Chapter 4

Sanitation

To control and prevent sanitary related diseases it is important that adequate sanitation, hygiene promotion and safe water supply are implemented together. This is as important in cold regions as it is in the tropics. With this in mind the similarities and differences of providing effective sanitation in cold climates, as opposed to warm or hot ones, are discussed in this chapter.

4.1 Excreta disposal

The importance of hygienic, safe excreta disposal and its relationship with the incidence of faecal-orally transmitted diseases is well established, and covered in some depth in more general guidebooks on emergency water and sanitation, such as those listed at the end of this chapter. In this section the effects of cold weather on pit latrines and open defecation are discussed, as well as some alternative methods of excreta disposal.

Open defecation

Open defecation fields are often suggested as an emergency option for areas with a hot, dry climate. In more temperate or humid conditions, the risk of transmitting pathogens to a new host via the feet of people using the defecation field increases. The desiccating effect of the heat – which keeps pathogenic organisms sealed inside the dry excreta – becomes ineffective, and flow of rainwater spreads faecal material more widely. In sub-zero ambient temperatures the chances of transmitting pathogens via feet decreases again: excreta in open defecation fields quickly become frozen.

In terms of comfort and safety, however, it may be necessary to define a lowest temperature, -10°C for example, below which open defecation is extremely uncomfortable, especially if water is to be used as the method of anal cleansing. Exposure to the cold may result in buttocks becoming frost-bitten.

Pit latrines

In cold regions several factors increase the rate at which sludge builds up in pit latrines, relative to the rate in warmer climates:

- Biological processes, both aerobic and anaerobic, which normally reduce the volume of sludge, effectively halt in sub-zero temperatures. Biological processes restart in the warmer months, provided that temperatures increase to above 0°C; their activity will increase as ambient temperatures rise.
- Frozen ground is largely impermeable. Therefore liquor from the sludge in the pit is not able to soak away in the winter.
- In very cold conditions, with temperatures less than -10°C, excreta falling into the pit may freeze before the pile has time to slump. The pit will not be filled efficiently, instead containing a frozen mound of excreta and void spaces.

The above factors imply that the volume of pits per capita, allocated for sludge storage, needs to be greater in cold regions than in warm ones.

Calculations of pit volume use the formula: [43]

$$V = N \times P \times R$$

where V = The sludge storage volume of the pit (m^3)
N = The effective life of the pit (years)
P = The average number of people using the pit
R = The estimated sludge accumulation rate each person (m^3/year)

In cold regions the value of R may be as much as double that of a warm area.

There are benefits to locating pit latrines close to human accommodation, in cold regions. The close proximity will make the latrine more accessible in cold or unpleasant weather and some protection from the accommodation can help to stop cold draughts. Unpleasant smells and flies are minimised best by fitting a tight lid on the latrine opening: water in a water seal, as used in a pour-flush latrine, is likely to freeze during cold periods; a raised vent pipe, as used in a ventilated improved latrine (VIP latrine) will draw cold air into the latrine building. A vent pipe that can be closed in winter may help in areas where summer temperatures make the removal of smells absolutely essential.

Constructing pit latrines in winter

General construction techniques for use in winter are described more fully in Chapter 5. In particular, this includes how to use antifreeze admixes to make concrete suitable for unreinforced latrine slabs. If concrete is not properly cured then it can be structurally weak and liable to collapse.

[43] Franceys et al. (1992)

Soil that is hard and structurally sound in winter may go soft in the spring, causing collapse of latrine pits excavated when the ground is firmer. If a latrine pit is dug in winter in frozen ground that is likely to thaw in spring, steps should be taken to prevent the latrine slab from falling in. Extra support can be provided for latrine slabs by embedding two parallel sections of iron pipe, planks or poles into the surrounding soil, making sure they protrude at least 1m on either side of the hole (see Figure 4.1). This spreads the load from the latrine slab over a wider area of soil, including more stable ground than that which is close to the pit sides.

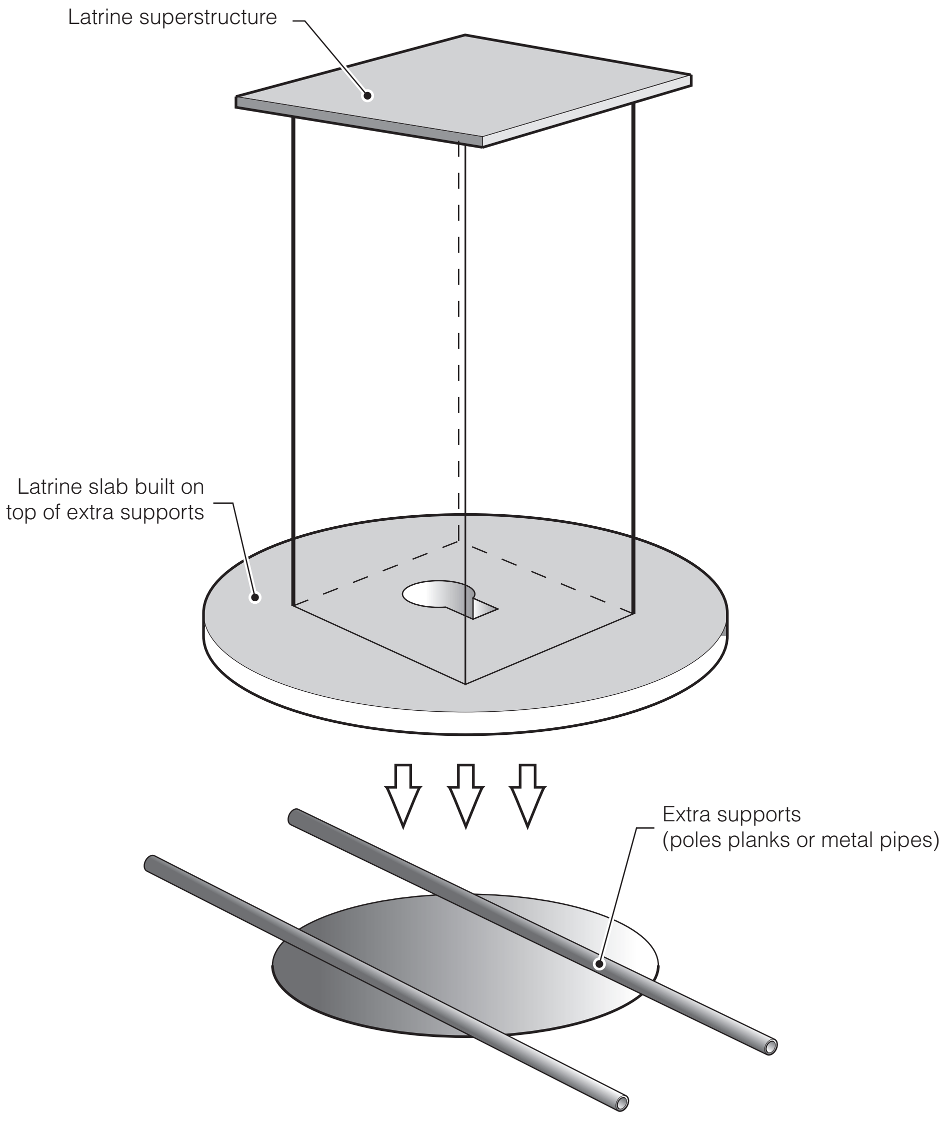

Figure 4.1. Additional support for latrine slabs

Where the soil has been frozen and covered with snow, some aid agencies have successfully used digging machines mounted on the back of snow vehicles to excavate pits. Otherwise normal diggers for construction may be the only option.

Honey-buckets and honey-bags

Established as a solution to excreta disposal problems in rural Alaska, this system is an alternative to pit latrines for when the ground conditions are such that digging pits is impossible. Heavy duty plastic bags, known as 'honey-bags', are used to line bucket latrines.

When a bag is full it is either:

- left under a small shelter outside, where its contents freeze solid. A few weeks later the honey-bags are picked up by a truck and taken to a central wastewater treatment plant; or
- deposited into a larger collection vessel, which is emptied at a later date.

The honey-bag system works well when outside temperatures are very cold (consistently below 0°C) but requires trucks, vehicle access to the area, and a central wastewater treatment facility. Also, with this system, water cannot be used as a method of anal cleansing, as additional unnecessary volume of waste is created: paper has to be used. Therefore in areas where water is the preferred method of anal cleansing, the honey-bag system may not be acceptable for cultural reasons.

Hand-washing facilities

If people and especially children experience discomfort when hand-washing after defecation, that is if the process makes their hands cold, they will be tempted not to wash. Therefore attempts should be made to make this process as pleasant as possible, by:

- periodically pouring hot water into the small water containers that store water for hand-washing at communal latrines, and taking steps to insulate these water containers; and
- providing material for people to dry their hands on: water evaporating off people's hands is what makes them feel cold. Disposable paper is the most hygienic method, although a place to dispose of used paper should be provide, such as a burning pit.

The presence of latrine attendants, on site, would greatly facilitate both the above suggestions.

Figure 4.2 shows a hand-washing facility designed for use in a cold region of China. Heated water is stored in an insulated bucket, and used water is collected in a bowl which can be emptied periodically at a designated drainage or disposal point.

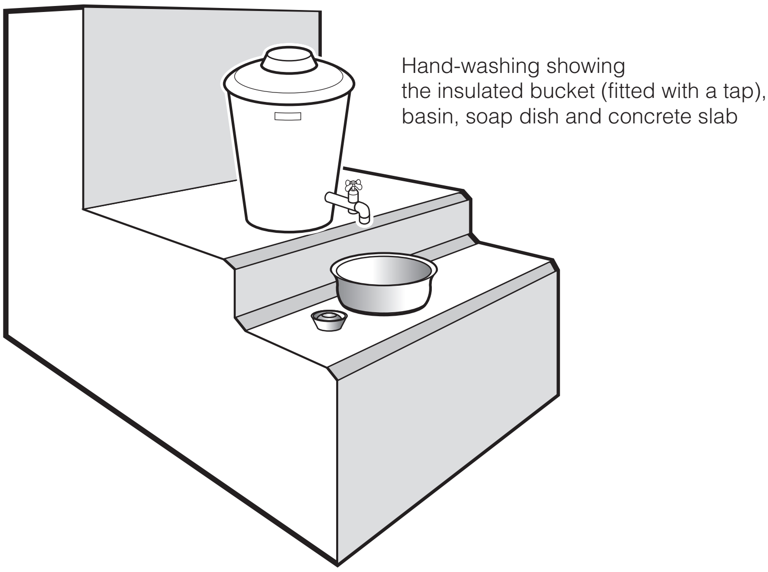

Figure 4.2. A hand-washing facility, showing the insulated bucket (fitted with a tap), basin, soap dish and concrete slab

4.2 Conventional sewerage systems

As with the provision of a water supply, in areas where infrastructure existed before the disaster, the first priority should be to renovate the old system, partly just to prevent further decay.

Experienced engineers are necessary to renovate urban sewerage properly. Some measures that are applicable to repairing sections of sewerage include the:[44]

- rapid repair of sewers, with temporary arrangements to by-pass damaged sections;
- cleaning and flushing of blocked sewers and the treating of sewers with strong disinfectants to prevent the spread of pathogens and limit smells from broken manholes and sewers;
- dewatering of wastewater treatment plants or pumping stations awaiting repair, and arranging temporary haulage of sewage to a burial site or other treatment plant; and
- providing temporary measures, e.g. pit, trench or borehole latrines, aqua-privies and possibly urinals. Use of a honey-bag system may also be appropriate where ground conditions do not suit pit latrines (see section 4.1).

[44] adapted from Assar (1971)

Wastewater treatment

As many countries in colder regions of the world have developed infrastructure, wastewater treatment facilities may exist even in rural areas. Therefore a brief description of conventional wastewater treatment methods is relevant here, in addition to descriptions of more basic methods of excreta disposal. Useful books on the theory of wastewater treatment are *Wastewater Engineering*[45] and *Small and Decentralised Wastewater Management Systems*[46].

Large-scale wastewater treatment

Although non-engineering aid workers would be ill-advised to attempt to design wastewater treatment systems, some knowledge of the basic principles involved may be useful when dealing with local engineers and contractors. This section gives a general overview of the processes involved. Figure 4.3 shows the likely flow of wastewater through a conventional treatment works and the sequence of treatment stages. Some of the processes are described briefly below.

Activated sludge (secondary, aerobic process)

Activated sludge is a secondary treatment where bacteria and protozoa feed on the organic matter within wastewater. The active organisms require oxygen from air which is bubbled through the wastewater, or mixed in by fast-spinning aeration rotors partially immersed in the wastewater. The organisms are dispersed throughout the wastewater, and are kept in suspension by the mixing provided by the aeration system. Afterwards, the mixture undergoes a sedimentation process which separates the water from the sludge, which is comprised of the organisms that feed on the organic matter. Some sludge is recycled to start the activated sludge process anew, the rest may be dried, incinerated, or treated further in an anaerobic digester unit. Much sludge is eventually applied to farmland.

Rotating biological contactors (RBCs) (secondary, aerobic process)

In this process wastewater flows past several slowly rotating disks that are half-submerged in the liquid. Biological predators (bacteria and protozoa) live attached to the disks, which rotate so that oxygen is taken into the layer of water covering the part of the disks which is exposed to the air. The bacteria and protozoa need the oxygen to respire, so it is bad for the process if the disks stop turning (although very slow rotation is satisfactory).

Percolating filters (secondary, aerobic process)

This is a common alternative to the activated sludge process. By a moving arm wastewater is trickled over gravel beds by a moving arm and is collected from the bottom of the bed. Bacteria and protozoa live on the surface of the gravel, and feed on organic matter in the wastewater. Spaces in the gravel allow air to get to the bacteria and protozoa, and the gravel provides a surface to which the active organisms attach themselves.

Anaerobic sludge digestion

This is a means of treating the solids (sludge) removed during sedimentation stages. Bacteria that can survive without oxygen break down organic matter in an anaerobic (no oxygen) environment in a tank. One product of the reaction is methane, which is often used as a fuel to heat the anaerobic digestor because the process is most effective at warm temperatures.

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[45] Metcalf and Eddy (1991)
[46] Crites and Tchobanoglous (1998)

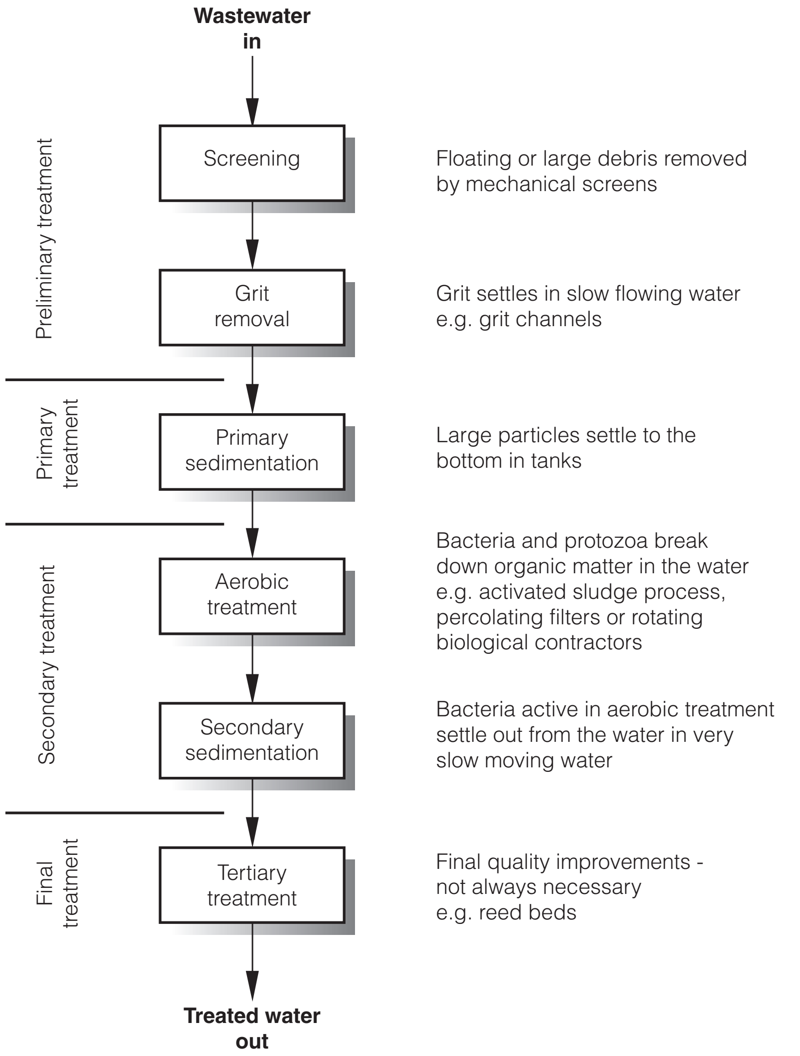


Figure 4.3. Flow of wastewater through a conventional treatment works

Wastewater stabilisation ponds

Stabilisation ponds are used in some cold countries as an alternative to conventional treatment facilities. Facultative or anaerobic ponds are the most suitable, since fully aerobic ponds (maturation ponds) are shallower, and are therefore more likely to freeze. If freezing is inevitable, it is worth noting that a shallow, aerobic pond will warm more quickly in the springtime, allowing treatment to recommence as bacterial activity increases. Aerated lagoons, consisting of large lagoons in which spinning rotors (surface aerators) are installed, can provide more rapid treatment, but require skilled staff and mechanical and electrical equipment. Ponds need a holding capacity large enough to store wastewater for the whole winter, because biological action effectively halts at less than 0°C.

The discharge rate of treated wastewater from a system of ponds is designed to be equal to the rate of treatment of the wastewater. However in the warmer months this rate will be greater than the rate in the winter, when the rate of treatment is negligible.

The following rough calculation relates the necessary average summer treatment rate to the mean rate of inflow of wastewater, all of which is merely stored during the winter months. If the inflow is constant throughout the year, at flow Q (m^3/day) then:

Winter treatment rate = 0 (zero) m^3/day

Design treatment rate for **summer** = $Q \times (1 + N_w/N_s)$ m^3/day

where N_w = Number of winter months
N_s = Number of summer months

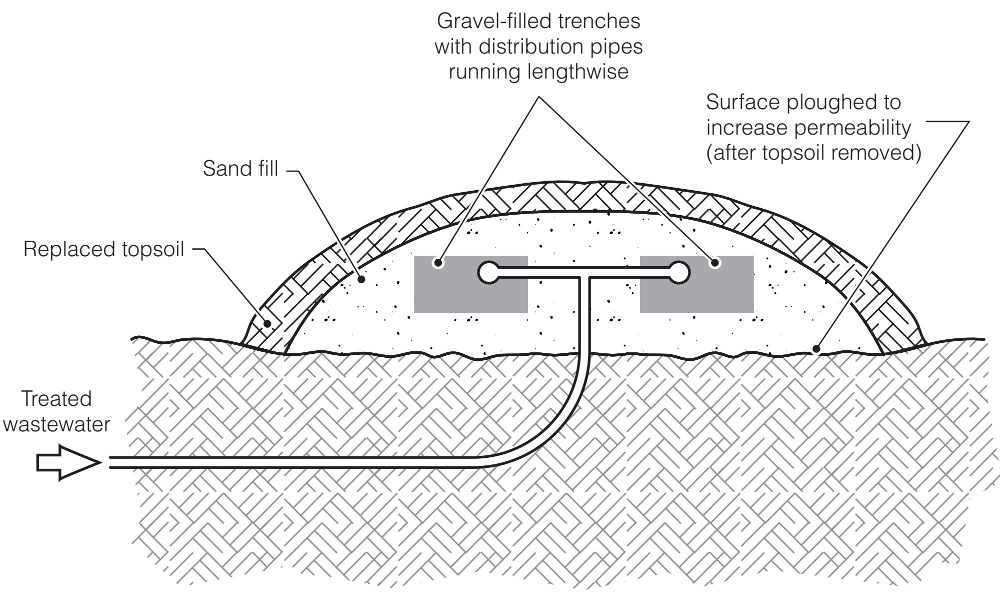
The summer treatment rate will, however, vary. After winter there will be a large volume of wastewater to be treated, but treatment rates will be slow until temperature increases further. Treatment will be most rapid during the warmest months and rates will slow down again as winter approaches.

Small-scale wastewater treatment
Small-scale wastewater treatment systems that aid workers may potentially use or encounter include septic tanks, portable aerobic units, and package plant treatment units.

Septic tanks
Septic tanks provide partial treatment of wastewater in anaerobic conditions (without oxygen) at ambient temperatures (i.e. with no heating). Treated effluent normally goes to a soakaway in the ground.

The use of septic tanks remains viable in temperatures above 0°C. However the rate of sludge accumulation is very high at low temperatures, when the rate of bacterial reaction processes is considerably reduced. Regular desludging is an absolute necessity in cold regions, with sludge being taken either to a wastewater treatment facility or to a designated disposal site.

Portable aerobic units
Self-contained wastewater treatment units that consist of rotating biological contactors in a glass-reinforced plastic shell are manufactured by Klargester and Clearwater in the UK (see section 7.4). Usually the units are semi-submerged in the ground, which provides structural support, although Klargester have also produced a version mounted inside a container unit that the British army have used in Bosnia.



Key design criteria

Design infiltration rate	7.5l l/m^2 day
Height at centre	1 - 1.5m
Width of bed	< 3m
Shape in plan	Long and narrow
Pumping rate	7 - 10 l/min
Side slope (max)	3:1
Longitudinal distribution pipes	25 - 40 mm
Holes in distribution pipes	5mm at 0.5m spacing

Figure 4.4. Raised mound system for disposal of treated wastewater[47]

Disposal of treated wastewater from small-scale units

Disposal of treated wastewater may be difficult due to frozen ground. One solution is the raised mound system, where treated effluent is pumped into gravel-filled trenches that distribute it evenly along the length of such a mound. Effluent soaks down quickly into the soil below because:

- the mound is constructed from highly permeable sand;
- treated waste is pumped in batches to retain as much heat as possible in the mound; and
- the ground surface underneath is protected from frost by the mound and the surface is prepared by ploughing to help break up large clods of earth.

The mound system is illustrated in Figure 4.4.

[47] adapted from Easson et al. (1988)

4.3 Solid waste management

In many ways the disposal of solid waste in cold regions is exactly the same as in warmer ones. In terms of collection, however, the increased logistical difficulties of a severe winter may mean that regular collection is not possible if the available vehicles are badly suited to driving in snow, or if operators are reluctant to perform the service at the coldest time of year. To avoid the random dumping of wastes and to protect the environment, it is advisable to establish a series of local dumping areas that can be cleared in the spring.

Disposal of solid waste in landfill sites may or may not be possible in winter due to frozen ground and unavailability of suitable digging equipment. Burning solid waste may be the best solution, if substances that would produce dangerous fumes or residues are separated from other materials and not burned.

If honey-bags are used as a method of excreta disposal in rural areas, a special area in the village dump should be allocated for their winter storage. Before the winter ends (and the bags begin to thaw), honey-bags should be either removed for treatment or emptied into a watertight storage lagoon or tank from which wastes can be transported by tanker for treatment.

4.4 Disposal of the dead

In addition to the usual considerations of burial and cremation, low temperatures will have both positive and negative implications on this process.

On the positive side:

- the cold will reduce the rate of biological decay processes;
- low temperatures will suppress unpleasant smells; and
- any unheated building can be used as a morgue.

On the negative side:

- cremation could be impractical since fuel may be extremely valuable during a time of disaster;
- burial may also be difficult due to hard, frozen ground; and
- pathogenic organisms may survive for long periods (even years) within or in close proximity to corpses.

4.5 Environmental sanitation in mountainous areas

Excreta disposal in mountainous areas

Accessibility, the hardness of the ground, and the availability of materials will all affect the excreta disposal options that are suitable for mountainous areas. Some useful points are:

- As in all refugee camps, latrines or defecation areas should be located downhill of the camp at the earliest possible opportunity.
- Pit latrines are an option only if it is logistically feasible to supply a few basic materials (for screens and slabs) to the area, and if the ground is not too hard.

- If materials can be brought into the area, but the ground is too rocky or hard to dig pits, raised platform latrines can be constructed above natural hollows.
- If access to the area for trucks or tractors is possible, and the temperatures are consistently below 0°C, a honey-bag system (see section 4.1) could be organised. The honey-bag system also avoids the pollution of surface water with faecal material, which inevitably results from the use of raised platform latrines or open defecation.

Solid waste and mountain camps

Arrangements for collection and disposal of waste in mountainous regions need to be very simple, involving the hand-picking of rubbish, that is issuing people with plastic bags to collect refuse and carry it to a central burning or collection area. Factors to consider include:

- Airdrops produce large volumes of solid waste which will be widely scattered.
- Transport to and from mountainous areas is incredibly expensive. Burning waste in situ may be more feasible.
- Collection of waste from some areas will be dangerous because of either natural (such as avalanches, rockfalls) or manmade (such as mines or unexploded armaments) hazards. It may be immoral to ask people to collect from those areas.

In Northern Iraq, firefighters who were part of British mobile support teams successfully involved children in solid waste collection by turning it into a game!

4.6 Books on sanitation

The following books may be useful to people providing sanitation in emergencies in cold regions:

1. Assar, M, 1971, *Guide to Sanitation in Natural Disasters*
2. Easson, M, et al., 1988, *Sanitation Technologies for Temperate and Cold Climates*
3. Franceys, R, et al.,1992, *A Guide to the Development of On-site Sanitation*
4. Davis, Jan and Lambert, Bobby, 1995, *Engineering in Emergencies*
5. Metcalf and Eddy, 1991, *Wastewater Engineering*
6. Smith, Dan, 1996, Edited *Cold Regions Utilities Monograph*
7. Harvey, P.A., Baghri, S. and Reed, R.A., 2002, *Emergency Sanitation*
8. Crites and Tchobanoglous, 1998