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Restration and Recovery Technologies for Illegal Dumping of Waste Pollution

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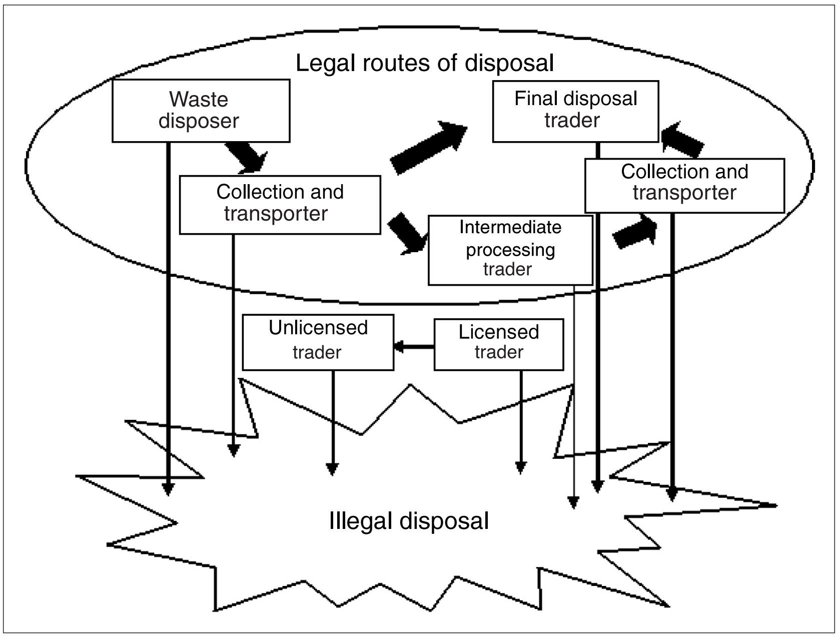
1 Introduction

As society's concern for safety and security has increased in recent years, so too has the Japanese citizen expectations that science and technology will help address these issues. Greater contributions to safety and security will be required of science and technology policy in the future[1].

The illegal dumping of waste is a problem that must be addressed since it threatens society's safety and security. As illustrated in Figure 1[2], the illegal dumping of waste that should be reused, recycled for use as resources, or properly processed or disposed of is an ongoing problem. Illegal dumping of waste is not only an impediment to the creation of a sound material-cycle society, but it also causes serious environmental problems by polluting the environment with toxic substances included in the dumped waste. Pollution from illegal dumping has characteristics that differ from the typical environmental pollution caused by other human and industrial activities. In addition, the restoration and recovery of sites where illegal dumping have occurred poses a variety of problems, including not only technical issues but also enormous economic costs and impact on surrounding environments.

Social and technological factors contribute both to illegal dumping and the countermeasures



Based on Reference[2], with some modifications

Figure 1 : Flow chart of illegal waste disposal

that can be taken against it. From a different perspective, there are both preventative measures that can be taken before the act of illegal dumping and responsive measures that can be taken afterwards. Social factors such as the cost of waste disposal are intimately related to the incidence of illegal dumping. In order to address the root causes of illegal dumping, the social and economic structures that contribute to it must be sufficiently understood so that effective preventive systems can be introduced. This article focuses on the technical aspects involved both before and after illegal dumping, looking at the problem from a science and technology perspective. In addition, by summarizing and analyzing the status of illegal dumping, environmental pollution and the technological countermeasures taken, this article addresses those science and technology policy issues that should be directed as preventative technologies for illegal dumping and as pollution recovery technologies.

2 Status of illegal dumping and characteristics of environmental pollution

2-1 Nationwide situation in Japan[2-3]

Figure 2 illustrates trends in the illegal dumping of industrial waste over the past 12 years. Cases of illegal dumping increased annually from FY 1993 through FY 1998, reaching well over 1,000 cases in FY 1998. The number of cases of illegal dumping remained high (above 1,000 annually) through FY 2001 but began declining in FY 2002. The volume of waste dumped, however, did not show a corresponding decline. This is because of the large differences in volume among cases of illegal dumping, with just a few large-scale cases accounting for the bulk of an entire year's volume. For example, of the 745,000 tonnes noted in Figure 2 for FY 2003, a single case in Gifu City (Tsubakibora area) accounted for 567,000 tonnes, or about 76 percent of the entire annual total.

Figure 3 summarizes the number of cases and volumes in FY 2004 according to the types of industrial waste dumped. In terms of the number of cases, rubble, wood scrap, and mixed construction waste were the most common types, accounting for around 64 percent of the total. Including additional types of construction-related waste, construction waste accounted for about 71 percent of the total. In terms of volume, however, construction-related waste plastic chips, alone, accounted for 56 percent, with all forms of construction waste accounting for 86 percent of the total. Looking at the statistics for past fiscal years, in terms of the number of cases, little change is seen in the relative composition of the various types of waste. In terms of volume,

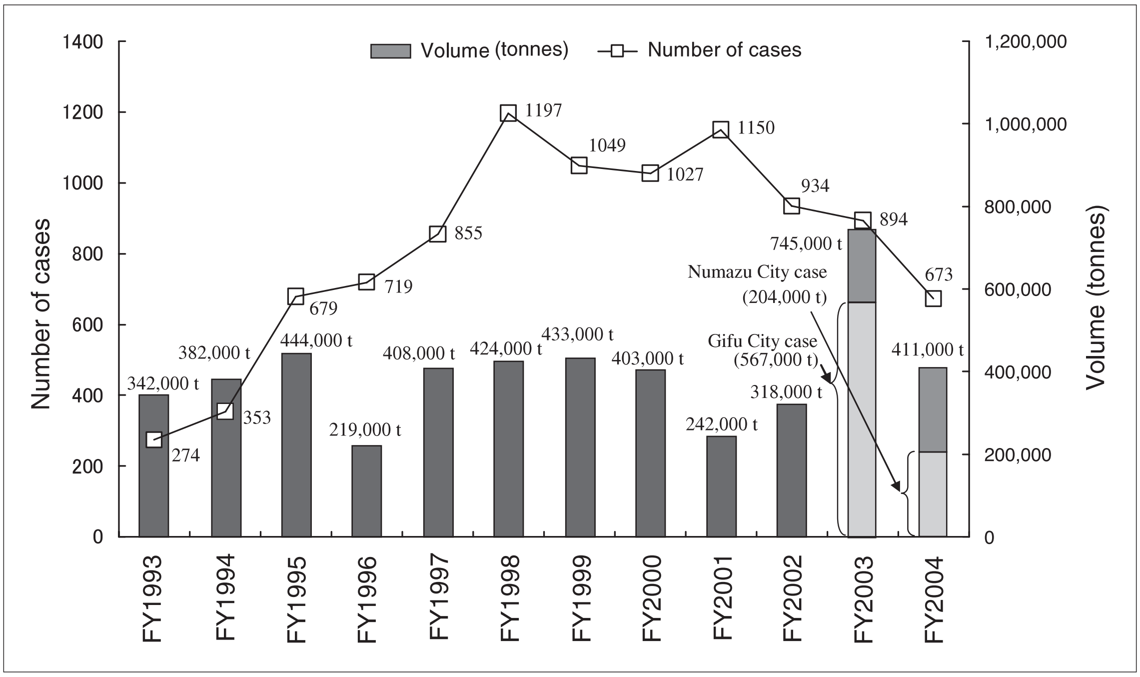


Figure 2 : Cases of illegal dumping of industrial waste and the volumes dumped[3]

however, composition can be seen to vary from year to year with rubble, wood scrap, and mixed construction waste each accounting for about 20 percent of the total, overall, while specific types of waste were particularly common in fiscal 2003 and 2004 because of a single large-scale case of illegal dumping.

As for those who engaged in illegal dumping, waste-generating enterprises were the most common, accounting for about 48 percent of all cases, in terms of numbers. In terms of volume, waste-generating enterprises and unlicensed enterprises accounted for the majority of cases. Forests and agricultural land accounted for about half the illegal dumping sites (by land use category), indicating a preference for areas that are not easily observed. Looking at the prefectures where most dumping occurred, Ibaraki and Chiba Prefectures figured prominently, suggesting a pattern of waste from the greater Tokyo area being transported to surrounding areas. The number of cases of dumping found in municipalities in outlying regions such as Aomori and Nagasaki Prefectures is also notable.

Table 1 shows the status of efforts undertaken to eliminate the problems resulting from recent cases of illegal dumping. In terms of the number of cases, 30-35 percent have yet to be addressed. In terms of volume, due to a large-scale incident (FY 2003), there is a significant difference between the volume that has been partly addressed and the volume yet to be addressed. Because countermeasures require a long time to implement, complete elimination has only been possible in less than 10 percent of all cases.

2-2 Characteristics of large-scale incidents and the countermeasures taken against them

The following characteristics are typical of environmental pollution resulting from illegal dumping[4].

- The types of waste buried vary widely, and

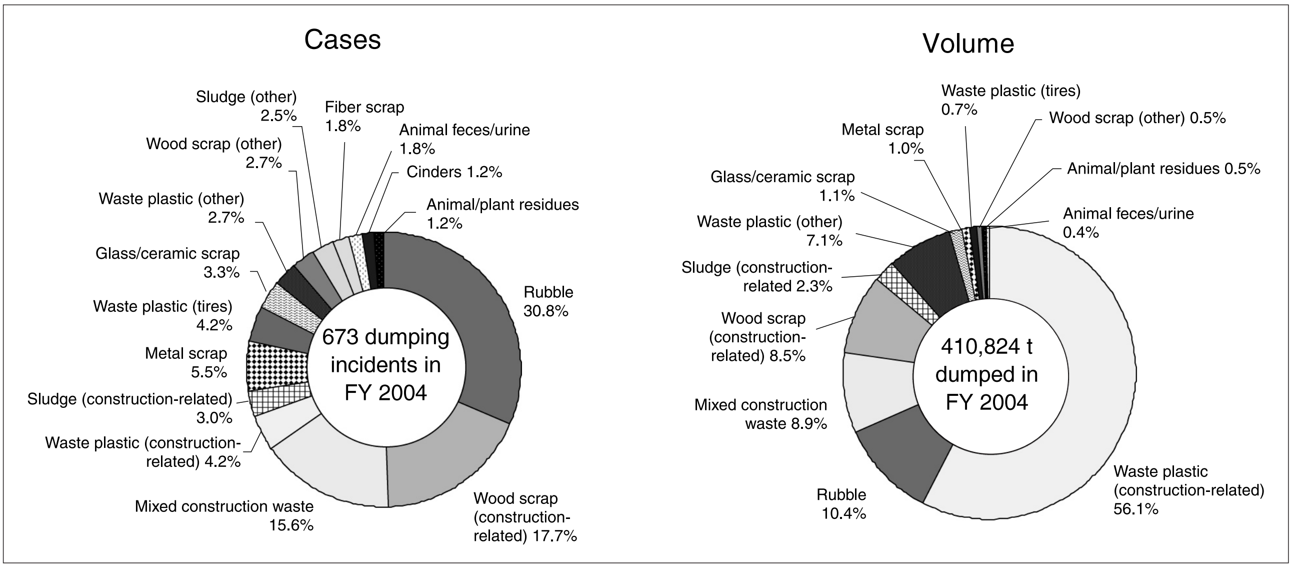


Figure 3 : Illegally-dumped waste (number of cases and volume)[3]

Table 1 : Status of elimination of problems resulting from illegal dumping(responses carried out within each fiscal year)[3]

Status	FY 2004		FY 2003	
	No. of cases	Volume (t)	No. of cases	Volume (t)
Completed	387 (57.5)*1	37,081 (9.0)	463 (51.8)	62,990 (8.5)
Partially addressed	71 (10.5)	279,370 (68.0)	75 (8.4)	65,225 (8.8)
Not addressed	215 (31.9)	94,373 (23.0)	298 (33.3)	613,125 (82.3)
Others*2	0	0	58 (6.5)	3,639 (0.5)
Total	673 (100)	410,824 (100)	894 (100)	744,978 (100)

*1 Numbers in brackets are percentages of the overall total
*2 No response from surveyed municipality

Table 2 : Large-scale illegal dumping cases

Date of discovery, location	Extent	Dumped waste	Pollution status and major pollutants
1990, Teshima, Kagawa Prefecture	Estimated area of 69,000 m^2, volume of about 560,000 m^3, and wet weight of about 600,000 tonnes	Mainly shredder dust, along with paper-making sludge, slag, dehydrated cake, cinders, etc.	Lead, PCB, 1, 2-dichloroethane, cis-1,2-dichloroethylene, 1, 2- trichloroethane, trichloroethylene, tetrachloroethylene, 1, 3-dichloropropene, and benzene
2002, border between Aomori and Iwate Prefectures	15 ha and 150,000 m^3 on Iwate Prefecture side, 12 ha and 670,000 m^3 on Aomori Prefecture side, 820,000 m^3 total	Wide variety of components, mainly bark compost, matter for RDF, cinders, incineration ash, sludge, etc., thoroughly mixed with dirt and buried	Dichloromethane, 1, 2-dichloroethane, cis-1,2-dichloroethylene, trichloroethylene, tetrachloroethylene, and benzene, dioxins, carbon tetrachloride, nitrate nitrogen, and nitrite nitrogen
2004, Tsubakibora, Gifu Prefecture	Estimated 130 m x 200 m x at least 20 m deep, volume of about 753,000 m^3, of which 605,000 m^3 is mixed waste and 148,000 m^3 is concrete rubble	Mainly construction waste, 37% dirt and sand, 30% ceramic/rock/concrete rubble, 21% wood scrap, 7% plastics, etc.	Lead, hexavalent chromium, methane 47 vol. %, hydrogen sulfide 15,000 ppm Water-quality testing of the dump site found high COD and nitrogen concentrations

Prepared based on References[5-8]

include many different pollutants.

- When countermeasures are taken, it is necessary to apply them in stages, i.e., emergency, urgent, and permanent measures.
- The terrain of polluted sites is often complex, making accurate surveying and recovery measures difficult.
- There is little information available on such pollution.
- It is generally difficult to identify the polluters.

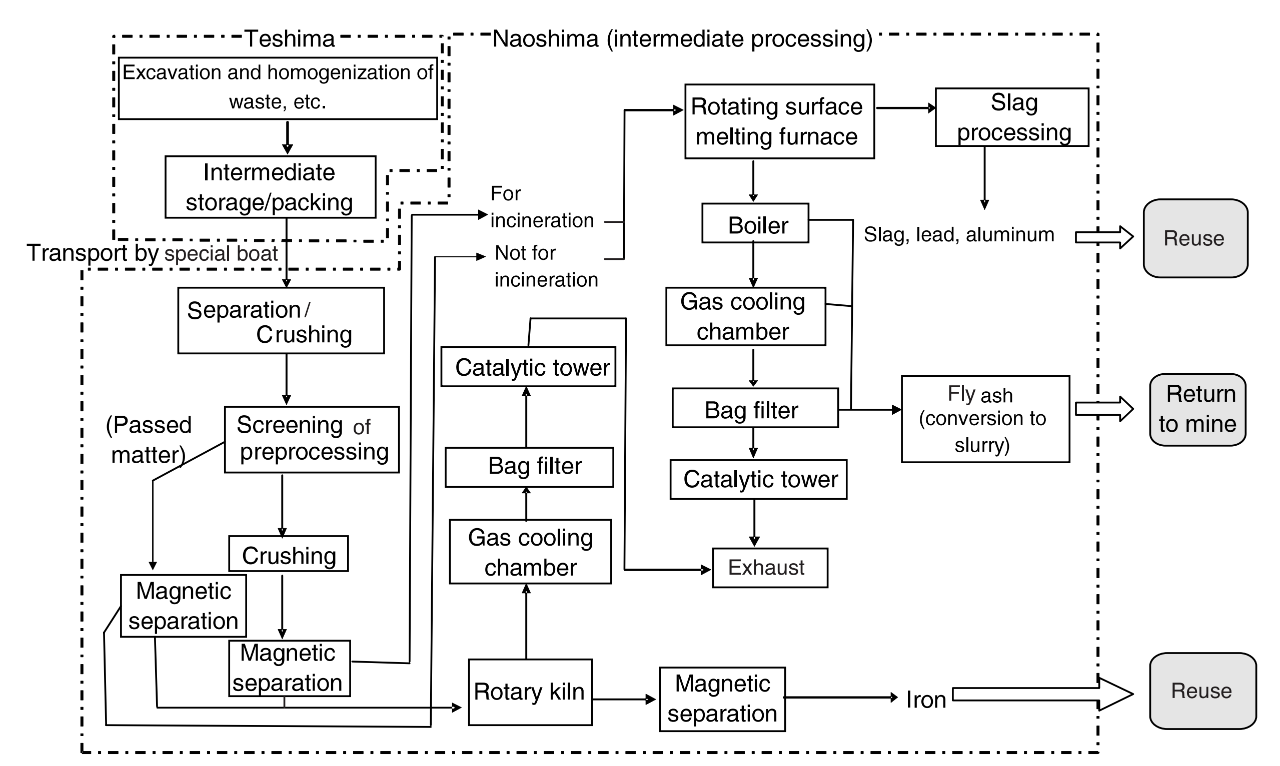
In addition, the occurrence and degree of environmental impact differs depending on the types of pollutants involved and the scale and location of the illegal dumping carried out. Table 2 shows the characteristics of some cases of large-scale illegal dumping around Japan[5-8].

Currently, measures are being taken to solve the problems on Teshima Island and on the Aomori-Iwate prefectural border, in particular, but recovery will take a long time, as shown in Table 1.

(1) Teshima Island, Kagawa Prefecture

Teshima, in Kagawa Prefecture, is a small island west of Shodoshima in the Seto Inland Sea. There, businesses such as an intermediate waste disposal operation, using sludge to raise earthworms in order to manufacture soil amendments, applied to change businesses in 1977 and, around 1983, began transporting and burying large quantities of shredder dust, waste oil, sludge, and so on, as well as openly burning some of it. This resulted in on-going complaints and appeals to the prefectural government from local residents about the damage being done to the environment. In 1990, the Hyogo Prefectural Police raided the site on suspicion of violations of the Waste Management and Public Cleansing Law. This stopped any further illegal waste dumping but left serious, widespread environmental pollution. Currently, all waste disposal on Teshima is now carried out based on the three basic principles of consideration for the environment and for safety, achievement of recycling, and disclosure of information. The more than 600,000 tonnes of waste (mixed with contaminated soil) that were dumped on Teshima are now being transported 5 km by a specialized ship, the Taiyo, to the island of Naoshima for intermediate processing. At a rate of 60,000 tonnes per year, this undertaking will take 10 years to complete[9].

Figure 4 illustrates how these wastes are being processed on the two islands[10]. The primary intermediate process is melting. On Teshima, an impermeable wall has been built along the coastline to prevent leachate carrying toxic substances from the waste layer reaching the sea. Furthermore, temporary environmental protection measures have been taken, including the relocation of scattered waste sites to prevent the spread of contamination and to facilitate the construction of new facilities, and laying gas-permeable waterproof sheets to prevent the scattering of waste and the inflow of rainwater. Seepage water and wastewater are processed at an advanced wastewater treatment facility. The



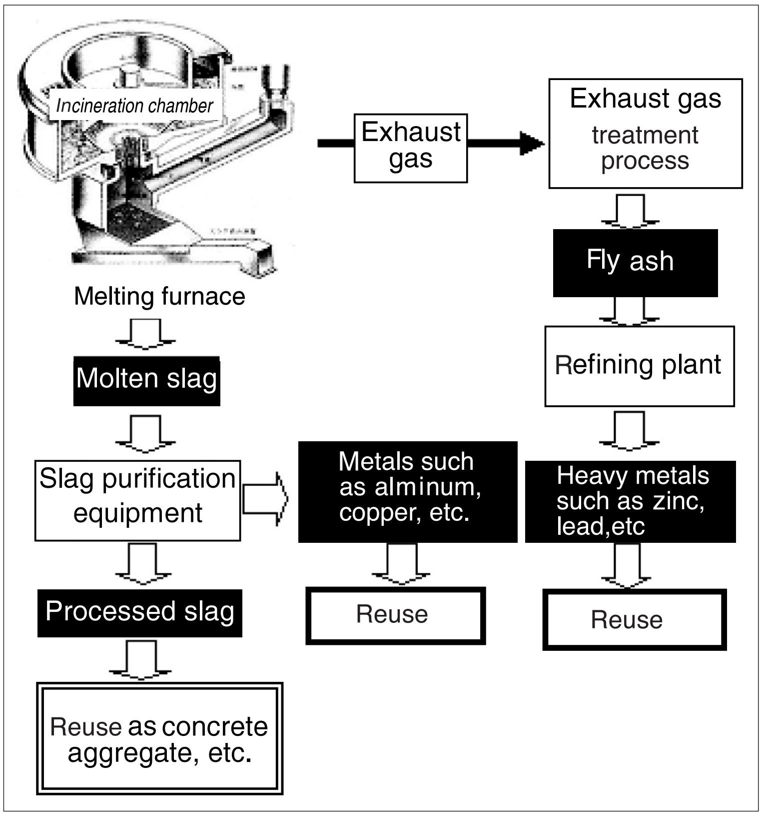
Prepared based on Reference[10]

Figure 4 : Flow chart of waste processing on Teshima and Naoshima

characteristics of the waste change markedly when it is excavated. In order to safely operate the melting furnace during intermediate processing and in order to produce a stable, inert resource from the melting process, the waste that is processed must first be homogenized. The moisture content, composition of its main components, and the flammable volume of the waste are all particularly important. High moisture content can cause handling problems at the processing facilities, as well as increasing fuel use during melting. In order to efficiently carry out melting at about 1,300°C, the CaO/SiO_2 ratio, which has a major effect on melting flow temperature, must be correctly adjusted. In addition, the heat value of the substances being melted must also be controlled. In order to homogenize the waste being processed in this way, lime is mixed in as a melting agent and the resulting exothermic reaction is used to regulate moisture content. After this curing process is completed, the waste is transported to Naoshima on trucks developed especially for disposal work.

At the intermediate processing facility, this waste is then melted along with general waste. The melting furnace has two towers, each capable of processing 100 tonnes per day. It is expected to take 10 years to process all of the waste from Teshima. Melting generally produces molten slag and fly ash. Ordinarily, molten slag can be effectively used as-is for concrete aggregate and so on. However, Teshima's waste contains much shredder dust along with copper wire, aluminum, and stainless steel from auto parts, which form metal particles in the slag. Therefore, separating and refining this metal not only raises the quality of the slag, it enables effective use of the separated metal. Special crushing and selection, along with separation by specific gravity, are used for this recovery process.

Figure 5 illustrates the process involved in melting and byproduct generation[11]. After quality control is carried out on the slag, it is used in Kagawa Prefecture as a material for public works and so on. The fly ash contains a lot of metal, such as zinc and lead, so it is transported to a copper smelting plant already operating on Naoshima and used as a raw material for heavy metal extraction. There is a separate rotary kiln for iron lumps, rocks, and other materials unsuited for melting. The exhaust gas produced is processed in the same way as the melting furnace system.



Based on Reference[11], with some modifications

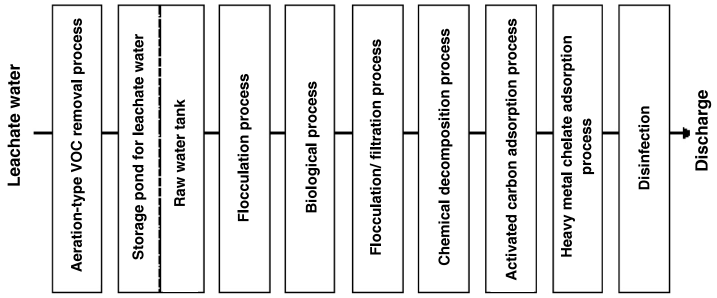
Figure 5 : Flow chart of reusing process of intermidiation byproducts

(2) The border between Aomori and Iwate Prefectures

Illegal dumping along the border between Aomori and Iwate Prefectures began in the early 1990s when an industrial waste disposal company in Hachinohe City, Aomori Prefecture, started illegally dumping the industrial waste it received from a similar company in Saitama Prefecture. On-site investigation and guidance by a public health center began in 1994, and detailed surveys of contamination began in 2000. The waste-generating enterprises connected with the site are primarily in the Tokyo area, but range from Hokkaido to Kyushu.

Recovery measures for the site are being taken by both prefectures. Aomori Prefecture has set up an impermeable wall to prevent the leaching of toxic substances into the rainwater or groundwater. In addition, it has implemented water purification using an advanced wastewater treatment system that can handle mixed contaminants. Toxic landfill waste is removed to an industrial waste processing facility (high-temperature melting using a gasification melting furnace) in Aomori City.

Figure 6 illustrates the advanced wastewater treatment process, described above. Because the water seeping from the contaminated site contains volatile organic compounds (VOCs) such as dichloromethane and benzene, the raw water is first treated with VOC processing equipment. It is then aerated to produce a gas phase from which the VOCs are removed by activated carbon adsorption. Subsequently, biochemical oxygen demand (BOD)*1 components are removed through the use of a biological treatment process, and fine particulate matter is removed using a flocculation/filtration process. Next, an ozone/ultraviolet advanced oxidation process (using chemical decomposition equipment) removes dioxins and other persistent substances and chromatic components. Activated carbon processing equipment removes the few remaining organic components, and chelate adsorption equipment selectively removes heavy metals. This mixed processing system has not been in operation long, but because there has apparently been little seepage from the most contaminated areas, the raw water has been less contaminated than expected, and the quality of the processed water has therefore been very good. When the cleanup process starts excavating areas



	BOD	COD	SS	Dichloro-methene	Dioxins	Boron
Raw water (VOC raw water tank)	59	57	22	<0.02	3.3	1.0
Treated water (discharge facility sampling tank)	<0.5	5.3	<1	<0.02	0.0001	0.82
Setting of processed water quality	60 or less	90 or less	10 or less	0.2 or less	1 or less	10 or less

Units for water quality are mg/l, except for dioxins (pg - TEQ/l) Prepared from Aomori Prefecture technical documents

Figure 6 : Flow chart of the advanced wastewater treatment facilities for illegally dumped waste on the Aomori side of the prefectural border (above), and examples of water quality values (below)

containing many contaminants, the seepage of more heavily contaminated water may result.

On the Iwate Prefecture side of the border, measures are being taken to remove all the waste. Post-excavation selection is performed, and the waste is transported to industrial waste processing facilities, centered on a major cement plant located in the prefecture. The waste is incinerated, burned, or melted. Reportedly, 23,600 tonnes, 20.7 percent of the total, had been removed as of December 10, 2005. The total volume removed during FY 2005 was 30,108 tonnes.

(3) Tsubakibora, Gifu City

In Tsubakibora, Gifu City, an industrial waste disposal business located in that city began dumping construction waste in a valley next to its disposal facility. Detailed environmental surveys revealed hexavalent chromium levels exceeding allowable environmental standards for soil and lead levels exceeding soil component standards in the waste layer, but the overall risk from toxic substances was judged to be low. In addition, following urgent measures, the matter has reached a stage where concrete actions and possible issues have been narrowed down for each of three permanent measures, i.e., leaving the waste in-place, removing part of it, or removing all of it.

2-3 Legal systems related to illegal dumping

A 1997 revision of the Waste Management and Public Cleansing Law strengthened the responsibility of waste-generating enterprises to assist in the recovery of environments damaged by illegal dumping and imposed serious penalties for improper disposal. However, cases that already existed before the law was implemented have caused long-term problems. They have contributed to public mistrust of industrial waste management, becoming major impediments to the formation of a sound material cycle society. Therefore, the Law on Special Measures Concerning the Removal of Environmental Problems Caused by Specified Industrial Wastes was passed and implemented in June 2003. It mandates the necessary funds, for the period from FY 2003 through FY 2012, to enable prefectures and so on to systematically and steadily implement their own measures to remove and prevent problems in living environments related to illegal dumping that occurred before the revision of the Waste Management and Public Cleansing Law. Under this law, the Minister of the Environment is to set forth basic policies for the systematic and steady removal and prevention of environmental problems, and prefectures and cities with public health centers are to develop specific action plans based on these basic policies. Subsidies from the national government are available for the removal and prevention of specified environmental problems, and prefectures and municipalities can issue bonds in order to meet their expenses. An overview of the removal and prevention of problems is provided in Figure 7.

3 Pollution remediation technology and characteristics

3-1 Commonly used methods for remediation

Remediation from pollution due to illegal dumping requires the setting of appropriate priorities at the time the contamination or environmental damage is discovered. These priorities can be classified according to the urgency of the measures needed[4]:

(i) Emergency measures: Measures that can be taken immediately when quick testing and surveys have judged that the risk to human health, etc. is very high. They include the evacuation of residents, prohibition of the drinking of groundwater, removal of the contamination source, etc.

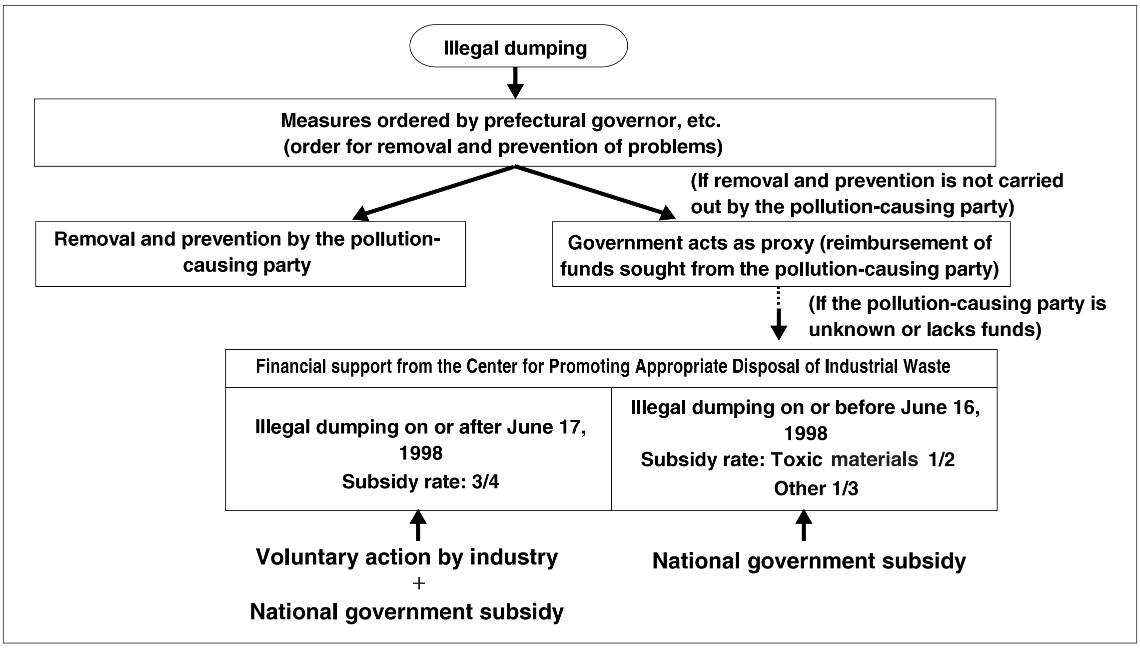
(ii) Urgent measures: Based on detailed site surveys, these include measures such as covering or walling-off contaminated areas to minimize damage by preventing the spread of pollutants to surrounding areas.

(iii) Permanent measures: Based on drilling surveys and test application of recovery technologies, these include measures such as applying appropriate technologies to ensure permanent safety.

The contaminants found at illegal dumping sites and surrounding areas can include the waste itself, the soil, and the water. Technical means to permanently ensure their decontamination can be roughly divided into decontamination and containment (isolation and management). Decontamination may be carried out on-site by removing contaminants from the site or off-site by excavating the site and moving the contaminants elsewhere for further processing. Removal can mean either isolation, moving to other sites using mechanisms for decomposition, or the destruction of the contaminated substances.

3-2 Technologies that target solids

There are no specific, clearly designated technological systems called "remediation technologies for pollution resulting from illegal dumping." Typically, those technologies already used for other forms of soil and groundwater pollution remediation are modified for use against specific targets, as required. Table 3 shows



Source: Ministry of the Environment

Figure 7 : Flow chart for the removal and prevention of problems related to illegal dumping of industrial waste

remediation technologies for some common soil and groundwater contaminants such as VOCs, heavy metals, dioxins, PCBs, and other refractory organic contaminants.

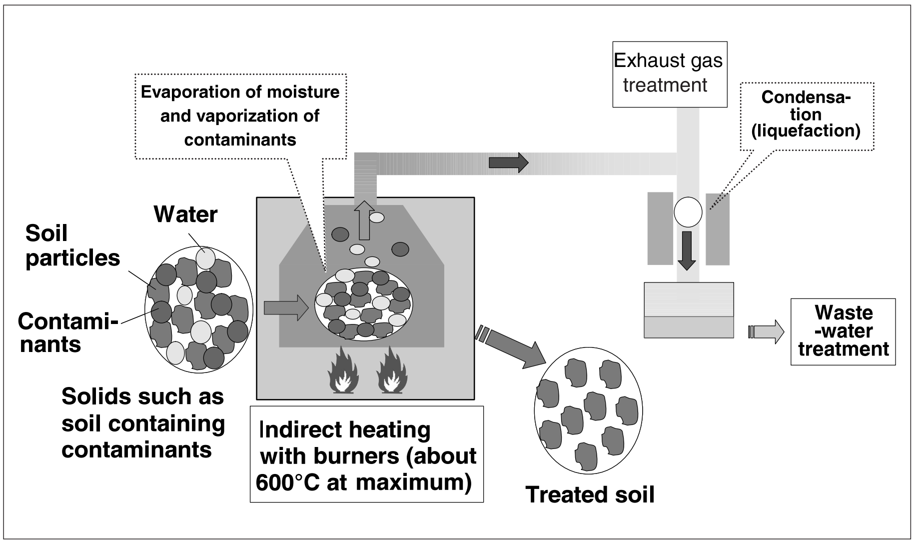
(1) Physicochemical and thermochemical processing

Figure 8 shows an example of separation technology using indirect heating that applies external heat to a target substance. Moisture expelled by heating, contaminants and particulate matter then enter the wastewater through the cooling and condensation of exhaust gas, so the exhaust gas and wastewater must be processed as well. Generally, separation technology requires separate facilities for the processing of contaminants after their separation and recovery.

Refractory organic contaminants are difficult to decompose. High-temperature or combined high-temperature/high-pressure processing technologies such as incineration, melt-solidification, and hydrothermal oxidation are therefore used. Processing is often carried out after excavation. Incineration involves burning at a temperature of about 800-900°C, while melt-solidification involves burning at a high temperature of around 1,300-1,400°C inside a melting furnace, turning solids into molten slag. Melt-solidification requires large energy inputs because it uses electricity or fuels such as kerosene but, since it involves high-temperature manipulation, it can completely decompose refractory organic substances. The major types of melt-solidification treatment used are surface melting, coke beds, rotary kilns, and electric. Slag generated by the melting of inorganic components such as silica dioxide and aluminum oxide contains heavy metals within its mesh-like structure, so there is little likelihood of their elution. This makes the slag suitable for effective use as aggregate in buildings and so on. Another technology in the melt-solidification category is

Table 3 : Treatment technologies for VOCs, heavy metals, and other toxic materials in soil and groundwater

Target	Classification by processing location	Principle of technology		Examples of treatment technology		Examples of target substances
Solids (soil), liquids (groundwater)	In-situ decontamination	Separation	Contaminants are separated by converting them from a solid or liquid to a gas through volatilization, etc.	Physicochemical technology	• Pumped water, pumped water aeration • Soil gas aspiration (simultaneous aspiration of soil gases and groundwater) • Air sparging (includes bioremediation)	Organochlorine solvents such as trichloroethylene and tetrachloroethylene and VOCs such as benzene
					• Soil flushing • Solidification, deliquefaction	Heavy metals
		Decomposition	Decomposition through chemical (dechlorination) or thermochemical processes	Physicochemical technology	• Oxidation-reduction (use of permeable reactive barrier using iron powder)	Organochlorine VOCs
				Biological technology	• Bioremediation • Biostimulation • Bioaugmentation	Organochlorine solvents and VOCs such as benzene
Solids	Excavation and removal decontamination	Separation		Physicochemical and thermochemical technology	• Lime processing • Heating (indirect heating desorption, etc.)	Organochlorine solvents and other VOCs and cyanide compounds
		Decomposition		Physicochemical and thermochemical technology	• Heating • Incineration • Melt-solidification • Alkaline catalytic chemical decomposition	Dioxins (melt-solidification) Petroleum VOCs (oils), heavy metals, PCBs
				Biological technology	• Bioremediation	Organochlorine solvents, petroleum VOCs



Based on technical documents from Konoike Construction Co., with some modifications

Figure 8 : Example of a contaminant desorption system using indirect heating

an electric resistance melting technique that uses heat from electrodes for melting (the geomelt method). This technique is used for contaminants with high dioxin densities and contaminated soil found at industrial waste incineration sites[12].

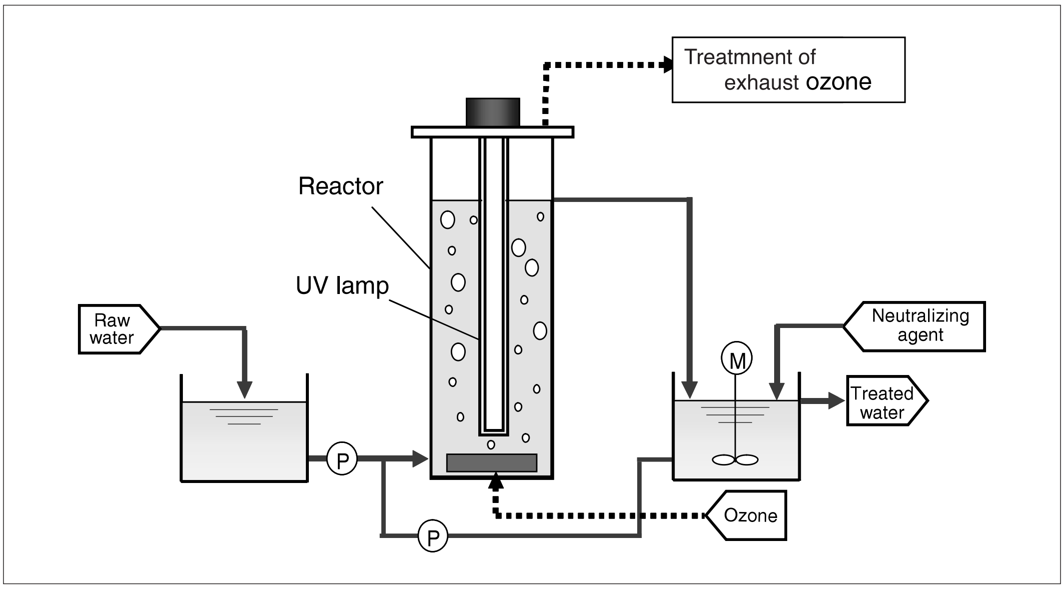
(2) Biological processing

Microorganisms have the ability to decompose various organic compounds. Bioremediation is being developed as a recovery technology that uses biological functions in open environments contaminated by illegal dumping. Bioremediation includes biostimulation, which introduces methane and other organic matter which microorganisms need in order to grow, nutrients such as nitrogen and phosphorus, and air into contaminated soil in order to increase the activity of indigenous microorganisms and to promote decontamination, and bioaugmentation, which introduces cultured microorganisms with a high degree of decontamination activity related to specific target contaminants in order to promote active decontamination. In addition, a passive method such as natural attenuation simply involves waiting for indigenous microorganisms to naturally reduce contaminant densities after physicochemical processes and so on have been used to decontaminate high-density contamination as much as possible. Bioremediation is mostly used to decontaminate soil and groundwater contaminated with petroleum components, especially benzene, and with organochlorine solvents that have low boiling points (trichloroethylene, tetrachloroethylene, etc.). Bioremediation is generally less expensive than other physicochemical processing technologies, but it requires relatively long periods of time to work, is difficult to apply to high-density contamination sites, and is affected by temperature and coexisting substances. In addition, the impact of microorganisms on surrounding environments must be fully assessed. Concern must be given to environmental safety when introducing new microorganisms from the outside.

3-3 Technologies that target water

Decontamination of water at illegal dumping sites usually involves processing of the water that seeps from the dumped waste and the surrounding area. This seepage water is a common characteristic of illegal dumping and typically contains a mixture of many different contaminants. Processing technology for this polluted water should therefore be either a single operation that includes multiple functions or a combination of many single-function operations. This requires advanced wastewater treatment technology.

An advanced treatment technology that has been increasingly adopted for use on persistent substances in recent years is advanced oxidation processing. This process uses physical means or ozone, hydrogen peroxide, ultraviolet rays, or



Prepared based on Reference[13]

Figure 9 : Example of advanced water treatment equipment using an ozone/ultraviolet advanced oxidation process

other substances with strong oxidizing power to cause the oxidative decomposition of persistent substances in water. Figure 9 shows an example of advanced treatment equipment that combines ozone and ultraviolet irradiation[13].

In addition to the above, activated carbon adsorption has long been used as an advanced treatment technology that is very effective at removing hydrophobic organic compounds. In addition, membrane separation processes capable of screening at the μm-nm level - in other words, at the molecular level - are being developed along with new materials such as macromolecules. Furthermore, chelate adsorption using chelate resins with specific binding capacities is widely used for the removal of heavy metals.

4 Trends towards increased safety and security in recovery and resource recycling

4-1 Lowering the environmental risks of recovery

The goals of technological recovery regarding pollution from illegal dumping are removal of the contamination, reduction of environmental risks caused by the contamination, and restoration of the contaminated area.

This involves the following key issues.

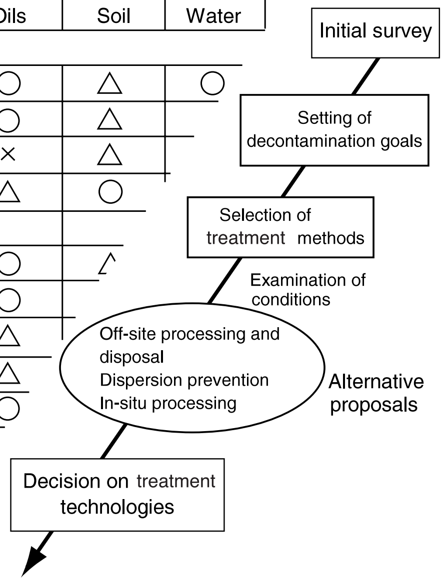
- Establishment of rational methods for the selection of recovery technologies
- Appropriately representing lowered environmental risk due to recovery

Recently, it has become possible to optimize procedures for the selection of recovery technologies because, as depicted in Figure 10, information on the technologies applicable to different contaminants and media has now been collected and arranged into clear standards to assist the selection process[14]. Until now, selection has usually taken place based on the kind of qualitative standards shown in Figure 10 or based on past experience but, in the future, it will be important to make this process as quantitative as possible. Research and development on this subject is being carried out, for example, through joint research by a Hokkaido University research group and private sector businesses[4].

After illegal dumping is discovered, it is necessary to assess the condition of the environment at the site and in the surrounding area. It is vitally important to know the risks posed to human health and to the affected ecosystems. At the same time, it is necessary to assess, as quickly as possible, the state of contamination both on the surface and in the three-dimensional space comprising the affected site. Currently, such monitoring is carried out using the existing survey and measurement

Technology	Contaminant			Target medium	
	VOCs	Heavy metals	Oils	Soil	Water
Dispersion prevention technology					
Impermeable wall	○	○	○	△	○
Barrier reservoir	○	○	○	△	
Reactive barrier	○	△	×	△	
Solidification/deliquefaction	△	○	△	○	
In-situ processing technology					
Pumped water processing	○	○	○	△	
Soil flushing	○	○	○		
Solidification/deliquefaction	△	×	△		
Soil gas aspiration	○	×	△		
In-situ melt-solidification	○	○	○		
Electrical separation	×	○			
Air sparging	○	×			
Bioremediation	○	×			

○ = very appropriate △ = somewhat appropriate × = not appropriate



Based on Reference [14], with some modifications

Figure 10 : Evaluation of applicability and selection of recovery technologies

methods available for soil, groundwater, and air pollution assessment. However, this approach relies either on drilling, which is expensive and cannot always be carried out in some areas, or on the external diagnostic method of high-density electronic surveying, which has accuracy problems. There is, as yet, no simple and quick analysis method that can reliably detect, identify, and measure a variety of contaminants. Furthermore, there are no methods or procedures available for assessing the entire scope and range of pollution based on the limited data available.

4-2 Safety of the technology used

According to the safety-related data available for various industrial fields, the waste disposal sector has a high accident rate. Such accidents are common at facilities using methods involving relatively new technologies. The example described below relates to a case when gasification melting furnaces were first introduced.

About four months after the melting furnace equipment at the Teshima intermediate processing facility began operating, a small explosion occurred[15]. The cause was an accumulation of flammable gases, mainly hydrogen gas derived from the materials being processed, in the space above the conveyor belts where it was set alight (static electricity is suspected) causing a fire and an explosion. The hydrogen gas was generated by the excessive moisture in the waste excavated from the Teshima site reacting with the metals present and the lime mixed in to improve melting. Therefore, a specified period for the dissipation of hydrogen gas had to be set. However, it was found that even after a considerable amount of time, the amount of hydrogen generated increased inside the melting-furnace facilities when the temperature rose. Furthermore, despite the negative pressure maintained inside the facilities, the low-density hydrogen still apparently accumulated around the top of the conveyer. In order to prevent further problems of this sort, sufficient gas dissipation at the intermediate processing facility before processing, sufficient ventilation, temperature control, and so on have had to be strictly enforced.

It is vital that a multifaceted structure be put in place that can prevent abnormalities occurring in basic safety policies or processes, thereby reducing the risk of such accidents and minimizing the effects of any accidents that do happen.

In the case of Teshima, as mentioned above, the results of all environmental monitoring and environmental protection data from the operation

Table 4 : Examples of measures to prevent illegal dumping

Measure	Details of implementation	Government
Adoption of an on-site observation system with mobile data terminals	PDAs (personal digital assistant) with GPS (global positioning system) and digital cameras are used to collect real-time image and text data from a wide area using a network system enabling strengthened observation and enforcement regarding illegal dumping.	Tochigi Prefecture, Chiba Prefecture, Shizuoka Prefecture
Test consignment of tracking system for proof of appropriate disposal processes	Testing is underway of an image verification system that involves GPS units installed on waste disposal vehicles and tracks them to ensure that they follow appropriate routes and dispose of waste properly.	Kagawa Prefecture
Test tracking through insertion of GPS terminals into industrial waste	Testing is underway of a system that inserts water- and shock-resistant GPS terminals into industrial waste and tracks transport vehicles over the internet.	Tochigi Prefecture
Placement of surveillance cameras to monitor illegal dumping	Suspicious vehicles and the like attempting to illegally dump waste are automatically detected and photographed by continuously operating surveillance cameras, which then transmit the images to government computers where they are recorded.	Sendai City
Mandatory stickers for registered collection and transport vehicles	Registered waste collection and transport vehicles are required by law to display stickers allowing easy identification of licensed versus unlicensed vehicles.	Chiba Prefecture
Reward system for information on illegal dumping	Monetary rewards are provided to those who provide information leading to the detection of illegal dumping.	Kiryu City, Gunma Prefecture, etc.
Rating and bonding system for industrial waste disposal firms	Based on applications from industrial waste disposal firms, rating inspections are carried out and the results are made public. A bonding system for industrial waste disposal firms is in place in case removal and prevention of problems becomes necessary.	Iwate Prefecture

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of the facilities have been made available to the public via the internet and various other methods[9]. Recently, other environmental protection facilities have also been actively implementing similar information disclosure measures.

4-3 Prevention of illegal dumping

A root cause of much illegal dumping is that the waste-generating enterprises involved do not always pay the appropriate fees, so that waste disposal companies are unable to make enough profit. First, it is important to ensure business viability, so waste disposal companies must improve their trustworthiness as excellent businesses. Policies and procedures are needed that enable waste-generating enterprises to select reputable and reliable waste disposal companies. A number of new government policies and experimental initiatives are underway, centered on the local governments that directly monitor illegal dumping. Table 4 shows several examples. In addition, the Ministry of the Environment and the National Institute for Environmental Studies have developed satellite monitoring systems for the early detection of illegal dumping in order to prevent its spread and minimize its impact, and are studying the usefulness of this system in practice[16-17].

4-4 Resource recycling

As can be seen in the use of the molten slag and fly ash from Teshima (Figures 4 and 5), the effective recycling of resources obtained through pollution recovery, processing and environmental decontamination is very important.

When restoring polluted sites to their original condition, where and how best to implement resource recycling are key issues. Local conditions around the site should also be considered. In the case of Teshima, the placement of the intermediate processing facilities on the site of an existing copper refinery helped make more effective use of the fly ash produced.

5 Key issues that should be promoted as standards for Japanese environmental protection and shared infrastructure development

Overall, Japanese science and technology, as applied to environmental protection, is among the best in the world. For example, according to the Delphi survey led by the National Institute of Science and Technology Policy in FY 2004[18], themes in the environmental field where Japanese technology is seen as leading the world include "Technology for the efficient recovery of rare metals from fly ash as a domestic source of supply." In addition, Japan is seen as leading in "Technology for economically and practically desalinating seawater and purifying polluted water using reverse osmosis membranes or other methods" and in the "Methodology for tracing and identifying recycled materials (plastics and metals)."

In the future, science and technology will be expected to make even greater contributions to environmental protection. In order to combine environmental protection with a safe and secure society, the following important issues should be addressed in terms of shared infrastructure development.

(i) Research and development of analytical methods and simulation technology for damage forecasting, impact assessment, and vulnerability detection
(ii) Research and development of measurement and sensing technology for the early detection of abnormalities
(iii) Construction of information provision systems and information networks that are resistant to disaster and highly reliable
(iv) Comprehensive risk management

6 Current and future prevention and progression prevention of illegal dumping and responses after the fact

Illegal dumping is not something that happens over a short period of time. Indeed, based on past cases, it can take a very long time for the first signs to become apparent and for the dumping to be exposed. Environmental damage caused by illegal dumping can differ in both scope and scale from that caused by other human activities. Furthermore, while some instances of illegal dumping can be dealt with using existing methodologies, other cases require different approaches that take specific circumstances into account. These issues can be considered by dividing them into the prevention of illegal dumping, progression prevention, and responses implemented after the fact.

6-1 From the perspective of the prevention and progression prevention of illegal dumping

Based on past experience, there are various social and economic factors that contribute to illegal dumping. In addition, there are regions and terrain where illegal dumping is especially easy to carry out. Therefore, support tools are required that can effectively monitor and control illegal dumping. For example, experiments with the installation of GPS on relevant transport vehicles and with early monitoring systems involving satellites and GIS are already underway.

When illegal dumping occurs, satellite monitoring systems can play a role in detecting it early enough to prevent its spread, thereby minimizing environmental pollution. Existing systems already have sufficient ability to detect relatively large-scale illegal dumping. However, the necessary increases in resolution needed for the detection of smaller-scale localized dumping, and the fact that these systems are easily influenced by cloud cover, are still major problems. Furthermore, it is difficult to obtain frequent observations from existing commercial satellite orbits and costs are an even greater concern than technical issues. In order for local governments to effectively utilize satellite observation, raising the cost-performance per bit of information through multipurpose use would be desirable. Joint use for forest management and disaster preparedness is one possibility. Emphasizing collaborative and cooperative use across different fields should therefore accompany technical progress.

6-2 From the perspective of responses implemented after the fact

(1) Development of quick and systematic survey tools for environmental impact

When, unfortunately, illegal dumping does occur, it is vital to quickly and clearly assess the degree of contamination and judge its environmental impact so that responses can be properly prioritized. For example, it is essential to develop tools that can quickly and accurately determine the type and characteristics of the waste deposited and any soil and toxic substances mixed with it. Furthermore, these tools should be easy for local governments and so on to use in their investigations. Increased accuracy and faster detection and response times are also needed in the development of non-destructive analysis equipment that can be used in contaminated areas and, to achieve this, collaboration among different research institutions and manufacturers is essential. More venues are therefore needed for technical exchange as well.

(2) Development of optimal pollution recovery technology and application methods, in response to the characteristics of environmental risk

The type of environmental risk posed by illegal dumping depends on the contaminants in the contaminated area and the characteristics of the environmental media located there. Along with the development of appropriate recovery technology, it is useful to be able to simulate events over the short and long term in order to predict potential risks and select the appropriate combinations of recovery technologies in response. In order to reduce costs, methodologies should be developed that can optimize the use of specific technologies, either alone or in combination, in response to specific pollution situations.

In addition, when dealing with wastes and soil combined together in complex mixtures, the goal should be to develop processing technologies that can effectively minimize secondary environmental impacts and optimize the conversion of wastes into usable resources. In order to promote effective technical responses to problems that do occur, such as the case of Teshima, Kagawa Prefecture, as discussed elsewhere in this report, it is useful to promote the sharing of information on pollution recovery. The application of technology to illegal dumping differs from case to case but, in light of the fact that there are many similar instances of soil and groundwater pollution, a database of recovery technologies should be compiled and made available for use by all involved parties and governments when a problem occurs. Governments, research institutes, and businesses should therefore collaborate in order to research and analyze new cases of environmental accidents and recovery procedures based on past experience, forming an appropriate technical infrastructure.

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Glossary

*1 BOD

The amount of oxygen required by aerobic bacteria to carry out oxidative decomposition in water. It is an index of water quality. Generally, it is the amount consumed over five days at 20°C, expressed in terms of mg/l or ppm. While chemical oxygen demand (COD) is used in oceans and lakes, BOD is used as an index of river pollution.

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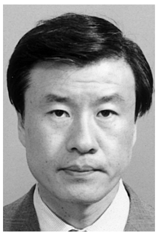

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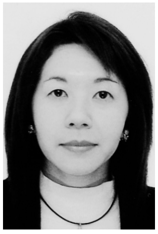

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