liner system, consisting of combinations of geomembrane and compacted clay layer or watertight asphalt concrete and double geomembrane liner, were shown in “Revised Joint Order” of 1998. Therefore, the change of technology in soil liner and geomembrane liner and those applying examples are described below.

Soil Liner

Change of Seepage Control Work by cohesive soil:

Low permeability of cohesive soil was utilized from the ancient times. Large-scale earth dam for water reservoir was already constructed by using clayey soil at the birthplace of ancient civilization before Christ.

In Japan, it is said that the oldest reservoir with earth dam is Sayama Pond in Osaka, and it is thought that it

was constructed in the first half of the seventh century. After that, many large-scale reservoirs for agriculture represented by Man-no Pond in Kagawa Prefecture, that was assumedly constructed in 704, were made by earth dam form. However, the embankment constructed by cohesive soil in these reservoirs did not have clear positioning as seepage control structure. The use of clayey soil as low permeable materials, which has a significance of engineering and the long history, is for impervious core of zoned embankment dam. As for the earth dam, it is not clear when zoned embankment dam was constructed first in Japan because it was considered to be the same as homogeneous type to all appearances, however, it seems to have been already used for a reservoir in the first half in the 17th century. In contrast, the rock fill dam with impervious zone consisting of clayey materials, which was a comparatively new type, was constructed first in western United States in the middle of the 19th century, and Obuchi Dam in Gifu Prefecture, Japan completed in 1952 is the oldest case in Japan.

Application to landfill: Disposal of municipal waste in America and European countries at the old times was performed using a natural hollow or an abandoned mine, so that the natural clayey soil layer existing under or around the disposed waste functioned necessarily as hydraulic barrier. Also in Japan, inland landfills in Tokyo after 1890’s were located at a swamp, a valley, low land and a former rice field, and it can be said that the sites where clay layer existed as natural liner were selected.

In landfills, a general idea of barrier system was taken into account in 1970's, and compacted clay layer was widely used as barrier system in the U.S.A by applying the technology from the above-mentioned fill dam. In Japan, compacted clay having thickness of 50cm was laid as barrier system at the landfill of Hokusatsu regional association of integrated administration in Kagoshima Prefecture in 1986.

On the other hand, as for the applicability to barrier system of bentonite mixed soil having lower permeability, many studies were carried out in Sweden, Germany and Canada from about 1980, and it was put to practical use. The study on bentonite-sand mixture was started from the end of 1980's in Japan, but it was intended for underground disposal of low-level radioactive waste at first. The study on the applicability to barrier system of bentonite mixture soil has been carried out from middle of 1990's. The representative result of using it to practical landfill was that in regional solid waste disposal site of Futatsuzuka in Hinode Town, of which construction was started in 1995. After that, bentonite mixted soil has been widely used as a clay liner of double liner system provided in the Revised Joint Order.

Geomembrane Liner

Synthetic rubber sheet or synthetic resin sheet is widely used as roofing sheet of a building and as barrier of water retention reservoir or waste water pond since it was used for underground waterproofing in West Germany in the latter half of 1930's. In Japan, experimental constructions using synthetic rubber sheet were carried out in 1957 for roof waterproofing and in 1967 for lining of a reservoir for agriculture. Then, Japanese industrial standard for “Roofing sheets of synthetic polymer” (JIS A 6008) was established in 1969.

On the basis of the use of rubber sheet for lining of agricultural reservoir, regulating reservoir, and so on, it is said that the use of similar rubber sheet on the Nakata landfill site of Chiba City in 1977 was the first case of application of barrier system to landfill in Japan. After that, by the promulgation of the Joint Order in 1977, the use of geomembrane as a barrier of landfill

became common in the first half of 1980's. On the other hand, barrier system using geomembrane for landfill was prescribed in 1984 in the U.S.A. because compacted clay was commonly used as landfill liner, and the use of geomembrane was obliged to landfill in 1988 in Germany. However, while the study on geomembrane as a barrier for landfill had been started from about 1980 in Europe and the United States, it was from about 1990 in Japan.

In Europe and the US, high-density polyethylene (HDPE) sheet which has high resistance against chemicals approved by such studies was widely used for landfill from the beginning. In contrast, in Japan, on the basis of the practical use for agricultural reservoirs, etc, synthetic rubber (ethylene-propylene-diene monomer: EPDM or thermoplastic polyolefin: TPO) sheet and polyvinyl chloride (PVC) sheet were mainly used in 1980's. However, based on the results of researches on durability and weatherability of geomembranes and the developments of new products, synthetic resin sheets made from various materials, such as HDPE and TPU (thermoplastic polyurethane), also have come to be widely used from the beginning of 1990's, and such a variety in geomembrane liner became one of the characteristics of landfill structures in Japan.

CHANGES IN LEACHATE TREATMENT TECHNOLOGIES

In the middle of 1960s, leachate treatment was performed by applying a trial-and-error method using sewage disposal technologies of those days. The purpose of the leachate treatment was to reduce organic materials.

Biological treatment technologies were considered by reduction of BOD substances and Nitrogen contained in organic materials, then the activated sludge method was adopted for reduction of BOD substances, and the acidic coagulating sedimentation method of physicochemical treatment technologies was examined by COD reduction. Other methods that are used for the biological treatment include such as trickling filtration method, contact aeration method and rotary disk method. These methods also began to be gradually examined by leachate treatment. Since the agricultural damage caused by leachate was a starting point, the leachate treatment technologies were examined not only with BOD reduction but also with nitrogen reduction from the beginning. In 1975, the activated carbon absorption method was employed as an advanced treatment method for reduction of COD and color removal from the leachate.

As a time progresses, the composition of MSW landfilled is shifting toward the incinerated residue and incombustibles. The contaminating component of leachate also changed, and the rate of the organic materials fell while mineralizing, it has complicated more. Therefore, the case which adopts a chelating adsorption method as advanced treatment of heavy metals began to appear.

The state subsidy for leachate treatment facilities started to in 1977, and the number of introduction of institutions increased rapidly after it.

In the 1980s, the problem of scaling caused by calsium contained in leachate has become conspicuous at the MSW leachate treatment facilities. When the leachate with high calcium content flows into water treatment facility, it reacts with CO_2 in the water and in the air to form $CaCO_3$ that is deposited in the facility . There are two ways to prevent the formation of calsium carbonate. One is calsium removal method and other one is scale inhibition method. The ulating sedimentation method which is one of calsium removal method was adopted as the leachate treatment process for the first time in 1983. Furthermore, when the rate of content of the incineration ashes in the waste increased

more, the highly concentrated chloride ion in leachate flowing out from MSV landfill is creating a problem. The problem with salt at the industrial waste landfill is also appearing.

An example that the chloride ion has an adverse effect is the chemical damage to agricultural products in a downstream region. As the measure for this problem, the desalination equipment utilizing the electrodialysis method appeared in 1995, and the desalination equipment utilizing the reverse osmosis method was introduced in 1999.

Existence of chlorinated hazardous substances such as dioxins in incinerated residue was pointed out in 1983, and the pollution control measure for the public waters that prevents the pollution with the leachate of the final waste disposal site was examined. Since dioxins were poorly soluble, in 1997, it was presupposed that "the means for removal of a suspended substance is put into practice with leachate treatment equipment, and SS concentration of treated water is made into 10 or less mg/L" in the "Guidelines for occurrence prevention of dioxins concerning refuse disposal". Also, in 1997, as advanced technologies for removal of dioxins, the coagulating membrane separation methods were offered. While they are basically used to deal with SS type dioxins, the introduction of membrane separation technologies that are able to reduce the SS to nearly undetectable levels is an effective way to solve the problem. On the other hand, the research and development for dealing with soluble dioxins were examined, and the method including the accelerated oxidation process (the AOP method) using powerful oxidizers, such as ozone and ultraviolet rays (UV), was introduced in 1998.

RESULTS OF INVESTIGATION INTO THE FIRST USE OF BARRIER SYSTEM FOR LANDFILLS AND CHANGES IN LEACHATE TREATMENT TECHNOLOGIES

The first uses of various barrier systems and leachate treatment technologies for landfill in Japan, which were provided by questionnaire survey to the members of the LSA, NPO, are shown in Table 1 with the changes in laws, ordinances, and regulations related to the final disposal site.

From the result of the investigation, it has been confirmed that the geomembrane liner was used first at Nakata landfill site of Chiba City in Chiba Prefecture in 1977 when the Joint Order, which was the first technical standard for landfills in Japan, was established. No precedent for constructing lining system could be obtained, therefore it can be said that the history of barrier system for landfill in Japan started at that time. On the other hand, the first use of double liner system was the composite liner, which consisted of a geomembrane and a low-permeability compacted clay, in 1988. After that, other two types of the double liner system, which is provided in the present standard in Japan, were constructed before 1998 when the amendment of the Joint Order including the obligation to apply the double-layer liner systems was made.

In consequence of the comparison between social backgrounds and history of constructing landfill liner shown in Table 1, it has been cleared that the changes in lining systems, especially in double liner systems, in Japan were closely related to the occurrence of social problems on landfill structure.

About leachate treatment, activated sludge method and coagulating sedimentation method were used first in Fukuoka City in 1968. Then, various processing technology is developed and applied in accordance with the processing purpose.

Table 1 Changes in Laws, Ordinances and Regulations Rerated to Landfill and the First uses of Various Barrier Systems and Leachate Treatment Technologies

Year	Laws, Ordinances, etc. Related to Landfill	First uses of barrier System and Leachate Treatment Technology	
		Barrier System (DL) means Double Liner	Leachate Treatment Technology
1954	Promulgation of "Cleansing Law"		
1966	Beginning of the study on an aerobic landfill structure		
1968			Activated sludge method and Coagulating sedimentation method (Fukuoka City)
1970	Promulgation of "Waste Management and Public Cleansing Law" (Waste Management Law)		Ammonia stripping method
1971	Promulgation of the cabinet order and the regulations of "Waste Management Law"		Trickling filtration method (Fukuoka City)
1975			Sand filtration method and Activated carbon adsorption method(Fukuyama City)
1977	Promulgation of "Order Determining Engineering Standards Pertaining to Final Disposal Site for Municipal Solid Wastes and Final Disposal Site for Industrial Wastes" (Joint Order)	EPDM Sheet (Nakata landfill site, Chiba City) PVC Sheet (Mie Prefecture Environ- mental Conservation Agency)	
1978	Publication of "Commentary on Waste Treatment Facility Structure Guide- lines"		Chelate adsorption method (removal of heavy metal) (Ayabe City)
1979	Establishment of "Guidelines for Land- fill"		
1980		Watertight Asphalt Concrete (Tokyo Administrative Association of Municipal Waste Disposal Site)	
1982		TPO Sheet (Chuno Regional Associa- tion of Integrated Administration in Gifu Prefecture)	
1983			Lime soda method (Calcium removal) (Niihama City)
1986	News on the polluted water outflow accident in Tobuki landfill site	Compacted Clay (Hokusatsu Regional Association of Integrated Administra- tion in Kagoshima Prefecture)	
1988	Revision of "Landfill Guidelines"	HDPE Sheet (Imafuku landfill site, Miyazu City) (DL) Compacted Clay (Kohoku Regional Association of Integrated Administra- tion in Shiga Prefecture)	
1989	Publication of "Commentary on Land- fill Guidelines"		
1990		LDPE Sheet (Tsukui District Regional Association of Integrated Administra- tion in Kanagawa Prefecture) (DL)Watertight Asphalt Concrete (Uwajima City, Ehime Prefecture)	
1992	News on the possibility of the leakage of leachate in Yatozawa landfill site	(DL)Geomembrane (Hadano-Isehara Ad- ministrative Association for Environ- ment and Sanitation)	
1993		TPU Sheet (Shintoku Town, Hokkaido)	

1995		(DL)Bentonite Mixture Soil (Tokyo Santama Area Regional Association of Waste Disposal)	Electrodialysismethod (DesalinizationTreatment) Carrier method
1996		(DL) Cement Stabilized Soil (Miyakonojyo City)	
1997	Guidelines for occurence prevention of dioxins concerning refuse disposal		Membrane Separation method (Removal of dioxins)
1998	Amendment of the Joint Order		Accelerated oxidation method
1999			Reverse osmosis method
2000	Establishment of “Guidelines for the Functions of Landfill”		

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