# CHAPTER 1
# Introduction

In the 1990s events in Bosnia, former Soviet Union countries, Afghanistan and Northern Iraq showed that humanitarian disasters are not limited to “the South”, Africa, or the Tropics, but may strike anywhere in the world. One result was that relief agencies have been tested in ways previously unimaginable. Relief workers have also had to be ever more adaptable in order to provide life-saving water supplies and sanitation facilities in areas where freezing conditions occur.

## 1.1 Who this book is aimed at

Aid workers working in ex-Soviet states, China, Eastern Europe or any other country in cool temperate or cold regions should find sections of this book of relevance to them. Techniques are described fairly simply, so that a broad range of emergency staff will be able to understand them, although engineering design recommendations are also included.

## 1.2 How to use “Out in the Cold”

This guide is written, hopefully, in such a way that readers can dip in at any subject, by using the contents and index pages. Basic information is not covered extensively because “Out in the cold” is designed to provide supplementary information that can be used together with the information given in more general emergency manuals, such as those listed on page 3.

## 1.3 Scope

Water supply and sanitation (watsan) techniques appropriate for emergencies in warm regions are well documented. Excellent manuals exist, for example “Engineering in Emergencies” by Jan Davis and Bobby Lambert (1995), which describes many techniques that could be used successfully anywhere in the world. However, there are some techniques that are not covered in the emergency manuals because the tendency has been to concentrate on water supply and sanitation systems that are appropriate for use in Africa, south Asia and other warm places.

Techniques introduced in this manual are specifically designed to be used in emergencies in areas where freezing conditions are likely to cause problems, although wider issues relating to the provision of water supply and sanitation in all cold areas are also discussed.

“Out in the Cold” takes into account that areas can be cold either because of their geographical location (high latitude, or non-tropical continental interior), or because an area is mountainous and at a relatively higher altitude than the surrounding area. Specific points relating to mountainous areas are incorporated in the text.

### *Cold regions*

If the definition of a cold region is taken to be an area where the mean (average) temperature is below 1°C for more than one month of each year, then over 1 billion people live in such an area[1]. For the purposes of this book the regions considered include anywhere where the temperature is likely to fall below 0°C for long enough to have an adverse effect on water supply or sanitation.

### *Levels of development*

Levels of development in different regions of the same country, or in different countries are often highly variable. This is even more confusing in countries in colder regions, many of which were highly developed prior to any disaster. For example, cities in the former Soviet Union countries or eastern Europe have almost certainly had working water supply, sewerage, gas and electricity systems in the past, but in some of these areas, regional disaster has greatly reduced the local level of development. Many rural and urban areas within the former Soviet Union countries, central Asia or eastern Europe could now be considered as underdeveloped, regardless of their previous level of development.

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[1] Smith (ed., 1996)

## 1.4 Emergency Engineering Manuals

The following manuals provide technical advice for use in emergency situations, although they do not specifically address cold climate emergency considerations:

1. Assar M, 1971, Guide to Sanitation in Natural Disasters, WHO, Geneva, Switzerland
2. Davis, Jan and Lambert, Robert, 1995, Engineering in Emergencies, A Practical Guide for Relief Workers, RedR, London, UK
3. House, Sarah and Reed, Bob, 1997, Emergency Water Sources, Guidelines for Selection and Treatment, WEDC, Loughborough, UK
4. MSF, 1994, Public Health Engineering in Emergency Situations, MSF, Paris, France
5. Ockwell, Ron, 1986, Assisting in Emergencies, A Resource Handbook for UNICEF Field Staff, UNICEF, Geneva, Switzerland
6. UNHCR, 1982, Handbook for Emergencies, Part One, Field Operations, UNHCR, Geneva, Switzerland
7. UNHCR, 1992, Water Manual for Refugee Situations, UNHCR, Programme and Technical Support Section, Geneva, Switzerland

A full bibliography, including books about utilities engineering in cold regions and emergency watsan, can be found, starting on page 88.

# CHAPTER 2
# Preliminary Issues

During the first stages of an emergency or soon after the emergency organisations arrive, a comprehensive assessment of the situation is a prerequisite to the formation of a plan of action. In cold regions climatic conditions make it necessary to consider factors additional to those present in warmer areas. It is important to bear in mind that the provision of shelter during emergencies in cold regions is one of the most important tasks. Water supplies, sanitation and service infrastructure will all be developed to comply with the types of shelter being used.

## 2.1 The effects of climate

Winter freeze-ups affect water supply and sanitation options, logistics, construction techniques and the health of the population. Even people’s attitudes to work are adversely affected by poor climatic conditions. Therefore, to increase the effectiveness of aid provision, it is essential to obtain reliable information about local climatic conditions.

Some questions to consider are:

***About the winter***

- When does the winter period start and finish?
- Are temperatures below freezing at night only or also during the day?
- What are the average daytime and night time temperatures in winter?
- What is the minimum temperature likely to be?
- How much snow can be expected and at what time of year?

***About the summer***

- How long does the summer period last?
- Is there a period when there will not be a frost, even at night?
- What are the average day-time and night-time summer temperatures?

### *Additional climatic data*

- How much precipitation falls as rain? When?
- How many hours of daylight and darkness are there in the summer and how many in the winter?

Apart from talking to local people, climatic information may be available from local meteorological stations (at airports or military establishments), media companies (TV, radio or newspaper), or on the Internet.

Monthly temperature and precipitation data for many cities around the world are given in "The World Weather Guide" [2].

## Winterization studies

A winterization study should be carried out, every summer, in relation to all aid operations that face the prospect of continuing during a cold winter. The aims of such studies are, firstly, to predict factors that will, or could affect the provision of aid during the winter period and, secondly, to determine what can be done by way of preparation to overcome the difficulties.

Likely issues include:

### *Water supply and sanitation (watsan)*

- Is it necessary or desirable to alter any water supply or sanitation practices because of winter conditions?
- Which systems are at risk of freezing, what damage will result if they do freeze and what can be done to protect those systems?
- Is it necessary to complete all construction projects before the start of winter or is it possible to continue constructing new facilities in winter?
- How will the winter affect the maintenance of watsan facilities?
- Is it possible to collect solid waste from all areas in winter?

### *Logistics*

- Is there a need to stockpile certain items, for example food, fuel, blankets, warm clothing or shelter materials, and is it possible to do so?
- How will winter weather (e.g. snow) affect access to disaster-affected areas and what effect will that have on current systems, such as hauled water?

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[2] Pearce and Smith (1998)

***Physical threats***

- What risks of flooding exist, including from snowmelt in the spring?
- Is there a risk from avalanches or landslides?

***Human issues***

- How will adverse weather affect local people's attitudes, for example people may show less motivation to work in cold weather, or may become so preoccupied with money, food, shelter and warmth that water supply and sanitation become a very low priority?
- What winter-related health problems are likely?
- What can be done to help the most vulnerable members of the community, such as older people and young children?

### Mountain climates

The concept of a cold region includes not only regions where the predominant climate is cool temperate or cold, but also mountainous areas where the extra altitude causes a reduction in the ambient temperature. A fall in temperature of between 1.5°C (in moist air) and 3°C (in very dry air) should be expected for every 300m of altitude gained[3]. Mountainous areas can also be quite exposed and people living in those areas could also suffer because of high winds and feel colder due to the windchill effect (see page 70).

The ability of a displaced population to survive in the mountains is greatly hindered if they are not used to living in such conditions. This happened in Northern Iraq, after the "Gulf War" in 1991, when some Kurdish refugees originated from mountainous areas, but many people had fled to the mountains from much warmer areas, and suffered greatly as a result.

## 2.2 Location of sites and facilities

When deciding on the location a camp, buildings, latrines and other structures it is necessary to consider not only the practicalities of construction, but also the local level of development, socio-political issues and possible religious constraints. The issues of women's security (and the security of other people too), and whether there is enough privacy may also affect whether facilities are used to their full potential.

Beware also of unexpected physical threats in cold regions, for example flooding, in spring, caused by melting snow, which as well as causing damage to structures,

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[3] Walker (1988)

could cause unsanitary conditions if pit latrines or defecation fields become submerged, and threats from avalanche or landslides.

## Urban and rural locations

The provision of water supply and sanitation will always be closely related to the type of shelter in which the affected population is living. This is more so in cold regions where the provision of shelter is obviously a high priority. Shelter options are discussed at greater length in the section starting on page 67.

In terms of watsan, appropriate systems for use in emergencies vary, depending on whether the affected population is in a rural or urban location, or whether they are living in a temporary camp. The main differences between the urban and rural cases will be differences in the levels of technology used.

In an urban setting repair of existing water supply and sewerage networks should be a matter of priority in order to minimise further deterioration. These systems require the knowledge of experienced engineers. An advantage of repairing such systems is that large numbers of people will quickly receive the benefits of clean water and sanitary conditions, reducing the associated health risks. As a guide only, some measures appropriate for the renovation of an urban sewerage system are included in chapter 4.

Also in urban areas, aid agencies often find themselves repairing local facilities: arranging simple fixing of doors, windows, floors and so on. Local people are often unable to obtain construction materials for financial, logistical or political reasons[4].

In rural locations, or camps, the emphasis of watsan provision moves towards the development of new sources of water, and setting up new sanitation systems. However, in some countries, even small villages are likely to have systems that could, and should, be renovated if at all possible.

## Mountain locations

Here the positioning of water supply distribution points, latrines and any other facilities must take account of the place where people will have to queue. This is partly to minimise the time people take to walk to the facilities in the cold, but also to take care that people are not forced to cross steep or loose areas of mountainside to get there. Areas for distribution should also be organised carefully to minimise the risks from exposure and physical harm.

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[4] Buttle (1998)

## 2.3 Appropriate technology for cold regions

### Water supply technology

Equipment from donor agencies, which has been well tried and tested in Africa, is not always suitable for use in colder countries. Oxfam storage tanks, for example, have had problems with the water freezing over: the tank liners could easily be damaged by ice forming on the water's surface. This problem has been overcome, in some instances, by erecting the tanks indoors. Problems can also occur with distribution networks: ice forming in pipes and valves is liable cause damage.

The technology used for an emergency water supply in Africa will not survive a winter in central Asia: it is necessary to use technology and techniques that are specifically designed for use in cold regions. Examples include insulating water tanks, burying pipes, and designing water treatment processes that take into account slower rates of reactions and the higher viscosity of water at lower temperatures. Water supply matters are discussed at length in chapter 3.

### Environmental sanitation technology

As in warmer climates, sanitation options always need to be considered in the context of cultural and religious acceptability, however cooler temperatures do affect the range of technologies that it is possible to use. The actions of pit latrines and septic tanks are impeded by cold temperatures. However technology that is used in everyday life in, for example, Alaska can be successfully adapted for use in humanitarian disasters in cold regions.

The rates of biological reactions, which are critical to the decomposition processes that are used to treat excreta and wastewater, are greatly reduced at low temperatures. In some areas the result is that excreta will have to be stored throughout the winter, until ambient temperatures are sufficient to allow for treatment. In other cases, provision for emptying of on-site excreta disposal facilities more frequently and more reliably than in warm climates can solve the problem. Excreta disposal technology and other sanitation issues are discussed more thoroughly in chapter 4.

# CHAPTER 3
# Water Supply

Although the subject of water supply is covered in some detail in many emergency manuals, there are additional factors which will affect the provision of fresh water for domestic supplies in conditions where the ambient temperature is close to or below 0°C: chemical reactions are slower at low temperatures and biological processes also take more time. The physical properties of the water, as it occurs as liquid water, ice or snow, being also temperature dependent, therefore also affect processes involved in supplying water and the range of technology that can be used.

## 3.1 Properties of water, ice and snow

### Water density

As liquid water cools its density gradually increases, a behaviour that is typical of most liquids. However water has a maximum density at 4°C, below which the density decreases slightly: the water expands, until ice begins to form at 0°C. As it congeals into ice it gains approximately one eleventh of its liquid volume, consequently ice is less dense than water, and floats.[5]

The fact that water is most dense at 4°C causes a quality fluctuation in the water in lakes, in cold regions. During the autumn, as the water slowly cools, the layers "turn over" causing a sudden, temporary, increase in Total Dissolved Solids (TDS)[6]. Also, in winter, the warmest water in lakes is at the bottom whereas during the summertime it is at the surface.

### Water viscosity

As water temperature decreases, its viscosity increases. This increase in viscosity reduces the settling velocity of particles (affecting the design of sedimentation tanks) as well as increasing the energy requirements for mixing and pumping operations. Further details are given on page 25.

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[5] Davis and Day (1964)

[6] Smith (ed., 1996)

### Ice formation

When water freezes and becomes ice the effect of its expansion can exert pressures as high as 2500 kg/cm$^2$, which is the equivalent of a static head of water approximately 25 km high. This inevitably causes problems if water freezes in pipes, pumps or other containers, because they are not able to withstand such large pressures and forces.

### Snow

Properties of snow vary greatly according to how old it is. New snow a relatively good thermal insulator, because it is less dense than old, more compacted snow. Generally, snow is a relatively good insulator: its thermal conductivity, even when dense, is much less than that for ice. This affects heat loss from buildings and the rate of freezing of lake and river ice[7]. A snow covering of 1 to 10 cm in depth will raise the temperature of the surface of the ground by 1.1°C above air temperature, for each centimetre of snow depth (although the ground temperature will not be greater than 0°C). Even at pipe-burial depths (e.g. 0.75m to 2m) a covering of snow will raise the temperature of the soil by at least 0.1°C per cm of snowcover, compared to the temperature at the same depth of uncovered or cleared ground[8]. In Canada and Alaska, settlers used to pile snow against their wooden buildings in order to increase the insulating properties of the walls.

## 3.2 Sources

If a supply adequate for survival has been established then top priority should be given to the restoration of local water systems, if present, to prevent further deterioration. If the area has no such “urban” supply, or if it is temporarily unusable, the water source options for abstraction of water for drinking, cooking and washing obviously depend on what exists in the local area. The possibility that trucking water into an area will be impossible in winter due to snow covered roads or simply due to expense will also necessitate the development of local water sources.

Appendix A (page 74) contains flowcharts that can be used to aid to the selection of appropriate water sources for emergency use in cold regions. Whilst these flowcharts concentrate on technical issues, it must be stressed that social, religious, environmental, and financial (cost) implications are also important factors to be considered when selecting appropriate water sources.

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[7] Langham (1981)

[8] Steppuhn (1981)

"Emergency Water Sources" [9] offers a comprehensive description of many issues connected with this subject. However this section describes some of the factors that will affect the choice of supply in a cold region, which are additional to the normal factors of proximity, water quality, adequate volume and cost that will always affect source selection decisions.

## Groundwater

Being warmer than surface water, with temperature and quality that are generally constant throughout the year, groundwater offers several advantages over surface water as a potential water source in cold regions. Advantages include:

- The higher temperature makes it less likely that water will freeze in storage tanks or distribution pipes.
- The reliability of temperature and quality means that the same water treatment regime can be used all year round. Seasonal quality and temperature variations of surface water sources could make treatment options more complicated because they need to take account of these variations.

Possible problems associated with using groundwater include:

- Above ground pumps are liable to maintenance problems or damage from frost although submerged ones will be protected by the water. See also the "Mechanics" section starting on page 65.

The above factors should be weighed up against the advantages and disadvantages of using groundwater which are common to warm or cold climates, such as:

- Properly protected wells and boreholes can have extremely low levels of faecal pollution, minimising health risks and treatment costs.
- Water quality varies depending on local hydrogeological conditions. The water may have a high mineral content, including dissolved metals and salts, which could make the water unpotable; or minerals such as arsenic and fluoride which have associated health problems. In any case, a full physical and chemical analysis of the water should always be carried out.
- Location and development of groundwater sources can be very expensive.

### *Wells and boreholes*

When constructing wells and boreholes in areas where the ground is liable to freeze, bentonite (clay) should be used, in preference to concrete, for grouting the

[9] House and Reed (1997)

annular space around the casing, to prevent the flow of surface water (containing pollutants) down the outside of the hole. Concrete, used in warmer regions, can bond tightly to steel well casings, whereupon frost heave, caused by annual freezing of the ground, then pulls the casing apart, ruining the well or borehole[10].

In permafrost areas, the frozen ground acts as an impermeable layer above groundwater aquifers. Surface water features such as rivers and lakes cause the permanently frozen ground to thaw below them, so that it is possible to locate groundwater closer to the surface near to surface water features. Figure 3.1 shows how boreholes located on the inside of river bends can access groundwater at a depth where the ground of the surrounding area is permanently frozen.

### *Springs*

It is easy to assume that spring boxes are not likely to suffer from problems with the water freezing inside, because the water is continually flowing and because the water, having originated underground, would normally be slightly warmer than surface water. However in mountainous areas freeze-ups, and other problems are possible.

In mountainous areas, water emerging from springs is likely to be quite cold already, having originated higher up the slope. This increases the likelihood of the water freezing during a cold spell. If outlets from a spring box do freeze up, the resulting back pressure may cause subterranean water flow channels to alter their course, causing the spring to emerge at a different place. It is therefore advisable to guard against freeze-ups by covering spring boxes with a layer of soil, of a depth equivalent to the depth of maximum winter frost penetration in the ground, so that water in the spring box is never cooled to below 0°C. A thickness of 0.75m to 1m of soil cover is adequate for most situations.

Secondly, construction of spring boxes scree can also cause problems. In scree subterranean flows which alter course periodically may cause the spring to emerge at a different place. The spring protection then has to be moved to the new location where the water emerges from the ground, or new protection facilities built. Scree movements are also likely to damage spring boxes, necessitating continual maintenance.

Both problems suggest that cheap local materials should be used for spring box construction, as it is possible that they will be either destroyed or rendered inactive by shifting flows of water.

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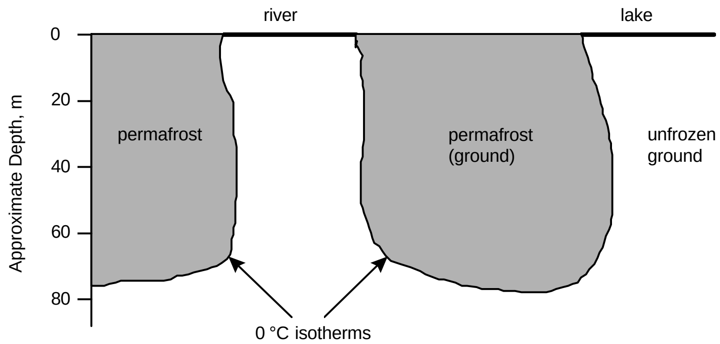
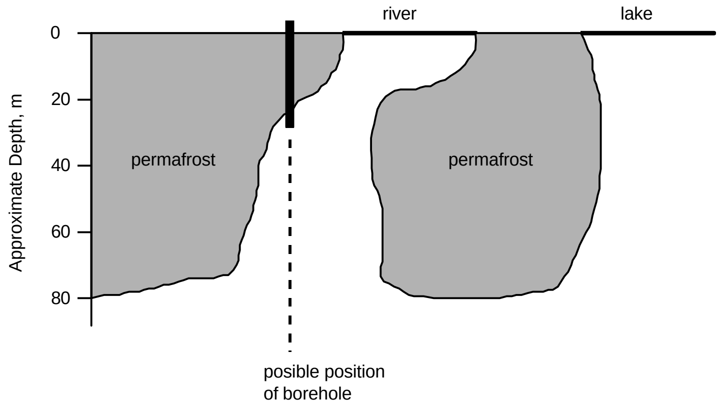
[10] Smith (ed., 1996)

**Figure 3.1: The effect of a shifting river, in a permafrost area, on groundwater depth and on the location of boreholes[11]**

**Initial Ground Condition (e.g. 400 years ago)**




**Present Ground Condition (after river has moved)**




[11] adapted from Smith (ed., 1996)

## Surface water

### *Quality*

Surface water is always liable to be contaminated by faecal pollution anywhere in the world, particularly at a time of disaster, when normal excreta disposal facilities may not be functioning properly. The presence of faecal coliforms in the water is an indicator that it has been recently polluted with faecal matter, and that dangerous bacteria and other pathogens could be present. However, assumptions are often made, incorrectly, concerning the quality of surface water in cold regions.

One myth is that bacteria cannot survive in very cold water. Bacteria can actually survive longer in cold water, although their rate or metabolism is greatly reduced. If the bacteria are consumed by humans their rate of development will, once more, increase and is likely to cause disease. Living coliforms have been detected in military camps in the arctic that had been abandoned years earlier[12]. The possibility of faecal organisms surviving a winter in a refugee camp, only to cause health problems through the water supply in the summer, should not be discounted. There are also certain bacteria which are adapted to live in colder conditions (psychrophilic bacteria). If present in drinking water, certain of these could cause health problems.

The above factors emphasise the need for proper water supplies to be established, with frequent and thorough water testing for quality.

### *Rivers and streams*

Many cold region countries have higher concentrations of industry than in Africa, and modern farming methods are used. In addition to pollution caused by broken sewerage systems, the destruction or running down of industry and farms during a time of disaster makes it highly likely that rivers and lakes will be polluted by chemicals and livestock wastes. Laboratory testing of water samples is the only reliable way to determine pollution levels and if pollution is detected then this will obviously affect the decision whether or not to use rivers and streams as sources.

### *Seasonal constraints*

Quality monitoring is necessary at all times of the year to ensure that seasonal variations in water quality can be dealt with by water treatment.

In winter the flow volumes in rivers and streams can be greatly reduced in comparison to summer flows. This is partly because precipitation upstream falls as snow, which stays on the ground instead of melting and flowing into water courses;

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[12] DiGiovanni et al. (1962)

and also because small streams are liable to freeze solid instead of joining larger water courses. Some small streams are likely to dry up altogether.

The reduction in flow originating from surface water runoff also implies that a greater proportion of river water originates from groundwater sources, such as springs, in winter. If the concentration of minerals in the groundwater is higher than that in surface water runoff (and it is likely to be) then the concentration of dissolved minerals in the river will be higher in winter.

River water quality is considerably worsened, in the spring, because of the seasonal thaw. Ice and snow that accumulated on the surface of the land in winter melts, washing pollutants into the river. The result is a sudden temporary increase in Total Dissolved Solids (TDS) and turbidity.

Also during the spring, large blocks of ice that are released from areas where the river had been frozen over will float downstream. These blocks can wreak havoc, causing damage to water intake structures and bridges unless very substantial protection structures are built.

### *Lakes and ponds*

#### *Seasonal water quality variations*

As with rivers and streams, the quality of water in lakes and ponds varies according to the season. The causes of these quality variations are seasonal changes of the water temperature:

- In the autumn it is common for the layers of water to invert, disturbing sediments from the bottom of the lake and causing a sudden temporary increase in turbidity and total dissolved solids.
- In winter impurities are slowly rejected from surface ice as it forms, which increases the concentration of dissolved solids in the water below the ice.

These variations of water quality with the seasons are shown in figure 3.2a .

#### *Purification of lakes or ponds by brine pumping*

In very cold areas it is possible to purify a shallow lake or pond, in preparation for use as a water source the following year, by a process known as brine pumping.

As ice forms on the surface of a lake or pond, impurities are slowly rejected and are therefore concentrated in the remaining water. If most of the water becomes frozen, which is more likely in shallow lakes than in deep ones, then the small amount remaining as a liquid may, therefore, be highly saline; this water is very unlikely to be suitable for use as a source for domestic supply. However if that liquid portion of the lake water is pumped out and discarded, the majority of soluble pollutants will be removed from the lake in one action. When the ice melts in the spring, the water in the lake contains substantially less Total Dissolved Solids (TDS) than the year before, and may therefore be more suitable as a source of drinking water.

Purification of lakes by brine pumping is illustrated in figure 3.2b .

### *Ice cutting from lakes*

Since impurities are rejected from ice forming on the surface of lakes, the ice remains fairly pure. Provided it is stored carefully, cut ice is a valid source of water. Cut ice has been used as a source of water in remote villages in Alaska for many years.

Obvious dangers are that ice may not be thick enough to support lots of people moving around on it, and the results of falling in could be fatal. This technique is only valid for very small communities.

### *Intakes*

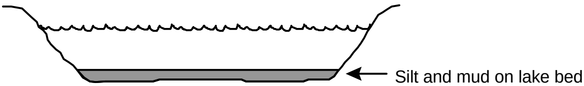
Intakes for extracting water from lakes that are liable to freeze over need to incorporate various design features to prevent damage of equipment. For pumping from an ice covered lake or river one temporary solution is to pump intermittently using a portable pump which is located on the ice while pumping and removed in between times. The pipe from the pump to the holding tank or booster pump should be propped at a continual gradient so that water drains out, back into the lake after the pump has been removed. Possible intake arrangements for winter and summer pumping are shown in figure 3.3 .

# Figure 3.2: Seasonal quality variation of water in lakes and quality improvement by brine pumping

**a) SEASONAL QUALITY VARIATION**

**SUMMER**

Water quality at its best, compared to other times of the year




**AUTUMN**

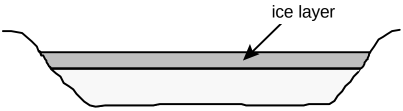
Water quality temporarily poor

Water in the lake inverts because it is most dense at 4 °C and water temperature is falling. Sediments are stirred up causing an increase in turbidity and total dissolved solids.

**WINTER**

Quality not as good as in summer

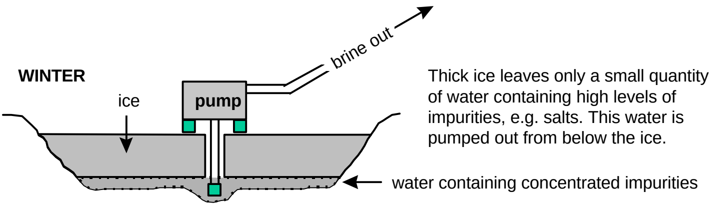
Ice rejects impurities as it forms, increasing the concentration of impurities in water below the ice.




**b) BRINE PUMPING (to improve water quality)**

**WINTER**

Thick ice leaves only a small quantity of water containing high levels of impurities, e.g. salts. This water is pumped out from below the ice.




**NEXT SUMMER**

Water quality improved

Ice melts and fills the lake with relatively pure water

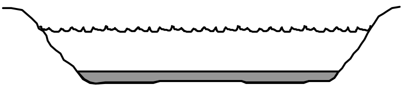
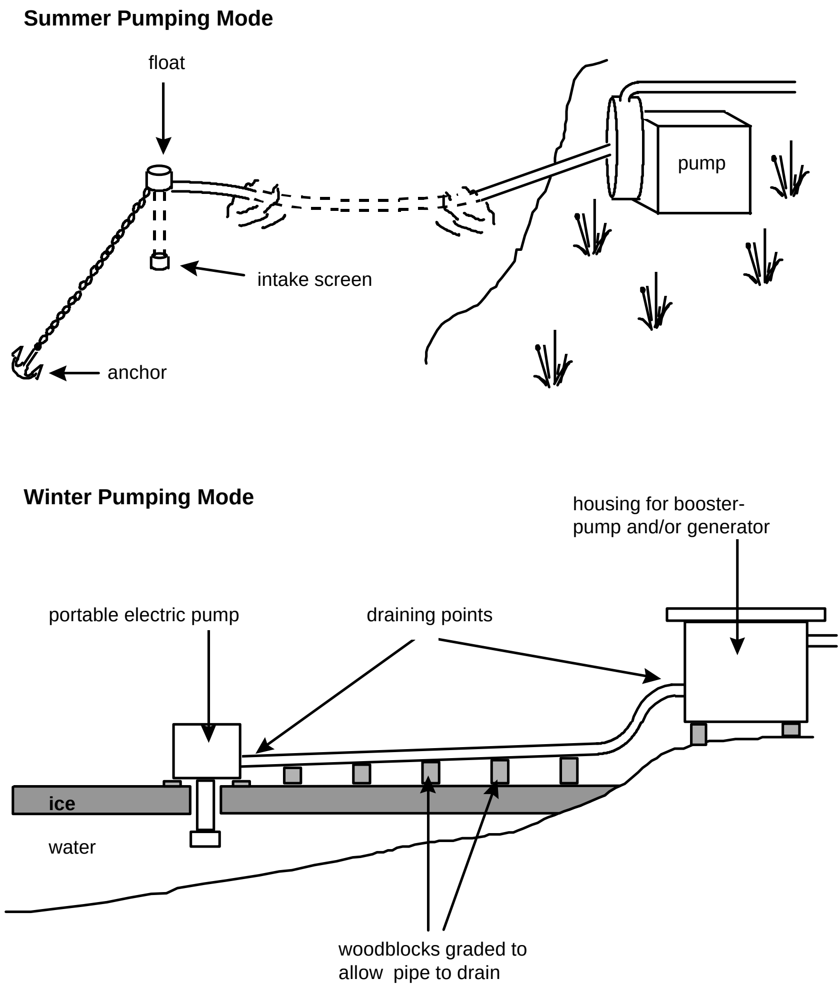


**Figure 3.3: Temporary water intakes showing arrangements for summer and winter pumping[13]**




[13] adapted from Smith (ed., 1996)

### *Infiltration galleries*

In large rivers, in winter, the main flow may be under a thick layer of ice and its path through river gravels can shift frequently. This makes water abstraction difficult, because it can be difficult to locate the flow and because the shifting flow means that the point of abstraction may have to be moved frequently. Smaller streams can cease to flow altogether. Utility providers in Alaska overcome these problems by using infiltration galleries that span the width of the riverbed. These are effective because they avoid the necessity to locate the flow under the ice and, even when surface flow has ceased altogether, subsurface flow of water may continue.

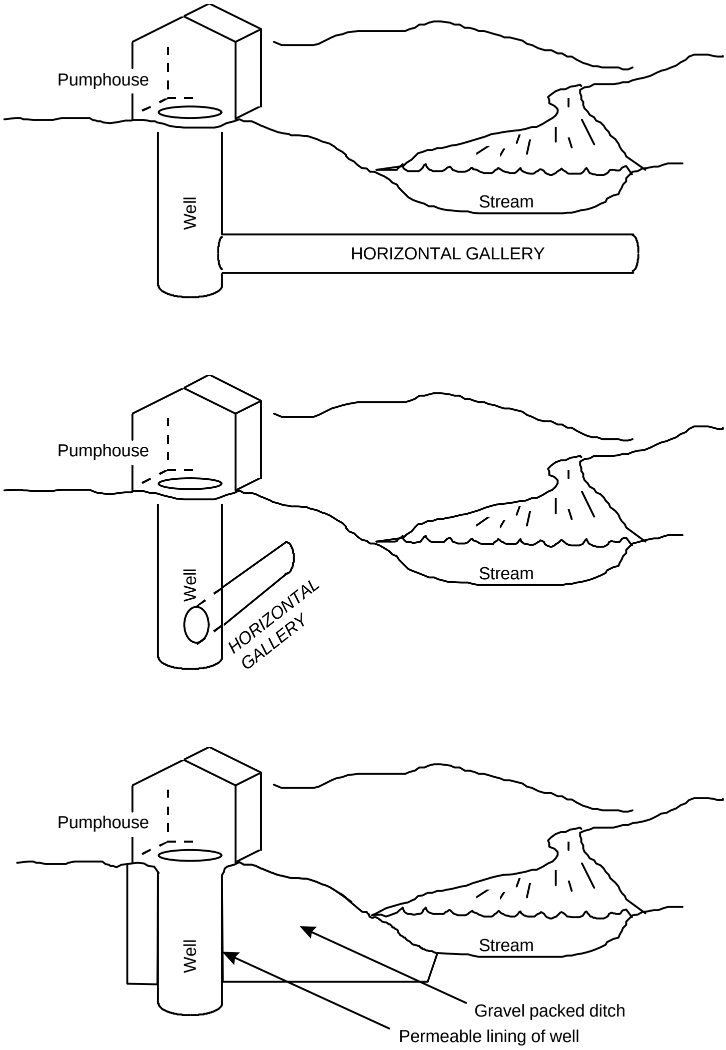
Infiltration galleries are expensive and take considerable effort to construct, and therefore can not be classified as a low technology solution to water source problems in an emergency. Repair or renovation requires experienced engineering skill. However it may be viable to construct collect collector wells with either a horizontal infiltration gallery parallel to the waters' edge or with a gravel filled channel connecting the well to the main body of surface water. Figure 3.4 shows possible arrangements for infiltration galleries and collector wells.

Construction of infiltration galleries requires the following:

- Digging machinery.
- The ground in which the gallery is to be placed is not frozen or, in a permafrost area, the ground is in the thaw bulb area where the ground is kept at above 0°C by the heat of the water in the main water body.
- The ground is permeable. (A coarse grained medium, such as sand or gravel is better than a fine grained one, such as silt.)

Infiltration galleries beside small streams can continue to yield water even when the stream is completely frozen, due to subsurface flow.

## Figure 3.4: Forms of infiltration galleries[14]




[14] adapted from Smith (ed., 1996)

## Snow

For a while snow was the main source of water for Kurdish refugees who were surviving in the mountains of northern Iraq in 1991[15], and was also used in some rural parts of Bosnia in the winter time. Therefore it is worth considering snow as a water source even if only as a temporary or seasonal option. Factors to consider include:

- The distribution of heavy duty plastic bags so that teams can collect large volumes more easily. It may be necessary to issue cooking vessels and fuel, to melt the snow.
- After melting, snow should be boiled to kill pathogens (see water treatment section). Alternatively small quantities could be batch treated with chlorine tablets.

However:

- Snow is easily contaminated, therefore it is essential to define and rope off suitable areas/snowfields for use only as a water source.
- Snow should never be eaten, as it greatly lowers the body temperature, causing risk of hypothermia.
- Potential hazards exist in mountainous areas, such as loose snow-fields where there may be a risk from avalanches, or where people collecting water may be exposed to risk of injury from exposure or falling.

Snow has been used as an emergency water source in the past and, as such, should be considered seriously for future use.

## Hauled water

The use of tanker trucks and water trailer tanks pulled by tractors to bring water into a disaster area is an established practice where it is difficult or impossible to do anything else. The practice is logistically complicated, very expensive, and other arrangements should be made if at all possible. In cold regions there are some additional factors to consider:

- In winter vehicles may not be able to reach certain areas, especially mountain regions. In these circumstances very local water sources must be utilised, or the entire population will have to move away from the area.

[15] Potts (1993)

- Trucks and tractors should be equipped with snow chains and shovels, and should not be forced to make dangerous journeys (e.g. along icy mountain roads) unless it is absolutely unavoidable.

## 3.3 Water storage

### Tanks

Tanks donated by international aid organisations have had problems with water freezing inside, valves freezing up and snow breaking flimsy canvas roofs. Short of redesigning the tanks, the only way to overcome these problems is to locate the tanks inside buildings (e.g. warehouses, other industrial buildings or barns).

Locally-made tanks can overcome some of the problems associated with being located outside in a cold area. The design should take into account several factors which will help to reduce the probability of the water freezing inside, and minimise damage to the tank if it does so.

#### *Size and shape*

The outer area of a tank (including surface, sides and base) should be minimised to reduce heat loss:

- A single tank with a large capacity will lose heat less quickly than several smaller ones with the same total storage capacity. This is because its surface area to volume ratio will be smaller in comparison.
- Round tanks have a lower surface area to volume ratio than rectangular ones. Therefore they lose heat less quickly.
- Using straight (non-corrugated) steel sides also reduces the surface area of the tank sides, limiting the rate that heat is lost from it.

#### *Insulation*

There are several ways to insulate an outside tank from the surrounding cold air:

- Spray-on polyurethane foam insulation. This minimises the volume of materials to be transported, but application requires dry weather; minimal wind conditions; tank surface dry and clean, surface temperature above 15°C and air temperature not less than 10°C.

- Insulating boards can be glued or strapped to the outside of the tank. Boards should be less than 75mm thick to allow installation on curved surfaces. For moist locations use a closed cell material that will not absorb water, e.g. closed cell polystyrene or polyurethane. If possible protect boards from weathering, birds and animals by covering with a cladding material such as plastic sheeting.
- If ground conditions permit (i.e. it is stable and can be excavated) a tank located underground is less likely to freeze due to the insulating effect of the earth above.

Tanks should be insulated from the ground by mounting them on insulating concrete or wooden bases. This is for two reasons:

1. The water is kept as warm as possible, minimising the risk of it freezing
2. If frozen ground is allowed to defrost it can become structurally unstable. Insulating tanks from the ground avoids this problem. Air vents incorporated in the underside of a concrete base also help to maintain the low ground temperature[16].

Aggregates used to make insulating concrete are listed on page 57.

### *Other factors affecting tanks*

- Outlet valves are also better protected if insulated. A foam lined valve-box will help to prevent damage from frost.
- Attachments protruding on the inside of a tank (e.g. ladders) will be ripped off, if surface ice forms and then the water level goes up or down. This could rupture the tank walls. Therefore avoid designing any features on the inside of tanks.
- Tank roofs need to be designed to carry snow loads. See the “Construction” section in chapter 6 for more details.

Figure 3.5 is a diagram of a temporary storage tank showing features that would be useful for cold regions.

## Ground storage lakes

The issue of the surface area to volume ratio applies to lakes, as well as tanks, although the surface through which most of the heat will be lost is the top surface of the water. Therefore an artificial lake should be deep, rather than shallow, to minimise probability of freezing. Caution is necessary before a decision is made to

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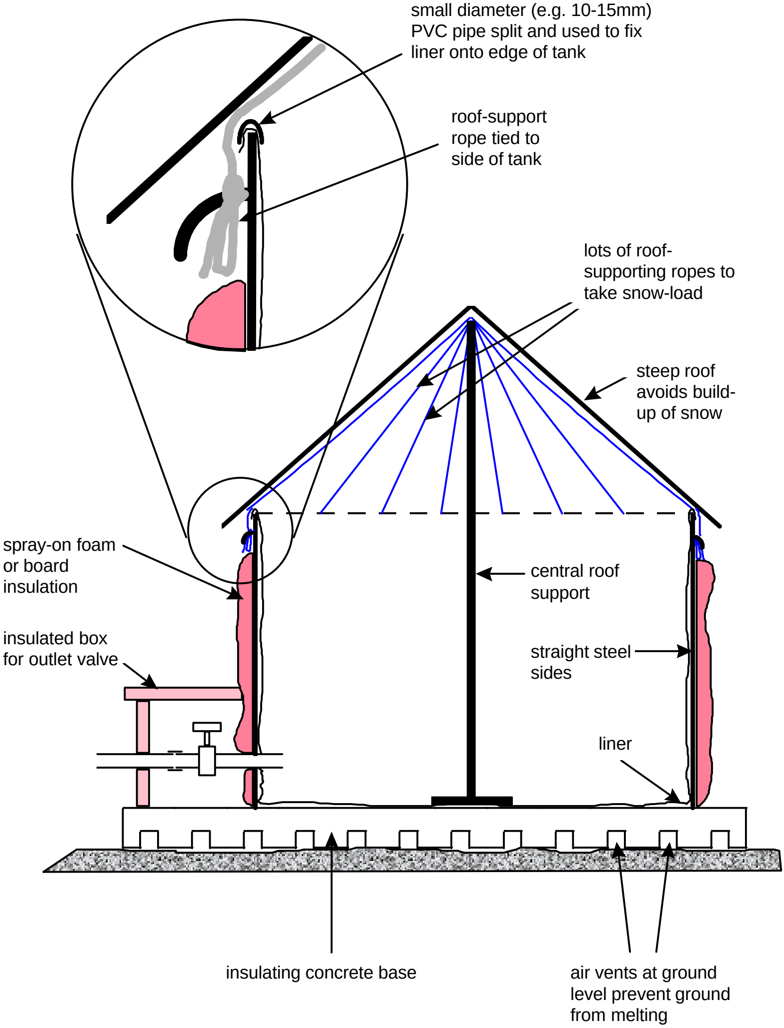
[16] Alter and Cohen (1969)

**Figure 3.5: Temporary storage tank, showing design features appropriate for cold regions**



deepen an existing lake; as well as stirring up pollution from the bottom of the lake it is possible to dig through the waterproof layer whereupon the lake may drain. Consultation with qualified engineers is essential if artificial lakes or modification of an existing lake is to be properly considered as an option for water storage.

## 3.4 Water treatment

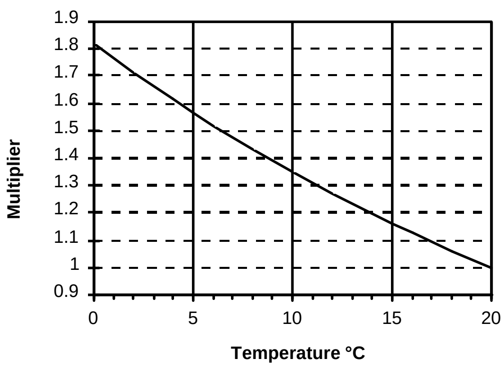
Cold water is more viscous than warm, and rates of chemical and biological reactions are slower at lower temperatures. Awareness of the effect of these factors will contribute to the implementation of an efficient water treatment regime.

### Mixing and pumping requirements

The increased viscosity of water, when cold, affects the energy requirements for mixing water with coagulants and for the power required for pumping operations. Figure 3.6 is a graph showing the correction factor for the effect of temperature on viscosity-dominated processes. This should be used to calculate the extra energy required for pumping or mixing operations involving cold water.

Note that viscosity is often quoted at 20°C, so the correction factor shown for 20°C is 1.0 . If water temperature is reduced from 20°C to just above 0°C then the rate of viscosity-dominated processes will be reduced by a factor of about 1.75 and the extra energy required rises accordingly.

**Figure 3.6: Graph of correction factors for the effect of temperature on viscosity-dominated processes**[17]




[17] adapted from Smith (ed., 1996)

## Sedimentation tanks

The function of sedimentation tanks is to reduce the turbidity of water by allowing it to deposit suspended solids in the still water of the tank. In emergencies the aim is to produce a water supply with a turbidity of less than 5 NTU in order to maximise the efficiency of the chlorination process, although chlorination will function relatively effectively at turbidities of up to 20 NTU. The design of sedimentation tanks is well explained in "Engineering in Emergencies" [18] and other emergency manuals.

The footprint (area in plan) of a sedimentation tank is often calculated using:

$$\text{Area (m}^2\text{)} = \text{Design Flow Rate (m}^3\text{/s)} \div \text{Settlement Velocity (m/s)}$$

If the settlement velocity is miscalculated, the result is that the wrong size of tank will be built. Therefore to obtain accurate results, it is imperative in cold regions that jar tests to determine settlement velocity of suspended solids should be done at the correct (outside) temperature. Similar jar tests, which determine how much Alum (or other coagulant) to add to a water system before sedimentation, should also be carried out at the correct (outside) temperature.

## Chemical disinfection

Chemical processes are slower in cold water, a prime example being the reaction when water is chlorinated. Some text books on the subject look at the "CT" value (Concentration of residual disinfectant × contact Time). How the CT value is affected by temperature varies according to the author. Patwardhan[19] states that for every 6°C drop water temperature the CT value needs to be increased by a factor of 1.5 to 3.5, while the United States Environmental Protection Agency states that to achieve a consistent inactivation of *Giardia Lamblia* the CT values for chlorine need to be approximately doubled for each 10°C drop in temperature[20].

In practice, tests used to calculate the chlorine quantity and contact time required should be done at the correct temperature. If not, tank design may allow insufficient contact time, or insufficient doses of chlorine could be added to ensure proper disinfection of the water.

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[18] Davis and Lambert (1996)

[19] Patwardhan (1989)

[20] USEPA (1990)

## Filtration

Two factors affect the use of filter beds to treat water in cold regions: the increase in water viscosity causes greater headloss in water flowing through filters, and the reduced rate of bacterial activity at low temperatures affects the working of slow sand filters.

### *Slow sand filters*

Slow sand filtration is usually effective when the biological action of the schmutzdecke (a thin bacterial layer at the top of the sand) efficiently breaks down organic matter. The factor by which the number of *E.Coli*, in the water is reduced is normally in the range 100 to 1000, however the factor can be as low as 2 if water temperature is less than 2°C [21]. Although chlorination is sometimes used as a further treatment method for disinfecting water, following slow sand filtration and depending on how effectively a filter removes faecal coliforms, at low temperatures further treatment by chlorination will almost certainly be necessary.

In conditions where the ambient temperatures are sub-zero there are two approaches to coping with the ice:

1) Cover filters with a roof and an insulating soil layer to help prevent the formation of an ice block.

2) Design the structure, around the filter, to withstand the expansion forces of the ice. This method has been used successfully in the USA, using filter sidewalls of 15cm thick concrete, covering earth embankment walls sloped at 1:2 [22]. Slow sand filters have been kept running with a floating ice block. Although the rate of removal of *E.Coli* is small, this is effective so long as the ice does not touch the schmutzdecke, which could cool it to below 0°C.

### *Rapid gravity (roughing) filters*

Rapid gravity filtration, or roughing filtration, is effective in cold regions, although head losses through the filter will be are increased due to the increased viscosity of the water. Relative head loss increases by 2.5 to 3.5 percent for each degree (Celsius) that the water temperature is reduced [23].

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[21] Huisman and Wood (1974)

[22] Hendricks (ed., 1991)

[23] Smith (ed., 1996)

### *Removing glacial flour*

One use of roughing filtration is to remove glacial flour from a water supply. Glacial flour is created by the abrasive action of glacial ice rubbing rocks against the bedrock, creating very fine particles that appear as reflective specks in the water. They can be difficult to remove, however removal is possible by treating with between 10 and 30mg/l of Ferric Chloride followed by settling, roughing filtration or both[24].

Factors affecting the feasibility of this treatment for glacial flour:

- In emergency situations Ferric Chloride is often more difficult to obtain, and more expensive, than Alum, which is the most common coagulant. Other coagulants could also be effective, and jar tests using, for example, alum are worth experimentation.
- People may already be accustomed to drinking water containing glacial flour. If the water quality is adequate in terms of bacterial content, then removal of glacial flour could be unnecessary.

## Boiling water

In cold areas, heaters are obviously highly desirable, for reasons of comfort and survival irrespective of water supply or treatment options. If heaters or stoves are widely used or readily available, boiling water is an effective way to kill disease-causing organisms. As a disinfection method, boiling is suited to the treatment of small quantities, with each household treating its own drinking water.

> *For disinfection purposes water should be brought to a rolling (vigorous) boil, and boiling continued for one extra minute for every 1000 metres of altitude above sea level[25]. Alternatively boil water for between five and ten minutes[26].*

Key factors affecting the suitability of boiling as a method of water disinfection are:

- The amount of fuel available: it takes between 0.5 and 1 kg of wood to sufficiently boil each litre of water, depending on altitude. This figure will be larger still if ambient temperatures are cold. Fuel may be too scarce, and consequently too expensive, to use for water disinfection purposes.
- Local people must be aware both of the required boiling time for effective disinfection, and of hygenic water storage practices.

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[24] Ryan (1990)

[25] UNHCR (1982) and Ockwell (1986)

[26] Davis and Lambert (1995)

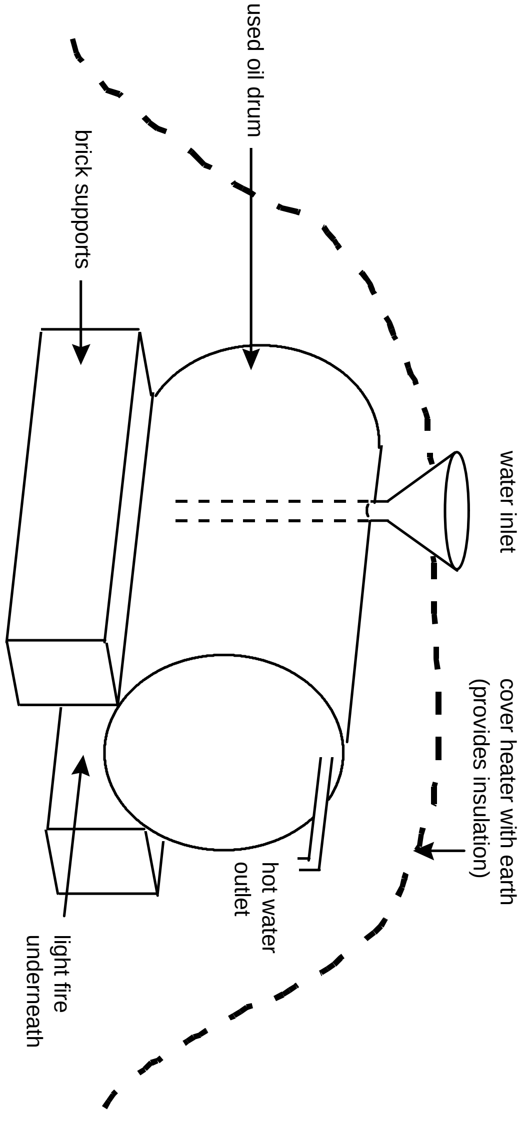
## Heating water for washing

When people wash regularly the incidence of contact related diseases is reduced. Children, especially, will be encouraged to wash more often if hot water is available; washing clothes in hot water is an effective way to kill the eggs of lice (see the section on health, starting on page 68). The provision of hot water facilities, for washing purposes, will make a positive contribution to the overall health of refugees in cold areas.

In some areas it is appropriate to provide communal washing and bathing areas. Known as “hamams” in central Asia these are usually segregated by sex or have male-only and female-only bathing times. Not only do they allow people to stay clean, in many cultures they are also important as social centres.

For small-scale production of hot water, simple “put and take” water heaters can be constructed from oil drums, as shown in Figure 3.7 .

## Figure 3.7: Put and take water heater




**Note 1:** Users put in cold water and immediately receive the same volume of hot.

**Note 2:** The outlet should be as close to the top of the oil drum as possible. This prevents people from pouring in more water than they wish to collect

## 3.5 Distribution systems

In cold regions, the distribution system is one of the most vulnerable components of a water supply system. Water in pipes is likely to freeze solid, expanding as it does, causing damage to pipes and leakage of water after the pipes have thawed. Methods of avoiding freezing of water inside the pipes include burial, insulation and keeping the water continually flowing, Selection of the correct pipe material reduces the probability of damage, should water freeze inside.

### Temporary measures to prevent pipes freezing

If pipes have to be laid quickly, for possible burial at a later date, the best method to prevent them from freezing up is to arrange for pipes to be drained when not in use. For example, pipes leading from a water source to raw water bulk storage tanks can be drained when water is not being pumped, and arrangements made to drain water out of a temporary distribution system at night.

Alternatively water should be kept continually moving inside the pipes. Either:

a) Leave some taps running at distribution points, which is very wasteful and therefore requires large quantities of water to be readily available, or

b) For a pumped system the water can be recirculated, although it requires that at least two parallel pipes are laid along the entire length through which water is to be pumped, and for several valves and joints to be used (see figure 3.8).

#### *Surface laid pipes*

Uninsulated surface laid pipes are most at risk from freezing. By measuring the air temperature and the temperature of water entering the pipe it is possible to calculate approximate values of:

a) How long water will take to cool down to the freezing point and

b) The maximum permissible length for an unprotected surface-laid pipe, for a given flow rate, so that the water in it does not cool to 0°C.

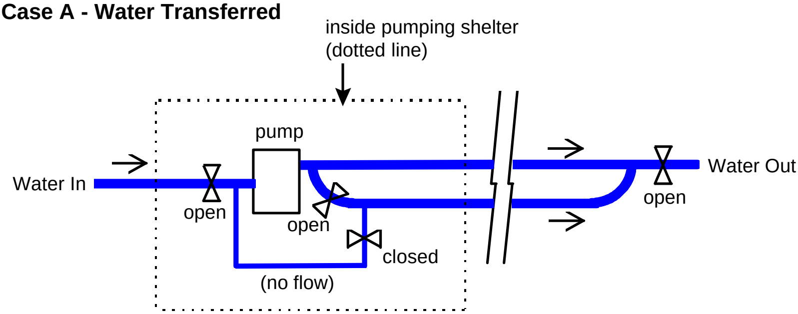
Appendix C (page 80) shows one method of calculating these values.

### Pipe burial and insulation

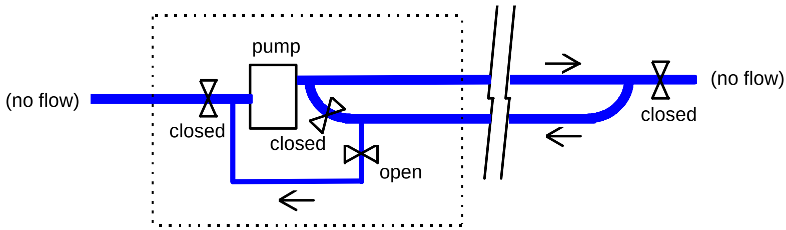
In areas where the ground is not permanently frozen, effective protection against seasonal freezing can be provided by burying most major pipework in the ground. The depth of burial is critical and should, ideally, be greater than the maximum depth of frost penetration. The penetration of frost increases throughout the winter reaching a maximum sometime (at least a few weeks, but can be months) after the coldest period of the winter.

# Figure 3.8: Recirculating pumped system

**Case A - Water Transferred**




**Case B - Water Not Transferred (recirculated through main pipes)**




Note 1:  represents a gate valve which can be open or closed

Note 2: When water is not being transferred the pump is run either continually or periodically (every half hour or so)

Note 3: This system is suitable for short periods where water is not transferred. For longer periods, the pipes and pump should both be drained.

Local engineers should have some knowledge of the depth of maximum frost penetration. Otherwise it can be determined by digging trial holes, after the coldest part of the winter, and determining at what depth the soil is not frozen by analysing its texture and/or temperature.

Insulation of pipes is effective on its own or in combination with pipe burial. If both methods are employed then the minimum desirable depth is still at least 0.5 to 1.0 m, which means that daily air temperature fluctuations will have an insignificant effect, and protection is provided from loads on the ground's surface. In terms of reducing frost penetration a 1.2m wide, 50mm thick polystyrene foam insulating board laid directly above a buried pipe is roughly equivalent to 1.2m of sand or silt cover or 1.0m of clay cover[27]. Although expensive, preinsulated HDPE pipes (discussed on page 34) are also suitable for burial.

## Pipe materials

Damage to pipes from water freezing inside can be avoided or mitigated by selection of a suitable pipe material.

### *Medium and high density polyethylene (MDPE and HDPE*

- Because MDPE and HDPE have low thermal conductivity, the insulating effect can mean that water is less likely to freeze in them than in pipes made from other materials, especially metal ones.
- Even at -60°C polyethylene remains ductile, so if water does freeze in the pipes they are unlikely to crack. HDPE pipes have been known to survive several freeze-thaw cycles. Heat welded joints are also strong enough to resist the pressures of water expansion on freezing.
- Being flexible and sometimes available on long rolls also makes MDPE or HDPE pipes relatively easy to install.

### *Polyvinylchloride (UPVC*

- This is ductile at 20°C, but can become brittle at very low temperatures (e.g. less than -10°C) or with prolonged exposure to sunlight.
- Generally having thinner walls than MDPE or HDPE pipes, UPVC pipes offer less insulation and are more prone to accidental breakage.
- PVC pipes require thrust blocks at changes in pipe direction to prevent ice expansion from pulling the slotted joints apart[28].

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[27] Smith (ed., 1996)

[28] Davis and Lambert (1995)

- Many different grades of PVC are available, quality and material properties being highly variable, depending on the quality of the manufacturing process. Therfore, imported PVC may be much stronger than locally made pipes.

### *Metal*

- The major disadvantage with pipes made from iron or steel is that they are prone to corrosion, although various coatings can be applied to minimise the effects.
- Metal pipes are strong, but can still be damaged by ice forces.
- Small diameter metal pipes can be defrosted electrically (see page 36).

### *Others*

- Asbestos cement pipes become particularly brittle at low temperatures and should not be used unless permanently and properly buried.
- Acrylonitrile Butadiene Styrene (ABS) pipes have similar properties to PVC although they require a thicker wall section for the same pressure rating pipe, and are more vulnerable to damage by sunlight

### *Preinsulated HDPE pipes*

Suitable, although expensive, for use when pipes are buried, these are also effective if laid in the open air, since the polyurethane foam insulation is commonly well protected by a waterproof layer of UPVC, for example. They are also useful for when water or sewage pipelines cross bridges (and therefore can not be buried). Thermal properties of bare and preinsulated HDPE pipe are compared in table 3.1 .

Appendix B (page 78) shows the thermal properties of some construction materials, including those used to make pipes.

### Table 3.1: Thermal properties of HDPE pipe, bare and insulated[29]

| | Ambient Temp. = -18°C | | | Ambient Temp. = -34°C | | |
|---|---|---|---|---|---|---|
| | No Insulation | With 50mm Polyurethane foam | | No Insulation | With 50mm Polyurethane foam | |
| Pipe Diameter (mm) | Time to Freeze (Hrs) | Time to Freeze (Hrs) | Heat Loss (W/m) | Time to Freeze (Hrs) | Time to Freeze (Hrs) | Heat Loss (W/m) |
| 50 | 1 | 57 | 2.7 | <1 | 29 | 5.0 |
| 75 | 3 | 107 | 3.4 | 1 | 55 | 6.5 |
| 100 | 4 | 149 | 4.1 | 2 | 77 | 7.7 |
| 150 | 9 | 241 | 5.4 | 5 | 125 | 10.2 |
| 200 | 16 | 333 | 6.6 | 8 | 172 | 12.4 |
| 300 | 34 | 530 | 8.9 | 17 | 274 | 16.8 |
| 400 | 53 | 692 | 10.6 | 27 | 357 | 20.0 |

## Defrosting pipes blocked by ice

When water service pipes to houses become blocked by ice, there are two main ways that they can be defrosted. A large electric current can be passed down metal pipes, which warms them up, or hot water can be fed into blocked pipes made from metal or plastic. This subject is discussed comprehensively in "The Cold Regions Utilities Monograph" [30].

### *Defrosting using electric current*

Small diameter metal pipes, such as those used for connections from water mains to individual houses can be defrosted by passing a large electric current through them. Welding machines, generators or heavy service transformers may be used to source the current.

This method is only suitable for use with relatively small pipes. An 800 amp welding machine (working at 50 amps) defrosting a 75m length of 40 mm steel pipe will take about 5 hours. If 100 amps is used, the time should be quartered, since the time taken to defrost is proportional to the heat produced, which is proportional to the amount of electrical power used.

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[29] Figures from Urecon Ltd., Quebec, Canada

[30] Smith (ed., 1996)

Electrical power used is given by the equation:

$$P = I^2 \times R$$

where: I = electrical current (Amps)

R = electrical resistance of the circuit (Ohms)

Larger pipes will have lower electrical resistance, so will take longer to heat up.

**This method is potentially dangerous**, and adequate safety precautions must be taken, especially to **keep people away from live electric cables**. The following are also important factors that need to be carefully considered before attempting to use electrical current to defrost water pipes:

- Welding machines can only operate at their maximum current rating for about five minutes. If longer times are required the current taken should be no more than 75% of the maximum rating.
- Generally operate at low voltage (less than 20 volts). It is the high current which will heat up the pipes.
- The diameter of wire used to connect welding machines to pipes is very high. In principle the cross sectional area of the wire should be greater than that of the metal in the pipe, so that it has less resistance and does not get hot. Specific information on appropriate cable sizes, relating to cable length and applied current is given in The Cold Climate Utilities Monograph[31].
- Make good electrical connections to pipes and check them before turning on the current.
- This method is suitable for underground pipe only, not indoor plumbing, which can be thawed simply by warming up the house.
- Before operation, disconnect earth connections to household plumbing, or disconnect the service pipe altogether, otherwise there is a risk of fire. Remove water meters from the pipe section to be defrosted
- Current can jump from water pipes to nearby gas pipes, which will reduce the effectiveness of this technique.
- In an emergency, welding machines are likely to be needed for vehicle and building repairs, not just defrosting water pipes. Think carefully before removing them from their normal activities.

[31] Smith (ed., 1996)

### *Defrosting using hot water*

This is suitable for metal or plastic pipes. A flexible pipe is fed into sections of frozen underground pipe: hot water is continually pumped through the flexible pipe so that it melts any ice blockage that the pipe may have.

The main advantage of this method is that it involves minimal technology: a large (20 to 100 litre) water container, fitted with a hand pumping mechanism can be used as a hot water reservoir, refilled from stoves and kettles. Also this method is suitable for any diameter of pipe, whereas using electrical current it is only practical to defrost small diameter metal pipes.

Problems are sometimes experienced because pipes can have internal obstructions from bends, mineral deposits, valves and so on. This method is reported to be about 50% successful, on average.

## Distribution points

It is preferable to locate water distribution points inside a shelter for two reasons:

1. It avoids the problem of water freezing inside standposts or handpumps and
2. Shelter will provide a more comfortable and safer environment in which people can wait while queuing for water or filling containers.

The location of distribution points in relation to accommodation will obviously affect the length of time that people will have to walk (in cold weather) in order to fetch water. Even a trip of five minute’s duration may constitute a serious risk of exposure to old or sick people.

### *Drainage of water distribution areas*

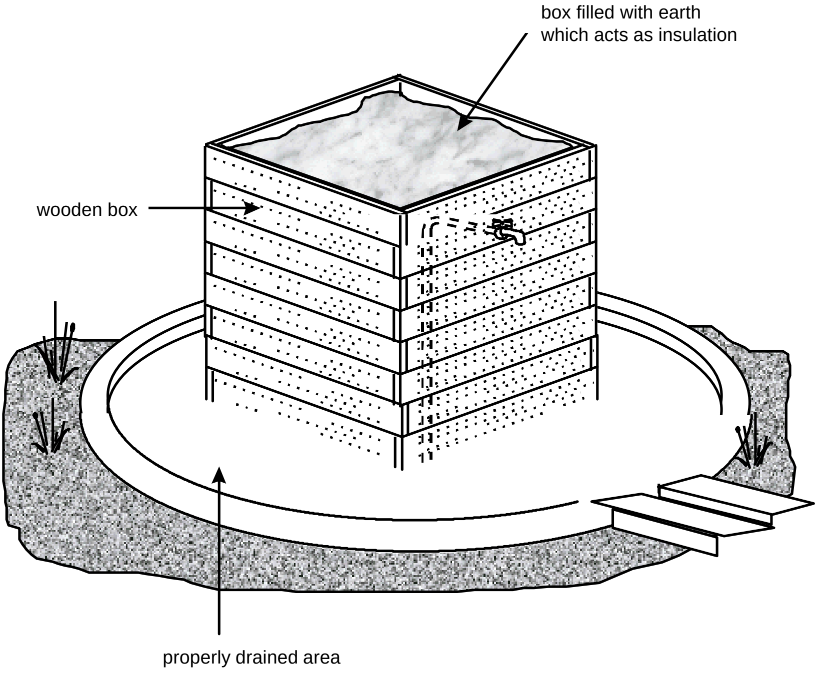
An important consideration for water distribution points, in any climatic region, is that of how to provide drainage away from the immediate area. The construction of a properly drained area, for example a concrete slab draining to a soakaway, will avoid the health problems associated with puddles of standing water, which can contaminate wells and boreholes, and help to avoid a build-up of ice that poses the immediate hazard of slipping and falling to people using water distribution points.

In the summertime standing water provides a potential breeding site for insects that transmit disease.

### *Protection of simple stand pipes*

As well as simple insulation, for example by wrapping sacking around exposed pipes, simple stand pipes can be protected from the cold, by constructing a wooden box around them, which is filled with soil in winter and can be removed during the summer for maintenance. Soil in the “Tap box” acts as insulation. This principle is illustrated in figure 3.9 . An improvement to the tap box shown is to put a lid on it to prevent rain from getting in, since soil containing moisture is less insulating than dry soil.

**Figure 3.9: "Tap box" protection of a temporary stand-pipe**



***Handpumps***

Whatever type of handpump is used, some damage due to freezing is possible. Features useful for all types of handpump include:

- Locating pumps in a pump house will help to prevent water freezing inside.
- Ice is likely to form on concrete aprons around boreholes and wells. Care should be taken to provide good drainage, and to encourage people not to splash water around if at all possible.
- Bentonite grout, not concrete, should be used in the annular space around borehole casings. Concrete forms strong bonds with casing steel, then frost jacking (see page 58) of the concrete can pull sections of casing apart, damaging the structure of wells and boreholes.

## Table 3.3: Comparison of types of handpump

| Lift Pumps | Suction Pumps |
|---|---|
| Cylinder below water level<br>• Cylinder never freezes | Cylinder above ground<br>• Water may freeze in the cylinder, causing damage |
| Protect above ground pump parts by making a small diameter "weephole" in the riser pipe just above the cylinder (below groundwater level)<br>• Water slowly drains out of the above ground section when pump is not being used<br>• Causes small loss in pumping efficiency | Protect cylinder by using a foot valve with a drain-back capability (slight leak)<br>• Cylinder drains when pump is not in use<br>• Causes small loss in pumping efficiency |
| No need to prime cylinder | Cylinder may need priming<br>• Priming water left near pump may become contaminated, leading to contamination of borehole<br>• Priming water may freeze during the night |
| More difficult access to cylinder for maintenance | Easy access to cylinder |

## 3.6 Water supply in mountainous regions

In the Western world people frequently make the assumption that mountain streams are safe to drink. Although they are sometimes potable because the population density in mountainous areas can be very low, if refugees arrive in such an area then this is obviously no longer true. In refugee camps in mountainous areas treatment of the water for removal of pathogens is almost certainly necessary. A proper water supply system should be designed and implemented.

Also affecting the quality assessment of surface water sources in mountainous areas is the fact that *E.Coli* is not a reliable indicator organism for protozoan cysts, including *Giardia* and *Cryptosporidium*, so even if water tests as free from faecal coliforms there may be potentially fatal diseases present in the water. Infectious parasitic cysts can live in water for up to three months[32]. *Giardia* is certainly capable of existing in cold and mountainous areas (as anyone who has been trekking in Nepal will know).

### Water sources and treatment

Possible temporary water sources in mountainous areas should include snow fields and glacial streams. Use and treatment of these sources is discussed further in the water sources and treatment sections of this chapter.

In northern Iraq in 1991, airdrops of water in plastic bottles fixed to pallets were made. According to observers, some 95% of all bottles were destroyed upon impact with the ground[33]. Water was also transported into the area, in storage tanks, by helicopter. This was very expensive: each litre of water cost £2.30 (about US$3.50).

If boiling is used as a method of water disinfection then the effect of altitude on the boiling point of water means that in order to destroy disease carrying pathogens the water must be boiled for longer. Boiling times should be increased by one minute for every 1000 metres of altitude above sea level[34] (see also page 28).

A flowchart to aid water source selection for refugee camps in mountainous areas is shown in figure 7.2 in Appendix A (page 76).

### Break-pressure tanks

For gravity fed water supplies flowing over large vertical distances, excessive internal pressures can cause damage to pipes. The maximum internal pipe

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[32] tripprep.com (1998)

[33] Cuny (1994)

[34] UNHCR (1982) and Ockwell (1986)

pressures occur at the lowest points in the system, but break-pressure tanks located above these can help to reduce that maximum pressure. Break-pressure tanks are designed to allow the flow to discharge into the atmosphere, reducing the hydrostatic pressure to zero. An example design of a break pressure tank is shown in
figure 3.10 .

To decide where to position break pressure tanks it is necessary to understand the theory of hydraulic flow in pipes: this theory is well explained, with examples, in "A Handbook of Gravity-flow Water Systems" [35].

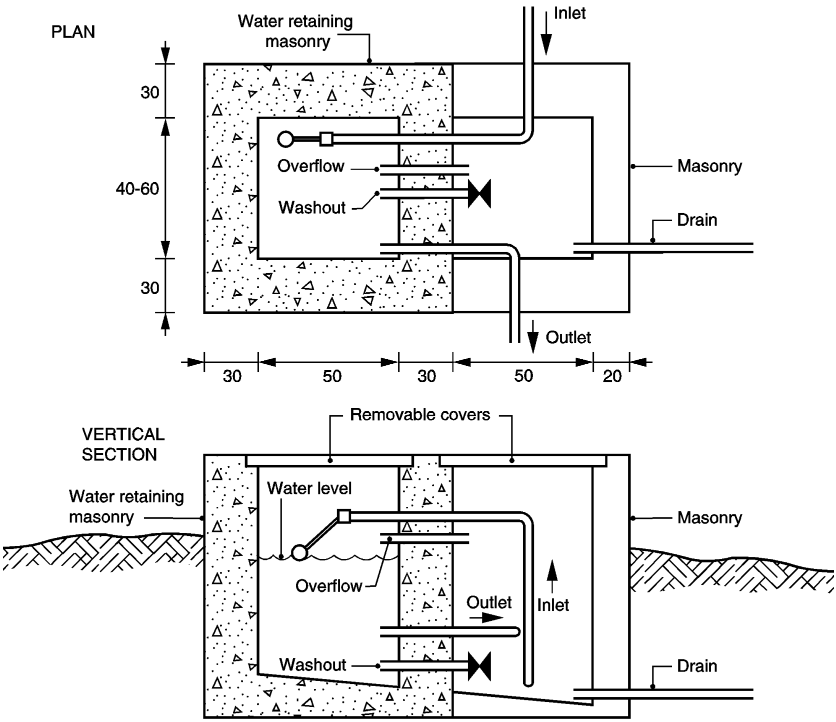
## 3.7 Books on water supply

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

1. *Engineering in Emergencies*, by Jan Davis and Bobby Lambert (1995)
2. *Emergency Water Sources*, by Sarah House and Bob Reed (1997)
3. *A Handbook of Gravity-flow Water Systems*, by Thomas D Jordan (1984)
4. *Cold Regions Utilities Monograph*, edited by Dan Smith (1996)

[35] Jordan (1984)

**Figure 3.10: Example design of a break pressure tank[36]**




**NOTES:**
1. Discharge may or may not have control valve
2. Outlet pipe set 10-15 cm above floor of tank
3. Internal dimensions depend upon fittings

[36] from Smith (1999)

# CHAPTER 4
# Sanitation

For the control and prevention of sanitary related diseases it is important that hygiene promotion, adequate sanitation 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 Renovation of an urban sewerage system

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

Experienced engineers are necessary to perform urban sewer renovation properly. Some possible measures that are applicable to repairing sections of a sewerage network are given below: [37]

- Rapid repair of sewers with temporary arrangements to by-pass damaged sections.
- Cleaning and flushing of blocked sewers. Treating sewers with strong disinfectants to prevent spread of pathogens and limit smells from broken manholes and sewers.
- Dewatering treatment plants or pumping stations awaiting repair, and arranging temporary haulage of sewage to burial site or other treatment plant.
- Provide 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 page 46).

[37] adapted from Assar (1971)

## 4.2 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 watsan, such as those listed on page 3. In this section the effects of cold weather on pit latrines and open defecation are discussed, as well as some possible alternative methods of excreta disposal.

### Open defecation

This is often suggested as an emergency option for areas with a hot, dry climate. However, when more temperate or humid conditions are considered, 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, that had kept pathogenic organisms sealed inside the dry excreta, becomes ineffective, and flow of rainwater can spread faecal material.

When sub-zero ambient temperatures are considered, excreta in open defecation fields will quickly become frozen, once more reducing the chances of transmission. 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.

### Pit latrines

In very cold regions, several factors effectively reduce the rate at which the volume of sludge in pit latrines reduces in volume relative to the rate in warmer climates:

- Frozen ground is largely impermeable. Therefore liquor from the sludge in the pit is not able to soak away in the winter.
- Biological processes, both aerobic and anaerobic, which normally reduce the volume of sludge, will 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.
- 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 the necessary pit volume use the formula: [38]

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

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)

The value of R may be as much as double that of a warm area where people have similar eating habits, etc..

### *Constructing pit latrines in winter*

General construction techniques for use in winter are described more fully in the section starting on page 55. In particular, this includes how to use antifreeze admixes to make concrete suitable for unreinforced pit latrine slabs. If concrete is not properly cured then it can be structurally weak and liable to collapse.

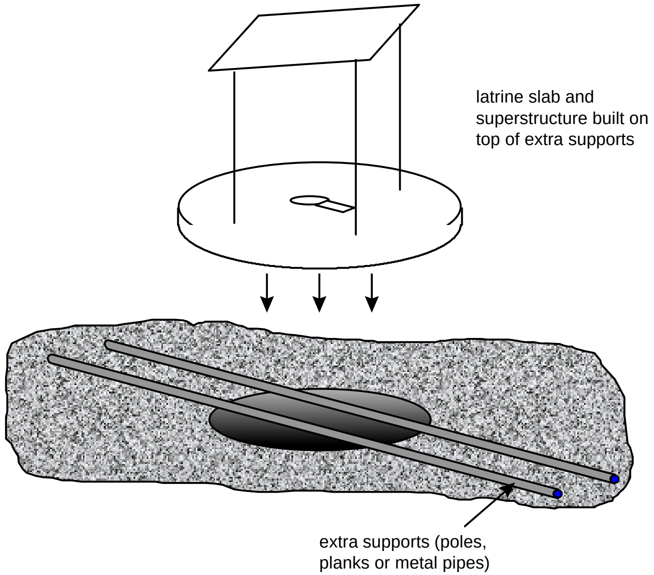
Soil that is hard and structurally sound in winter may go soft in the spring, causing pit latrine collapse. If ground is frozen, when constructing latrines in winter, and it is liable to melt in the spring, steps should be taken to prevent the latrine slab from falling in. For example, extra support can be provided beneath latrine slabs:

1. Dig the pit as usual.
2. Embed 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).
3. Construct latrine slab and superstructure as normal.

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. Otherwise normal diggers for construction may be the only option.

[38] Franceys et al. (1992)

**Figure 4.1: Additional support for latrine slabs**




## 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:

a) Left under a small shelter outside, where it freezes solid. A few weeks later the honey-bags are picked up by a truck and taken to a central wastewater treatment plant, or

b) 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 too much 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.

## Excreta disposal in mountainous areas

Accessibility, the hardness of the ground and availability of materials will 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 could be organised. The honey-bag system also avoids the pollution of surface water with faecal material, which inevitably follows using raised platform latrines or open defecation.

## Hand washing facilities

If, when hand-washing after defecation, people (especially children) experience discomfort, they will be tempted not to wash resulting in unhygenic practices. Therefore attempts should be made to make this process as pleasant as possible, such as:

- Periodically pour hot water into the small water containers that store water for hand-washing at communal latrines. Possibly take steps to insulate these water containers.
- Provide material for people to dry their hands on, because water evaporating off people's hands will make them feel cold. Disposable paper is the most hygienic method, although people may try to steal it, for example to light fires. A place to dispose of used paper should be provide, such as a burning pit. A latrine attendant, situated near the hand-washing area, could distribute some paper to all latrine users.

## 4.3 Wastewater treatment

Due to the high level of development of many countries in colder regions of the world, 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. A useful book on the theory of wastewater treatment is “Wastewater Engineering”[39].

### 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 4.2 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)*

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. Afterwards, the mixture undergoes a sedimentation process which separates the water from the sludge. Some sludge is recycled to the start of the activated sludge process, the rest is disposed of by drying and incineration, or in an anaerobic digester unit.

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

Wastewater flows past several slowly rotating disks that are half submerged in the liquid. Biological predators (bacteria and protozoa) live on 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. 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.

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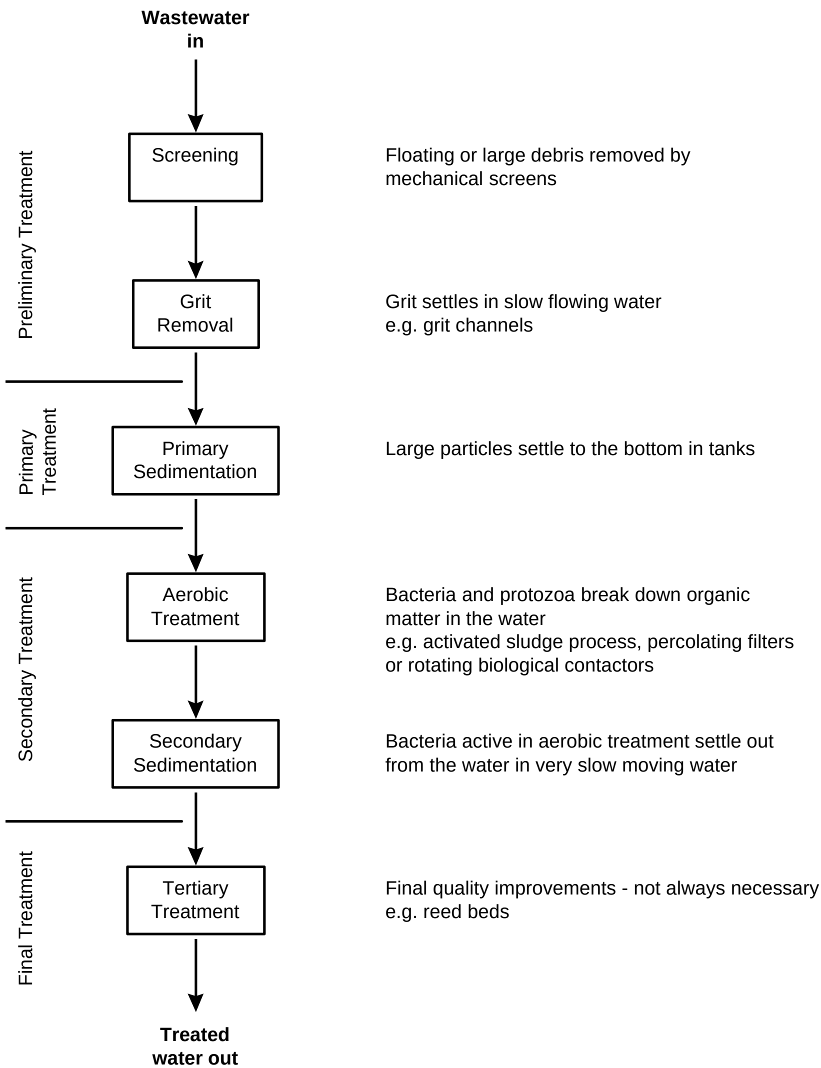
[39] Metcalf and Eddy (1991)

## Figure 4.2: Flow of wastewater through a conventional treatment works



### *Anaerobic sludge digestion*

This is a means of treating the solids 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 to generate power to heat the anaerobic digestor because the process is most effective at warm temperatures.

## 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, because aerobic ones may freeze and because aerated ponds 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.

### *Winter and summer treatment rates*

The rate of flow, of treated wastewater, out of the waste stabilisation ponds system is equal to the rate of treatment of the wastewater. In the warmer months this rate will be greater than the rate in the winter (which is zero).

As a rough guide, if the inflow is constant throughout the year, at flow Q ($m^3$/day) then:

**winter** treatment rate = 0 (zero) $m^3$/day

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

where $N_w$ = Number of winter months

$N_s$ = Number of summer months

## Small-scale wastewater treatment

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

### *Septic tanks*

Septic tanks provide partial treatment of wastewater in anaerobic conditions (without oxygen). 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.

### *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 (addresses on page 85). 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.

### *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 when 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.

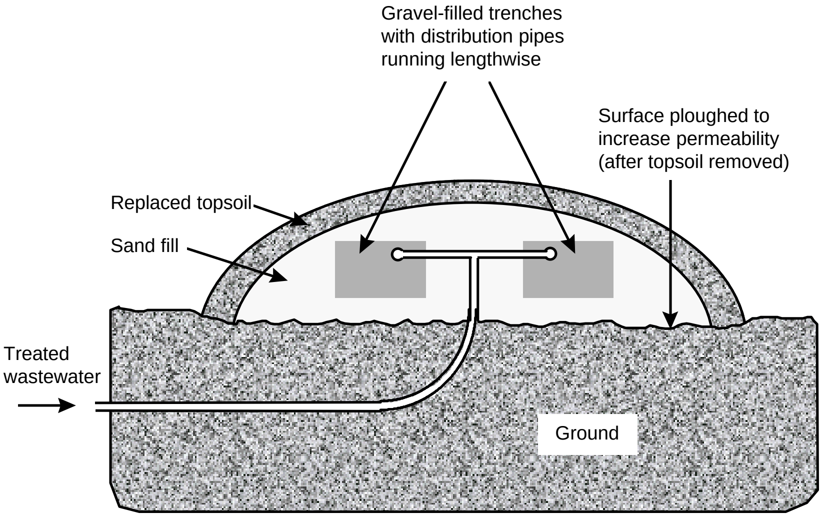
The mound system is illustrated in figure 4.3

## 4.4 Solid waste management

In many ways the disposal of solid waste in cold regions is exactly the same as in warmer ones. However in terms of collection, the increased logistical difficulties of a severe winter may mean that 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 random dumping, 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 or may not be possible in winter due to frozen ground and unavailability of suitable digging equipment. Burning solid waste may be the solution, if substances producing dangerous fumes or residues are separated from other materials and not burned.

**Figure 4.3: Raised mound system for disposal of treated wastewater[40]**




**Key design criteria**

| | |
|---|---|
| Design infiltration rate | 7.5 l/m$^2$.day |
| Height at centre | 1 - 1.5 m |
| Width of bed | < 3 m |
| 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 | 5 mm at 0.5 m spacing |

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

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 end of winter (and the bags begin to thaw), honey-bags should be either removed for treatment or emptied into a watertight method of storage (lagoon or tank) from which wastes can be transported by tanker for treatment.

### Solid waste and mountain camps

Airdrops produce large volumes of solid waste which may be difficult to collect in a mountainous area. Any attempt to arrange for collection and disposal will have to be extremely simple, such as issuing people with plastic bags to collect refuse by hand and carry it to a central burning area. In Northern Iraq, fire-fighters who were part of British mobile support teams successfully made solid waste collection a game for children!

## 4.5 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 mechanisms;
- Low temperatures will suppress unpleasant smells;
- 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;
- Pathogenic organisms may survive for long periods (even years) within or in close proximity to corpses.

## 4.6 Books on sanitation

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

1. *Guide to Sanitation in Natural Disasters*, by M Assar (1971)
2. *Sanitation Technologies for Temperate and Cold Climates*, by M Easson, et al. (1988)
3. *A Guide to the Development of On-site Sanitation*, by R Franceys et al. (1992)
4. *Engineering in Emergencies*, by Jan Davis and Bobby Lambert (1995)
5. *Wastewater Engineering*, by Metcalf and Eddy Inc. (1991)
6. *Cold Regions Utilities Monograph*, Edited by Dan Smith (1996)
7. *Emergency Sanitation*, by Sohrab Baghri (1999)

# CHAPTER 5
# Technically Related Issues

## 5.1 Construction

### Using concrete in freezing temperatures

In cold regions, concrete structures (slabs, walls) can suffer from lack of strength, caused by small cracks in the material. These cracks form while the concrete is curing, due to ice expansion within the concrete material. It is worth bearing in mind that local construction contractors and builders should be competent at making concrete of reasonable quality, and their skills are worth using.

Methods of improving the quality of concrete, by altering the curing process, are suggested here.

#### *Heat addition*

If the concrete is kept warm, it reaches a "critical hardness" before its temperature falls below freezing. The concrete can then be allowed to cool without any significant loss of strength resulting from the expansion of contained water turning into ice. There are several ways to keep concrete warm: [41]

1) Construct components (e.g. latrine slabs) indoors or, for insitu concrete, construct a shelter so that the whole area can be heated to above 0°C; or

2) Mix insitu concrete using warm water, then cover formwork with insulation to retain heat (known as "thermos curing"); or

3) Heat formwork by means of electrical wires. Alternatively heat the concrete itself by burying resistance wire, which can be warmed electrically, within the mixture.

Such methods are expensive since they involve addition of heat and use a lot of energy.

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[41] Krylov (1998)

### *Antifreeze admixtures*

Antifreeze chemicals can be added to the concrete, while mixing the dry ingredients. These prevent the water in the mix from becoming solid ice and expanding in the spaces between aggregate particles before the critical hardness is reached. With their addition the concrete can cure properly.

There are many chemical compounds that lower the freezing point of water, but most will upset the chemical processes taking place inside concrete as it cures. Sodium Nitrate ($NaNO_2$), Potassium Carbonate ($K_2CO_3$), Potassium Chloride (KCl) and Sodium Chloride (NaCl) are all possible antifreeze admixtures.

Antifreeze admixtures force the water, within the concrete, to remain at least partially liquid until the temperature falls below the “eutectic point”, the temperature at which no matter how much antifreeze is added, the solution will completely freeze. The temperature of the eutectic point varies depending on which compound is used. Because some ice crystals form at temperatures above the eutectic, the operating range for each mix is usually limited to temperatures a few degrees higher than that temperature[42].

### *Unreinforced concrete (for dome shaped latrine slabs)*

One of the cheapest and most common antifreeze admixes is Sodium Chloride (table salt). Its eutectic point is at -21°C, so it should be safe to use where the minimum daily temperature does not fall below -15°C. However, chlorides are highly corrosive to steel reinforcing bars so, while acceptable for unreinforced concrete, they cannot be used in reinforced concrete.

Concrete made with an admixture of Sodium Chloride is suitable for making unreinforced latrine slabs, in subzero temperatures down to -15°C. In colder regions Calcium Chloride, which has a eutectic of -55°C, could be used. Chlorides should be added as between 5% and 10% of the dry mixture by weight. While curing, latrine slabs should be covered with a tarpaulin to prevent the wind-chill effect from lowering the concrete temperature even more.

### *Reinforced concrete*

Sodium Nitrate and Potassium Carbonate (Potash) are non-corrosive to steel reinforcing bars. Recommended amounts to add depend on the ambient temperature, and are shown in table 5.1 as a percentage of the weight of the dry concrete mixture.

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[42] Krylov (1998)

As with unreinforced concrete, structures should be covered with tarpaulins while curing, so that wind-chill cannot cool them to below the ambient temperature.

**Table 5.1: Amount of antifreeze admix added to concrete, by percentage of dry weight[43]**

| Admixture | Minimum daily temperature (°C) | Admix added (% weight of dry mix) |
|---|---|---|
| Sodium Nitrate ($NaNO_2$) | 0 to -5 | 4 to 6 |
| | -6 to -10 | 6 to 8 |
| | -11 to -15 | 8 to 10 |
| Potassium Carbonate ($K_2CO_3$) | 0 to -5 | 5 to 6 |
| | -6 to -10 | 6 to 8 |
| | -11 to -15 | 8 to 10 |
| | -16 to -20 | 10 to 12 |
| | -21 to -25 | 12 to 15 |

### *Insulating concrete*

Insulating concrete is used in Alaska as insulation for buried pipes that may be prone to stress, under a road for example. It can also be used as a base for water tanks to prevent loss of heat, or to maintain the structural integrity of frozen ground.

Insulating concrete can be made using polystyrene beads, pumice or expanded shale, as the aggregate instead of gravel, to make a lightweight mix with high strength and thermal resistance[44]. The density and thermal properties of insulating concrete are shown in Appendix B on page 78.

## Constructing on frozen ground

Properties of soil can differ greatly during different seasons. Frozen ground is fairly stable structurally, but it may become very weak and unstable when it thaws in spring or summer. Ground instability can cause the walls and floors of buildings to crack or subside.

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[43] figures from Krylov (1998)

[44] Smith (ed., 1996)

In winter, construction on top of soil banks, which are liable to subside or collapse in the spring, should be avoided. Ground which is frozen in the winter time but could become marshland when winter ends should also be avoided. Consultation with local people should establish this fact; plants in the area could also give indications of seasonal marshland.

Note that water tanks are especially likely to face problems of structural damage. Firstly because they are very heavy, and secondly they need to be located on high ground. Construction of water tanks on a bank of earth may appear to be a good idea in winter but it could lead to disaster in the spring. Thirdly, the relatively high temperature of stored water can melt the water in the soil, causing collapse. The design of water storage tanks is discussed in detail in section 3.3, starting on page 22.

In general there are three factors affecting construction on hard, frozen ground, which is not necessarily frozen in the summer:

1. Mechanical digging equipment may be necessary. SIDA (Swedish International Development Agency) has, in the past, used mechanical digging equipment mounted on snow vehicles.
2. Ground may become unstable in the spring/summer. Particular care is necessary when constructing at the top of slopes or on ground that could be marshy in the summertime. Use local knowledge to determine where it is safe to build.
3. Construction work is best done in the summer although, obviously, this will not always be possible. Unfrozen ground is much easier to work, and it can easily be established whether the ground is strong enought to support structures. In addition, construction materials may be more easily available at warmer times of the year due to better logistical links.

### *Frost jacking*

After several years the action of repeated freezing and thawing of the ground can have the effect of forcing piles and telegraph poles to start rising out of the ground. One method of avoiding this is to wrap piles in several layers of plastic sheeting to allow the soil to move independently of the piles. Borehole casings are also liable to frost jacking, which can be alleviated by using bentonite as annular grouting instead of concrete.

### Calculating snow loads

Roof structures must be able to support the weight of snow that settles on them. The following equation can be used to calculate the load: [45]

$$L = F \times H \times D \times A$$

where L = total load exerted on the roof (kg)

F = footprint (plan area) of the roof ($m^2$)

H = maximum expected depth of snow on the ground (m). Use the 30 or 50 year expected maximum depth of snow if designing a structure for long-term use.

D = density of snow ($kg/m^3$). Old snow with a density between 200 and 400 $kg/m^3$ weighs more than new snow with a density of as little as 100 $kg/m^3$ . Canadian design criteria use D=240 $kg/m^3$ but an attempt should be made to determine a local value if possible.

A = conversion factor taking into account that roofs are generally more exposed than the ground, hence higher wind speeds over them cause less snow to settle. In Canada A=80% (0.8) is used for general calculations of flat or sloping roofs or A=60% (0.6) is used for roofs in very exposed areas.

## 5.2 Logistics

The effects of cold climates on aid provision are accentuated in winter, one of the main reasons being the effect of the weather on logistics. In some areas road and rail links are liable to closure due to snow blockage, and air support may be hampered by foul weather. In other areas frozen lakes may provide landing sites for aircraft, and roads that are poor in the summer may be better to drive on when frozen.

This section deals with the implications of winter logistics in respect to water supply options and other issues. Some recommendations for vehicle maintenance are given in section 5.3 starting on page 65.

### Water haulage

Hauling water by truck is not possible if roads are blocked with snow, or if ice makes the trip too dangerous for the driver. The effect that this will have on water

[45] Figures and theory from Boyd (et al., 1981)

supply will be that the emphasis must be on using very local sources of water, despite the fact that the quality of these sources may be less than ideal. Therefore, in some cold regions, the option of expensive treatment of poor quality water is preferable to hauling in water by truck, which may be impossible in winter.

## Stockpiling for winter

Problems of bringing diesel fuel into an area by road will affect the ability of agencies to run their vehicles and pumps; similarly fuel for heating and cooking purposes could be more scarce in winter due to transport difficulties. Therefore it is worth considering, carefully, whether it is feasible to stockpile quantities of fuel before winter arrives, tackling the problems of storage, security, and distribution.

Materials worth stockpiling include fuel, medical supplies, building materials, water treatment chemicals and other hardware that may be needed to implement repairs to water supply or sanitation systems.

## Use of vehicles for personal transport

Obviously, vehicles for the transport of personnel or materials need to fulfil requirements necessary for summer and winter driving. Four wheel drive vehicles offer distinct advantages in mountainous areas in winter, and in other areas where the quality of roads is poor.

In terms of safety do not set out in winter without:

- Snow chains and shovels, in case the vehicle becomes stuck
- Food, water and four season sleeping bags, in case the driver and passengers have to stay out all night or longer.

The value of keeping warm should not be underestimated. Besides being more comfortable, personnel will also work more efficiently. Cab heating and tea making facilities are important and should not be considered luxuries.

## Chemical control of snow and ice on roads

The purpose of applying chemicals and abrasive materials to road surfaces is to increase the friction between the wheels of vehicles and the road surface. Vehicle journeys are made safer, and the stopping distances that vehicles require are reduced.

Abrasives and/or chemicals should only be applied to a relatively thin covering of ice or snow, such as that created after a snowplough has initially cleared the road of snow, or to an icy surface created when ambient temperatures fall below 0°C after rain.

**Table 5.2: Advantages and disadvantages of chemicals and abrasives[46]**

| Material Applied | Main Advantages | Main Disadvantages |
|---|---|---|
| Sodium Chloride (Rock Salt) NaCl | Effective between 0°C and -9.5°C<br>Immediate traction<br>Salt particles quickly bore through the ice layer<br>Low cost | Ineffective below -12.3°C<br>Low rate of solution |
| Calcium Chloride, $CaCl_2$ | Effective down to -29.1°C<br>High rate of solution<br>Liberates heat on dissolving | High cost<br>Pavement remains wet afterwards |
| Mixtures of NaCl and $CaCl_2$ | Effective down to -17.9°C<br>Faster than either chemical applied alone | High cost<br>Pavement stays wet longer than with $CaCl_2$ |
| Mixtures of abrasives and chemicals | Effective In very cold weather<br>Immediate improvement in skid resistance if clean ploughing is impossible<br>Free flowing material<br>No freezing of stockpiles<br>Abrasive anchored to the road | Clean-up problems in the springtime<br>May not remove all ice and snow, depending on amount of chemical added<br>Damage to vehicles at high speed |
| Abrasives | Immediate improvement to skid resistance | As with abrasive mixtures (above)<br>Easily brushed off road by tyres |

The quantities of chemicals recommended for ice control and snow removal are shown in table 5.3. These quantities are designed to produce a 30% melt within 30 minutes of the beginning of snow accumulation.

46 From Keyser (1981)

## Table 5.3: Recommended applications of chemicals to paved roads with an average daily traffic of 500 vehicles or more[47]

| Air Temp. (°C) and road conditions | Application - - before snowfall or freezing rain | - to melt loose snow (per cm depth) | - to clean up thin crusts after ploughing | - to clean up thick crust of hard snow or ice |
|---|---|---|---|---|
| a) -4 or higher, in shade<br>b) -7 to -4, in sun | 55 to 115 kg of NaCl or mixture (if NaCl is removed by wind or traffic) | 100 kg of NaCl | 85 kg of NaCl | 170 kg of NaCl or 85 kg of mixture |
| c) -4 or higher, temp. is falling<br>d) -7 to -4, in shade<br>e) -12 to -7 in sun | 55 to 115 kg of NaCl or mixture (if NaCl is removed by wind or traffic) | 170 to 225 kg of NaCl or 135 kg of mixture | 130 kg of NaCl | 170 to 280 kg of NaCl or 170 kg of mixture |
| f) -7 to -4, temp. is falling<br>g) -12 to -7, in shade<br>h) -18 to -12, in sun | 70 to 140 kg of NaCl or mixture | 165 kg of mixture | 170 kg of mixture | 280 kg of mixture |
| -18 to -12, in sun | No chemical application | No chemical application | 210 kg of mixture | 340 kg of mixture or 1700kg of treated abrasive (abrasive mixed with salt) |
| Below -18 | No chemical application | No chemical application | Abrasive mixed with salt | 340 kg of mixture or 1700kg of treated abrasive (abrasive mixed with salt) |

**Note 1:** All mixtures in the above table are NaCl and $CaCl_2$ in a 3:1 ratio

**Note 2:** All quantities (above) are given in kg per km of 2-lane road

[47] From Keyser (1981)

### *Side effects of using chemicals to treat roads*

It should be noted that the use of chemicals can have some adverse side affects, particularly on the environment, so they should be used sparingly and only when necessary. These include:

- Damage to certain species of plants;
- Potential pollution of shallow wells, ponds or streams that are used as water sources;
- Reduction in soil fertility in the surrounding area;
- Corrosion of concrete reinforcement, if the concrete is permeable;
- Corrosion of vehicles, if damaged surface coatings expose raw metal.

## Logistics in mountainous regions

In mountain areas poor accessibility can severely affect the feasibility of hauling water for use in refugee camps. Possible methods include water trucks or tanks pulled by tractors, although difficulties can be expected with water spilling out of tanks on steep gradients. Winter weather could make access problems worse. Transport of water tanks, full of potable water, by means of helicopters was used in the mountains of northern Iraq in 1991, although the operation was extremely expensive.

The logistics for supplying shelters, blankets, other materials and food are also, obviously, potentially very difficult. One possibility, that has proved necessary in the past (e.g. to supply the Kurdish people in Northern Iraq) has been for civilian NGOs to work with the military, co-ordinating air drops and other supply routes. Although many NGOs are reluctant to work with the military, on the grounds of neutrality, in some circumstances their logistical expertise should not be ignored, even if only to seek logistical advice. Pack animals have also been used effectively to transport water and materials into otherwise inaccessible areas.

### *Supply by air*

Transporting equipment for water supply or sanitation facilities by helicopter is the only quick way to reach some mountainous areas, assuming there are no roads to the area. Helicopters have been used successfully (if expensively) to bring water, in tanks, to refugee supply points in the mountains.

In 1991, in Northern Iraq, air drops of potable water, in plastic bottles strapped to pallets, were made using C90 Hercules aircraft. Approximately 95% of all bottles broke upon impact with the ground[48]. Air drops of food or materials, including those used in watsan construction, may be more feasible, but airdrops are so expensive that other methods of transport should be used whenever possible. Airdrops are the option of last resort.

### *Use of pack animals*

Use of pack animals is a common transport solution in many mountainous countries, for example in Nepal. The British army sometimes uses pack animals, instead of helicopters, to transport materials: when the helicopters are needed elsewhere or are too expensive to use for transporting non-essential materials.

Mules, donkeys and horses are all suitable for use in mountainous regions. They can reach areas which are inaccessible to road transport and could be used to transport materials for water supply or sanitation systems, as well as tents, blankets, food and other equipment. The approximate requirements and capabilities of different animals are shown in Table 5.4 .

## Table 5.4: Requirements of horses, donkeys und pack ponies[49]

| | |
|---|---|
| **Food (per animal per day)** | 10 lbs (4.5 kg) of hay and 10 lbs (4.5 kg) oats/grain |
| **Drinking water (per animal per day)** | 8 to 10 gallons (40 to 50 litres) |
| **Maximum carrying load** | Pack pony or horse: 70 to 75 kg |
| | Donkey: 45 kg |
| **Average speed** | 3 to 4 mph (4 to 6 km/h) |
| **Distance covered in one day** | 20 to 30 km |

**Note 1**: The above figures are approximate. They will vary depending on the size of the animals and the type of terrain to be covered.

**Note 2**: The above figures are for guidance only. Local advice should also be sought.

[48] Cuny (1994)

[49] Kohler (1999)

## 5.3 Mechanics

### Engines and pumps

Diesel and other engines are almost certain to experience running problems due to the cold, especially if it is not possible to keep vehicles indoors when not in use, or if mechanical water pumps have to be left outside at all times.

Most starting problems can be avoided by keeping pumps and vehicles indoors, especially at night, or by starting the engine periodically (for example running an engine for 10 minutes every hour or two). Use the skills of local mechanics, who will already be adept at keeping engines running in the cold. Problems that are likely to affect the engines of vehicles and pumps are listed, with solutions in Table 5.5 .

#### *Diesel fuel*

Diesel fuel, whether local or imported, must be suitable for use in cold weather. Additives are available in some countries that, if necessary, can be put into warm weather diesel to prevent it from gelling. In the UK this fraction is known as the “middle distillate flow improver”; in Iran there is an additive called “Nesto” [50]. Note that these additives must be put into the fuel in advance, and will not remedy the problem after the fuel has gelled

In some countries drivers mix a small quantity of petrol (gasoline) or kerosene in with the diesel fuel. Each 10% by volume of added diluent (up to 50% maximum) will lower the “cloud point”, the temperature at which the fuel begins to gel, by about 2°C. However the diesel should then be used carefully, since the risk of fire or explosion increases, and this method is only advisable for emergencies because regular use would lead to reduced power output and possible wear of injection equipment[51].

Diesel fuel may gel after driving from a warm area into the mountains, where the ambient temperatures are much lower especially at night. Diesel is very likely to gel during the first night, which will hamper any activities, scheduled for the next morning, which involve driving.

[50] Goulding (1998)

[51] Owen (ed., 1989)

**Table 5.5: Mechanical problems with vehicle or pump engines**

| Engine Problem | Solution |
|---|---|
| **Diesel gels**<br><br>Diesel partially solidifies when left for periods of time, undisturbed, in freezing temperatures.<br><br>Engine will turn over but not fire, inspection of fuel tank reveals gelled diesel | ***Prevention***<br><br>Use diesel designed for use in the cold or put additives into standard diesel.<br><br>Light a fire under the fuel tank at night.<br>**Warning**: diesel is not likely to catch fire, but do not try this with petrol which is highly flammable!<br><br>***Repair***<br><br>Change fuel filters (probably clogged); fill filter casing with warm diesel and heat diesel in the tank by building a fire underneath it. |
| **Water freezing in cooling system**<br><br>Check in radiator if in doubt | ***Prevention***<br><br>Use more antifreeze in the cooling system.<br><br>***Repair***<br><br>Warm things up slowly, do not start engine otherwise water pump could break. When sure everything is unfrozen start engine and look for leaks. May have to replace pipes and gaskets and/or get radiator repaired. |
| **Oil too viscous**<br><br>Engine has difficulty turning over<br><br>Only happens in extremely cold conditions or when oil is unsuitable for use in the cold. | ***Prevention***<br><br>Use correct grade of oil.<br><br>Light fire under the engine at night<br>(diesel vehicles only - petrol is explosive!)<br><br>***Repair***<br><br>Change engine oil for more suitable grade<br><br>Light fire underneath the engine sump |
| **Engine will start but runs badly**<br><br>Engine too cold or<br><br>Icing in carburettor (petrol engines only) | ***Prevention***<br><br>Increase the idling speed, wrap multiple layers of tin foil (insulation) around various water pipes, or hang sacking over the radiator grill (reducing its efficiency to dissipate heat) |

## 5.4 Shelter

In emergencies the functions of shelter are to protect people from the elements, to help people to feel more secure, and to provide privacy and space for personal or group needs.

### Rehabilitation of urban shelter

In the urban case, local housing is the obvious place for refugees to live, if there is any to spare. Community centres, schools, churches, mosques or sports halls may also be used.

The role of aid agencies in providing shelter for urban disasters becomes that of fixing and repairing (floors, windows, roofs, etc.). It may be possible to employ and co-ordinate local craftsmen to do much of this work.

When people move back into previously vacated housing, there are likely to be problems of broken or frozen water supply or sewer service pipes to the houses. Advice on defrosting metal and plastic pipes in which water has frozen solid is contained in the section starting on page 35.

### Tents

Tents, huts and other shelters may be used in rural locations where there is a scarcity of proper construction materials due to strained logistics. Temporary shelter may also be necessary while reconstruction of permanent housing takes place. Several factors are relevant to the use of tents in cold regions:

- Heavy duty, waterproof, tent material is preferable to provide protection against the cold. If the material is not sufficiently waterproof then people will tend to throw plastic sheeting over the top. This can cause the tent material to rot because condensation on the inside will be unable to escape through lack of ventilation.
- The heat retaining properties of tents without an in-built ground sheet can reportedly be improved by excavating the floor down by half a metre or so.
- Wooden, raised floors in tents help to keep the occupants warm by avoiding the necessity to walk, or sleep, on the cold ground. Giving people some form of bed also significantly increases their comfort, for the same reason.

# CHAPTER 6
# Human Issues

## 6.1 Health

If the environment is too cold, and people have insufficient shelter, blankets, clothes or food, people will tend to huddle together. This encourages the transmission of diseases through the air, by lice or through direct contact. Likely health implications are discussed in this section.

### Air-borne diseases

*Diseases: measles, pneumonia, meningitis, whooping cough, influenza, and respiratory problems.*

Transmission of disease through the air is the most frequent source of health problems in cold regions[52]. Efforts should be made to reduce overcrowding, provide heating and implement measles vaccination procedures.

### Water-washed diseases

Diseases transmitted by poor washing practices include faecal-oral diseases and those passed by direct human contact. Provision of washing facilities with warm water and privacy is likely to encourage good personal hygiene. Hygiene education programmes will also help to reduce the incidence of water-washed diseases.

#### *Faecal-oral transmission*

*Diseases: cholera, hepatitis, typhoid, dysentery.*

Faecal-orally diseases are as likely to be present in cold regions as in warm ones. Pathogenic organisms do not develop as quickly in cold weather but are likely to survive much longer. In Greenland the US army detected coliform organisms in water samples taken from sites that had been abandoned four years previously[53].

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[52] Buttle (1998)

[53] DiGiovanni (et al., 1962).

In refugee camps in very cold areas, if open defecation has been practiced previously, the winter freeze can offer an opportunity to clean up excreta from around the camp. Solid excreta can be easily removed to a burial site. This, in turn, reduces the likelihood of outbreaks of faecal-oral disease in the spring when the excreta would have thawed.

If no hot water is available or no method of drying hands, people may be reluctant to wash their hands after defecating, due to the discomfort involved. Methods of providing hot water are discussed on page 29.

Water as a method of anal cleansing may also be impractical, again for reasons of comfort. Alternative methods, for example using paper, can be proposed but may not be culturally acceptable. In that case discussion of the subject with the people and with community leaders is vital, if sensitive, to maintain effective camp sanitation.

### *Transmission by direct contact*

*Diseases: Skin and eye diseases, scabies, conjunctivitis, trachoma, mycosis*

Efforts to alleviate crowding and to keep people warm enough that they do not have to huddle together, will reduce the levels of transmission of skin and eye diseases. If possible the provision of hot water will greatly encourage people to wash themselves, especially children.

## Diseases transmitted by vectors

### *Mosquitoes*

Although mosquitoes are not able to survive in consistently cold areas, there are some countries, such as Azerbaijan, where they exist in sufficient number in the summertime for malaria to be endemic, despite having severe winters. Mosquitoes are also known to transmit diseases other than malaria.

### *Flies*

Flies develop more slowly in cold weather and, while they could be transmitters of faecal-oral disease in warm regions, this is unlikely anywhere where the ambient temperature is less than 0°C. Measures to manage sanitation and solid waste will also minimise fly-breeding.

#### ***Lice***

*Diseases: typhus, recurrent fever*

Lice are transmitted from person to person very easily in cold regions. Firstly, because people may huddle together and secondly because lice eggs in clothes will not be killed by cold water.

Lice are difficult to treat effectively. Possible measures are:

- Powdering people and clothes
- Washing clothes in hot water, although the temperature of the water must be quite high. A temperature of 70°C for one hour is necessary, according to MSF (1994), or 54°C according to Davis and Lambert (1995).
- Hot ironing of clothes, after washing them, will also help to kill lice eggs present in the seams of clothing.
- Reduction of overcrowding.

### Other health problems

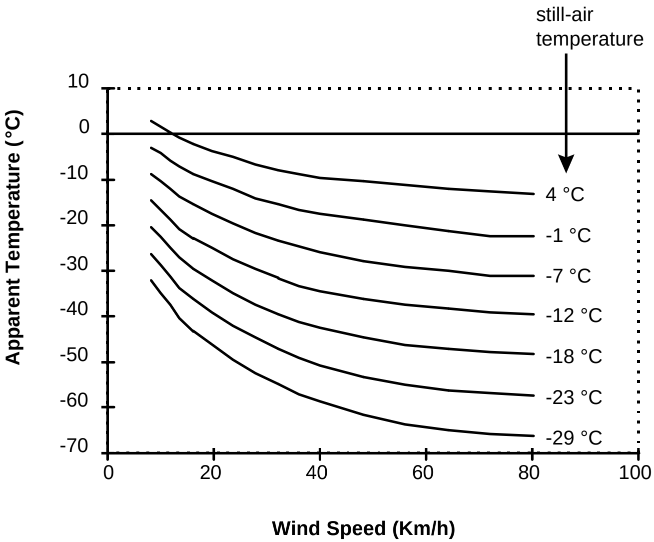
Other likely health problems in cold climates include:

- Burns from stoves.
- Carbon monoxide poisoning if people use heaters in confined spaces, without adequate ventilation.
- Exposure caused by low temperatures, inadequate food, shelter, blankets or clothes. See also the section on the effects of windchill, below.

#### ***Windchill***

Increasing wind speeds have the effect of making the human body feel colder than the temperature recorded by thermometers. This effect is known as the windchill effect. It is caused by the wind increasing the rate of evaporation of water from the surface of the body, which removes heat. Figure 6.1 shows how, for different air temperatures, the apparent temperature decreases as the wind speed increases. Note that the effect would be even more pronounced if people were wet, after rain for example, which would cause the body to lose heat even more quickly.

**Figure 6.1: Graph showing apparent temperature variation with wind speed, known as the wind chill effect[54]**




## 6.2 Socio-political issues

The cold can affect attitudes and morale, especially in winter. On the other hand, people involved in emergencies in cold climatic regions may have a wealth of knowledge to draw on because they have always lived in cold countries.

Some possible negative effects of the winter on watsan provision are:

- Motivation of workers (including aid workers) may be generally lower in winter than in summer.
- As winter approaches the priorities of local people will probably become food, fuel, shelter and obtaining income. Watsan may not be a high priority for them at that time of year. They may be used to constructing watsan facilities in the warmer months only.

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[54] Figures from cdc.gov (1998)

More developed countries (many cold region countries are more developed) have more to lose when disaster strikes. When disaster strikes a country with highly developed infrastructure and communications systems, the resulting damage is greater, in monetary terms than that which a less developed country would experience. People in developed countries are reliant on shops for basic commodities and may also have fewer practical survival skills than people from less developed countries.

Local political systems will greatly affect material supply. Politics, corruption and bureaucracy, possibly imposed by the local people so that they are properly consulted on aid issues, can all make it difficult to procure necessary items.

## 6.3 Personal effectiveness

Warm people work more effectively, including aid workers. The value of dressing sensibly, eating properly and consuming regular hot drinks should not be underestimated.

Some more factors that could improve the comfort and effectiveness of aid workers are:

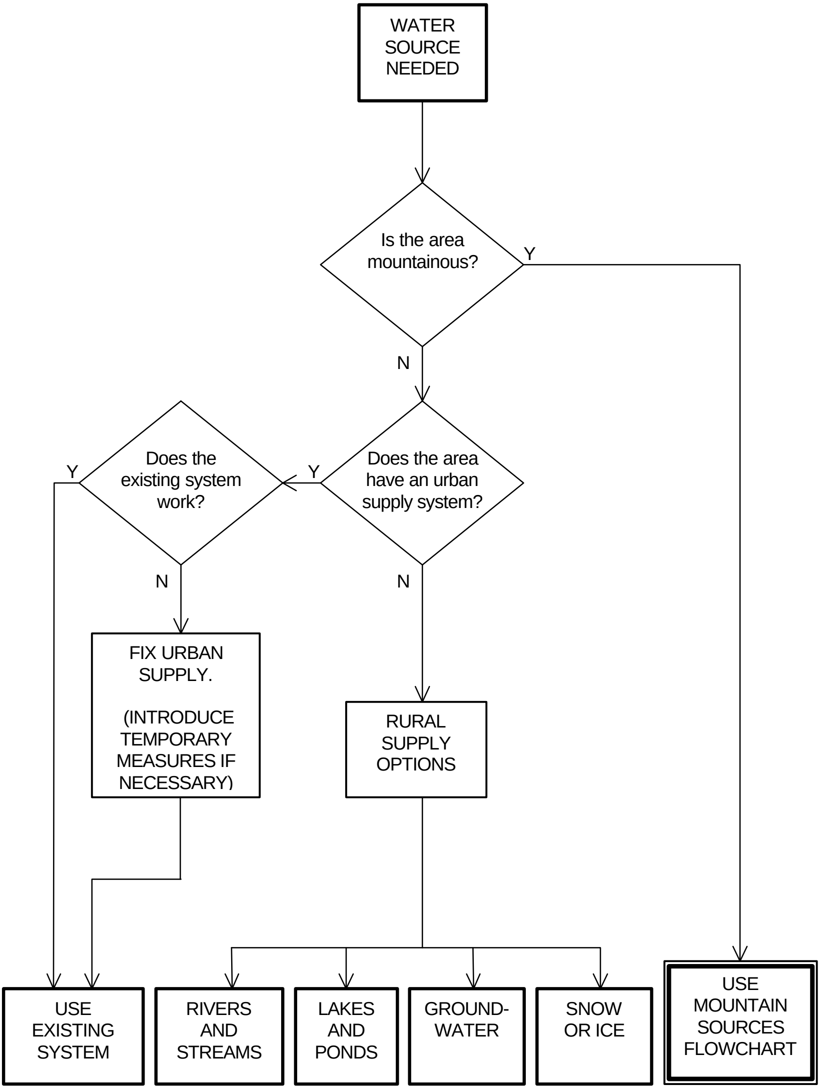
- Personal kit should include warm, waterproof clothes, hat and gloves and sturdy boots. Note that the windchill factor could make conditions seem much colder than the reading on a thermometer.
- Personal medical kits should contain adequate medication for respiratory tract infections (coughs and colds).
- Ensure that vehicles have shovels, snow chains and tools as well as spare tyres. Taking food, water and four season sleeping bags (one per person) is also advisable.
- Beware of additional health risks such as hypothermia, frost-bite and snow-blindness. Beware also of carbon monoxide poisoning, which can be fatal and can occur when small stoves are used in badly ventilated, confined areas.

# CHAPTER 7
# **Additional Information**

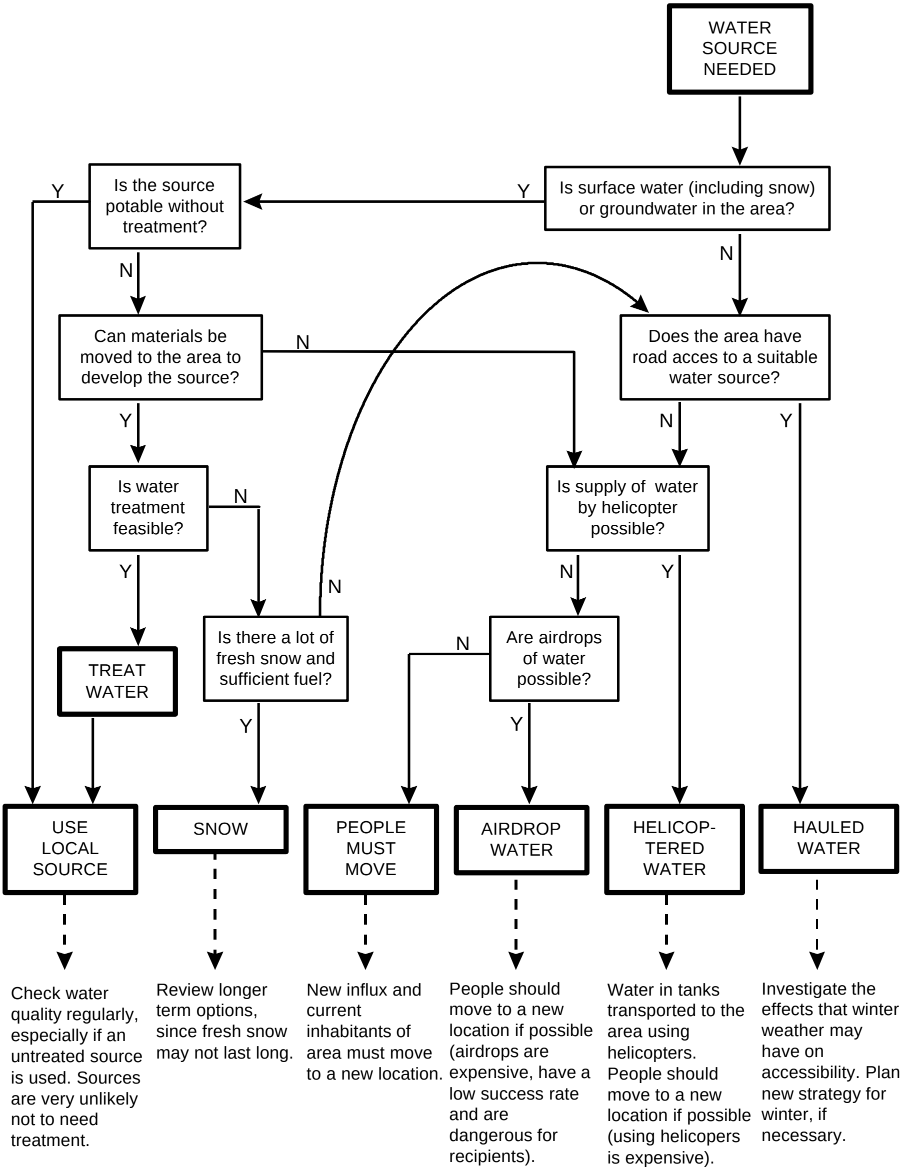
## 7.1 Appendix A - Water Supply Flowcharts

Figures 7.1 and 7.2 can be used to consider possible water sources for emergencies in cold regions. They deal with physical and technical aspects of water source selection alone and should therefore be used in conjunction with figure 7.3, which also considers the wider issues, including security, socio-political or cultural constraints, and other considerations associated with the use of each potential water source.

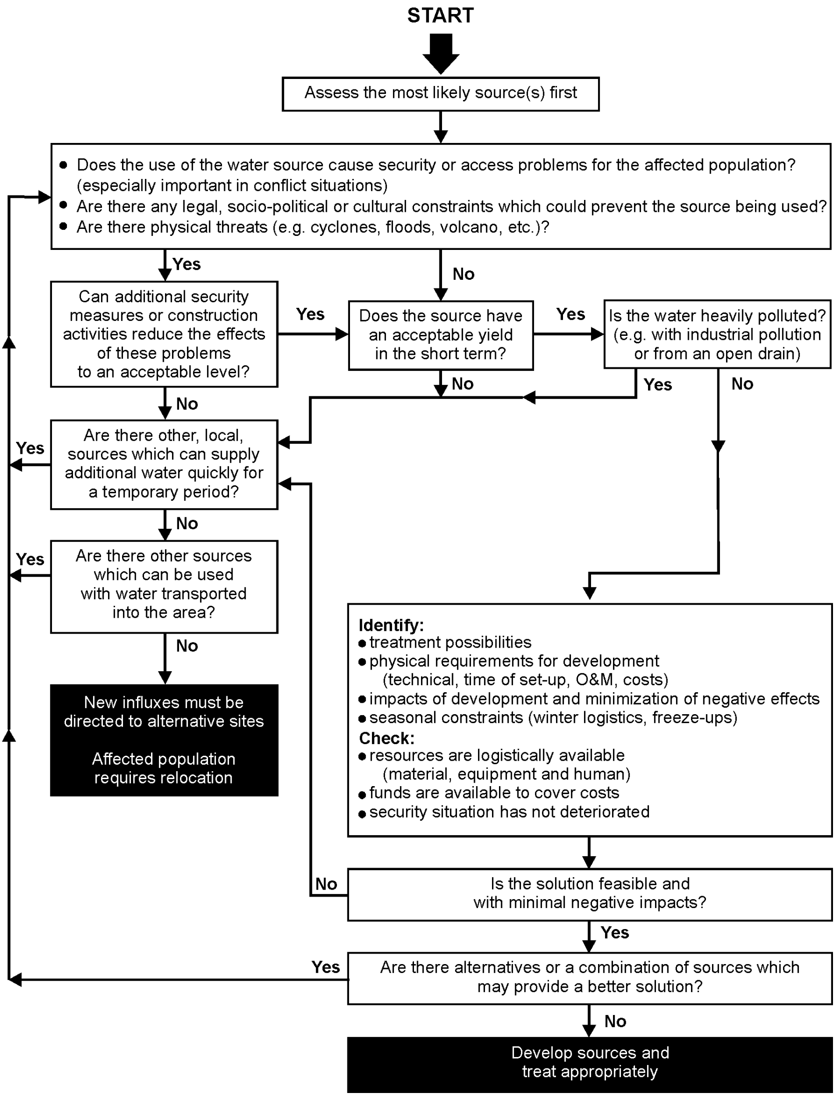
**Figure 7.1: Flowchart for water source selection in cold regions**



## Figure 7.2: Flowchart for water source selection in mountainous areas



## Figure 7.3: Flowchart for assessing the suitability of water sources for survival supply, in cold regions[55]




[55] Adapted from House and Reed (1998)

## 7.2 Appendix B - Thermal properties and density of materials

### Table 7.1: Thermal properties and density of construction materials

| Material | Dry Density kg/m$^3$ | Specific Heat Capacity kJ/kg °C | Thermal Conductivity W/m °C |
|---|---|---|---|
| Polyurethane foam | 32 | 1.67 | 0.024 |
| Polystyrene foam | 30 | 1.26 | 0.036 |
| Rock wool, glass wool | 55 | 0.84 | 0.040 |
| Wood, plywood, dry | 600 | 2.72 | 0.17 |
| Wood, fir or pine, dry | 500 | 2.51 | 0.12 |
| Wood, Oak, dry | 700 | 2.09 | 0.17 |
| Concrete, insulating mix | 200 to 1500 | | 0.07 to 0.60 |
| Concrete | 2000 | 0.67 | 1.7 |
| Asphalt | 2000 | 1.67 | 0.72 |
| Wood stave | | | 0.26 |
| Polyethylene, high density (HDPE) | 950 | 2.26 | 0.36 |
| Polvinyl chloride, (PVC) | 1400 | 1.05 | 0.19 |
| Asbestos cement | 1900 | | 0.65 |
| Steel | 7500 | 0.50 | 43 |
| Ductile iron | 7500 | | 50 |
| Aluminium | 2700 | 0.88 | 200 |
| Copper | 8800 | 0.42 | 375 |

## Table 7.2: Thermal properties and density of materials found in the environment

| Material | Dry Density kg/m$^3$ | Specific Heat Capacity kJ/kg °C | Thermal Conductivity W/m °C |
|---|---|---|---|
| Air, no convection (0°C) | | 1.00 | 0.024 |
| Air film, outside, 24km/h wind (per air film) | | | 0.86 |
| Air film, inside (per air film) | | | 0.24 |
| Snow, new loose | 85 | 2.09 | 0.08 |
| Snow, on ground | 300 | 2.09 | 0.23 |
| Snow, drifted and compacted | 500 | 2.09 | 0.7 |
| Ice at -40°C | 900 | 2.09 | 2.66 |
| Ice at 0°C | 900 | 2.09 | 2.21 |
| Water at 0°C | 1000 | 4.19 | 0.58 |
| Peat, dry | 250 | 2.09 | 0.07 |
| Peat, thawed, 80% moisture | 250 | 1.34 | 0.14 |
| Peat, frozen, 80% ice | 250 | 0.92 | 1.73 |
| Peat, pressed, moist | 1140 | 1.67 | 0.70 |
| Clay, dry | 1700 | 0.92 | 0.9 |
| Clay, thawed, saturated (20%) | 1700 | 1.76 | 1.6 |
| Clay, frozen, saturated (20%) | 1700 | 1.34 | 2.1 |
| Sand, dry | 2000 | 0.80 | 1.1 |
| Sand, thawed, saturated (10%) | 2000 | 1.21 | 3.2 |
| Sand frozen, saturated (10%) | 2000 | 0.88 | 4.1 |
| Rock, typical | 2500 | 0.84 | 2.2 |

## 7.3 Appendix C - Design of surface pipes to prevent freezing[56]

Table 7.3 shows values of the design times, $t_d$, for how much time (in minutes) water in surface laid pipes will take to reach the freezing point (0°C), for different ambient temperatures and with the water starting at different initial temperatures.

Figure 7.4 shows the shape of graph obtained for one particular pipe, (e.g. 50 mm, 2 inch MDPE pipe).

Users can either use the data in Table 7.3 to make an estimate of the design time, using interpolation, or can use the equation on page 83 to obtain a more accurate figure.

***Notes***

1. The design time values in this section are calculated on a conservative basis. Real-life values of $t_d$ should be slightly greater than the values given here, which are for guideline purposes only.
2. The average wind speed has been taken as 30 km/h for these calculations. At lesser wind speeds, the design times will be greater than those shown in the graphs.

***How to use "design times"***

1. For water that has stopped flowing in a pipe, $t_d$ is the maximum time (minutes) that the water should be allowed to stand with no risk of freezing.
2. For flowing water the maximum length of pipe, $L_p$, (metres), in which the water will not reach freezing temperatures can be calculated using:

$$L_p = \frac{t_d \times q_w \times 60}{A}$$

Where: $L_p$ = Length of pipe (m)

$t_d$ = Design time (mins)

$q_w$ = Flow rate of water ($m^3$/sec)

$A$ = Internal cross sectional area of the pipe ($m^2$)

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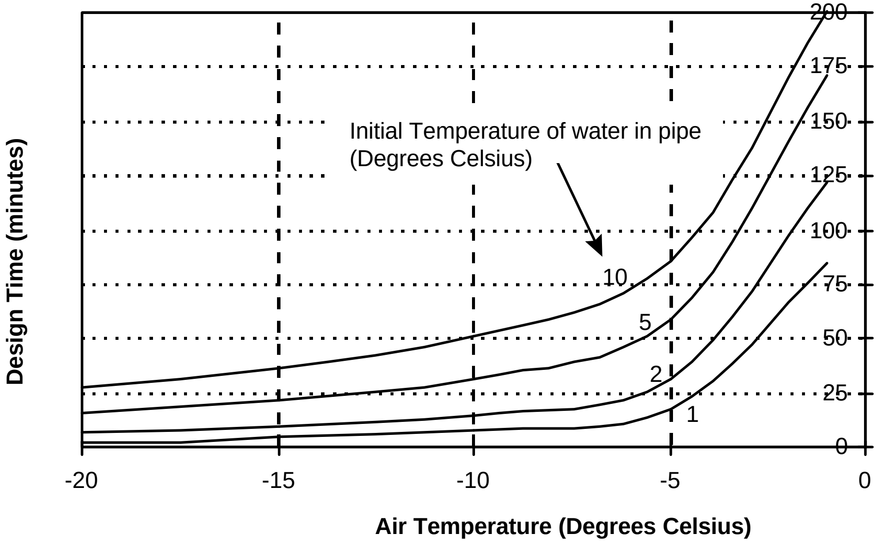
[56] Pipe products data taken from BSS (MDPE pipes), Extrudex (PVC pipes) and Stantons PLC (ductile iron pipes). Contact addresses on page 86.

***Assumptions made***

1. Pipes are thin-walled, i.e. the thickness of the pipe wall is much less than the diameter of the pipe.
2. Thermal resistance across the water / pipe-wall contact area is negligible.

**Figure 7.4: Design times $t_d$ for 50 mm (2 inch) MDPE pipe (mean wall thickness of 4.6 mm, pressure rating 12 bar) for wind speed = 30km/h**



## Table 7.3: Design times $t_d$ for water to cool to 0°C from different starting temperatures, for surface laid pipes of different materials and diameters.

| Outside Temp. (°C) | Design time (minutes) for zero wind speed | | | | Design time (minutes) for wind speed = 30 km/h | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial Water Temperature (°C) | | | | | | | |
| | 1 | 2 | 5 | 10 | 1 | 2 | 5 | 10 |
| **50 mm (2 inch) MDPE pipe (wall thickness of 4.6 mm, pressure rating 12 bar)** | | | | | | | | |
| -1 | 189 | 272 | 377 | 438 | 84 | 122 | 171 | 201 |
| -5 | 38 | 68 | 129 | 187 | 17 | 31 | 59 | 86 |
| -10 | 17 | 33 | 69 | 110 | 8 | 15 | 32 | 51 |
| -15 | 11 | 21 | 46 | 77 | 5 | 10 | 21 | 36 |
| -20 | 8 | 15 | 34 | 59 | 4 | 7 | 16 | 28 |
| **90 mm (3.5 inch) MDPE pipe (wall thickness of 8.2 mm, pressure rating 10 bar)** | | | | | | | | |
| -1 | 404 | 583 | 810 | 945 | 186 | 270 | 381 | 452 |
| -5 | 82 | 147 | 279 | 404 | 39 | 69 | 133 | 195 |
| -10 | 38 | 70 | 149 | 239 | 18 | 34 | 72 | 116 |
| -15 | 23 | 45 | 99 | 168 | 11 | 22 | 48 | 82 |
| -20 | 17 | 32 | 73 | 128 | 8 | 16 | 36 | 63 |
| **50 mm (2 inch) PVC pipe (wall thickness of 2.5 mm, pressure rating 9 bar)** | | | | | | | | |
| -1 | 189 | 272 | 376 | 437 | 84 | 122 | 171 | 200 |
| -5 | 38 | 68 | 129 | 186 | 17 | 31 | 59 | 86 |
| -10 | 17 | 33 | 69 | 110 | 8 | 15 | 32 | 51 |
| -15 | 11 | 21 | 46 | 77 | 5 | 10 | 21 | 36 |
| -20 | 8 | 15 | 34 | 59 | 4 | 7 | 16 | 27 |
| **100 mm (4 inch) PVC pipe (wall thickness of 4.5mm, pressure rating 9 bar)** | | | | | | | | |
| -1 | 460 | 663 | 921 | 1074 | 210 | 306 | 432 | 512 |
| -5 | 94 | 167 | 317 | 459 | 44 | 79 | 151 | 220 |
| -10 | 43 | 80 | 169 | 272 | 20 | 38 | 81 | 132 |
| -15 | 27 | 51 | 113 | 191 | 13 | 25 | 55 | 93 |
| -20 | 19 | 37 | 83 | 145 | 9 | 18 | 41 | 71 |
| **118 mm (DN 100 mm) ductile iron pipe (wall thickness of 9 mm, working pressure rating 40 bar)** | | | | | | | | |
| -1 | 529 | 757 | 1039 | 1195 | 222 | 318 | 437 | 502 |
| -5 | 106 | 188 | 354 | 507 | 44 | 79 | 149 | 213 |
| -10 | 47 | 89 | 187 | 297 | 20 | 37 | 79 | 125 |
| -15 | 29 | 56 | 123 | 207 | 12 | 24 | 52 | 87 |
| -20 | 21 | 40 | 91 | 157 | 9 | 17 | 38 | 66 |
| **170 mm (DN 150 mm) ductile iron pipe (wall thickness of 10 mm, working pressure rating 40 bar)** | | | | | | | | |
| -1 | 834 | 1195 | 1639 | 1885 | 351 | 502 | 689 | 793 |
| -5 | 167 | 296 | 558 | 799 | 70 | 125 | 235 | 336 |
| -10 | 75 | 140 | 295 | 469 | 32 | 59 | 124 | 197 |
| -15 | 46 | 88 | 195 | 327 | 19 | 37 | 82 | 138 |
| -20 | 33 | 63 | 143 | 248 | 14 | 27 | 60 | 104 |

***Equations used to calculate design times***[57]

Values of $t_d$ can be calculated using the design equation:

$$t_d = \frac{A \times R \times C \times \ln\left|\frac{T_{wi} - T_a}{T_{w0} - T_a}\right|}{60}$$

Where $t_d$ = Design time (mins)

$A$ = Internal cross sectional area of the pipe ($m^2$)

$R$ = Thermal resistance of pipe (m.°C/W)

$C$ = Specific volumetric heat capacity of water (4,190,000 $J/m^3$.°C)

$T_{wi}$ = Initial water temperature (°C)

$T_a$ = Ambient air temperature (°C)

$T_{w0}$ = Water freezing temperature (0 °C)

[57] equations from Smith (ed., 1996)

Values in the design equation are derived from:

$$R = R_p + R_{af}$$

$R_p$ = Thermal resistance of pipe material (m.°C/W)

$R_{af}$ = Thermal resistance of pipe / air interface (m.°C/W)

$$R_p = \frac{r_p - r_w}{\left(r_p + r_w\right) \times \pi \times k_p}$$

$r_p$ = Outer radius of pipe (m)

$r_w$ = Inner radius of pipe (m)

$k_p$ = Thermal conductivity of pipe material (W/m.°C)

$$R_{af} = \frac{1}{2 \times \pi \times r_p \times \eta_a}$$

$\eta_a$ = Convection heat transfer coeff. at pipe / air interface (W/m$^2$.°C)

$$\eta_a = N \times W \times \left(\frac{T_{w1} - T_a}{r_p}\right)^{0.25}$$

$N$ = Constant. (1.12 W/m$^{7/4}$.°C$^{5/4}$)

$$W = \sqrt{0.56 \times v_a + 1}$$

$v_a$ = Wind speed (m/s)

## 7.4 Appendix D - Addresses

### Table 7.4: Manufacturers and suppliers

| Manufacturer | Address | Products/Service |
|---|---|---|
| Stella-Meta | Laverstoke Mill, Whitchurch, Hants., RG28 7NR, UK<br>Tel:(44) 1256 895959<br>Fax:(44) 1256 892074 | Portable Water Treatment Units (British army supplier) |
| SDL Technologies | 4 Habosem St., PO box 6699, Ashdod 77166, Israel<br>Tel:(972) 8 856 4314<br>Fax:(972) 8 852 4289 | Portable Water Treatment Units (Israeli) 5 to 200 $m^3$/hr container units |
| Clearwater PLC | Clearwater House, Clearwater Industrial Park, Bristol Road, Bridgewater, Somerset, TA6 4AW, UK<br>Tel:(44) 990 275252<br>Fax:(44) 1498 880285 | Wastewater treatment (RBC) units |
| Klargester Environmental Engineering Ltd. | College Road, Aston Clinton, Aylesbury, Bucks., HP22 5EW, UK<br>Tel:(44) 1296 633 000<br>Fax:(44) 1296 631 770 | RBC units, also portable version in container units |
| Urecon Ltd. | 1800 Ave. Bedard, St. Lazare de Vaudreuil, Quebec, J7T 2G4, Canada<br>Tel:(1) 450 455 0961<br>Fax:(1) 450 455 0350 | Preinsulated HDPE pipes |
| BSS | Fleet House, Lee Circle, Leicester, LE1 3QQ, UK<br>Tel:(44) 1162 567 103<br>Fax:(44) 1162 567 283 | Polyethylene pipes |
| Extrudex products | British Industrial Plastics Ltd., Aycliffe Industrial Estate, Darlington, Co. Durham, DL5 6AN, UK<br>Tel:(44) 1325 315 122 | PVC pipes |
| Stanton PLC | Lows Lane, Stanton-by-Dale, Ilkeston, Derbyshire, DE7 4QU, UK<br>Tel:(44) 115 930 5000<br>Fax:(44) 115 932 9513 | Ductile iron pipes |

## Table 7.5: Agencies and organisations

| Name | Address | Function or service |
|---|---|---|
| REDR | 1 Great George Street, London, UK<br>Tel:(44) 171 233 3116<br>Fax:(44) 171 222 0564 | Register of engineers available for disaster relief work |
| UNHCR | Centre William Rappard, 154 Rue de Lausanne, 1202 Geneva 21, Switzerland<br>Tel:(41) 22 739 8111<br>Fax:(41) 22 731 9546 | UN commission concerned with the well-being of refugees. Often acts as a coordinating organisation in the field |
| IFRC | 17 Chemin des Crets, PO Box 372, 1211 Geneva 19, Switzerland<br>Tel: (41) 22 730 4222<br>Fax: (41) 22 730 0395 | International Federation of Red Cross and Crescent Societies<br>International humanitarian organisation |
| ICRC | 19 Avenue de la Paix, CH 1202, Geneva, Switzerland<br>Tel (41) 22 734 6001<br>Fax: (41) 22 733 2057 | International Humanitarian/Aid organisation |
| MSF Belgium | 24 Rue Deschampheleer, 1800 Bruxelles, Belgium<br>Tel:(32) 2 414 0300<br>Fax:(32) 2 411 8260 | International aid organisation |
| MSF Holland | Postbus 10014, 1001 EA Amsterdam, Netherlands<br>Tel:(31) 20 520 8700<br>Fax:(31) 20 620 5170 | International aid organisation |
| MSF France | 8 Rue Saint-Sabin, 75544 Paris Cedex 11<br>Tel: (33) 1 40 21 29 29<br>Fax: (33) 1 48 06 68 68 | International aid organisation |
| Oxfam | 274 Banbury Road, Oxford, OX2 7DZ, UK<br>Tel:(44) 1865 312 135<br>Fax:(44) 1865 312 600 | International aid organisation |

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