B. GUIDELINES FOR SOLID WASTE MANAGEMENT

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B.1 Proposed Guidelines for Health-care Waste Management for Hanoi

(1) Basic Policy

Principle

1. Solid health-care wastes should be classified into hazardous waste and normal waste, in order to reduce the risks of infection, toxic contamination, and so on.
2. Normal health-care waste may be treated in the same way as the normal municipal waste is.
3. Liquid health-care waste and health-care wastewater should be treated properly or discharged to sewer system.
4. Hazardous health-care waste should be segregated, stored, collected, and treated in adequate manner and affordable way.
5. All persons at risk of exposure to hazardous health-care waste should be informed about their risk correctly and be trained periodically.
6. Health-care waste minimization program shall be established.

Health-care establishments are essential facilities for residents' daily life and activities in the city. Many patients are cured in health-care establishments. On the other hand, health-care establishments are generating the wastes, not only solid waste but also liquid waste (wastewater). These wastes contains the domestic waste as well as waste generated from medical activities, which is called "medical waste". The medical wastes include used syringes, used bandages, bloods, parts of human organs, and so on. Most of them have risks of infection and some of them have a risk of injury because of their needles. There is another risk of mixing of these medical waste and domestic waste. The wastewater from health-care establishments also has a risk of infection, if it was discharged without appropriate treatment. Some health-care establishments have frequently discharged their wastewater without treatment in Hanoi when there were floods.

Therefor, we should pay sufficient attention and cares for the health-care waste, in order to prevent the health-care establishment staffs, patients and waste management workers from infections and injuries. The health-care wastes and wastewater should be treated by appropriate processes with safety, in order to improve the urban sanitation and environment. There shall be the control system of wastewater discharge in the case of floods, at least.

(2) Classification of Health-care Waste

Principle

1. Health-care wastes are divided into normal waste and hazardous waste.
2. Hazardous health-care waste should be classified into 4 categories, based on their characteristics of shape and risk of hazards.
   (1) Needles
   (2) Non sharp infectious (health-care) waste and pharmaceutical/chemical residues
   (3) Highly infectious non sharp (health-care) waste
   (4) Radioactive (health-care) wastes

1) Types of Health-care Waste

The waste generated from health-care establishments and medical institutes are classified as below by their characteristics.

Wastes from Health-care establishments and Medical Institute

WASTE	CONTENT	STATE	SOURCES
DOMESTIC WASTE including kitchen waste	Papers, Magazines, Plastic bags, Food residue, Bottles, etc.	Solid with Liquid	Patient care area, Restaurant, Kitchen, Food service center
MEDICAL WASTE			
(i) Cultures and Stocks	Cultures and stocks of infectious agents and associated biological matters, Discarded live and attenuated vaccines, and Culture dishes and devices used to transfer, inoculate and mix culture.	Solid & Liquid	Medical and Pathological laboratory,
(ii) Pathological Wastes	Tissues, Organs, and Body parts removed during surgery and autopsy.	Solid	Operation room, Emergency room
(iii) Waste Human Blood and Blood Components	Bloods, Products of blood, Serum, Plasma, and another blood components	Liquid	Operation room, Emergency room, Patient care area,
(iv) Needles	Hypodermic needles, Syringes, Pasteur pipettes, Broken glass, and Scalpel blade	Solid	Operation room, Emergency room, Patient care area,
(v) Surgery or Autopsy Waste	Soiled dressing, Sponges, Drapes, Lavage tubes, Drainage sets, Underpads, and Surgical gloves	Solid	Operation room, Emergency room
(vi) Dialysis Wastes	Contaminated disposable equipment and supplies such as tubing, filters, disposable sheets, towels, gloves, aprons and laboratory coats.	Solid	Dialysis room

WASTE	CONTENT	STATE	SOURCES
(vii) Laboratory Waste	Slides and coverslips, Disposable gloves, Laboratory coats, and aprons.	Solid	Medical, Pathological, and Pharmaceutical Laboratories
(viii) Animal Waste	Contaminated animal carcasses, body parts, and bedding of animals exposed to infectious agents during research, production of biological matters, or testing of pharmaceuticals	Solid	Medical, Pathological, Pharmaceutical Laboratories, and Manufacturing process
(ix) Discarded Medical Equipment	Discarded medical equipment and parts in contact with infectious agents	Solid	Any places
(x) Isolation Wastes	Biological waste and discarded materials contaminated with blood, excretions, exudations, or secretions from human beings or animals that are isolated to protect others from communicable diseases.	Solid & Liquid	Isolated patients area, and Medical, Pathological, Pharmaceutical Laboratories
(xi) Hazardous Drugs	Drugs have Genotoxicity, Carcinogenicity, Teratogenicity or fertility impairment, and	Solid & Liquid	
(xii) Drug-related Waste and Pressurized container	Packages, Bottles, Air tanks, Acrosol cans.	Solid	
(xiii) Drained Cleaning Water	Water used for cleaning the floor, equipment, body and blood, etc.	Liquid	Drainage system & Septic tank
RADIOACTIVE WASTE	X-ray equipment	Solid & Liquid	
OTHER WASTE			
Used Photograph Developing Agent	X-ray photographs developing agent	Liquid	X-ray photographs developing room
Sludge	Sludge from wastewater treatment facility and septic tank		Waste treatment facility & septic tank

2) Definition of health-care waste in coming regulation of HPC

Refer to the draft regulation of Hazardous Medical Wastes, they are classified as below.

Group A: Hazardous medical solid wastes, which are contagious

- parts of human bodies, human body juice, blood (infectious or not),
- organs cut-off from human bodies, small animal corpse after experiments, placenta ... Fluid from body: blood (infectious or not), vivisection...
- stool, urine, vomiting waste, bag for vomiting, saliva, sputum ...
- contaminated or infectious clothes (clothes of patients, clothes and gloves for medical staff in operating room, patient's bed, other infectious devices: blankets, pads) that cannot be used and have to be disposed. Contaminated or infectious cotton, band, gauze.

- Medical productions, artificial culture samples, micro organic samples in laboratories...
- Foods left by infectious patients

Group B: Solid/sharp hazardous medical wastes:

- used syringes, needles, lancets, scissors, clips,...
- bottles, boxes, glass pieces, plastic cans, bottles..
- broken bones

Group C: pharmaceutical products, chemicals:

Pharmaceutical products:

- addle, out of date medicine
- medicine hazardous to cells, vaccine, serum...

Chemicals, testing chemicals:

- organic solvent, inorganic compound
- Spraying jars, thermohydrometer that need treating under particular regulation and absolutely can not be burned in an incinerator.

Group D: radioactive medical solid waste:

Have to be treated under particular regulation for radioactive substance.

3) Definition of Health-care Waste by WHO

Three categories of' health-care waste are recognized by WHO:

- Normal (non-risk) wastes, including uncontaminated waste similar to domestic waste; may represent about 80% of the total waste production from health-care establishments.
- Hazardous health-care waste.
- Highly hazardous health-care waste.

Hazardous health-care waste includes:

- "Usual" infectious waste, excluding needles but including anatomical or pathological waste, and waste contaminated with human blood or other body fluids, excreta, and vomit. This category typically makes up about 75% of the hazardous health-care waste, or around 15% of the total waste, produced by health-care establishments.
- Chemical and pharmaceutical residues, e.g. cans bottles, or boxes containing such residues, and small quantities of outdated products.
- Non-recyclable and discarded pressurized containers, which are hazardous only if burned as they may explode. Many undamaged containers may be refilled.

Highly hazardous health-care waste includes:

- Needles, especially hypodermic needles.
- Highly infectious non-sharp waste, including microbial cultures, carcasses of inoculated laboratory animals, highly infectious physiological fluids, and pathological and anatomical waste.
- Stools from cholera patients or body fluids of patients with other highly infectious diseases.
- Bulk quantities of outdated hazardous chemicals, such as strong disinfectants, or significant quantities of waste containing mercury.
- Genotoxic waste, e.g. radioactive or cytotoxic waste, typically used in cancer chemotherapy but not in district hospitals. If minimal waste management programs are being applied, genotoxic substances should not be used in general hospitals, but may be used in the oncological departments of university hospitals.

(3) Generation of Hazardous Health-care waste

Principle

1. Health-care waste generation rate is 2.1-2.8 kg/bed/day.
2. Each health-care establishments in Hanoi generate 11-12 ton/month on average, i.e. 600 m3/month at present. A quarter of the amount is hazardous waste.
3. Health-care waste generation rate in Hanoi is estimated to be 16 ton/day in 1995.
4. Health-care waste generation rate is estimated to be 22 ton/day in 2005, 27 ton/day in 2010, and 37 ton/day in 2020, if same growth rate of municipal waste generation and collection rate is applied.

By the papers from DoH, the amount of health-care waste generation is 2.1-2.8 kg/bed/day. The similar data around the world shows 1.2-6.5 kg/bed/day. Therefor this figure is not so small. Because of the improvement of health-care services and advanced techniques (disposal devices, etc.), this figures suppose to be increasing.

By the report of Nguyen Huy Nga, health-care generation rate is 11-12 ton/month, i.e. 600 m3/month. URENCO collects 502 m3/month. It also says that URENCO has the contracts with 25 hospitals in Hanoi and collected 4000 ton of solid waste and semi-liquid waste in 1995. Hazardous waste amount was 25 %, while WHO says that amount of normal waste is 80% of total health-care waste normally. Therefor, the daily generation rate is calculated by the following formula.

[Collected Waste] = [Generated Waste] x [Collection rate]

=> [Generated Waste] = [Collected Waste] / [Collection rate]

* collection rate assumes to be 70%

[Daily Waste Generation] = 4000 / 365 / 0.7 = 15.7

If the combination of growth rate of waste generation and collection rate is increasing as same as municipal waste quantity estimation. The quantity of health-care waste generation will be 22 ton in 2005, 27 ton in 2010, and 37 ton in 2020.

(4) Segregation and Labeling of Hazardous Health-care waste

Principle

1. Health-care waste should be separated correctly and collected into the bin at the place where they are generated.
2. The waste collection bins are labeled correctly.

Careful segregation and separate collection of health-care waste may be somewhat onerous for hospital personnel but it is the key to safe, sound management of health-care waste. Segregation can substantially reduce the quantity of health-care waste that requires specialized treatment. To make separate collection possible, hospital personnel at all levels, especially nurses, support staff, and cleaners should be trained to sort the waste they produce.

The health-care establishments in Hanoi have already introduced the separation collection system. However waste bins are not enough. In any area that produces hazardous waste-hospitals, treatment rooms, operation rooms, laboratories, etc., three bins plus a separate needles container will be needed. Recommendations for the segregation of waste by WHO are given in the table below. The following important points should be noted:

- If hazardous and highly hazardous wastes are to be disposed of in the same way, they should not be collected separately.
- In a health-care establishment using genotoxic products, the safety procedures applicable to radioactive or genotoxic products should be enforced.
- If needles are to be encapsulated, it is convenient to collect them directly in the metallic drums or barrels used for encapsulation, which limits the hazards associated with handling.
- For hazardous waste and highly hazardous waste, the use of double packaging, e.g. a plastic bag inside a holder or container is recommended for case of cleaning.

Segregation of health-care waste

Waste		Receptacle		
Category	Description	Type	Color and markings	Characteristics
Hazardous	Non-sharp infectious waste; some pharmaceutical and chemical residues	Container or plastic bag in a holder	Yellow	Leak- proof
Highly hazardous	Highly infectious non-sharp waste	Container, or plastic bag in a holder	Yellow marked HIGHLY INFECTIOUS	Leak-proof, suitable for autoclaving
Needles	Needles	box or drum or cardboard box with cover	Yellow, marked NEEDLES	Puncture-proof, leak- proof
Normal	Similar to municipal waste, not contaminated by hazardous substances	Plastic bag or container	Black	No special requirements

* Stools of cholera patients should be collected in buckets because of the need for disinfection. Discharge to sewers or to the environment may contribute to the spread of the disease.

Selection of appropriate packaging is difficult in the health-care establishments that cannot afford for disposable plastic bags or containers. In such circumstances, hazardous waste may also be collected with paper bags, inside a container that will not be removed. Plastic or metal containers for hazardous waste should be disinfected, for example with sodium hypochlorite (bleach), before reuse. The bags should be sealed or containers firmly closed before they are filled to three-quarters of their capacity. The equipment should be simple, robust and locally available.

(5) Handling and Storage of Solid Health-care Waste

Principle

1. The staff who handles the waste should be trained about the risk of waste and appropriate handling measures.
2. When the staff handle the waste, they should wear the proper gloves, apron, boots, and so on.
3. Hazardous health-care wastes should be stored separately from normal waste.
4. Separated hazardous health-care wastes should be stored in the specific bins for them.
5. Separate storage yards and houses shall be installed.

1) Handling of health-care wastes

The health-care wastes have two risks of injury and infection, when the staffs handle them. At the health-care establishments, most of wastes are generated at patients' care area and operation rooms, and they are handled by nurses and another staffs. Most of them are put into the small baskets or buckets immediately by the staff. During this time, the staff is exposed to risks of injury by the needles, and another risk of contacting the infectious agents or toxic substances through the tears of gloves and injured skin.

For the prevention of these hazards, the staff shall be aware of these risks, and the appropriate rule for handling of wastes shall be introduced.

Hospital cleaning personnel also should be informed about the potential risks posed by waste handling. They should be trained in safe handling procedures and should wear protective aprons and gloves.

2) Storage of health-care wastes

Most of the health-care wastes are stored at the specified area. During the storage of health-care waste, there are possibilities of smells caused by decomposition and vermin and pests. If the packages of wastes were broken, a risk of distribution of infectious agents by vermin and pests is increasing. Therefor, the safely closed containers will be used and the storage area shall be kept clean and safe by daily work.

In some hospitals in Hanoi, there is good storage house for hazardous waste. However most of hospitals do not have the separated waste storage yards. Even though the waste is sorted at the generation source, the wastes will be mixed again, because there is no separation between normal waste and hazardous waste at storage yards. Therefore, the health-care establishments should have waste storage yards that satisfy the followings.

- The storage yards should have an impermeable, hard-standing floor with good drainage; it should be easy to clean and disinfect.
- There should be a water supply for cleaning purposes.
- The storage area should afford easy access for staff in charge of handling the waste.
- It should be possible to lock the store to prevent unauthorized persons.
- Easy access to waste collection vehicles is essential.
- There should be protection from the sun.
- The storage yard should be inaccessible by animals, insects, and birds.
- There should be good lighting and at least passive ventilation.
- The storage yard should not be situated in the proximity of fresh food

stores or food preparation area.

- A supply of cleaning equipment, protective clothing, and waste bags or containers should be located conveniently close to the storage yards.

(6) Collection of Solid Health-care Waste

Principle

1. Solid health-care waste should be collected by authorized or licensed staffs.
2. Solid health-care waste should be collected daily.
3. Health-care waste collection car should not be used for collection/ transportation of normal waste collection.

The waste should be collected daily. Normal waste may be stored in convenient places that facilitate collection by the municipal service, but hazardous health-care waste should be stored in a closed room. Waste should not be stored close to patients or where food is prepared. Infectious waste should be disposed of within 24 hours at maximum during the hot season and 48 hours during the cool season. Therefore, daily collection service is recommended.

Before containers of hazardous health-care waste are loaded in to a truck for transport, they should be sealed. Waste bags and containers should also be labeled with the address of the producer and the waste category. For safety reasons, however, it is strongly recommended that establishments applying minimal waste management programs in areas without adequate treatment facilities should dispose of hazardous health-care waste within their own premises.

URENCO has the contracts with 25 hospitals in Hanoi and collected 4,000 ton of solid waste and semi-liquid waste in 1995. By the new regulation, the hospitals in Hanoi will make contracts with URENCO for waste collection.

(7) Recycle/Reuse of Solid Health-care Waste

Principle

1. Careful and comprehensive management of stores will substantially reduce the quantities of chemical and/or pharmaceutical waste produced by health-care establishments.
2. Many undamaged pressurized gas containers, however, may be easily recycled, and should be returned to their original supplier for refilling.
3. Metallic mercury from broken thermometer, etc. should be collected and stored safely to sell.

1) Chemicals and pharmaceuticals

Ideally, the waste in these categories should be limited to residues of chemical or pharmaceutical products in their original packaging (bottles, boxes, cans, etc.). Waste minimization will also give rise to financial savings.

Proper management of chemical or pharmaceutical stores will be supervised by Chief Pharmacist of the health-care establishments and should include the practices listed below.

- Frequent ordering of relatively small quantities rather than large amounts at one time; this applies particularly to unstable products.
- Use of the oldest batch of a product before newer batches.
- Use of a// the contents of each box or bottle.
- Prevention of product wastage, e.g., in wards and during cleaning procedures.
- Checking the expiry date of any product at the time of delivery.

2) Pressurized containers

Aerosol cans are not generally recyclable and may be disposed of to landfills together with normal waste. Many undamaged pressurized gas containers, however, may be easily recycled, and should be returned to their original supplier for refilling. Pressurized containers must never be incinerated as they may explode, causing injury to workers and/or damage to equipment.

3) Mercury

Metallic mercury is a valuable product and also one of heavy metal pollutants. In case of a spill, e.g. from a broken thermometer, all droplets of mercury should be recovered with a spoon for later sale or reuse.

4) Recyclable needles

Health-care establishments with very limited resources should use recyclable needles, such as glass syringes with needles, and scalpels. Only items that are designed for reuse, i.e. that withstand the sterilization process should be recycled in this way. Before reuse, scalpels, syringes, needles, and other needles must be thoroughly cleaned and sterilized; disinfection alone is inadequate. Any failure in the sterilization process may result in the transmission of severe infections. Sterilization may be by chemical means, by flame exposure, or by autoclaving. Smaller district health-care establishments that lack autoclave facilities may consider sending items to

the closest general hospital for sterilization.

(8) Treatment of Hazardous Solid Health-care Waste

Principle

Hazardous solid health-care waste should be treated in the following way.

- Sterilization with chemical agent
- Destruction by chemical agent
- Incineration in proper facility

Adequate treatment should be applied for waste categories.

1) Infectious waste and needles

The above treatment methods are suitable for infectious waste and needles, except that:

- in the wet thermal process, shredding of needles is problematic;
- encapsulation is not suitable for infectious waste.

Incineration in single-chamber incinerators (like the one in Viet-Duc hospital) should be appropriate in hospitals that apply minimal waste management programs. Highly infectious waste, such as cultures and stocks of infectious agents from laboratory work should be sterilized by wet thermal treatment (e.g. autoclaving) at the earliest stage, i.e. inside the health-care establishment, and soon after production, if possible. For other infectious health-care waste, disinfection to reduce microbial concentration is sufficient.

Needles should also be incinerated whenever possible and can be incinerated together with other infectious waste. Encapsulation is also suitable for disposing of needles.

Blood should be disinfected before discharge into the sewer (unless there is an adequate wastewater treatment plant) or may be incinerated. After incineration or other disinfection process, residues may be landfilled.

2) Pharmaceutical waste

Sound management of pharmaceutical products, with a view to waste minimization, is of prime importance. Small quantities of chemical or pharmaceutical waste can be disposed of easily and relatively cheaply, but large amounts may require special, more costly treatment, such as high-temperature incineration. Comprehensive management of pharmaceutical

stores should be supervised by the Chief Pharmacist of the health-care establishment.

Small quantities of pharmaceutical waste are usually collected in yellow containers together with infectious waste and therefore follow the same disposal method being either incinerated or safely buried. It should be noted, however, that temperatures reached in a single-chamber furnace might be insufficient to disintegrate thermally resistant pharmaceuticals.

Small quantities of pharmaceutical waste, such as outdated drugs (except cytotoxics and antibiotics), may also be discharged to the sewer but should not be discharged into natural waters (rivers, lakes, etc.).

Significant quantities of pharmaceutical waste may be disposed of by the following methods:

- Incineration (if an incinerator able to reach a combustion temperature of 800°C is available); the incineration residues may be landfilled.
- Discharge to the sewer. Water-soluble, relatively mild pharmaceutical mixtures, such as vitamin solutions, cough syrups, intravenous solutions, eye drops, etc., may be diluted with large amounts of water and then discharged to sewers (where sewerage systems exist). This process should not be used for antibiotics.
- Encapsulation. When incineration is not feasible and water dispersion is not recommended, pharmaceutical waste should be encapsulated.
- Return to the original supplier if possible.

Note: Cytotoxic drug residues and other cytotoxic waste should never be mixed with other pharmaceutical waste, but should be processed separately.

3) Chemical waste

As for pharmaceutical waste, improved management of chemical waste starts with waste minimization efforts. The Chief Pharmacist of the health-care establishment should supervise the proper management of chemical stores.

The hospital's Infection Control Officer. Chief Hygienist or Chief Pharmacist should be appointed to supervise use of chemicals within a health-care establishment. The main users of chemical disinfectants, which are among the most hazardous chemicals used in the establishment, are likely to be the Infection Control Officer/Chief Hygienist and his or her staff.

Small quantities of chemical waste will include residues of chemicals in their packaging, outdated or decomposed chemicals, or chemicals that are no

longer required. These are generally collected in yellow containers, together with infectious waste, and follow the same disposal methods (either incineration or safe burying).

Large quantities of chemical waste should not be collected in yellow plastic bags or containers. There is no safe and cheap method for their disposal; the treatment options are the following:

- Incineration under subcontract by a public or private agency equipped for the safe disposal of hazardous chemical waste. The thermal reactivity of the waste should be checked; certain solvents will burn and can therefore be incinerated in simple incineration units, although it must be remembered that those containing halogens could cause air pollution.
- Return to the original supplier (if the supplier has facilities for safe disposal). In this case, appropriate provisions should be included in the original purchase contract for chemicals.
- Exportation to a country with the expertise and facilities to dispose safely of hazardous chemical waste. Shipment of chemical waste should comply with international agreements, such as the Basel Convention and the United Nations Recommendations on the transport of dangerous goods.

All three options are costly and may be unpractical, which makes it particularly crucial that chemical waste is minimized. The following recommendations should also be observed:

- Hazardous chemical wastes of different nature should never be mixed.
- Hazardous chemical waste should not be disposed of in sewer systems.
- Large amounts of chemical waste should not be buried as they may contaminate groundwater.
- Large amounts of chemical disinfectants should not be encapsulated, as they are corrosive and sometimes flammable.

4) Cytotoxic waste

Cytotoxic drugs are highly hazardous to the health of the individual and to the environment. Disposal options are the following:

- Return to the original supplier.
- Incineration at high temperatures, e.g. in rotary kilns or high-performance double-chamber pyrolytic incinerators (if available).
- Chemical degradation.

The following recommendations should also be observed:

- Residues from cytotoxic drugs or other cytotoxic waste should never be mixed with other pharmaceutical waste.
- Cytotoxic waste should never be discharged into natural water bodies or landfllled.

In countries where the above disposal procedures are not feasible, use of cytotoxic and radioactive products should be restricted to university research and teaching hospitals.

5) Radioactive waste

For safety reasons, medical use of radioactive isotopes should be restricted to university hospitals, and any hospital that uses radioactive products should appoint a qualified Radiation Officer. The rules for safe management of radioactive waste outlined in this handbook should be enforced.

6) Pressurized containers

Undamaged pressurized containers should be returned to the supplier for refilling, and adequate provision for this should be included in the original purchase contracts. If return is not possible, containers may be buried safely. Any residual pressure should be released before disposal. Aerosol containers cannot usually be refilled and should be buried. Pressurized containers should never be burned or incinerated because of severe risks of explosion.

7) Used batteries and thermometers

Batteries, thermometers, and various items of measuring equipment may have a high metal content, including toxic heavy metals such as mercury or cadmium. Disposal options are as follows:

- Recycling by specialized cottage industries. This is the best disposal solution when available.
- Exportation to a country with the expertise and facilities to dispose safely of hazardous chemical waste. Conditions of shipment should comply with the Basel Convention.
- Encapsulation. If neither of the two options above is feasible, encapsulated waste may be disposed of in an impermeable landfill (if available) or other landfill.

This type of waste should not be incinerated because of toxic metallic vapors emitted, nor should it be buried without encapsulation as this may cause pollution of groundwater.

However, if the quantities of wastes with high heavy-metal content are

minimal (similar to the quantities in municipal waste) and there are no opportunities for reuse of heavy metals within the country, they may also join the municipal waste stream.

(9) Final Disposal of Health-care waste

Principle

1. Hazardous health-care waste should not be landfilled without incineration or sterilization.
2. Manager and workers of landfill site should know the risk of health-care waste.
3. Residue of health-care incinerator may be landfilled.
4. Big pieces of human body may be buried in cemetery after chemical treatment.

Waste may be landfilled in municipal disposal sites if it cannot be treated before disposal. However, health-care waste should not be deposited or scattered on the surface of open dumps. If landfill is planned, the following minimal requirements should be met:

- measures established by a municipal authority for the rational and organized deposit of municipal wastes that could be used to dispose of health-care wastes;
- if possible, engineering work instigated by the municipal authority to prepare the disposal site to retain wastes more effectively,
- rapid burial of health-care waste, so that human or animal contact is as limited as possible.

In addition, it is recommended that health-care waste is deposited in one of the following two ways:

- in a shallow hollow excavated in the mature municipal waste, in the layer below the base of the working face, where it is immediately covered by a 2-m layer of fresh municipal waste; scavenging in this part of the site must be prevented.
- in a deeper pit (1-2 m) excavated in mature municipal waste (at least 3 months since being landfilled) which is then backfilled with the mature waste that was dug out; again, scavenging in this part of the site must be prevented.

Alternatively, a specially constructed small burial pit could be prepared to receive health-care waste only. The pit can be 2 m deep and filled to a depth of 1 m. Each load of waste should be covered with a soil layer 10-15cm deep. (Lime may be placed over the waste if coverage with soil is not possible.) In case of a disease

outbreak involving especially virulent pathogens (such as the Ebola virus), both lime and soil cover may be added. Access to this area should be restricted and closely supervised by responsible staff to prevent scavenging.

Before health-care wastes are sent for land disposal, it is prudent to inspect the proposed landfill site to ensure that there is satisfactory control of waste deposition.

(10) Health-care waste Incinerator Management

Principle

1. Waste should be incinerated at required conditions in terms of temperature, retention time, etc.
2. Operators of incinerator should be trained about risks of health-care waste and theory and function of incineration process.
3. Waste incinerator should satisfy the effluent gas emission standards.
4. Existing incinerators should improve their gas cleaning function, i.e. exhaust gas filter system.

Waste incinerators are designed to incinerate the waste at high temperature in order to decompose the compounds. Because of high temperature, pathogenic agent and another microorganisms are sterilized. But if required operation condition is not achieved, all parts of waste could not be incinerated and heated enough. Therefore bad operation of incinerators brings the risk of remaining microbe.

For the good operation, training of operators is essential. Managing authority of incinerator should hold a training seminar for them periodically, at least yearly.

In Hanoi, several hospitals have incinerators. But they are not operating completely because of air pollution. Two of them are not so old, but they do not have gas cleaner process. One of the reasons why they did not introduce the gas purifier is limit of budget. Gas purifiers are always expensive and cost for about 40% of incinerators with complete processes. If they can improve these incinerators, waste incineration capacity is increased. There is a possibility of supporting network for small health-care establishments' waste management by big establishments.

For good operation of waste incinerators, they should make a budget plan in order to get the enough budgets.

(11) Health-care Wastewater Management

Principle

Wastewater from health-care establishments should be treated properly or connected to the urban sewage system.

1) Risks of wastewater from health-care establishments

Wastewater from health-care establishments is of a similar quality to urban wastewater, but may also contain various potentially hazardous components, discussed below.

(a) Microbiological pathogens

The principal area of concern is wastewater with a high content of enteric pathogens, including bacteria, viruses, and helminthes, which are easily transmitted through water. Contaminated wastewater is produced by wards treating patients with enteric diseases and is a particular problem during outbreaks of diarrhea disease.

(b) Hazardous chemicals

Small amounts of chemicals from cleaning and disinfection operations are regularly discharged into sewers. If the sewerage system authority have the effluent acceptance standards, the wastewater from health-care establishments should satisfy them and take measures to reduce the hazardous substances. If they do not, larger quantities of chemicals may be present in wastewater.

(c) Pharmaceuticals

Small quantities of pharmaceuticals are usually discharged to the sewers from hospital pharmacies and from the various wards. If the recommendations of the guidelines are not followed, more important quantities of pharmaceuticals including antibiotics and genotoxic drugs-may also be discharged.

(d) Radioactive isotopes

Small amounts of radioactive isotopes will be discharged into sewers by oncology departments but should not pose any risk to health if the recommendations of the guidelines are followed.

In developed countries, water use is commonly high and the sewage

therefore greatly diluted; effluents are treated in municipal treatment plants and no significant health risks should be expected, even without further specific treatment of these effluents. Only in the unlikely event of an outbreak of acute diarrhea diseases should excreta from patients be collected separately and disinfected. In developing countries, where there may be no connection to municipal sewage networks, discharge of untreated or inadequately treated sewage to the environment will inevitably pose major health risks.

The toxic effects of any chemical pollutants contained in wastewater on the active bacteria of the sewage purification process may give rise to additional hazards.

2) Wastewater management

The basic principle underlying effective wastewater management is a strict limit on the discharge of hazardous liquids to sewers.

(a) Connection to a municipal sewage treatment plant

In countries that do not experience epidemics of enteric disease and that are not endemic for intestinal helminthiasis, it is acceptable to discharge the sewage of health-care establishments to municipal sewers without pretreatment, provided that the following requirements are met:

- municipal sewers are connected to efficiently operated sewage treatment plants that ensure at least 95% removal of bacteria,
- sludge resulting from sewage treatment is subjected to anaerobic digestion, leaving no more than one helminthes egg per liter in the digested sludge;
- waste management system of the health-care establishment maintains high standards, ensuring the absence of significant quantities of toxic chemicals, pharmaceuticals, radio-nuclides, cytotoxic drugs, and antibiotics in the discharged sewage;
- excreta from patients being treated with cytotoxic drugs may be collected separately and adequately treated (as for other cytotoxic waste).

If these requirements cannot be met, the wastewater should be managed and treated as recommended in section (b).

In normal circumstances, the usual secondary bacteriological treatment of sewage, properly applied, complemented by anaerobic digestion of sludge, can be considered as sufficient. During outbreaks of enteric disease, however, or during critical periods (usually in summertime

because of warm weather, and in autumn because of reduced river water flow), effluent disinfection by chlorine dioxide (ClO_2) or by any other efficient process is recommended. If the final effluent is discharged into coastal waters close to shellfish habitats, disinfection of the effluent will be required throughout the year.

When final effluents or sludges from sewage treatment plants are reused for agricultural or aquacultural purposes, the safety recommendations of the relevant WHO guidelines should be respected.

(b) On-site treatment or pretreatment of wastewater

Many hospitals, in particular those that are not connected to any municipal treatment plant, have their own sewage treatment plants in overseas.

Wastewater treatment

Efficient on-site treatment of hospital sewage should include the following operations:

- Primary treatment
- Secondary biological purification. Most helminthes will settle in the sludge resulting from secondary purification, together with 90-95% of bacteria and a significant percentage of viruses; the secondary effluent will thus be almost free of helminthes, but will still include infective concentrations of bacteria and viruses.
- Guidelines for Solid Waste management Tertiary treatment. The secondary effluent will probably contain at least 20mg/1itre suspended organic matter, which is too high for efficient chlorine disinfection. It should therefore be subjected to a tertiary treatment, such as lagooning; if no space is available for creating a lagoon, rapid sand filtration may be substituted to produce a tertiary effluent with a much reduced content of suspended organic matter (< 10 mg/L).
- Chlorine disinfection. To achieve pathogen concentrations comparable to those found in natural waters, the tertiary effluent will be subjected to chlorine disinfection to the breakpoint. This may be done with chlorine dioxide (which is the most efficient), sodium hypochlorite, or chlorine gas. Another option is ultraviolet light disinfection.

Disinfection of the effluents is particularly important if they are discharged into coastal waters close to shellfish habitats, especially if

local people are in the habit of eating raw shellfish.

Sludge treatment

The sludge from the sewage treatment plant requires anaerobic digestion to ensure thermal elimination of most pathogens. Alternatively, it may be dried in natural drying beds and then incinerated together with solid infectious health-care waste. On-site treatment of hospital sewage will produce a sludge that contains high concentrations of helminthes and other pathogens.

Reuse of wastewater and sludge in agriculture and aquaculture

According to the relevant WHO guidelines (Mara & Cairncross, 1989), the treated wastewater should contain no more than one helminthes egg per liter and no more than 1,000 fecal coliforms per 100ml if it is used for unrestricted irrigation. It is essential that the treated sludge contains no more than one helminthes egg per kilogram and no more than 1000 fecal coliforms per 100g. The sludge should be applied to fields in trenches and then covered with soil.

3) Improvement plan for wastewater management of health-care establishments in Hanoi

(a) Improvement Needs

Several hospitals in Hanoi have on-site wastewater treatment facilities. But their operation is not good. There is not enough and adequate staffs and knowledge about proper operation. One hospital official said they have never removed the sludge from septic tank for over 5 years. Therefore the treated water quality may not satisfy the standards.

Most of hospitals discharge the wastewater into sewer and into open drains directly without treatment. They have septic tanks, but they do not work well because of bad maintenance. Especially some hospitals are always at the threat of floods at rainy season. They cannot wait for the urban sewage system construction. Therefor four hospitals are selected for improvement of wastewater treatment by the discussion with DoH. The details of improvement plan for the four hospitals are shown below.

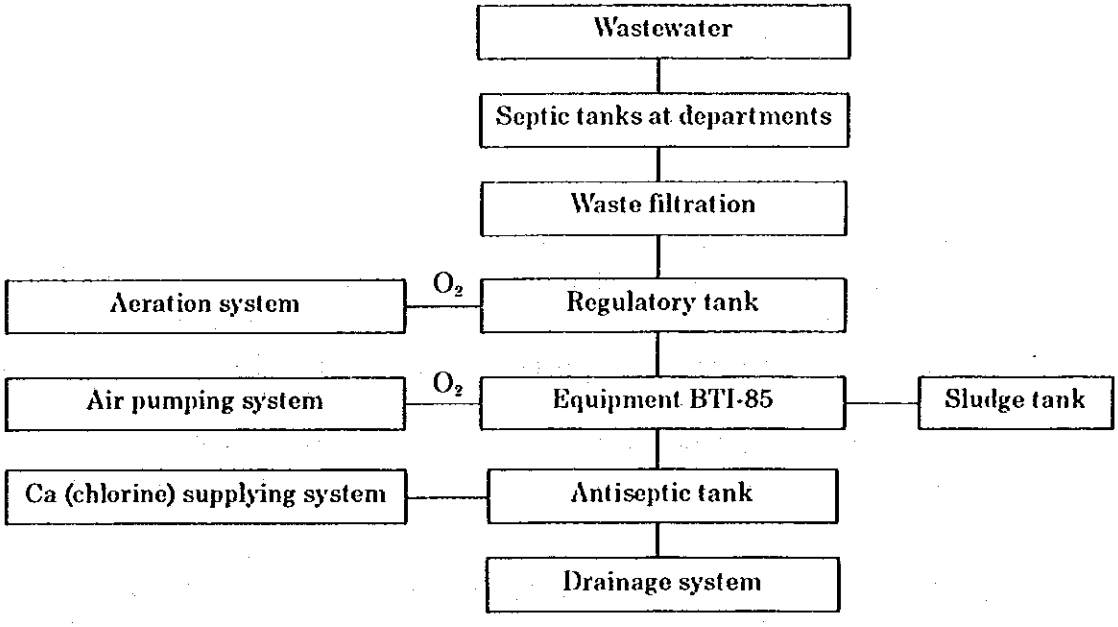
Improvement Plan of Wastewater Treatment for the Four Hospitals in Hanoi

No.	Name of hospital	Address	Hospital grade	Current number of beds	Amount of wastewater (470-600) N (litters/day)	Amount of waste (2.1-2.8) N kg/day
1	Dong Da hospital	Dong Da	3	240	112,800-144,000	504-672
2	Hanoi Tuberculosis center	Hai Ba Trung	3	50	23,500-30,000	105-140
3	Saint Paul hospital	Ba Dinh	1	450	211,500-270,000	945-1,260
4	Hai Ba Trung hospital	Hai Ba Trung	2	450	211,500-270,000	945-1260

Note: N- design number of beds in the hospital

Dong Da hospital has a leading contagious disease department in Hanoi. The Saint Paul and Hai Ba Trung hospitals are general hospitals of Hanoi. All of the above hospitals have high annual bed-occupancy rate. (According to statistics, in the first 6 months of 1999, the occupancy rate in Saint Paul hospital is 113.2%, TB center 107.8%, Dong Da hospital: 102.7% and Hai Ba Trung hospital 95.4%)

(b) Wastewater treatment plan



Treatment Flow Diagram for Hospital Wastewater Treatment Facility

The treatment system is described below.

1. Waste collecting-classifying tank
   One tank is needed for collecting wastewater, eliminating crude residue in wastewater and wastewater is pumped to treatment area built at a site

convenient for hospital wastewater collection.

The tank has a volume of $10m^3$ and reinforced concrete covered with oil to prevent erosion. The waste separating net is made of inox (ϕ 10). Two submersible pumps with capacity of $25m^3/h$ are installed (one is stand-by pump)

2. Regulatory tank

   One regulatory tank is needed for regulating the flow of and composition in wastewater. The tank has a capacity of 98 m3 per hour, and is built of reinforced concrete covered with oil to prevent erosion. There are also 2 submersible pumps with capacity of $12m^3/h$ and 2 aeration pumps with capacity of 3kg of $0_2/h$.

3. Biological tower BT1-85:

   There are 3 towers with capacity of $85m^3/day$, and 1 cyclic pump with capacity of $5m^3/h$.

4. Antiseptic tank

   One tank is needed to condition good contact between Chlorine and wastewater for chlorination. The tank has capacity of $98m^3$, and is built of reinforced concrete. There is a flow gauge so that the quantity of Chlorine is regulated.

5. Sludge tank

   A $70m^3$-tank is needed to decompose residues generated in the treatment process. The material is reinforced concrete; its surface is covered with oil to prevent erosion. Inside, there is a submersible pump with capacity of $5m^3/h$.

6. Operating house

   An operating house built of brick with concrete floor is needed to contain the electric cabinet to control the system for stirring quantifying and supplying Chlorine, (by mixing bottle and quantitative pump).

(12) Training of the staffs related the health-care waste handling and safety at work

Principle

1. All staffs in health-care establishments should be aware of risks of human-care waste and the importance of segregation.
2. All staffs in health-care establishments and the waste collection services should be trained about appropriate handling of waste.

In health-care establishments and regions that operate minimal management programs, the health and safety practices and the training should be implemented.

This is of particular importance, since minimal programs of waste management are likely to result in greater risks of exposure for workers than the more comprehensive managerial methods.

For personnel who handle wastes, including hospital cleaners and technicians, training in safety measures should cover the following issues:

- packing, handling, and storing of hazardous health-care waste;
- needs to wear protective gloves and aprons when handling waste containers;
- operations of on-site treatment and disposal methods, such as single chamber furnace operations, encapsulation, and safe burying.

Technicians in charge of chemical disinfection should be trained to implement appropriate safety precautions and emergency measures and be informed about chemical hazards. Nurses and cleaning personnel should be made aware of the occupational risks linked to handling of needles.

B.2 Technical Guidelines for Construction and Operation of the Sanitary Landfill and Industrial Waste Treatment

(1) Criteria for Selection of Sites for Sanitary Landfill

Principle

First of all, the site selection criteria must follow the relevant Vietnamese laws and regulations.

Factors that must be considered in evaluating potential sites for the long-term disposal of solid waste include (1) transportation distance, (2) location restrictions, (3) available land area, (4) site access, (5) soil conditions and topography, (6) climatological conditions, (7) surface water hydrology, (8) geologic and hydrogeological conditions, (9) local environmental conditions, and (10) potential ultimate uses for the completed site.

Acquisition of land is not easy task at all. It would be difficult to acquire land that would satisfy all the conditions. It is possible to make up for some unfavorable conditions by applying some extra environmental measures.

Vietnamese regulation for sanitary landfill:

There are two national regulations regarding sanitary landfill in Vietnam. One is "Regulation on Designing – Constructing – Operating and Controlling Urban Landfill Site" by MOC. But it has not been approved yet. The other is "Environmental Regulation on Landfill Site" by MOSTE, and it is now under preparation. Each regulation provides the criteria for selection of sanitary landfill sites.

General Criteria for Evaluation of Suitability of Landfill Sites:

1) Transportation Distance

Transport distance significantly affects costs of waste transport from collection areas to landfill sites. The longer the distance, the higher the costs of transport.

2) Legal Restrictions on Location of Landfill Sites

Under the existing Vietnamese law, it is not allowed to construct landfill sites near airports, in flood plains, wetlands, seismic impact zones, and other unstable areas.

3) Land Area

The larger the area of landfill sites, the longer the useful period and the more economical. It is desirable that the area is large enough to use 5 years at least.

4) Site Access

Access roads must be provided if landfill sites are to be constructed in areas not accessible with existing roads. An access road is often significant cost item.

5) Site Conditions and Topography

The sanitary landfill requires daily application of cover soil over dumped waste. It is desirable that soil that can be used as cover soil is obtained near the landfill site. To assess the suitability of soil as cover soil, it is necessary to analyze soil characteristics.

The local topography must be considered because it will affect types and design of landfill, equipment requirements, and extent of land preparation necessary to make the site usable.

In Hanoi, flat land areas were used as landfill site. However, mountain and valley areas can be potential landfill sites.

6) Climatologic Conditions

Local weather conditions must also be considered in the evaluation of potential sites. Wet weather in Hanoi area may necessitate division of landfill areas into several segments for effective control and reduction of leachate volume. Wind strength and wind patterns must also be considered carefully. To avoid blowing or flying debris, windbreaks must be established.

7) Surface Water Hydrology

The local surface water hydrology of the area is important in understanding the existing natural drainage and runoff characteristics. Other conditions including flood condition must also be identified. Because mitigation measures must be developed to divert surface runoff from the landfill site, great care must be taken to know existing and intermittent flow channels and characteristics of the contributing watershed.

8) Geologic and Hydrogeological Conditions

Geologic and hydrogeological conditions are perhaps the most important factors in assessing the environmental suitability of the area for landfill site. Data on these factors are required to assess potential pollution of landfill site and to know what must be done to the site to ensure that the movement of leachate or gases from the landfill will not impair the quality of local ground water or contaminate other subsurface or bedrock aquifers. Especially favorable geologic condition having good waterproof clay layer is appropriate as landfill sites in Hanoi.

Local Environmental Conditions:

It is desirable that the landfill sites would be located at some distance (a few kilometers) from residential or commercial sites to minimize impacts of environmental pollution on local residents. In case landfill sites are located near residential areas, more measures and cares must be taken to reduce unfavorable impacts.

Ultimate Use of Completed Landfills:

One of the advantages of landfill is that, once it is completed, a sizable area of land becomes available for other purposes. Because the ultimate use of landfill site affects the design and operation of the landfill, it is desirable that post closure landfill use is planned before designing. If a landfill site is to be used for some municipal function in future, an area-by-area planting program should be implemented in progress with completion of landfill.

(2) Potential Sites for Landfill in Hanoi

HPC should use Nam Son Landfill site until it would be full. It is recommended that HPC should identify and select future candidate landfill sites in the following manner.

1. Consider Minh Tri, one of the three sites that were identified during the pre-feasibility study for Nam Son landfill can be candidate sites. Characteristics of each site are shown in the table below.

Characteristics of the Tree Candidate Places Identified as Candidate Landfill Site During the Pre-feasibility Study Conducted by TUPWS

Name of Commune	Characteristics
Minh Tri	The site identified has an area of 150 ha. There is possibility that the site can be expanded to adjacent areas. It is far from residential area. The site is not suitable for cultivation. The geological condition of the site is favorable as there is anti-penetration clay layer. During the time of the pre-feasibility study, there was a plan to develop a golf course in the site.
Bac Son	The site identified has an area of 60 ha, of which 20 ha is cultivated land. It is 52 km from the city center. An access road of 11 km would be needed. Relocation of 30 households is necessary. There is no land use plan for some projects.
Xuan Bang	The land area is 35 ha only. Relocation of 20 households would be required. It is 49 km from the city center. There are a military base and high voltage electric line.

2. Consider not only plain land but also mountain and valley areas as candidate landfill sites.
3. Consider land outside the HPC jurisdiction area if it is too difficult to acquire land within the area of jurisdiction.

(3) Types of Waste to be Accepted at Landfill Site

Principle

Landfill sites of HPC will accept only non-hazardous waste. Demolition and soil waste can be disposed of at the same municipal landfill site but should be separated from ordinary waste dumping area. Any waste contains hazardous substances listed in the regulation should not be accepted at the sanitary landfill. Data should be kept regarding type of waste disposed of, timing of disposal, area of disposal within the site.

"Environmental Regulation on Landfill Site" (MOSTE) lists types of waste acceptable at municipal disposal site, and types of waste not acceptable, as follows:

Acceptable Waste

Non-hazardous waste, having possibility to naturally disintegrate by time as follows:

- Daily waste
- Waste in streets, markets
- Paper, cartoon, branches and leaves
- Ash, rotten wood, textile, rubber and leather (except leather waste containing chrome)
- Waste from offices, hotels, restaurants
- Product waste which is not included in the list of hazardous waste from

industries (food processing, fishing, beverages, paper, leather shoes industries...)

- Thick Mud from water treatment station (industrial and residential) with 20% of dry drags (residues)
- Waste of synthetic resin
- Ash without hazardous components discharged from the processes of burning waste
- Ash discharged from burning fuels.

Non-acceptable Waste

- Hazardous wastes (special management of hazardous wastes is regulated by the regulation on hazardous wastes management issued by the Decree of Government.)
- Waste with high dangerous infection
- Radioactive waste
- Remains of pesticides containing PCB higher than 50 mg/Kg
- Waste, inflammable or explosive
- Waste containing a thick mud less 20% of concentration of dry drags (residues)
- Household utensils in large volume such as: bad, cupboards, tables, and refrigerators.
- Waste of construction materials, mineral materials
- Soils contaminated by dangerous components higher than Vietnamese standards TCVN 1995 for the quality of soil
- Remains of animals in great volume

Waste Receiving Control at Landfill Sites:

At landfill site, it is necessary to check not only quantity of incoming wastes but also types of wastes and area of dumping so as to be able to trace them when necessary. Transport truck drivers should submit data on types and amount of waste they brought, and dump waste at places instructed by a site controller. Landfill manager should prepare a land allocation plan for types of waste that need special attention.

(4) Construction of Sanitary Landfill

Principle

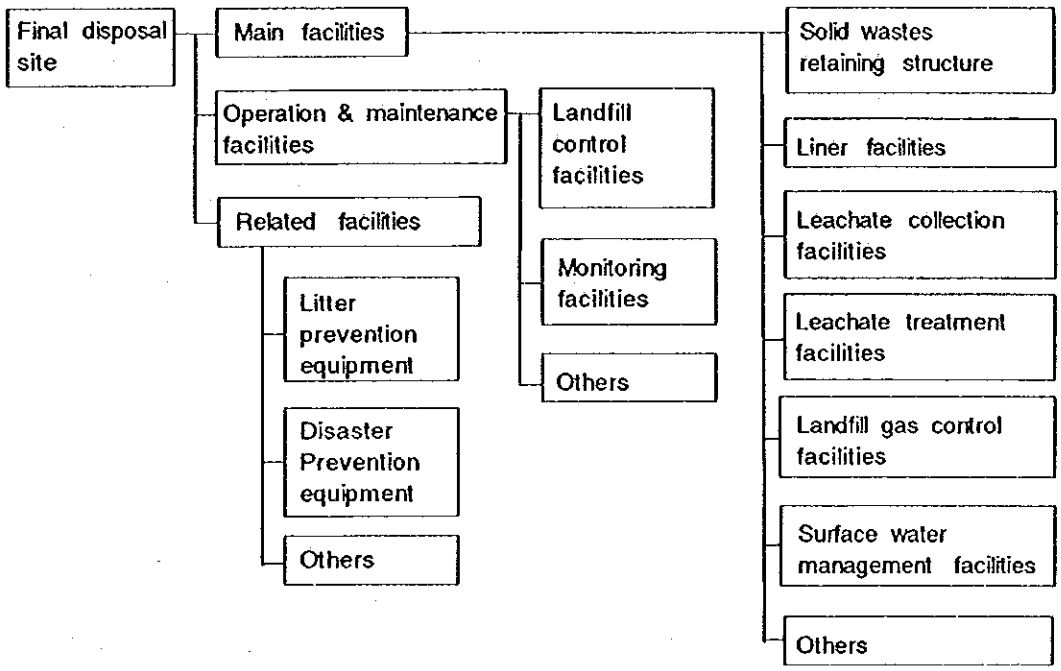
Construction and operation of sanitary landfill is followed with the regulations and guidelines.

1) Type and Structure of Sanitary Landfill

There are three types of sanitary landfill, aerobic-, semi-aerobic, and anaerobic- landfill. Semi-aerobic landfill is most appropriate type for Hanoi because of climate condition and requirement for quick stabilization for post-closure use. The facilities for Sanitary Landfill comprise of the following components.

(i) Main facilities
(ii) Operation & management facilities
(iii) Supporting facilities

The following figure shows components of the landfill facilities.



Facilities for Sanitary Landfill

2) Solid waste retaining structure

Structures of retaining facilities are constructed to avoid overflowing of dumped waste, collapse of working face. The structures ensure that dumped wastes are stored safely. These structures prevent seepage of effluent from the landfill.

Generally a landfill structure is to store solid waste, not water. However, in the event of an abnormal rainfall, the structures temporarily have to hold rainwater inside. Therefore, the structures must be strong enough for this purpose as well.

3) Liner facility

Liner facility serves for isolation of waste from the bottom soil, and avoids seepage of leachate into the surrounding soil.

Type and specification of liner facility depend on the local conditions of landfill site.

4) Leachate collection facility

The purpose of leachate collection facility is to quickly send seepage water and leachate to the leachate treatment facility. The leachate volume generated in a landfill should be kept at minimum level. If it can be removed immediately to the leachate treatment facility, there will be no trapped water in the landfill. Therefore water pressure acting on the liner facility and waste retaining facility will be reduced. The leachate collection facility is important facility influencing the selection of liner facility. These three facilities are closely inter-related and in principle they are designed as the so-called "Remove Leachate Quickly From Landfill" type of facility.

In the case of semi-aerobic landfill type, the leachate collection facility can also function as gas vent.

5) Leachate treatment facility

The purpose and function of a leachate treatment facility at the landfill site is to purify leachate so that the leachate when discharged, will not pollute the surrounding water bodies or underground water.

Since the volume and quality of leachate fluctuate with the rainfall, quality of landfilled waste, landfill type, etc., the following should be considered for stable leachate treatment.

- Selection of appropriate leachate treatment process
- Countermeasures for leachate quality fluctuations
- Countermeasures for leachate volume fluctuations

6) Landfill gas treatment facility

The purpose and function of a landfill gas treatment facility is to avoid disorderly gas release into atmosphere that might affect site workers and the environment.

Organic substances in landfilled wastes generate various kinds of gas as results of the decay, decomposition and stabilization by the microorganisms.

Gas treatment facility consists of two parts; one is the gas-venting pipe for

gas releasing control, and the other is the final gas treatment system for air pollution prevention.

Gas treatment facility shall be designed considering the following effects.

- Promoting waste decomposition with expanding aerobic zones within landfill site
- Decreasing generation of inflammable gas and bad odor, and improving leachate quality due to aerobic decomposition effects
- Promoting stabilization of waste layer by smooth water trapping
- Distributing easier post-closure landfill site management by landfill stabilization

7) Monitoring facilities

Monitoring facilities will be installed for the proper control of the sanitary landfill system. Monitoring parameters include landfilled waste, leachate, underground water, discharged water, gas, bad water, etc. which are generated at the landfill site.

Monitoring the landfilled waste layers during or after the landfill operation will check the changes in the solid waste composition, traces and measures the amount of settlement in the landfilled layers. The data obtained can be used for designing future leachate treatment plants or planning post-closure land use, etc.

The environment will be monitored during and after landfill operations.

The more the amount of data collected and analyzed the better for future planning of landfill. Therefore it is important that data on solid waste composition, leachate, underground water, gas, bad odors, etc. be regularly collected.

(5) Operation of Sanitary Landfill

1) Introduction

The landfill operation includes the whole series of works such as the delivery of solid wastes to landfill site, spreading, mixing, and application of cover soil and related temporary measures.

The solid waste is placed within the landfill site so as not to cause environmental problems in the sanitary landfill system. Landfill layer must stabilized with leveling and compaction. At the same time, it would also be important that effective and economic solid waste disposal within a limited landfill space be considered. Natural conditions such as the surrounding

environment, geography of the landfill site, weather, the type and daily amount of solid waste disposed, financial and technical aspects, etc. have to be considered before proceeding with the landfill works.

There is a close relationship between factors affecting the landfill operation and the functions of the sanitary landfill system. Landfill operation should not only depend on experiences of the supervisor of operation, but also on results of surveys on the technical and economic aspects.

It is estimated that a total of US$ 30 million would be needed for operation and maintenance of the sanitary landfill for the period from the opening of Nam Son Phase 2 Landfill Site in 2004 till 2020.

2) Landfill Methods

The method and order of landfill must be carefully selected so as to improve stabilization of the landfill, create a physically strong foundation, improve the usability of the completed landfill site, etc. Proper landfill equipment must be used to sufficiently compact the landfilled waste. To improve the potential usage of the completed landfill site, segmentation of landfill site should also be used when necessary. Data on the amount and type of landfilled solid waste, their changes over period must also be noted for future reference or for maintenance of landfill site.

The solid waste must be sufficiently compacted so as to stabilize the landfill foundation and prolong use period of landfill. A layer of cover soil must be systematically placed after landfill each layer of solid waste. This one-day's completed fill including the cover soil is called a cell. The daily cover soil should be prepared and supplied by selection of suitable construction waste.

For Hanoi, this cell method is recommended for sanitary landfill in view of large area of landfill, and push-up method is recommended for bedding and compassion. Soil covering should be daily applied. The cell method is very commonly applied throughout the world for sanitary landfill.

Under the cell method, we make cells of solid waste topped with a layer of cover soil. The size of each cell is determined by the amount of solid waste used per day. Since each cell is an independent landfill area, each cell acts as a firebreaker. It also prevents the solid waste from being scattered, emission of bad odors and harmful vectors from breeding. In the cell method, type and specification of cover soil must be carefully determined to facilitate smooth gas release and water flow.

3) Landfill Equipment

Landfill equipment should be selected after considerations given to the land structure, size, landfill method, solid waste type used in the sanitary landfill system. Landfill machines can be classified according to their functions into 1) equipment to spread and compact a landfill layer of uniform thickness, 2) digging equipment, cover soil spreading equipment, and 3) other machines required for smooth landfill operations.

Some heavy equipment is required for bedding and compaction of waste and cover material. Bulldozer and excavator with wide caterpillars, dump truck to move for cover material from stock yard to landfill site will be required for the planned sanitary landfill operation judging from amount of waste and cover material to be handled. Specifications of each equipment are as follows.

Bulldozer (for spreading and compaction)	Class 15 t/unit,	Capability: 45 m^3/hr/unit
Excavator (for excavation and loading)	Class 1.0 m^3,	Capability: 60 m^3/hr/unit
Dump truck (for transport of cover soil)	Class 11 t,	Capability 25 m^3/hr/unit (L=1 km)

(6) Environmental Monitoring

Environmental monitoring points as well as program should be planned considering meteorology, hydrology, and the current state of the environment quality.

The contents of the program for monitoring the environment quality in the landfill area include:

- Air environment monitoring
- Water environment monitoring (Underground and surface water)
- Settlement
- Odor
- Leachate

The environment quality control must be carried out in accordance with the following laws:

- Law on the environment and others relevant documents of Vietnam.
- The1995 Vietnam standards for environment.

In addition to the regular environmental monitoring activities, the following activities are useful for safe and responsible management of landfill site.

- Surveys and interviews with local residents with frequency of once or twice a year to understand their opinion
- Supervise waste transport activities, and repair and upgrade the access road and on- site roads.
- Supervise the activities of the employees and scavengers in order to provide them with protection equipment when necessary.

(7) Post Closure Landfill Management

Principle

HPC should do the following activities for post closure landfill management:

- Leachate collection and treatment at least for 10 to 20 years after closing landfill site
- Drainage control
- Gas management

Grading and landscaping

A closure plan must be prepared during the planning and design stage of a landfill site.

Post closure management period will be usually 20 – 30 years. But it depends on a primary landfill management plan that may assume different waste decomposition speed. Post closure management and environmental monitoring should begin immediately after the landfill is closed, and all the data of those activities must be kept and put into management report at the end of post closure management. Following issues are very important for post closure management.

- Routine inspections
- Infrastructure maintenance
  - Grading and landscaping
  - Drainage control systems
  - Gas management systems
  - Leachate collection and treatment
- Environmental monitoring systems

Site maintenance plan and site use plan after closure of landfill sites should be established by concerned agencies including Chief Architect Office, TUPWS and URENCO.

1) Routine Inspections

Routine inspections should be conducted to know the condition of landfill facilities during post closure period. It may be appropriate that URENCO

would conduct the inspection although a closed landfill may be used and managed by a different department of HPC such as Chief Architect Office or Green & Park Department. The responsible agency and its duties in regard to inspections will be identified and stipulated in the post closure plan.

2) Infrastructure Maintenance

Certain facilities such as drainage control systems, gas management system and leachate control systems are used during post-closure landfill management period. Operation and maintenance of those facilities have to be carried out systematically under an operation/maintenance plan. Grading and landscaping activities are also important to maintain landfill site in good shape.

Grading and Landscaping:

Closed landfill sites will have significant settlement, which will affect land surfaces and plants used for landscaping. Some equipment for landscaping and planting should be provided.

Drainage Control Systems:

Drainage facilities at closed landfills are subject to long-term settlement, which causes concerns for the preservation of gravity flow systems that discharge to surrounding environment. It may be necessary to install and operate storm-water pumps after many years of landfill settlement. Maintenance of drainage control systems must be coordinated with maintenance of land surfaces and re-vegetation of landscape plants.

Gas Management Systems:

Gas management will be required at closed landfills as long as landfill gas is produced. The gas extraction wells and gas collection pipes installed in the waste deposit or in the final cover need frequent maintenance because of the settlement of waste deposit.

Leachate Collection and Treatment:

Closed landfills with installed leachate collection systems must collect, remove and treat leachate as it is generated even after closure of landfill site. The leachate management system needs to be operated until such time as the generated leachate meets applicable standards in terms of quality. The maintenance of leachate collection and treatment facilities requires system operators who are skilled in handling changing quantities of wastewater that varies in strength.

Environmental Monitoring Systems:

The environmental monitoring systems to be operated and maintained during the post closure period are the systems designated in the closure plan and approved by the regulatory agency, DOSTE. Although each closed landfill will have specific monitoring requirements, typical systems to be maintained will include vent zone, water wells and well caps, gas probes, settlement indicator and notice signboard.

(8) Post Closure Landfill Use

Principle

Landfill sites can be used for other purposes including agricultural field, green park, sports facility sites, residential, commercial or industrial development sites.

Near urban areas, there may be strong competing pressures to restore landfills to an apparently normal land profile. Landfill sites may be used for the following purpose after certain period following closure of the sites.

- Agriculture arable land, grazing, exercise pasture
- Forestation woodland, tree screens, nature reserves
- Amenity open space, buffer zone, airport runways
- Recreation parks, playing fields, sports complexes, tracks, and golf courses
- Habitation residential area
- Commercial and Industry

It is reported that the land settlement would continue for 10 – 30 years after closing the site. It would be advisable to cover the land with plant during this period. Later the land can be used for agricultural area or green parks. Building structures can be constructed only after the settlement ends completely.

Important constraints affecting the use of a former landfill are as follows:

- Low load-bearing capacity
- Settlement (especially uneven settles)
- Presence of combustible and potentially explosive gases
- The corrosive characters of the decomposition products that affect concrete and steel and the varied biochemical internal landfill environment in general.

Those constrains continue for long time after closure of landfill sites. The duration of this aftercare period depends on climate (rainfall, temperature), nature of buried wastes, and design and operational features of the landfill.

Use of the post closure landfill sites for amenity or recreation would be very appropriate for Hanoi considering the above mentioned conditions.

(9) Industrial Waste Treatment Methods

Principle

- The waste generators before disposal at landfill sites should intermediately treat industrial hazardous waste. The waste generators could use contractors for the intermediate treatment.
- Certain kinds of industrial hazardous waste can be directly disposed of at the landfill if they meet all environmental criteria and technical requirements set by the relevant regulations.
- Various types of intermediate treatment methods such as mechanical, physical, chemical or thermal treatment shall be adopted depending on the characteristics of each hazardous waste.
- It is recommended that a sanitary landfill of suitable type should be constructed in Hanoi that exclusively accepts industrial waste.

1) Intermediate treatment methods

Objectives of treatment of industrial waste are volume reduction and stabilization and to make harmless.

Intermediate treatment processes can be generally divided into the following groups.

1. Mechanical processing
2. Physical/Chemical treatment processes, and
3. Thermal treatment processes

2) Mechanical processing

Mechanical processing is usually used as primary treatment before physical/chemical treatment or thermal treatment. Typical mechanical processing includes crushing, shredding, macerating, sorting/separating, and stirring/mixing.

3) Physical/Chemical treatment processes

There are various physical/chemical treatment processes depending on the purpose of treatment and type of industrial wastes. These processes are generally simple and relatively of low cost comparing with other methods, for example incinerating. Also from viewpoint of recycling and total cost minimization, physical/chemical treatment methods are very suitable. These methods can treat various types of industrial waste.

Typical physical/chemical treatment processes are as follows:

- Separation / filtration
- Chemical precipitation
- Stabilization / solidification
- Chemical oxidation / reduction
- Ozonation
- Evaporation

Stabilization/solidification is considered a key process of waste treatment process because sludge generated from industrial wastewater treatment process includes heavy metals such as heavy metal oxide, hydroxide and sulfides. Through this treatment process, the residue can be dumped into the landfill site safely or utilized as low-grade construction materials in order to reduce the waste landfill volume.

4) Thermal treatment processes

Thermal processes, which is mainly incinerating system, are designed to break down hazardous waste through either combustion or pyrolysis by exposing the material to high temperature in a controlled environment. Furthermore, thermal processes can reduce the volume of waste.

Different types of incinerators are used as a primary combustion chamber; the most common being the rotary kiln type. The rotary kiln combustion chamber is the most flexible type as compared to other types such as the liquid injection kiln or the fluidized bed type.

These incinerators should have the gas cleaning system.

Thermal treatment process can be considered as a kind of multi-purpose treatment system used for many types of waste. The plant and equipment required for thermal treatment, however, is expensive both in terms of initial cost and maintenance cost.

The slagging process might be added to incinerating process. The slagging process can reduce the residue volume and can stabilize the hazardous substances contained in the bottom and fly ash. However, this slagging system is even more costly than the ordinary incineration; typically twice as costly as the ordinary incineration.

5) Final disposal facilities (Landfill)

Final disposal facilities where industrial waste is finally buried are divided into the following three types.

(a) Control type landfill

This type of landfill can accept such industrial waste as cinders, sludge, and waste which is likely to be putrefied and contaminate the groundwater. The internal walls of the disposal facility are lined with rubber or plastic sheets (seepage control work) to prevent the water contained in the waste from leaking out of the facility. The water accumulated near the internal water blocking walls is collected to a leachate treatment station for purification before release.

(b) Shield type landfill

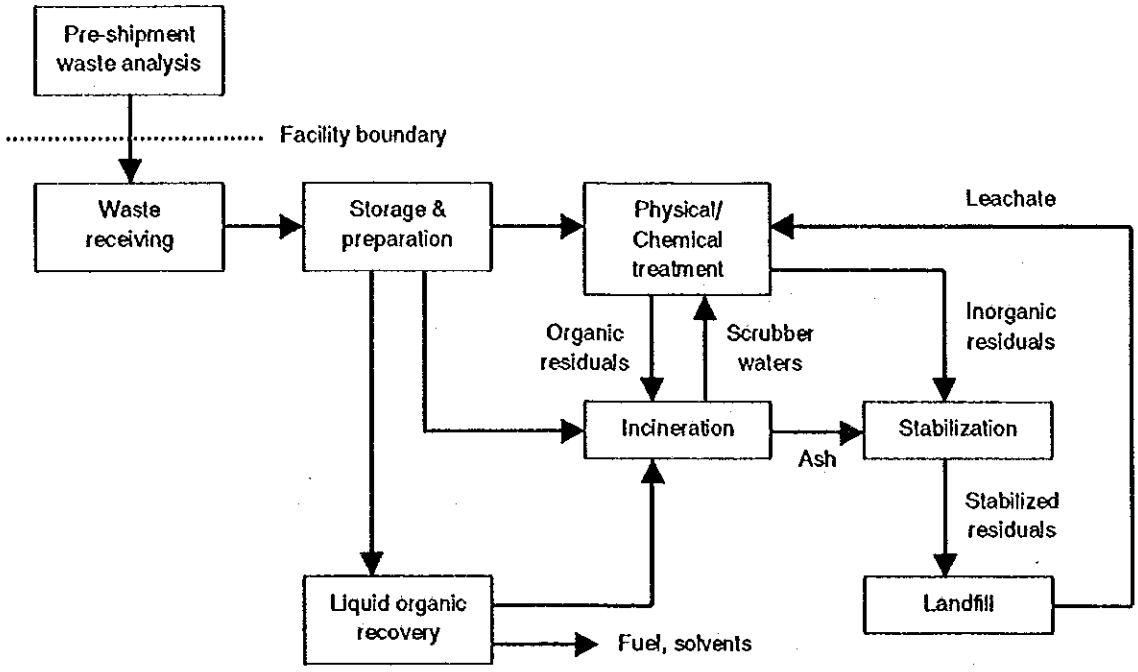
This type of landfill receives industrial waste, which is difficult to process into harmless substances. The facility is a rugged structure of reinforced concrete, with a roof provided to prevent rain from entering. The water accumulated inside should never be pumped out.

(c) Stable type landfill

This type of landfill accommodates only those wastes which never corrupt nor exude toxic substances from such as such as waste plastics, waste rubber, metal scrap, demolition debris (concrete fragments, etc.), or refuse glass and ceramics. There is no no artificial lining facility used between the disposal facility and the surrounding environment.

6) Combined Industrial Treatment System

An integrated industrial waste treatment system is to combine different treatment methods for high-efficient treatment. The following figure shows an example of hazardous waste treatment combination.



Waste management flow diagram for fully integrated hazardous waste management facility