STUDY ON A MULTI-SECURITY SYSTEM AT LANDFILL SITES

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SUMMARY:One landfill site varies from another according to the natural environment or the demand of local residents. No single multi-security system therefore is applicable to all landfill sites. Numerous safety measures can be incorporated into a multi-security system for a landfill site. Excessive safety measures, however, lead to an overdesign and deterioration in cost-effectiveness. In actual construction of a landfill site, measures should be adopted for key problems that help enhance the multi-security system, based on the geographical conditions and the demand of the local residents.

To ensure multi-security in the phases from planning to design, construction, operation and closure of the landfill site, and post-closure use of the site, preventive measures and reactive measures after malfunction occurred are required. The soft and hard components of the multi-security system were defined

1. INTRODUCTION

This paper reports the result of a three-year (2000 through 2002) study of the 11-member 1) R&D group on multi-security systems of the Landfill Systems & Technologies Research Association of Japan, NPO. The concept of multi-security is defined and the multi-security system at landfill sites is described to ensure safety at landfill sites.

2. MULTI-SECURITY SYSTEM

2.1 Concept of multi-security system

The multi-security system at a landfill site consists of the following three major components (Figure 1).

- Backup/fail-safe functions
- Maintenance functions
- Confidence in people

The backup/fail-safe functions ensure safety even when functions of parts of the landfill site are

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disrupted due to malfunction caused by expected risk factors because other parts compensate for the malfunction (fail-safe), or enables preparations for malfunction (backup). The maintenance functions enable early detection of and recovery from malfunction of respective parts by inspections or tests. Confidence in people means the ability to make a constant watch of the points of concern to identify the present condition, the environment in which reliable measures can be taken quickly in response to malfunction, and continuous transparency of information to third parties.

To ensure multi-security in the phases from planning to design, construction, operation and closure of the landfill site, and post-closure use of the site, preventive measures and reactive measures after malfunction occurred are required. The soft and hard components of the multi-security system were defined (Figure 2).

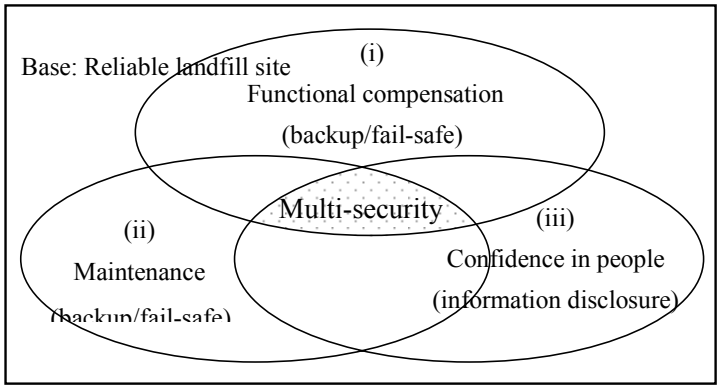


Figure 1. Concept of multy-security

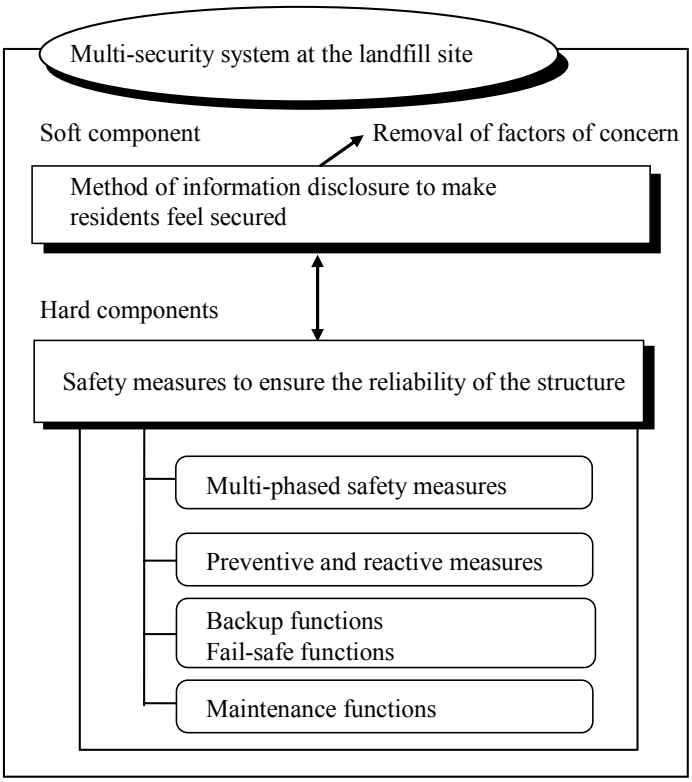


Figure 2. Multy-security system

2.2 Multi-security system that makes residents feel secured (soft components)

2.2.1 Removal of factors of concern for residents

Landfill sites that make residents feel secured are free from factors of concern. Factors of concern are closely related to the life of residents in the vicinity of the landfill site. Factors of concern are listed in Table 1, which was prepared based on the suggestions not only of the 12 R&D group members but also of non-members. The following six items were specified as major factors of concern for residents (Table 1).

- Water pollution
- Outflow of waste
- Sediment disasters
- Aesthetic deterioration
- Spread of dust particles
- Obnoxious odors and gases

2.2.2 Relationship among the factors of concern

A relation diagram (Figure 3) was drawn to relate factors of concern to specific measures. Relation diagrams involve listing as many factors as possible that have complex relations of cause and effect with one another, linking pairs of factors with a relation of cause and effect using arrows, and identifying the most important factors based on the directions and number of arrows.

Figure 3 is a relation diagram for "water pollution". Arrows concentrate at

- Has the facility been built on a stable ground?
- Are anti-pollution measures in contingency considered in the design phase?
- Is construction managed adequately?
- Are the waterproofing works and facilities sufficiently reliable and durable?
- Has a landfill method been adopted to prevent damage to the waterproofing works?

The above questions refer to the causes of concern related to the phenomenon of water pollution. Causes were also identified for the remaining five major factors of concern for residents. (Detailed discussions are omitted here.)

2.3 Multi-phased multi-security in the planning through post-closure land use phases (hard components)

2.3.1 Outline

The primary requirement of the multi-security system for constructing a safe and reliable landfill site is to satisfy the performance specifications and the criteria designated in governing ministerial ordinances. It is important to be able to take safety measures in the planning through post-closure land use phases that are found to be effective for attending to the factors of concern listed earlier. The measures need to complement one another as the components of a multi-security system rather than serving individual facilities constituting the landfill site.

Safety measures include "preventive measures" to prevent malfunction, "backup measures (functions)" to compensate for the malfunction and "maintenance measures (functions)" to maintain the functions of the landfill site including the backup functions. Landfill sites should be planned and designed so as to provide a comprehensive multi-security system against expected problems incorporating the above safety measures.

Examples of safety measures in the design phase are listed in Table 2.

Table 1 Factors of concern for residents

Factor of concern		In planning phase, design phase, construction phase	In service phase	In facility closure phase, the phase of post-closure land use
Environment	(i) Water quality	-Are measures taken to control water pollution? -Is the lining material of high quality? -Is the riverwater quality deteriorated? -Is turbid water discharged? -Is lining damaged in the construction phase? -Are headwaters or groundwater affected? -Is the ground stable? -Is an adequate water treatment capacity available? -Is the facility reliable during an earthquake?	-Is the groundwater polluted? -Is the monitoring facility working satisfactorily? -Has the lining material been damaged? -Can waste be put in a landfill according to the standards? -Is effluent treated before it is discharged? -Is the cover soil free from toxicity? -Is waste acceptance control adequate?	-Does the ground settle? -How long will the landfill site be operated? -Is the monitoring function maintained? -Have the closure standards been satisfied? -Are the damaged sections recoverable? -Does the post-closure use of land deteriorate water quality?
	(ii) Toxic gases and obnoxious odors	-Are measures taken to control water pollution? -Have adequate maintenance plans been developed? -Does the waste contain any toxic material?	-Do unpleasant odors develop? -Is monitoring facility working satisfactorily? -Can waste be put in a landfill according to the standards? -Is waste acceptance control adequate?	-How long will the landfill site be operated? -Is the monitoring function maintained? -Is the site polluted or odorous?
	(iii) Outflow of waste	-Are sufficient soil stabilization measures taken? -Is the fill material of high quality? -Is the structural material of high quality? -Is the facility reliable during an earthquake?	-Can the deformation of ground be checked? -Is the facility reliable during an earthquake? -Does the landfill operation in the rain involve any problems?	
	(iv) Spread of dust particles	-Are anti-pollution measures taken? -Does the waste contain any toxic material? -Is the landfill method appropriate?	-Is the facility for preventing the spread of dust particles working satisfactorily? -Is any toxic material spread?	-Is the monitoring function maintained? -Is capping material acceptable?
	(v) Vibration, noise and Traffic safety	-Does construction cause noise or vibration? -Do waste transport vehicles have any adverse effect? -Are vehicles for construction involved in traffic accidents?	-Do waste transport vehicles have any adverse effect?	
	(vi) Aesthetics and other factors	-Is there any adverse effect on aesthetics?	-Do crows flock together? -Do flies flock together? -Is there any adverse effect on aesthetics?	-Is there any adverse effect on aesthetics? -Is the site polluted or odorous?
Disaster	(vii) Flood disaster and Sediment disaster	-Is there any concern of downstream flooding? -Have measures been put in place against heavy rains during construction? -Does any landslide occur? -Does the ground settle?	-Can the deformation of the ground be checked?	-Does the ground settle?

Figure 3. Relation diagram of factors of concern for residents (Is water polluted?)

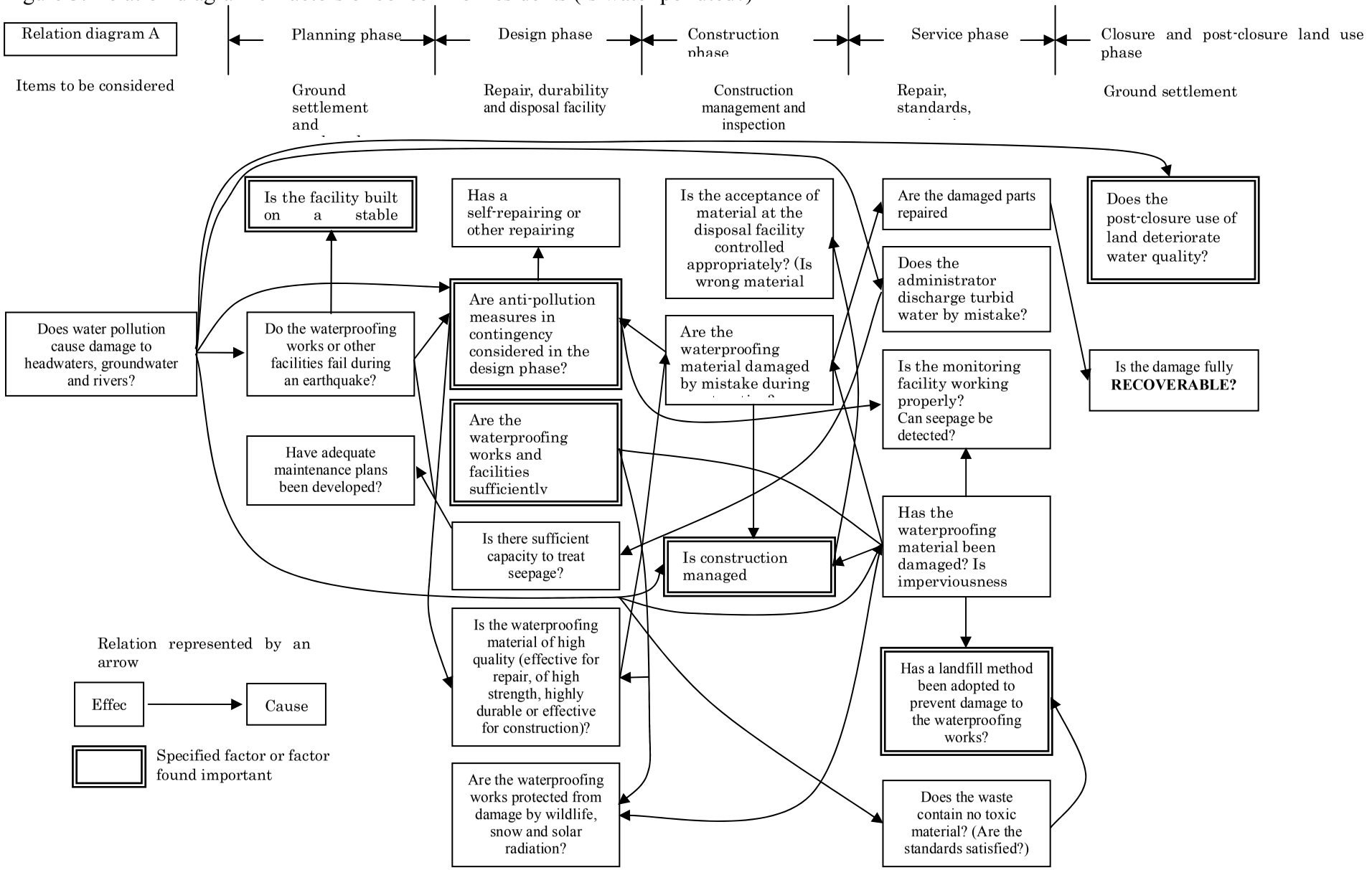


Table 2 Safety measures in design phase

Item \ Type of measures		Preventive measures	Reactive measures
Ground on which the facility stands		-Increasing the bearing capacity of foundation stratum (stabilizing the soil whenever required) -Securing stable slope gradient -Preventing groundwater uplift	
Major facilities	Storage structures	-Eliminating internal storage, making stability analysis to prevent circular sliding or sliding-induced collapse, and applying seismic design	
	Waterproofing works	-Studying maintenance methods after the commencement of service and at the end of landfill	-Studying maintenance methods after the commencement of service and at the end of landfill -Studying methods for verifying imperviousness and repair methods
	Leachate collection and drainage facilities	-Determining the flow area and the number of facilities to be installed according to the leachate amount	-Selecting a structure that enables quick collection and drainage without internal storage
	Leachate treatment facilities Leachate regulating facilities Leachate withdrawal facilities Leachate conveyance facilities	-Establishing a leachate treatment system according to the leachate quality and the conditions of effluent destination -Designing leachate treatment facilities to facilitate maintenance -Taking measures to control odors and prevent leachate and leakage	-Constructing a leachate regulating reservoir to minimize internal storage
	Stormwater collection and drainage facilities	-Designing stormwater collection and drainage facilities according to the amount of rainfall and the catchment area	
	Groundwater collection and drainage facilities	-Determining the flow area and the number of facilities to be installed according to the ground water and leachate amount	-Building a pipe network that enables water collection and drainage in the event of pipe clogging.
	Gas treatment facilities	-Designing the structure and layout of facilities considering the structural dimensions of the landfill	
Management facilities	Transport management facilities	-Selecting the waste to be disposed -Specifying the mode of transport	-Selecting the waste to be disposed -Specifying the mode of transport
	Monitoring facilities		-Establishing methods for monitoring imperviousness -Specifying the points of groundwater monitoring
Related facilities	Material transport roads	-Defining road configuration to accommodate design traffic volume -Developing road construction plans so as to use the site after the closure of the facility	-Defining road configuration to accommodate design traffic volume -Developing road construction plans so as to use the site after the closure of the facility
	Facilities to prevent the spread of dust particles	-Developing plans to prevent the spread of dust particles	-Establishing the method for preventing the spread of dust particles
	Disaster prevention facilities	-Defining the rainfall amount -Defining the development area -Determining the structure of the disaster prevention pond	-Defining the deveopment area
	Facilities to provide benefits to local community	-Reflecting local demand -Designing facilities on the land after the closure of the landfill site	
Common item		-Selecting optimal material and construction method	

Table 3 Backup functions in the event of water pollution

Phenomenon	Cause of malfunction	How was the malfunction identified?	Preventive measure	Rating	Reactive measure (maintenance and backup functions)	Rating
Water pollution	Leakage through geomembrane	Inspection during construction management	Optimizing quality management to ensure adhesion of geomembrane	○	Repairing geomembrane	○
	Defects at connections between structures	Inspection during construction management	Optimizing the handling of geomembrane, or simplifying structures	○	Repairing geomembrane and plates	□
		Groundwater monitoring	Optimizing the handling of geomembrane, or simplifying structures	○	Supplying air into the waste on a mandatory basis (including additional air supply facilities)	○
		Routine visual inspection	Reducing burdens on structural connections (e.g. settlement and waste)	○	Repairing malfunctioning sections, and structures	□
	Damage to the points where geomembranes are fixed	Inspection during construction management	Standardizing the guidelines for handling and protecting geomembranes, at the positions where they are fixed	○	Repairing geomembrane, and taking additional measures to protect geomembrane from burdens	○
		Routine visual inspection, and groundwater monitoring	Standardizing the guidelines for handling and protecting geomembranes, at the positions where they are fixed	□	Repairing using grouting method	□
	Damage to geomembrane due to excessive internal storage	Routine visual inspection, and groundwater monitoring	Optimizing operation standards	○	Repairing geomembrane	○
	Damage to geomembrane due to misoperation of heavy landfill equipment	Routine visual inspection, and groundwater monitoring	Optimizing operation standards	○	Repairing geomembrane	○
	Damage to geomembrane by wildlife	Routine visual inspection, and groundwater monitoring	Installing facilities to prevent the access of wildlife, and adopting the material protecting the geomembrane from wildlife	□	Repairing geomembrane	○
	Damage to geomembrane by earth cover	Routine visual inspection, and groundwater monitoring	Optimizing the method of providing earth cover	○	Repairing geomembrane	○
	Damage to geomembrane due to settlement of foundation ground	Routine visual inspection, and groundwater monitoring	Optimizing the structure of foundation ground and the compaction method	□	Repairing geomembrane, and modifying the soil	○
Leakage through leachate conveyance piping	Defect of connection with underground section	Groundwater monitoring	Waterproofing the connection, and optimizing the connection	○	Repairing the connection	○
	Defect of connection with a structure	Routine visual inspection, and groundwater monitoring	Waterproofing the connection with a structure, and optimizing the structure	○	Repairing the structural connection	○
Leakage through leachate treatment facilities	Damage to leachate storage tank	Routine visual inspection, and groundwater monitoring	Optimizing the structure of leachate storage tank	○	Repairing leachate storage tank	○
	Release of insufficiently treated water	Routine visual inspection, and groundwater monitoring	Optimizing water release standards	○	Modifying water release standards and facility operation method	□

2.3.2 Backup functions (fail-safe functions)

Backup functions ensure safety in the event of malfunction of a part of the facility because other parts compensate for the malfunction (fail-safe), or enables preparations for malfunction.

Malfunction cannot be fully eliminated despite adequate consideration or care in the planning, design and construction phases. The backup functions are therefore required to ensure multi-security.

Backup measures for water pollution, one of the major problems at landfill sites, are listed in Table 3. The columns and rows of the table represent the Following (Table 3).

-Columns

Phenomenon: Malfunction or defect
Cause of malfunction: Cause of malfunction or defect
How was the malfunction identified: Method of detecting the malfunction
Preventive measure: Measure to prevent malfunction
Reactive measure: Reactive measure for malfunction (e.g. repair to compensate for the malfunction)
Rating:

○Circle: Effective

△Triangle: Not so effective but worth considering

2.3.3 Maintenance functions

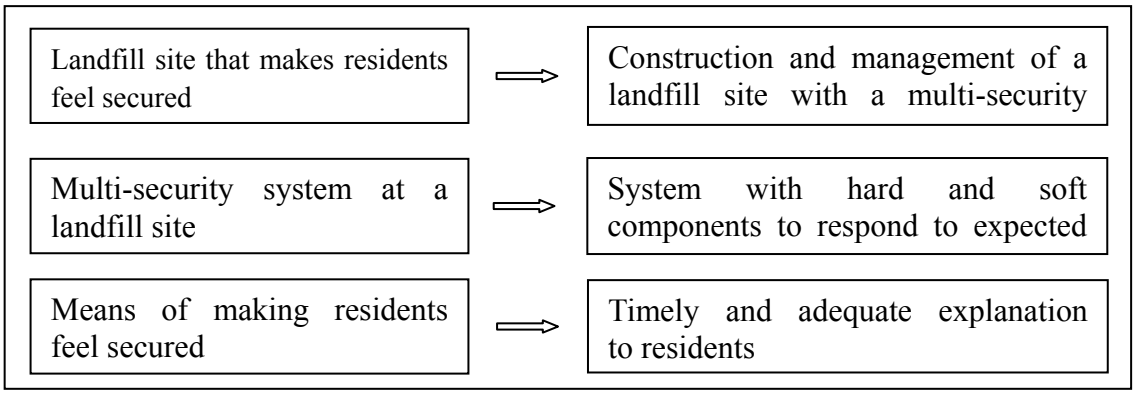
Maintenance functions provide for early detection of malfunctions of respective parts through inspection or tests and recovery from malfunction.

Landfill sites are required to maintain their functions over a long time from the start of landfill to the discontinuation of use of the facility. It is therefore necessary to maintain functions through timely maintenance. Even a little functional deterioration of waterproofing works in particular is likely to pose serious safety problems. Maintenance functions are therefore required to detect even a minimal functional deterioration and to restore the deterioration quickly. Maintenance functions are thus essential to the long-term safety of landfill sites.

Maintenance functions are generally required after the commencement of service. Adopting the functions is, however, difficult once a landfill site has been completed. Their adoption should therefore be considered fully in the planning and design phases. It should also be noted that the facilities or equipment to maintain the functions of a landfill site requires maintenance themselves.

3. CLOSING REMARK

Landfill sites with the multi-security system described above are the best choice for constructing and managing a landfill site that makes local residents feel secured. The mode of information disclosure is also a key factor for making the residents feel secured.



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