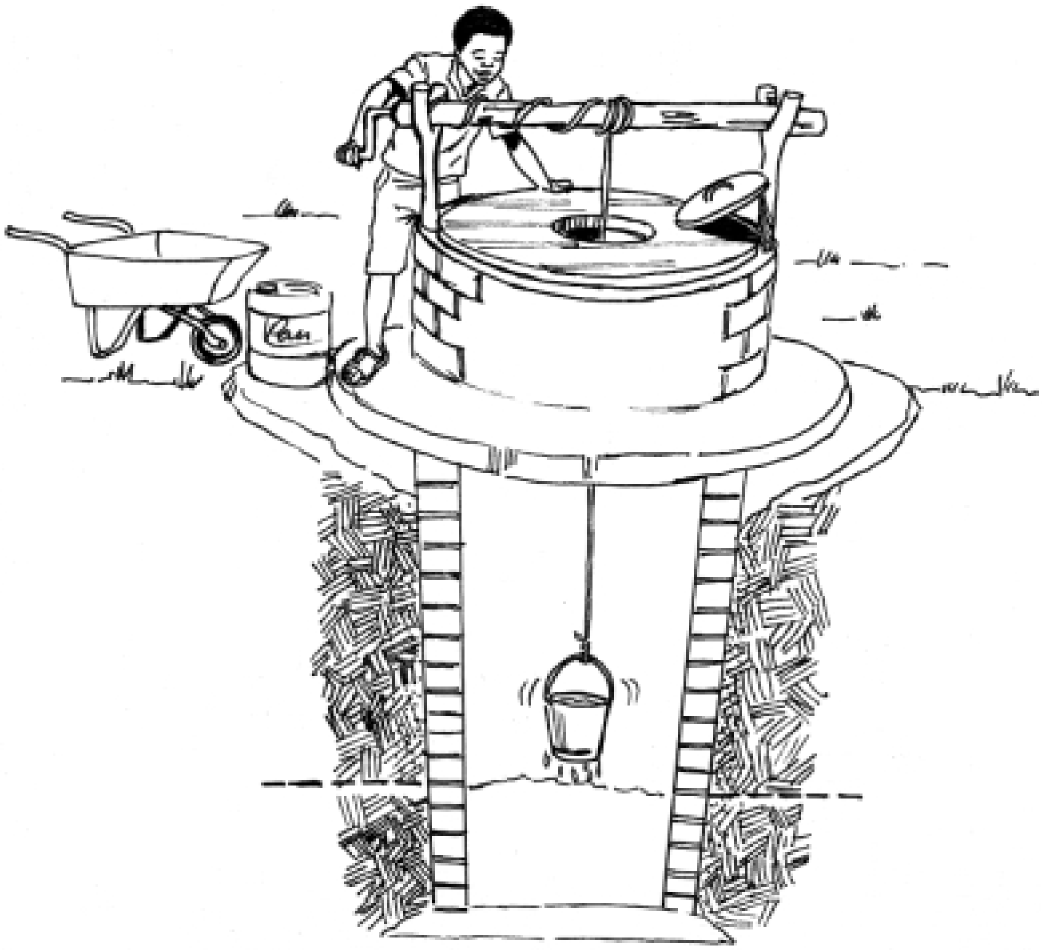
Guidelines on Protecting Groundwater from Contamination



TOOLKIT for WATER SERVICES: Number 3.4

This document provides guidelines and tools to help protect groundwater from contamination. It will be useful to Environmental Health Officers, environmental planners, health and hygiene educators, sanitation planners and pollution control officers working in Water Services Authorities, Water Services Providers, the Department of Health, the Department of Water Affairs and Forestry and Catchment Management Agencies.

Guidelines on Protecting Groundwater from Contamination

Published by
Department of Water Affairs and Forestry
Directorate: Information Programmes
Private Bag X313
PRETORIA 0001
Republic of South Africa
Tel: (012) 336 7500

Implemented by
Council for Scientific and Industrial Research (CSIR)

Editing
Anthea Josias and Kerry Harris

Artwork
Vusi Malindi

Layout and design
Gill McDowell

Specific contributions
Irené Saayman, Freeternity Rusinga, Alan Hon,
Kerry O'H Murphy

General contributions
John Weaver, Knut Ellingsen, Rheinhard Meyer, Oliver Sililo, Vusi Nkuna,
Ilse Wilson, Alana Potter, Richard Holden, Bolu Onabolu, Ian Pearson,
Boniface Aleobua, Ricky Murray, Phillip Ravenscroft, Wilna Kloppers,
Colin Forbes, Christine Colvin, Pannie Engebrecht, Gideon Tredoux

Inputs to Introduction
Irené Saayman, Pannie Engelbrecht, Oliver Sililo,
Christine Colvin, Kerry O'H Murphy

Produced under:
The NORAD-Assisted Programme for the Sustainable Development of Groundwater Sources under the Community Water and Sanitation Programme in South Africa

Foreword

Toolkit for Water Services

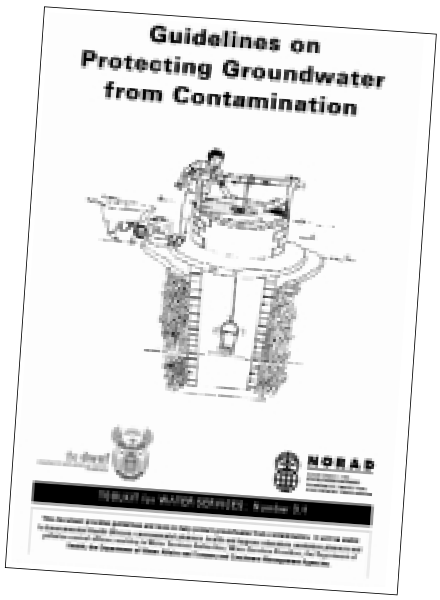
Groundwater has historically been given limited attention, and is not perceived as an important water resource, in South Africa. This is reflected in statistics showing that only 13 % of the nation's total water supply originate from groundwater. Because of the highly distributed nature of the water demand in rural and informal peri-urban settlements, regional schemes are, in most instances, not economically feasible. And because of decreasing available river and spring flows during low flow and drought periods, as well as wide-spread problems of surface water pollution in rural areas, groundwater will be the most feasible option for a large part of the new water demand.

The NORAD-Assisted Programme for the Sustainable Development of Groundwater Sources under the Community Water and Sanitation Programme in South Africa was managed by the Department of Water Affairs and Forestry (DWAF) between 2000 and 2004. The Programme undertook a series of inter-related projects aimed at enhancing capacity of water services authorities and DWAF to promote and implement sustainable rural water supply schemes based on groundwater resources and appropriate technologies.

Page 2 has a full list of the Programme outputs. The formats for these range from documents to software programmes and an internet portal, to reference sites where communities have implemented appropriate technologies. For more information on the "package" of Programme outputs contact your nearest DWAF Regional Office or Head Office in Pretoria.

It is our sincere hope that this Programme will contribute to the body of work that exists to enable more appropriate use and management of groundwater in South Africa.

The ***Guidelines on Protecting Groundwater from Contamination*** is Number 3.4 in the Toolkit for Water Services. This document provides guidelines and tools to help protect groundwater from contamination. It will be useful to Environmental Health Officers, environmental planners, health and hygiene educators, sanitation planners and pollution control officers working in Water Services Authorities, Water Services Providers, the Department of Health, the Department of Water Affairs and Forestry and Catchment Management Agencies.



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1.2 Implementing a Rural Groundwater Management System: a step-by-step guide

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2.1 Standard Descriptors for Geosites

3 Groundwater Protection
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Acronyms

CBO	Community-Based Organisation
CMA	Catchment Management Agency
CWSS	Community Water Supply and Sanitation
DPLG	Department of Provincial and Local Government
DWAF	Department of Water Affairs and Forestry
O&M	Operation and Maintenance
SABS	South African Bureau of Standards
SANS	South African National Standards
SSA	Support Services Agent
WMA	Water Management Area
WRM	Water Resource Management
WSA	Water Services Authority
WSDP	Water Services Development Plan
WSP	Water Services Provider
WSDP	Water Services Provision Contract
WUA	Water User Association

Introduction to the use of the guidelines

Protecting groundwater from contamination

Groundwater supply points are usually in the form of boreholes and springs. Sometimes wells are dug to supply water, but in South Africa there are not many wells. This is because the depth required to reach the groundwater table is often in excess of 10 metres, and because groundwater is most often located in fractured bedrock, making the development of wells very difficult. Groundwater contamination can occur through two major categories of pathways:

- aquifer pathways, and
- preferential flow pathways.

Aquifer pathways

The area below the ground, where contaminants can travel down through the underlying soils and rock, into the aquifer, is referred to as the aquifer pathway. It is comprised of the vertical distance for contaminants to reach the water table, and the horizontal distance (often referred to as setback distance) that contaminants travel until they reach the groundwater supply point. Minimum prescribed setback distances help provide a buffer (or barrier) between the contaminant source and the water supply point. The minimum setback distance decision charts, provided here, are specifically for protection of water supply points against pathogenic contamination (from germs and viruses) via the aquifer pathway.

Preferential flow pathways

A preferential flow pathway is a short cut that a contaminant can take from the surface to the groundwater, or to an abstraction point. This means that the contaminants take much less time to reach the groundwater / abstraction point, than they would if the contaminants were to travel through undisturbed soils, sub soils and underlying bedrock. Preferential flow pathways are often related to poor design and construction of groundwater supply points and to lack of proper protection measures.

Boreholes and wells present ideal preferential flow pathways, and so special attention is required to seal off the top (the head) and to implement other protective measures, so that contaminants have little chance of accessing the groundwater source from the surface. Springs occur where groundwater reaches the ground surface, under hydraulic pressure, and usually occur where steeply sloping ground intersects the water table, towards the bottom of a slope. Because contaminants are easily carried by runoff water or by sub-surface seepage down these slopes, such contaminants can gain ready access to unprotected springs.

Contamination threats

This document looks at seven different contamination threats:

- Animal kraals, stock watering points and dipping tanks
- Burial sites
- Informal vehicle servicing, spray painting and parts washing facilities
- Pit latrines
- Runoff water
- Subsistence agriculture
- Informal waste disposal

Each contamination threat is dealt with as follows

1. Background to the contamination threat
2. Tools for dealing with the contamination threat
3. References and additional reading

The **Background** gives an introduction to the topic, and deals with issues such as Groundwater vulnerability, impact on health, and guidelines (what to keep in mind).

The **Tool**s are provided with the purpose of making sound decisions to prevent pathogenic contamination of groundwater abstraction points.

More information on the tools

The tools provided in this document are generally:

- Checklists and decision tables
- Flowcharts
- Set-back distance charts

The simplest tool is the **checklist**. Checklists are used to present a series of step-by-step tasks to the user, and are often used to direct the user to other decision tools, such as to the flowcharts and set-back distance charts. A **decision table** is similar to a checklist, with the difference being that actions required of a user are identified as the result of a series of answers provided by the user. **Flowcharts** are used to provide more specific advice, usually related to a single task. **Set-back distance charts** are used to present potentially suitable set-back distances, taking into account specific settings related to geology, depth to water table, etc.

It is important to note that:

- Distance charts apply to water abstracted from unconfined aquifers.

  Water abstracted from confined aquifers is considered relatively safe from contamination via the aquifer pathway.

- Distance charts for boreholes and wells are applicable only to those equipped with motorised pumps.

- Only one distance chart addresses set-back distances for springs, and then only for lightly loaded contaminant sources.

- Distance charts are designed to address protection from pathogenic contamination via the aquifer pathway. They do not address preferential flow pathways or other types of contamination (e.g. from nitrates).

Details on the procedures for using these tools are provided below.

The checklist and decision tables

The ***checklist*** is a numbered set of questions, with options of possible answers. The user must tick the most appropriate answer for each question, and also make notes in the comments column on how the most appropriate answer to the question was arrived at.

The ***decision table*** is very similar to the checklist, but contains more than one question per row. Each row in the table represents a "case" of possible answers to questions, and ends with advice, set-back distances or directions on where to proceed in the document. For pit latrines (for example), the decision table directs the user to the appropriate decision chart (a set-back distance chart) for determining a recommended separation distance necessary to protect a water supply point, or for determining appropriate prevention measures for specific separation distances.

The flowcharts

The ***flowcharts*** present a step-by-step procedure for one or more of the following:

- Identifying major contaminant contribution factors;
- Identifying possible remedial action to avert groundwater pollution; or
- Determining how to establish whether the seasonal high groundwater table comes to within a certain distance (e.g. 2 metres) of the ground surface.

The set-back distance charts

The ***set-back distance charts*** relate separation distances in different geological categories to the survival time for pathogens as they travel through the soil and underlying aquifer. (An overview of the survival times of some pathogens in soil is presented in the **Background to contamination threat** section in each of the seven contamination threat sub-documents.) However, some cells in the chart are considered close enough to an abstraction point to fall within the influence of the pumping "cone of depression". These distances represent a special high risk zone for which travel times are significantly reduced, and the theory presented in the discussion that immediately follows does not apply to these cells.

Each cell of the chart contains the theoretical time of travel for groundwater over a specified setback distance (represented by the row in which the cell lies) through a particular aquifer material type (represented by the column in which the cell lies). These theoretical times of groundwater travel have been grouped into ranges and presented in the cells by different patterns and shades, for ease of use. The time ranges, related to protection zones, are thus presented as set-back distances in the charts.

The protection zones based on travel time are protection zones 2 or 3 or 4. The travel time range categories were obtained from ARGOSS (2001). Protection zone 1, closest to the groundwater abstraction point, is not based on groundwater travel time. Instead, it is based on the radius of influence of the borehole or well in question.

In essence, unlike the conventional “one size fits all” approach (e.g. the norm for set-back distance for pit latrines is 30 metres) the purpose of the charts is either to recommend minimum separation distances, or else to present potentially suitable protective measures dependent on a given set-back distance and on the hydrogeological conditions that exist at each site of interest. The charts should not be used for sites with the following hydrogeological conditions:

- Karstic / fractured dolomites or limestone.
- Shallow or non-existent soils over bedrock.
- Fault zones and dykes.

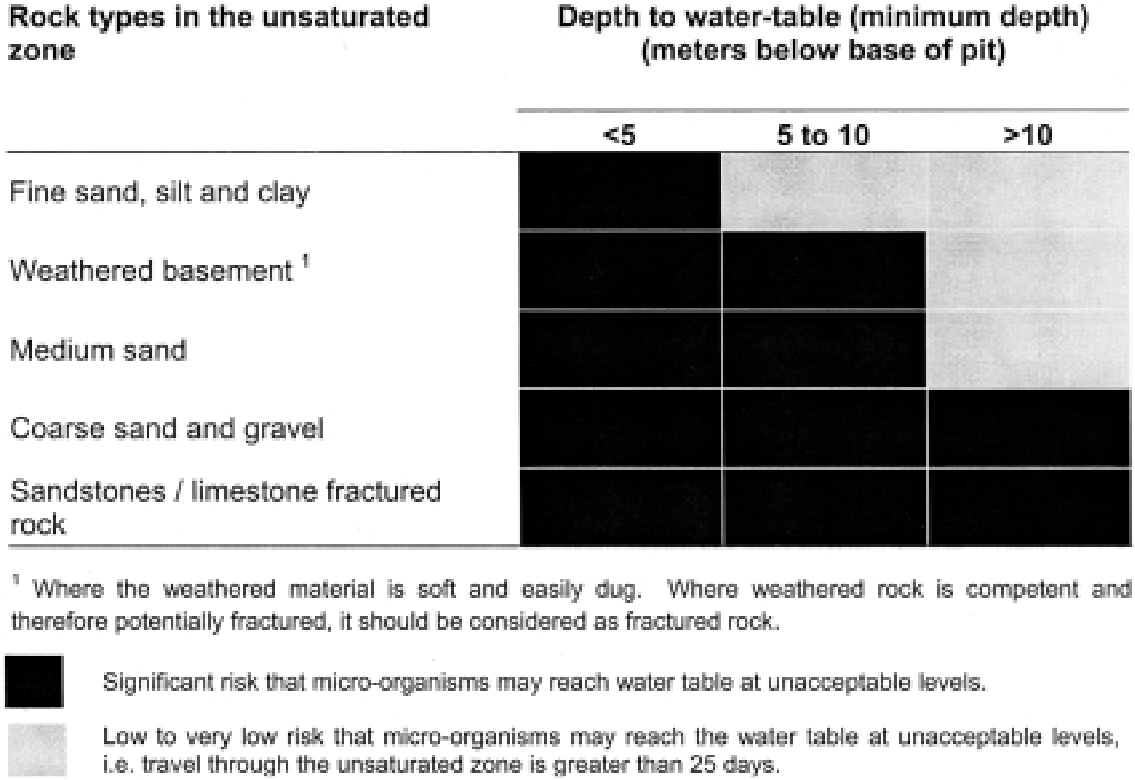
The assumptions made in the development of the decision charts are:

i) The aquifer is unconfined.
ii) The contaminants travel at the same speed as the groundwater.
iii) For boreholes that use electricity or diesel driven turbine pumps, the average pumping times are assumed to be 8 hours (WSM, 2001).
iv) The soil layer between the base of any contaminant source and the water table provides the vertical safety distance. **Table 1** presents a refined rule of thumb for adequate natural treatment (or attenuation) of pathogens within the unsaturated zone.

Based on **Table 1**, the minimum thickness of soil layer between the base of a pathogenic contaminant source and the water table adequate to provide natural treatment has been assumed and generalised to be 10 metres in these guidelines. By adopting this assumption, the term ‘shallow aquifer’ in these guidelines refers to situations where the water table is 10 metres or less, below the base of the contaminant source (e.g. below the base of a pit latrine). The term ‘deep aquifer’ applies to situations where the water table is more than 10 metres below this base.

The protection zones 1, 2, 3 and 4 are described below and in Figure 1, Figure 2 and Figure 3.

Table 1: Assessment of risk following attenuation of micro-organisms (pathogens) within the unsaturated zone (ARGOSS, 2001)



Rock types in the unsaturated zone	Depth to water-table (minimum depth) (meters below base of pit)		
	<5	5 to 10	>10
Fine sand, silt and clay			
Weathered basement [1]			
Medium sand			
Coarse sand and gravel			
Sandstones / limestone fractured rock			

[1] Where the weathered material is soft and easily dug. Where weathered rock is competent and therefore potentially fractured, it should be considered as fractured rock.

Significant risk that micro-organisms may reach water table at unacceptable levels.

Low to very low risk that micro-organisms may reach the water table at unacceptable levels, i.e. travel through the unsaturated zone is greater than 25 days.

Protection zones

Protection zone 1

Protection zone 1 is the radius of influence of the water supply borehole. The radius of influence can be defined as the radial distance to points where the water level (hydraulic head) in the aquifer is noticeably affected by the pumping well. No contaminant source or contaminating activity should be practiced in this zone (with the exception of pump engines).

A typical example from Drangert and Cronin (2004) highlights the need for avoiding the radius of influence of a pumped groundwater supply point. In this example, Drangert and Cronin (2004) presented a striking experience encountered in a less densely populated peri-urban area in Eldoret, Kenya, situated on a flat plateau with a 30 metres thick of Murram soil. Bacteria were not expected to be found in the neighbouring wells given that the soils are uniform and clayey. However contaminant-related bacteria were found in well water 20 to 30 metres away within 4 to 5 days. This encounter was attributed to the resulting cones of depression that are steep enough to result in average velocity of about 10 metres per day. The movement of water and hence pathogens from adjacent pit latrines contaminated the well.

Protection zone 2

Protection zone 2 is the distance outwards from the borehole, beyond the radius of influence, for which the travel time of groundwater is less than 25 days.

Protection zone 3

Protection zone 3 is the distance, outwards from the borehole beyond protection zone 2, for which the travel time of groundwater is between 25 days and 50 days.

Protection zone 4

Protection zone 4 is the distance, outwards from the borehole beyond protection zone 3, for which the travel time of ground water is more than 50 days.

If a well or a borehole happens to fall within any of the above protection zones, the following protection status actions could be taken:

Protection status 1:

Action: Stopping the contamination source / activity or moving it to a safer zone should be given high priority. If in doubt, seek the advice of a specialist. There should be regular monitoring of the water supply for indicator organisms and / or related contaminants, and the water abstracted for potable purposes should be disinfected.

Protection status 2:

Action: Alternative options are available:

1) stop the contamination source / activity, or else move it to a safer zone,
2) install effective protective measures, and(3) obtain the input of a specialist.

There should be regular monitoring of the water supply for indicator organisms and / or related contaminants, and the water abstracted for potable purposes should be disinfected as a precautionary measure.

Protection status 3:

Action: Alternative options are available:

1) If feasible, move the contamination source / activity to a safer zone
2) install protective measures, and
3) obtain the input of a specialist.

The water abstracted for potable purposes should be disinfected as a precautionary measure.

Protection status 4:

Action: Suggest disinfection of water used for drinking, especially if sanitary conditions in the home warrant it. If in doubt, install protective measures or obtain the input of a specialist.

Set-back distances

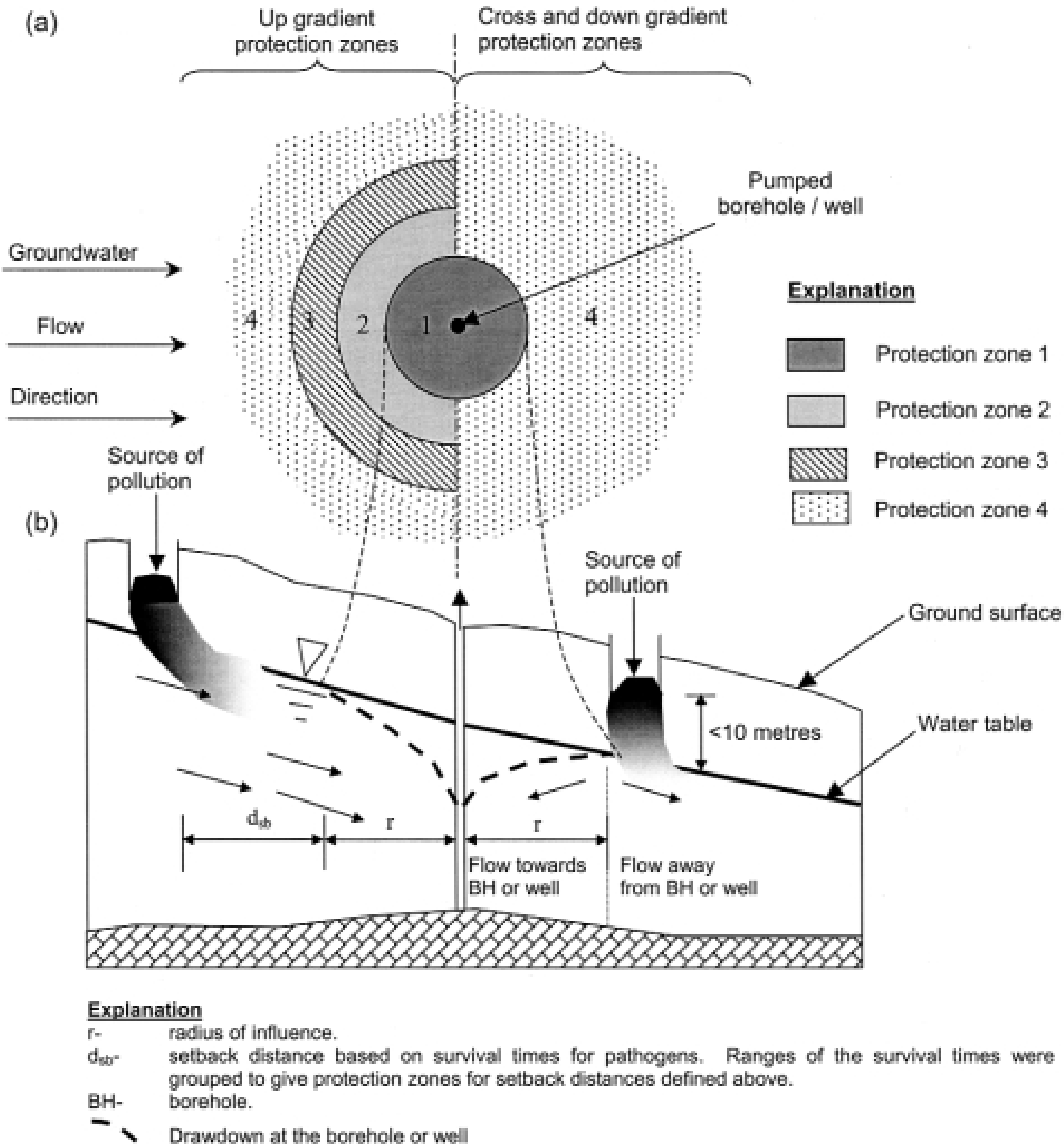
The set-back distance charts are not suitable for use when the contaminant source is located over karstic / fractured dolomites or limestones, shallow or non-existent soils over bedrock or fault zones and dykes, as there is potential for contamination of the groundwater resource no matter how far the setback distance is. Protection status 1 should be considered for these cases unless or until specialist input has been obtained.

Separate set-back distance charts have been produced for shallow and deep aquifers with boreholes or wells fitted with motor driven pumps, according to two pathogenic loading categories and two hydraulic loading rate categories.

Based on the definition of a shallow aquifer (above), the recommended separation distance for a source of potential contamination over a shallow aquifer is composed of the set-back distance and the radius of influence if the application area is up gradient of the water supply borehole. If it is cross gradient or down gradient then the recommended separation distance would theoretically be the radius of influence (see **Figure 1**). However, in fairly flat regions, the groundwater flow direction is not known (as is usually the case), and the up gradient protection zones of **Figure 1** are conservatively assumed to apply all round the borehole or well as shown in **Figure 2**.

For deep aquifers, the soil layer between the base of the application area and the top of the water table is assumed to be adequate for the natural treatment of small pathogenic loads (see **Figure 3**) and as such, only the zone within the radius of influence of the borehole should be avoided. However, this cannot be assumed to be true for heavy contaminant loads (e.g. from a community pit latrine), or for contaminants traveling under extra hydraulic pressure (e.g. from washwater being disposed to a pit latrine). In the latter cases, more conservative set-back distances should be adopted.

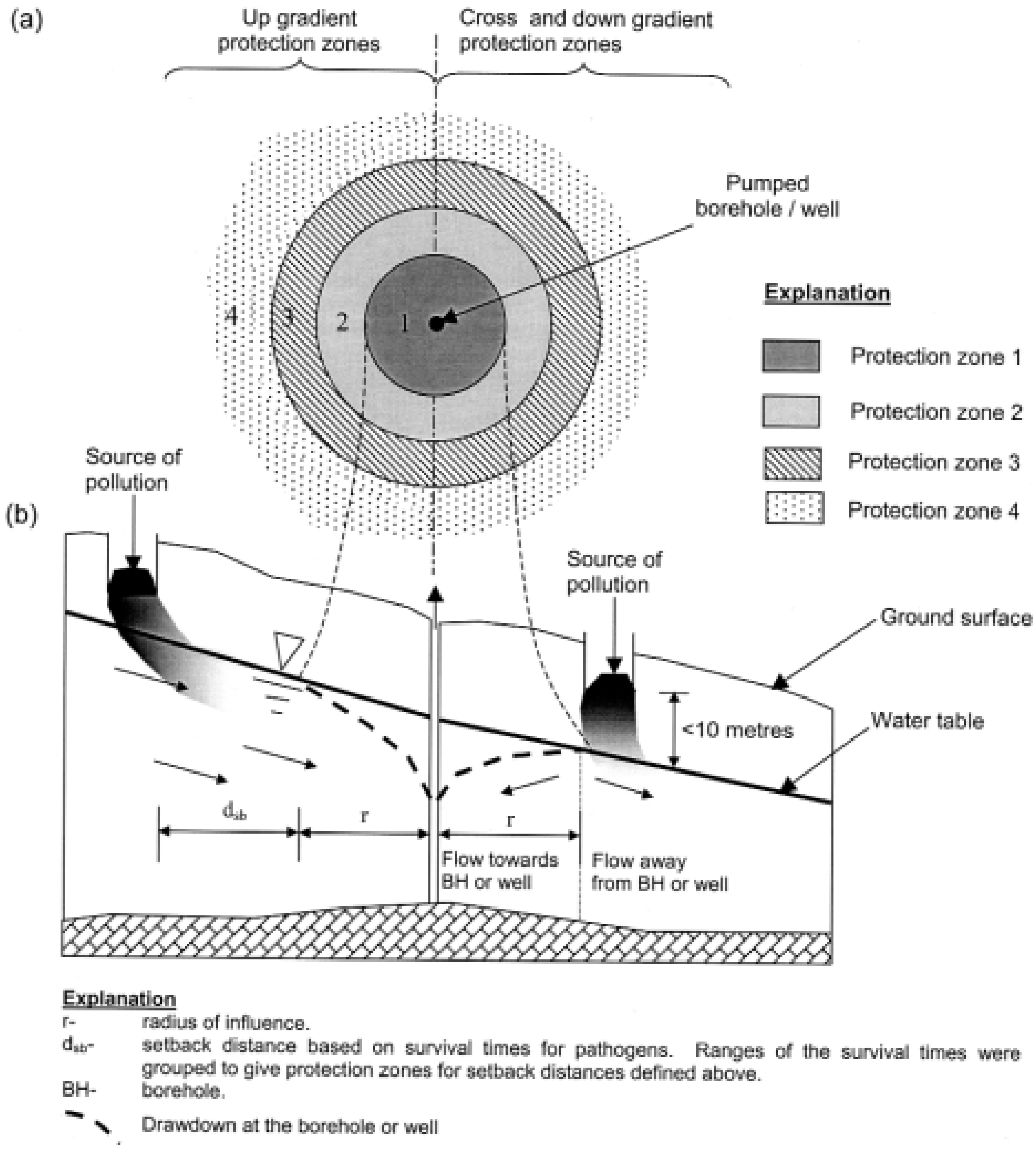
Figure 1: Protection zones for pumped boreholes and wells in a shallow aquifer (or a deep aquifer for heavily loaded contaminant sources) where the groundwater flow direction is known



(a) indicates the plan view

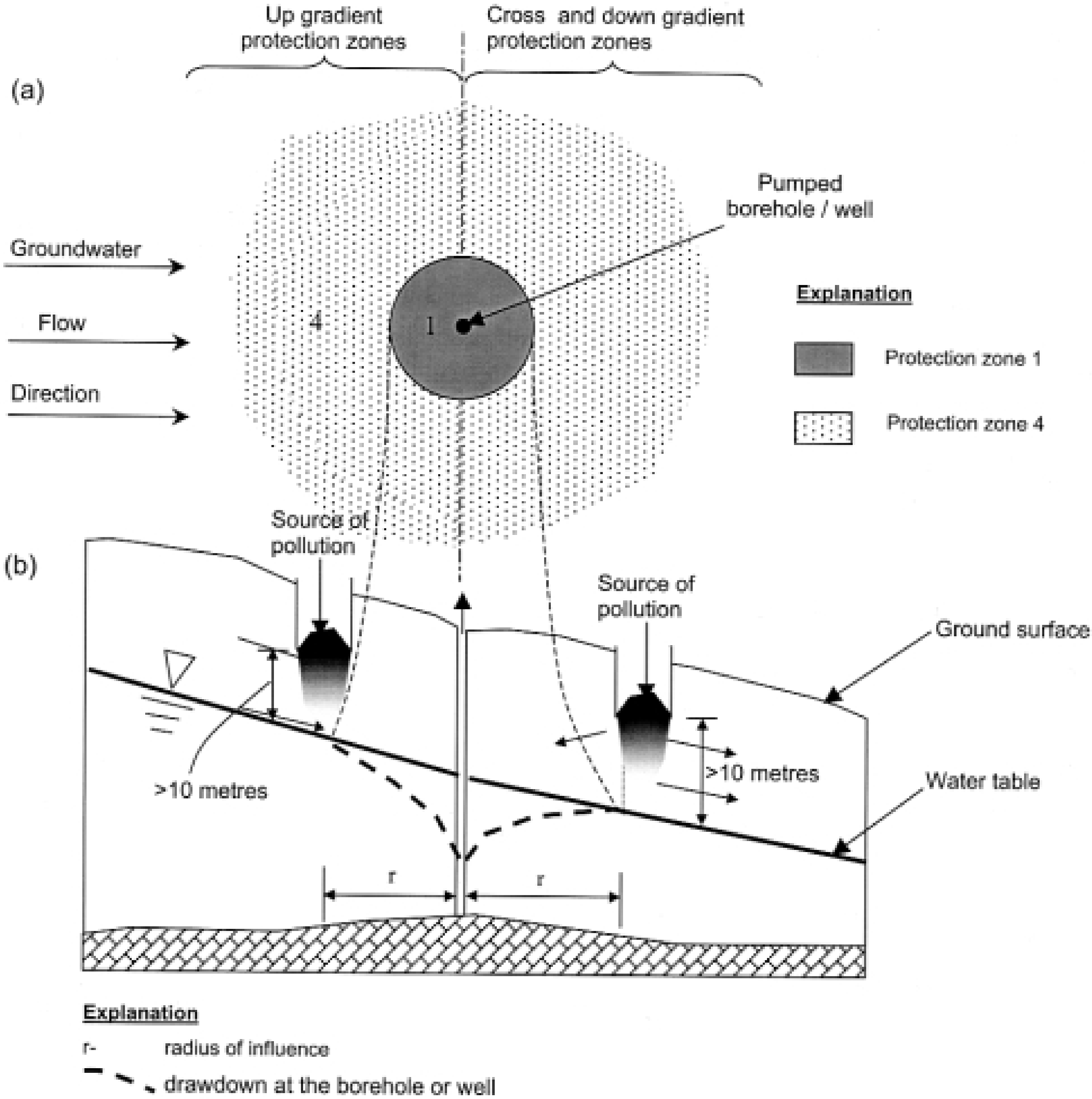
(b) indicates the sectional view (modified from Cromer *et al*., 2001)

Figure 2: Conservative protection zones for pumped boreholes and wells in a shallow aquifer (or a deep aquifer for heavily loaded contaminant sources) where the groundwater flow direction is NOT known



(a) indicates the plan view
(b) indicates the sectional view (modified from Cromer *et al*., 2001)

Figure 3: Protection zones for light contaminant sources, for pumped boreholes and wells in a deep aquifer or downslope of a pumped borehole or well for a shallow aquifer



(a) indicates the plan view

(b) indicates the sectional view (modified from Cromer *et al*., 2001)

Concluding remarks

The tools (containing checklists, decision tables, flowcharts and set-back distance charts) are only intended to guide the user, and not to provide final solutions. Although the suggested solutions may be adequate in many cases, the user of these guidelines should use judgement based on experience with the site in question, in providing remedial action. Where there is uncertainty, an expert's advice should be sought.

References and additional reading

ARGOSS (2001) *Guidelines for assessing the risk to groundwater from on-site sanitation*. British Geological Survey Commissioned Report, CR/01/142. Keyworth, Nottingham, UK:BGS.

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Protecting Groundwater
from Contamination by

Animal kraals, stock watering points and dipping tanks

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Implemented by
CSIR

Written by
Irené Saayman

Editing
Anthea Josias and Kerry Harris

Artwork
Vusi Malindi

Layout and design
Gill McDowell

Inputs
Kerry O'H Murphy, Freeternity Rusinga, Christine Colvin,
Gideon Tredoux

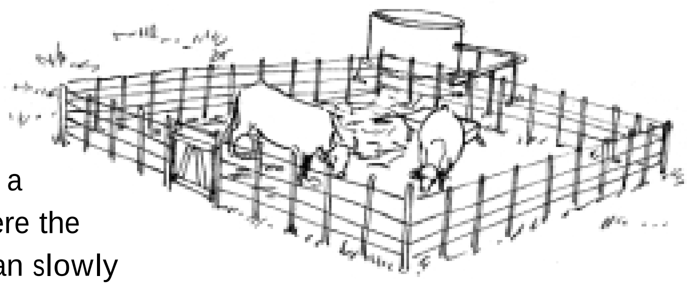
Animal kraals, stock watering points and dipping tanks

1 Background to the contamination threat

Introduction

Animal faeces are characterised by a high, rapidly bio-degradable organic content, a high concentration of nutrients, and a large number of potential disease-causing organisms (pathogens). Pathogens and nitrates are the main contaminants of concern for groundwater used for drinking purposes in rural areas. Contamination often results from the concentration of animals in animal kraals and at watering points. Groundwater resources may also be polluted through the poor management of animal dipping and the improper disposal of dipping fluid.

Groundwater resources are at less risk of being contaminated by animal faeces when livestock densities are low or when livestock are spread out over a wide area of land. This is because wastes will degrade naturally over a wide area of land. However, where animals congregate in large numbers, for example around water holes or in kraals, groundwater resources are at an increased and serious risk. This may result in large volumes of liquid (e.g. urine) and semi-solid faeces moving into the water table.



Rainfall, irrigation runoff, spilled water and water used for flushing purposes, can also result in faeces and urine being moved to or concentrated in one place. These contaminants may be carried to a surface water resource, or to a low-lying area where the water forms a puddle or pond. Here, the water can slowly seep into the ground, taking a number of contaminants with it.

Groundwater vulnerability

Many livestock watering points rely on groundwater. The distance of a borehole or well to a watering point either increases or decreases the risk of contaminated water gaining access to the groundwater via the borehole or well. The closer the distance of the watering point to the borehole or well, the greater the risk of contamination. Contamination can take place under the following conditions:

- Where an uncapped borehole casing extends only marginally above ground.
- Where the borehole casing has rusted through in places at the ground surface, contaminated water could flow straight into the borehole.
- Where the borehole is not properly closed at the surface, contaminated water could gain access to the groundwater by flowing down the outside of the borehole casing.

Thus, it is important that all boreholes are properly sealed and capped so as to prevent water from the surface, or any foreign material, from gaining access to the water source.

Dipping tanks are also of concern, because of the use and spillage of pesticides at such sites. Pesticides are designed to be toxic (poisonous), while some may also be carcinogenic (cause cancer). Even a small amount of pesticide in a water resource could be a serious health risk to people who use the water for drinking purposes.

In areas with high rainfall and shallow water tables, groundwater is particularly vulnerable to pollution from feedlots and stock watering points. Groundwater vulnerability is potentially significant in high permeability environments, such as sandy and gravelly soils, or where fractured bedrock lies close to the ground surface.

The risk of water from a spring, well or borehole being contaminated is increased when:

- There is little or no vegetation cover in the catchment area (or area upslope) of a local water source.
- Animal faeces such as manure are disposed near or in the water table, or near or in a water source. This reduces the time that unsaturated soils can remove potential contaminants before they reach the water table or the water source.
- There is high loading. The more faecal material there is in an area, the greater the amount of contaminants that can enter groundwater. Also, the more concentrated a pollution source is, the less likely it is that soils will be able to reduce / remove the contaminants sufficiently before they reach the water table.
- There is wet weather. Heavy rainfall produces storm water runoff. Runoff carries with it contaminants from the wastes it encounters. This is a problem that is worsened on bare ground. Storm water runoff eventually enters surface water bodies or else forms puddles and ponds in low-lying areas where the water slowly seeps into the ground. Some of the contaminants it carries may eventually reach the water table.
- There is a shallow water table. Where the water table is close to the ground surface, there is little depth of unsaturated soil available that can effectively remove / reduce contaminants before they reach the groundwater.
- There are highly permeable soils and rocks. Where soils consist of sand or gravel, or where there is fractured bedrock close to, or at, the ground surface, then should contaminated water sink into the ground or enter fissures in the rock, there is little likelihood of the contaminant being removed before the water reaches the water table.
- There is excess moisture in the waste. With excess moisture in the waste and in the underlying soils, nutrients and pathogens are able to travel further through the underlying soil than when drier conditions exist. Pathogens remain infectious for a longer time in moist conditions than in dry conditions.
- Livestock dipping tanks can leak, and pesticide spills can occur in and around such facilities. The closeness of such facilities to water abstraction points needs special attention.

Impact on health

Although faeces from animals present a lower health risk to humans than human faeces do, the risk remains very high. This is especially the case where animals are infected with a pathogen that could also infect humans (e.g. intestinal worms). Children, who play on ground frequented by lots of animals, are especially at risk. Infection may be spread when children rub their eyes or eat food with un-washed hands, and when toddlers put soil and foreign objects into their mouths.

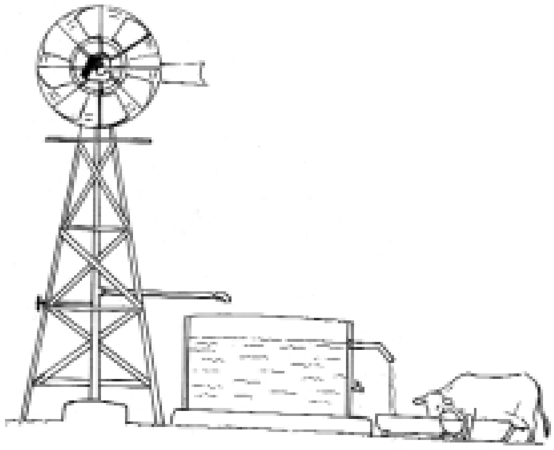
Water that has been contaminated by animal faeces can be harmful to health when used for drinking purposes, and this can result in diarrhoea, intestinal worm infestations, or any of a number of other infections. Water that has been contaminated by animal wastes can also be toxic (poisonous) or have a bad taste and smell.

Pathogens from faecal waste can be carried into soil with percolating water. In most settings groundwater is protected by the soil zone and a zone of aeration. In aerated, relatively dry soil conditions, pathogens are normally rapidly removed by the soil. In wet soil conditions and with sufficient nutrients, pathogens can survive for many days. Their survival depends on the presence of nutrients and water, and the absence of natural enemies. Nitrates, phosphates, potassium and other nutrients as well as moisture are needed by most types of pathogens to stay alive. However, viruses have been found to survive for long periods outside their host (e.g. humans), although they do not multiply in the sub-surface environment. Once in groundwater, pathogens can remain alive for up to 50 days, and in some situations can travel more than one kilometre in that time.

Drinking water infected with pathogens may induce severe health effects in users. The most common symptoms of pathogen ingestion are diarrhoea, vomiting, and cramps. People with severely weakened immune systems (that is, severely immuno-compromised) are likely to have more severe and more persistent symptoms than healthy individuals. Individuals who are severely immuno-compromised include those who are infected with HIV / AIDS, cancer and transplant patients taking immuno-suppressive drugs, and people born with a weakened immune system.

Research shows that the rate at which germs and viruses' die-off is much higher in the unsaturated soils above groundwater than in the groundwater. The greater the depth of unsaturated soil below a contaminant source, the more protected the underlying groundwater is likely to be.

The ability of germs to move through soils is dependent on the filtration capability of the soils. Fine silty soils are far better at removing germs than coarse sandy soils. The ability of viruses to move through unsaturated soils is dependent mostly on the adsorption capacity of the soils. Clay soils have a greater adsorption capacity than silty soils, and silty soils have a greater adsorption capacity than sandy soils.



When faecal wastes and urine decompose, nutrients in the form of ammonia, nitrates and phosphates are formed. Ammonia and phosphates are readily bound by soils, while nitrates remain mobile. As a result nitrates represent a significant threat to groundwater resources. Hand-dug wells that tap shallow aquifers are highly vulnerable to nitrate contamination in areas with high animal (livestock) concentrations. The nitrate contamination risk is normally lower for boreholes that tap deeper, confined aquifers, where anoxic conditions usually exist. High nitrate concentrations in drinking water can lead to short-term health impact, and have been linked to infantile cyanosis in bottle-fed babies and to related health problems in cattle.

Nitrates in drinking water are difficult to treat, and blending with low nitrate concentration water is the only viable option in cases where nitrate concentrations exceed the prescribed health limits.

Guidelines

For groundwater protection it is important that faecal material does not collect in one area, that it does not remain there and fail to dry out (that is, it remains or becomes moist), and that it does not come into contact with water.

- Do not allow concentrated animal wastes to come anywhere near a borehole, well or spring.
- Do not allow concentrated animal wastes to be disposed of, or stored, upslope of a borehole, well or spring.
- Do not allow any animal wastes to come into direct contact with surface water or groundwater.
- Do not allow liquids from animal wastes, or runoff or wash-water contaminated by animal wastes, to come close to any borehole, well, or spring.
- Do not allow standing water (e.g. a puddle), accessible to stock, to be located any where close to a borehole, well or spring.
- Animal manure, runoff water contaminated by manure, or wastewater from any manure storage area should not be allowed to gain access to a sinkhole, a borehole, a well, a spring, exposed fractured bedrock, a mine, a quarry or a storm water channel.

- When choosing a site for an animal kraal or livestock watering point:
  - Choose areas that do not have a shallow water table and that do not or will not contain stagnant water.
  - Choose areas that are not close to a borehole, well, spring, quarry, sinkhole, or mine.
  - Choose areas that are not upslope of a borehole, a well, a spring, a sinkhole, a mine, a quarry, exposed fractured bedrock, or a storm water channel.
  - Choose areas with low permeability soils.
  - Avoid areas with coarse sands, or gravel or areas underlain by fissured bedrock.
  - Construct rainfall runoff diversion ditches upslope and down-slope of kraals and watering points. The upslope diversion ditches are to lead runoff water away from the kraal, and the downslope ditches should divert contaminated runoff to a treatment facility such as an oxidation pond (the oxidation pond should be fenced off, and the inner pond surface properly sealed to help prevent contamination of groundwater).
  - Stock dipping tanks must be located far away and not upslope of any borehole, well, spring, sinkhole, mine, quarry, exposed fractured bedrock, or storm water channel. Location of stock dipping facilities requires the attention of a specialist.
  - Stock dipping tanks should be located over impermeable soils, and the seasonal high water table should be at least 3 metres (in impermeable soils) below the ground at the base of the tank.

2 Tools for dealing with the contamination threat

The tools presented in the following sections are meant to guide decision makers on the most appropriate actions to protect groundwater against potential contamination from animal kraals, stock watering points and dipping tanks. These tools take the form of checklists, flowcharts and decision charts.

Checklists

The checklists presented here are intended to help the decision maker to consider activities that may impact groundwater quality, and physical conditions that increase the likelihood of groundwater contamination. They are:

- **Checklist 1:** ***Sites used or proposed as animal kraals and animal watering points***
- **Checklist 2:** ***Sites used or proposed as animal dipping sites***.

The checklists contain questions, with a choice of answers, as well as attached recommendations on the most appropriate course of action to protect a groundwater resource. They serve as a first step to guide decision makers on the suitability of sites such as animal kraals and stock watering points. Questions presented by the checklists should be answered before moving to the **Flowchart: On-Site Test**, though the user may choose to move between sections where necessary. The questions are numbered, with options of possible answers (YES, NO or UNSURE). Tick the most appropriate box or block as you proceed through the checklist. The complete checklist should be answered, irrespective of whether an answer recommends a particular course of action. The user may choose to revisit and / or redo this questionnaire after completion of one or both the flowcharts.

If the site is currently being used or else is intended to be used as an animal kraal or watering point, the questions in **Checklist 1** should be answered. If the site is being used or else is intended to be used for the dipping of animals, the questions in **Checklist 2** should be answered.

Recommendations on an appropriate course of action and occasional references to other sections of this document series are presented next to the YES tick box. In most instances a YES answer would indicate the need to consult a specialist (an environmental waste management expert, hydrogeologist or toxicologist) on the suitability of the site. In the box for COMMENTS the reader should provide background on how a decision on the most appropriate answer to the question was arrived at and provide reference to supporting documents (if available). Justification of the answer given may include personal observation, or else indicate that the results were obtained through a flowchart.

Flowchart - On-site Test

This section presents the user with an on-site test sheet in the form of a flowchart, that serves to help the user judge the existence and depth to the seasonal high water table, from inspecting a pit dug at the site being evaluated. The flowchart ends in advice to the decision maker and gives further directions.

Set-back Distance Charts

Decision makers are also referred to the set-back distance charts for animal kraals and / or watering points. There are three decision charts, applicable only for animal kraals and watering points, for assessing setback distances from boreholes and wells that are equipped with motorised pumps:

- **Chart DML**: light contaminant load - for deep unconfined aquifers with boreholes and wells fitted with motorised pumps.

- **Chart S&DMH**: heavy contaminant load - for shallow & deep unconfined aquifers with boreholes and wells fitted with motorised pumps.

- **Chart SML**: light contaminant load - for shallow unconfined aquifers with boreholes and wells fitted with motorised pumps.

For animal kraals and stock watering points, heavy loading is applicable to sites where there is significant manure build-up, or where manure remains moist because of excessive animal numbers or because excess moisture is introduced as result of spillages at a watering point, or the result of rainfall, etc. In the above cases **Chart S&DMH** will be applicable.

In order to choose the applicable decision chart, further information on the depth to the water table is needed. If the depth to the expected highest seasonal water table is less than or equal to 10 metres, the aquifer is classified as a shallow aquifer. Otherwise it is a deep aquifer.

Checklist 1:
Sites used or proposed as animal kraals and animal watering points

Checklist 1: Sites used or proposed as animal kraals and animal watering points

Questions	Yes	No	Unsure	Comment
1 Does the seasonal high groundwater table come to within 2 metres of the ground surface?	☐ Groundwater contamination is more likely in high water table areas (especially in highly permeable soils). Steps should be taken to relocate the activity site to a more favourable location. Check the high seasonal water table. A specialist should be consulted on appropriate locations.	☐	☐ See the **Flowchart: On-site Test**, or obtain water level depths from any boreholes / wells in the vicinity, or consult a specialist, to establish whether a high water table exists in the area.	
2 Does the slope of the terrain result in, or make rapid surface runoff and erosion likely?	☐ Relatively steep slopes may result in the rapid transport of contaminants to a surface water body or to a landscape depression, from where it can enter groundwater resources. A specialist should be consulted.	☐	☐ The Feedlot Association recommends a ground slope of less than 6^{o} for feedlots. See the runoff guidelines for information.	
3 Does the edge of the animal kraal or watering point occur close to the bore-hole, well, spring or surface water source being used for domestic supply?	☐ Where water sources and animal kraals or watering points occur in close proximity, the possibility that the water source may be contaminated is high. Consider relocationg the animal kraal or watering point and test for water pollution. Consult a specialist.	☐	☐ See the appropriate **Set-back Distance Decision Chart** for guidance on the appropriate setback distance and / or potentially suitable protective measures for a particular set-back distance.	
4 Is the animal kraal or watering point upslope of a borehole, well or spring (including disused boreholes or wells)?	☐ Surface runoff and down slope seepage has the potential to contaminate any water sources located down slope. Consult a specialist.	☐	☐ See the appropriate **Set-back Distance Decision Chart** for guidance on the appropriate setback distance and / or potentially suitable protective measures for a particular set-back distance.	
5 Is the site underlain by fractured or broken bedrock, deep gravels or deep sandy soils?	☐ Highly permeable soils like sands and gravel, and fractured or fissured bedrock increase the likelihood of contaminants impacting the groundwater resources (especially in areas with high water tables). A specialist should be consulted on the suitability of the site.	☐	☐ See the **Introduction to Groundwater Protection** document (part of this series) for a background to aquifer types.	
6 Is part or all of the topsoil removed during the removal of manure?	☐ The topsoil layer is an important zone of microbial activity, which plays an important role in the protection of groundwater by killing off pathogens and by removing some of the nitrates from infiltrating contaminated water. Ensure that the topsoil layer remains intact when removing manure.	☐	☐	
7 Is the site also used for the storage of manure?	☐ High concentrations of animal manure could have a significant impact on the quality of water resources. Make sure that appropriate water resource protection measures are in place, such as ensuring that stored manure remains dry.	☐	☐	
8 Does runoff from the kraal, watering point or stock holding area flow towards a river / stream or a flow channel, or to a water source (e.g. dam) or does it come into near a borehole, well or spring?	☐ It is important that runoff contaminated with pathogens and nutrients (e.g. nitrates) be prevented from entering the water resource. It should instead be directed to an oxidation pond or treatment facility. Consult a specialist.	☐	☐	

Checklist 2:
Sites used or proposed as animal dipping sites

Checklist 2: Sites used or proposed as animal dipping sites

Questions	Yes	No	Unsure	Comment
1 Does the dipping occur in a unlined pit or excavation?	☐ It is much easier for pollution to enter the sub-surface where dipping occurs in a pit or excavation. Even if dipping fluid is spilled, bacteria in the topsoil layer have the ability to break down some of the organic based compounds, which reduces the impact to such pollution on the groundwater resource. Make sure that dipping occurs above ground. Consult a specialist.	☐	☐	
2 Does the seasonal high groundwater table come to within 2 metres of the ground surface?	☐ Groundwater contamination is more likely in high water table areas (especially in high permeable soils). Steps should be taken to relocate the activity site to a more favourable location. Check the high seasonal water table. A specialist should be consulted on appropriate locations.	☐	☐ See the **Flowchart: On-site Test** on how to establish whether a seasonal high water table exists at the site, or else obtain water level depths from any borehole / wells in the vicinity, or consult a specialist.	
3 Does the edge of the dipping site occur close to, or upslope of, a borehole, well or spring or a surface water source being used for domestic supply?	☐ The poisons that are used in animal dip can be extremely harmful to aquatic organisms, to animals and to humans if they were to enter a natural water source or into a water supply. Consider relocating the dipping facilities and test the water source(s) for contamination. A specialist should be consulted.	☐	☐ Seek the advice of a geohydrologist and / or a toxicologist.	
4 Is the dipping fluid disposed close to a surface water body, spring, well or borehole (including disused wells and boreholes)?	☐ The disposal of dipping fluid should occur in a responsible manner (e.g. at a site designated for this purpose, like a hazardous waste disposal site). This acitivity should cease immediately. If dumping has occurred, a specialist should be consulted and the impact on the water resource assessed.	☐	☐	
5 Is the site underlain by fractured or broken bedrock or gravels or coarse sandy soils?	☐ Highly permeable soils like sands and gravel, and fractured and fissured bedrock, increase the likelihood of toxic contaminants impacting groundwater resources, (especially in areas with high water tables). A specialist should be consulted on the suitability of the site.	☐	☐ See the **Introduction to Groundwater Protection** document (part of this series) for a background to aquifer types.	
6 Does the slope of the terrain result in, or make rapid surface runoff and erosion likely?	☐ Relatively steep slopes may result in the rapid transport of contaminants to the surface water body or to a landscape depression, from where it can enter groundwater resources. A specialist should be consulted.	☐	☐ The Feedlot Association recommends a slope of less than 6 deg. for the location of feed-lots. See the runoff management guidelines for more information.	
7 Does any area of ecological significance, like a wetland or river system, occur fairly close to the dipping tank or storage facility?	☐ Areas of ecological significance may host migratory birds or serve as habitats for endemic and / or endangered animals. Consult a specialist (e.g.a toxicologist).	☐	☐ Consult a specialist.	
8 Does runoff from the site flow towards a river / stream or a flow channel, or to a water source (e.g. dam) or does it come into close proximity with a borehole, well or spring?	☐ It is important that runoff contaminated with pesticides be prevented from entering a water resource. It should instead be directed to a specially constructed soak-away or treatment facility. See the runoff management guidelines. Consult a specialist.	☐	☐ See the runoff management guidelines for this series. Consult a specialist.	

Flowchart: On-site Test for Animal Kraals and Watering Points

Flowchart: On-site Test for Animal Kraals and Watering Points

Critical Components
- Geological formation
- Depth to water table
- Waste load (i.e. number of cattle / area)
- Topography (i.e. does water and / or waste accumulate at one point; flow to a water source?)

1 Make a pit or excavation of at lease 2m deep in the area of the cattle kraal, feedlot or feeding / watering point.
2 Note whether there is any seepage, wet soil, or standing water in the pit during excavation work.
3 Note changes in the texture and colour of the soil profile.

Pit is dry

Wet season

Indications are that the depth to the seasonal high water table is more than 2m.

Dry season

Consider that the water table will be higher at the end of the wet season. If it is not possible to make a reliable judgement on the height to which the water table rises in the dry season, the excavation test should be repeated in the wet season.

Pit is wet

Wet season

Under permeable* soils and rock conditions this may be as a result of a rising water table, while in areas underlain by low permeability soil and rock this may be the result of seepage from rainwater infiltration.

Dry season

Groundwater occurs near the surface. This may be because the site is an area of groundwater discharge (spring or seepage area) or occurs close to and level with a surface water feature (e.g. river, lake, wetland, vlei).

* The rate at which water drains away reflects the permeability of the soil. Permeable soils are typically sandy or gravelly. Impermeable soils typically have a high clay content. The relative clay content of soil is often reflected by its ability to be formed into a small ball.

BOX 1

To help protect groundwater from contamination as a result of high livestock concentrations, a separation of at least 2m in clay soils is recommended between the surface and the water table at its seasonal highest level.

At least 5m is recommended where the ground is highly permeable from the surface down to the water table. Where such conditions are suspected, the excavation pit should be deepened, if possible, in order to establish (i) the permeable nature of the ground deeper down, (ii) whether fissured or fractured bedrock is present, and (iii) that the water table does not rise to within at least 5 metres of the surface.

If it is not feasible to dig deeper than two metres, there may be other ways of confirming the depth of the water table, such as by investigating water levels in nearby boreholes, wells and quarries.

Please note that even for deep water tables under permeable soil / rock conditions, the potential for significant nitrate contamination is possible where heavy nutrient loads exist. If water flows into the pit and starts to pond, then repeat the flowchart test for a wet pit.

If the pit is dry, proceed to BOX 2

BOX 2

If the excavation is dry, the side walls of the pit should be examined. Note should be taken of colour changes in the profile that are not related to soil mineralogy or texture, as this probably indicates the level to which the water table rises at the end of the wet season. Take photographs and take samples of the soil in the pit walls for expert interpretation.

The potential for pathogenic and nutrient contamination of water sources may be limited by ensuring that rainfall runoff does not enter locations where large volumes of manure exist, through the construction of diversion ditches and berms upslope and down slope of such locations. The upslope ditches and berms should lead runoff water away from contaminated sites, and the down slopes ditches and berms should divert contaminated runoff to a treatment facility such as a sealed oxidation pond.

Further protective measures include the erection of roofing over areas where large volumes of manure are produced, and the manual removal of manure to a dry storage facility.

BOX 3

Shallow groundwater in areas where the ground is highly permeable from the surface down to the water table is vulnerable to contamination from sites supporting large numbers of livestock. Decision makers may wish to validate whether the water observed in the excavation does represent the actual water table. This can be done by referring to the hydrogeological reports, and / or by checking water levels in nearby boreholes and / or excavations (such as quarries). If there is still uncertainty, a specialist should be consulted. Seepage water may not represent a threat to a groundwater resource.

The potential for pathogenic and nutrient contamination of water sources may be limited by ensuring that rainfall runoff does not enter locations where large volumes of manure exist, through the construction of diversion ditches and berms upslope and down slope of such locations. The upslope ditches and berms should lead runoff water away from contaminated sites, and the down slope ditches and berms should divert contaminated runoff to a treatment facility such as a constructed (sealed) pond.

Further protective measure include the erection of roofing over areas where large volumes of manure are produced, covering manure storage piles with soil to help prevent rainfall infiltration, and / or the removal of manure piles to a dry storage facility.

BOX 4

High water table areas are generally not suited for the location of large numbers of livestock. The short distance from the surface of the water table means pollution can get easy access to the groundwater resource, with little or no natural removal of contaminants.

The possibility of moving the livestock gathering site to a location where it would represent less of a threat to water resources should be investigated. Consult a hydrogeologist or suitably qualified engineer on this.

The potential for pathogenic and nutrient contamination of groundwater resources may be limited by ensuring that rainfall runoff does not enter locations where large volumes of manure exist, through the construction of diversion ditches and berms upslope and down slope of such locations.

The upslope ditches and berms should lead runoff water away from contaminated sites, and the down slope ditches and berms should divert contaminated runoff to a treatment facility such as a sealed oxidation pond.

Further protective measures include the erection of roofing over areas where large volumes of manure are produced, covering manure storage piles with a soil cover to help prevent rainfall infiltration, and / or the removal of manure piles to a dry storage facility.

Set-Back Distance Charts for Animal Kraals and Watering Points:

1. **Chart DML**
2. **Chart S&DMH**
3. **Chart SML**

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Protecting Groundwater from Contamination by

Burial sites

TOOLKIT for WATER SERVICES: Number 3.4.2

This document provides guidelines and tools to help protect groundwater from contamination. It will be useful to Environmental Health Officers, environmental planners, health and hygiene educators, sanitation planners and pollution control officers working in Water Services Authorities, Water Services Providers, the Department of Health, the Department of Water Affairs and Forestry and Catchment Management Agencies.

Protecting Groundwater from Contamination by Burial Sites

Published by
Department of Water Affairs and Forestry
Directorate: Information Programmes
Private Bag X313
PRETORIA 0001
Republic of South Africa
Tel: (012) 336 7500

Implemented by
CSIR

Written by
Irené Saayman

Editing
Anthea Josias and Kerry Harris

Artwork
Vusi Malindi

Layout and design
Gill McDowell

Inputs
Pannie Engelbrecht, Gideon Tredoux, Freeternity Rusinga
Kerry O'H Murphy

Burial sites

1 Background to the contamination threat

Introduction

The natural decay of buried human and animal corpses can have a negative impact on groundwater, especially where mass burial sites are concerned. Contamination occurs as a result of organic residues and pathogens (germs and viruses) that are generated during the process of decay. Use of this contaminated water for drinking, preparing food and washing can be harmful to health, and can cause diseases such as diarrhoea, typhoid fever and cholera.

Groundwater vulnerability

Pathogens (germs and viruses) from decomposing corpses can move through the soil and they have the ability to survive in the soil for many days. If water is available, say from rainfall, the pathogens can be transported into groundwater.

Pathogens move through soils and rock fissures on suspended particles in water. Although normally associated with a host, germs are able to survive and even multiply (grow in numbers) in the sub-surface environment (soils and rock) if suitable conditions are present. Viruses have been found to survive for long periods in the sub-surface environment, although they do not multiply there.

The sub-surface environment is not the natural place for pathogens to live, and eventually they die there. In the case of enteric bacteria (e.g. cholera), die-off results from factors such as starvation, competition from other microbes, or predation. Viruses on the other hand, can survive without food. Viruses are rendered harmless by becoming bound to soil particles, by being desiccated (dried out) or by being attacked by enzymes produced by soil microbes.

The ability of bacteria to move through soils is dependent on the filtration capability of the soils. Fine silty soils are far better at removing bacteria than coarse sandy soils. The ability of viruses to move through unsaturated soils is dependent mostly on the sorption capacity of the soils: the greater the sorption capacity of the soil, the more trapped the viruses are in the soil. Clay soils have a greater sorption capacity than silty soils. Silty soils have a greater sorption capacity than sandy soils.

Research indicates that pathogen die-off rates are higher in unsaturated soils above groundwater than in groundwater. The greater the depth of unsaturated soil below a contaminant source, the more protected the underlying groundwater is likely to be. Groundwater in areas with high rainfall and shallow water tables is relatively more at risk of contamination (i.e. groundwater is more vulnerable to contamination) from burial sites. Groundwater vulnerability is also high in fractured rock and other high permeability environments, such as sandy or gravelly soils. The risk of groundwater being contaminated is increased when:

- Burial occurs near the water table or next to a water source. This does not give enough time for the geological sub-surface material to remove possible contaminants before they reach the water table or the water source.
- Burial is performed without coffins. Coffins act as a barrier to contamination, helping to prevent (or slow down) the escape of contaminants into the surrounding soils.
- High loading occurs. Mass burial sites, for example, produce a large quantity of contaminants, greatly increasing the risk of groundwater contamination.

Possible negative effects on human health

Where germs, viruses and other harmful substances (such as nitrates) do manage to pass into groundwater, this renders the water unsafe and potentially harmful to the health of users. Typical water borne diseases include diarrhoea, typhoid fever and cholera.

Guidelines

When selecting a site for a cemetery or animal burial ground:

- Choose an area with deep, low permeability soils.
- Ensure that seepage from decaying corpses will not enter the water table directly.

Avoid areas:

- That contain open surface water.
- Where shallow or emergent groundwater exists (albeit seasonally).
- That are located up slope, close to a water source.
- In or adjacent to recharge areas for important aquifers.
- In dips or hollows where surface water could collect or stormwater flows could occur.
- Below the 1-in-50 year floodline of a river.
- Close to wetlands, vleis, pans, estuaries and floodplains.
- That are unstable, such as fault zones, seismic zones, dolomitic or karst areas where subsidence and / or sinkholes are likely to occur.
- With shallow soils over bedrock or with exposed bedrock.
- With coarse sands or gravel.
- Where soil collapsing and sliding could occur, such as steep embankments and steep slopes where soil overlies sloping impermeable bedrock.
- In or near sensitive ecological areas.

2 Tools for dealing with the contamination threat

Decision aids in the form of checklists, a flowchart and setback distance decision charts are presented to guide decision makers on the most appropriate courses of action to follow.

Checklists

The checklists serve as a first step to guide decision makers on the suitability of sites for the burial of human and / or animal bodies. The checklists to be filled in are:

- **Checklist 1:** ***Site is currently being used for or proposed for human burial***
- **Checklist 2:** ***Site is currently being used for or proposed for the disposal of animal carcasses.***

The questions in the checklists should be answered before moving on to the **Flowchart: On-site Test**, though the user may choose to move between sections where necessary. The questions are numbered, with options of possible answers (YES, NO or UNSURE). Tick the most appropriate box as you proceed through the checklists.

In this way the checklist will serve as a "record of decision". The complete checklist should be answered, irrespective of whether an answer recommends a particular course of action. Recommendations on an appropriate course of action and occasional references to other sections of this document series are presented next to the YES tick box. In most instances a YES answer would indicate the need to consult a specialist (environmental engineer or hydrogeologist) on the suitability of the site for human and / or animal burial.

In the box for COMMENTS the reader should provide background on how a decision on the most appropriate answer was arrived at, and provide references to supporting documents (if available). Justification of the answer given may include personal observation, or the results obtained through the **Flowchart: On-site Test**. The user may choose to revisit and / or redo the checklists after completion of the **Flowchart: On-site Test**.

Flowchart - On-site Test

The **Flowchart: On-site Test** helps the user to determine whether the seasonal high water table level comes to within two or five metres of the ground surface. It is presented as one of the tools to help decision makers assess the suitability of sites for activities that may impact groundwater resources, and should also help broaden the decision maker's understanding of relevant geological and hydrogeological conditions at the site being evaluated.

Set-back Distance Charts

The **Set-back Distance Charts** provide decision makers with guidelines on the minimum set-back distances that should exist between a burial site and any community groundwater supply source. These supply sources typically include drilled boreholes, drilled tube wells, dug wells and springs. The decision charts are meant to provide a simplified, easy to follow guide on the suitability of sites for human and / or animal burial.

The hydrogeological settings evaluated are those that are typically exploited for water supply. These are: unconsolidated sedimentary deposits (silt, fine silty sand, medium sand and gravel), fractured hard rock environments and limestone. In these tables, only two depths to water table separation classes are considered: zero to ten metres below the burial pit base; and more than ten metres below the burial pit base (depth to water table).

There are three decision charts applicable to the guidelines for identifying suitable separation distances and associated protective measures:

- **Chart DML**: light contaminant load - for deep unconfined aquifers with boreholes and wells fitted with motorised pumps.

- **Chart S&DMH**: heavy contaminant load - for shallow and deep unconfined aquifers with boreholes and wells fitted with motorised pumps.

- **Chart SML**: light contaminant load - for shallow unconfined aquifers with boreholes and wells fitted with motorised pumps.

In relation to cemeteries, heavy loading is applicable to sites serving a community of approximately 3 000 (UNICEF, 2003) or more. For animal burial sites, heavy loading occurs when carcasses are buried *en masse* (e.g. where a number of stock, that have died at about the same time, are buried in close proximity to each other).

In these cases, **Chart S&DMH** will be applicable, assuming that the borehole or well used to supply water to a community is fitted with a motorised pump.

In order to use the appropriate decision chart, information on the depth to the water table from the base of the pit or excavation is needed. If the depth to the expected highest seasonal water table is less than or equal to 10 metres, the aquifer is classified as a shallow aquifer. Otherwise it is a deep aquifer.

Checklist 1:
Sites for the burial of human bodies

Checklist 1: Sites for the burial of human bodies

Questions	Yes	No	Unsure	Comment
1 Will the site also be used for the burial of animal carcasses?	☐ There are cultural reasons why animal and human burial should not occur at the same site. Exclude this activity from the site or consult a specialist.	☐	☐	
2 Will the site serve as a mass burial site in the event of a natural disaster or catastrophe?	☐ Local government health departments are responsible for the development of crisis contingency plans. These should include opions for the burial or cremation of human bodies. Mass burial may be one of the options considered. A specialist should ideally be consulted on sites selected for this purpose.	☐	☐ Consult a local Emergency Response Plan.	
3 Does the seasonal high groundwater table come to within 2 m of the ground surface?	☐ Graves should ideally be at least 2m deep. A shallow water table makes excavation to such depths difficult and often unhygienic. The burial of bodies in water also increases the chances that the local water resource will become contaminated. Immediate steps should be taken to relocate the burial site to a more favourable location. A specialist should be consulted.	☐	☐ See the **Flowchart: On-site Test** sheet on how to establish whether the water table comes to within 2m of the surface.	
4 Does the seasonal high groundwater table come to within 2 m of the base of grave excavations?	☐ There should be a separation of at least 2 metres between the base of the excavation and the water table. A short distance to the water table increases the risk of groundwater contamination. Moving the burial site to a more favourable location should be considered. A specialist should be consulted.	☐	☐ See the **Flowchart: On-site Test** sheet on how to establish whether the water table comes to within 2m of the surface.	
5 Does the slope of the terrain and / or the depth to bedrock restrict the depth of burial, or result in cover material being in short supply?	☐ Shallow burial depths increase the likelihood of problems at the surface (e.g. escape of odours), while steep slopes (>6 degrees) may be eroded. A specialist should be consulted.	☐	☐ Sites with a slope of more than 6 degrees are considered unsuitable for the burial of human remains (Fisher, 2001).	
6 Does the edge of the cemetery / burial site occur close to a borehole, well, or spring being used for domestic supply?	☐ Where groundwater abstraction points and burial sites occur in close proximity, the potential for contamination of the resource is likely to be high. Consult the separation distance charts, or else consult a specialist.	☐	☐ See the **Set--back Distance Decision Charts** for guidance on the appropriate setback distance.	
7 Does the burial occur into or onto bedrock, in ground consisting of gravels or coarse sandy soils, on a dike or in a fault zone?	☐ Ease of access for contaminants to aquifers in highly permeable soils like sands and gravel or in fractures and faults, increases the potential for groundwater contamination. A specialist should be consulted on the suitability of the burial site.	☐	☐ See **Introduction to Groundwater Protection** for a background to aquifer types.	
8 Is the burial site / cemetery upslope of a borehole, well or spring (including disused boreholes or wells)?	☐ Consult the separation distance decision charts, or else consult a specialist.	☐	☐ See the **Set--back Distance Decision Charts** for guidance on the appropriate setback distance.	

Checklist 2:
Sites for the burial of animal carcasses

Checklist 2: Sites for the burial of animal carcasses

Questions	Yes	No	Unsure	Comment
1 Does the disposal of animal carcasses occur at, or close to, a human burial site or cemetery?	☐ There are cultural reasons why animal and human burial should not occur at the same site or close to each other. Exclude this activity from the same site or consult a specialist.	☐	☐	
2 Is the mass dumping of animal carcasses practised at the site?	☐ The simultaneous dumping of carcasses increases the likelihood of groundwater pollution. A specialist should be consulted on the suitability of the site.	☐	☐ The dumping of 5 or more cattle carcasses in one pit, within a period of one week, is considered high. A similar mass / volume for other animals is also considered high.	
3 Does the seasonal high groundwater table come to within 2m of the base of the burial site?	☐ A shallow water table increases the risk of groundwater pollution. There should also be a separation of at least 2m between the base of the excavation and the water table. The short distance to the water table increases the risk of groundwater contamination. Moving the burial site to a more favourable location should be considered. Consult a specialist.	☐	☐ See the **Flowchart: On-site Test** for guidelines on how to establish whether the water table comes to within 2m of the surface.	
4 Does the slope of the terrain and / or the depth to bedrock restrict the depth of burial, or is cover material in short supply?	☐ Shallow burial depths increase the likelihood of problems at the surface (e.g. escape of odours, collapsing soils), while steep slopes (>6 degrees) may become eroded. Consult a specialist.	☐	☐ Sites with a slope of more than 6 degrees are considered unsuitable for the burial of animal carcasses.	
5 Does the edge of the animal burial site occur close to a borehole or surface water source being used for domestic water supply?	☐ Where water sources and burial sites occur in close proximity, there is a possibility that the water source may be contaminated. For the groundwater abstraction points, consult the separation distance decision charts, or consult a specialist.	☐	☐ See the section on **Set-back Distance Decision Tables** for guidance on the appropriate setback distance.	
6 Is the site used for the disposal of other kinds of waste (e.g. domestic waste)?	☐ For guidance on the management of waste disposal sites and the appropriate disposal of waste, the user is referred to the guidelines on Waste Disposal. Consult a specialist.	☐	☐	
7 Is the site used for diposing liquids (e.g. vehicle oil)?	☐ Liquid waste should only be disposed of at sites that have been evaluated by a specialist, and approved for the disposal of liquid waste. For guidance on the management of liquids, the user is referred to the guideline documents for Runoff water and Informal workshops. Consult a specialist.	☐	☐	
8 Does burial occur into or onto bedrock, or ground consisting of gravels or coarse sandy soils?	☐ Ease of access for contaminants to aquifers in highly permeable soils like sands and gravel or in fractures and faults, increases the potential for groundwater contamination. A specialist should be consulted on the suitability of the site.	☐	☐ See **Introduction to Groundwater Protection** for a background to aquifer types.	
9 Does the burial of animal carcasses occur upslope of a borehole, well or spring (including disused boreholes or wells), or close to a borehole, well, or spring used for domestic supply purposes?	☐ Please see the separation distance matrices (decision charts), or else consult a specialist.	☐	☐ Obtain a hydrocensus report of the area or else consider undertaking a hydrocensus.	

Flowchart: On-site Test for Burial Sites

Flowchart: On-site for Burial Sites (for the burial of human corpses or animal carcasses)

Critical Components
- Depth of burial
- Geological formation
- Depth to water table
- Volume of burial material
- Type of cover material used
- Climate

* The rate at which water drains away reflects the permeability of the soil. Permeable soils are typically sandy or gravelly. Impermeable soils typically have a high clay content. The relative clay content of soil is often reflected by its ability to be formed into a small ball.

1 Examine the excavation pit or open grave to establish hydrogeological conditions.
2 Select, for examination purposes, an excavation that is on the topographic low end of the site.
3 Where existing pits are dry, dig a test pit of 2m deeper than the others, until water or bedrock is reached, leave for a few hours, then examine it.

Pit is dry

- Wet season → The water table does not rise to the base of the excavation depth. → BOX 1
- Dry season → Consider repeating the examination during the wet season.

  The input of a soil specialist or hydrogeologist can be used to examine the walls of the pit for signs of a high water table. This is usually evident from a change in colour of soil inundated by the seasonal high water table.

Pit is wet

- Wet season
  - Impermeable* soils: Runoff results in the accumulation of water in open graves. → BOX 2
  - Permeable* soils: The local groundwater table is shallow. → BOX 3
- Dry season → The local groundwater table is shallow. → BOX 3

BOX 1
The vulnerability of water resources to contamination from the decay of buried human or animal remains depends on the site specific conditions, like the depth to the water table and topography.
A separation of at least 2m is recommended between the base of burial pits and the seasonal high water table.
For heavily loaded sites (such as a mass burial site for animal corpses), a minimum separation depth of 5m below the pits n permeable environments is recommended.

BOX 2
Ensure that rainwater does not accumulate in open graves. This is best achieved by ensuring that graves are not dug and left open for too long during the rainy season, and by directing surface runoff away from open graves.

BOX 3
High water table areas should ideally not be used as burial sites.
A high water table at the end of the rainy season limits the depth of burial, and may have health implications. Exposure to water hastens the decay of coffins and facilitates the movement of contaminants into the groundwater.
Investigate the possibility of closing the burial site and establishing a new one in an area with a deeper water table.
Consult a hydrogeologist or suitably qualified engineer for advice.

Set-Back Distance Charts for Burial Sites:

1. **Chart DML**
2. **Chart S&DMH**
3. **Chart SML**

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Protecting Groundwater
from Contamination by

Informal vehicle servicing, spray painting and parts washing facilities

TOOLKIT for WATER SERVICES: Number 3.4.3

This document provides guidelines and tools to help protect groundwater from contamination. It will be useful to Environmental Health Officers, environmental planners, health and hygiene educators, sanitation planners and pollution control officers working in Water Services Authorities, Water Services Providers, the Department of Health, the Department of Water Affairs and Forestry and Catchment Management Agencies.

Protecting Groundwater from Contamination by Informal Vehicle Servicing, Spray Painting and Parts Washing Facilities

Published by
Department of Water Affairs and Forestry
Directorate: Information Programmes
Private Bag X313
PRETORIA 0001
Republic of South Africa
Tel: (012) 336 7500

Implemented by
CSIR

Written by
Alan Hon

Editing
Anthea Josias and Kerry Harris

Artwork
Vusi Malindi

Layout and design
Gill McDowell

Inputs
Kerry O'H Murphy

Informal vehicle servicing, spray painting and parts washing facilities

1 Background to the contamination threat

Introduction

Workshops for informal vehicle servicing, spray painting and parts washing have the potential to contaminate groundwater and surface water resources in the vicinity. Where these activities occur in close proximity to water supply boreholes / wells, and where the boreholes and wells are not correctly protected at the well head, the threat of groundwater pollution increases.

These workshops often use and store oils, fuel, solvents, paints, and cleansing agents (e.g. detergents). Oils, fuels, solvents and cleansing agents are generally made from petroleum or coal. Some solvents, oils and cleansing agents are made from plants (e.g. thinners, methylated spirits and brake fluid). Most solvents evaporate easily in air, but oils are generally not soluble in water. Examples of commonly used oils, fuels and solvents are paraffin, engine oil, petrol, diesel, turpentine and thinners. Used solvents and cleansing agents, when spilled onto the ground, are potentially able to penetrate deeply into the ground and to carry contaminants down with them.

Most oils, fuels and solvents have a negative effect on humans, animals and plants.

Groundwater vulnerability

The risk of groundwater contamination depends on the type of liquid and the amount spilled or disposed of, amongst other factors. Thicker liquids will remain at the ground surface longer, whereas thinner liquids will seep rapidly into the ground.

Liquids tend to move more slowly through loamy, silty or clayey soils than through sandy or gravelly soils. When spilled onto sands, gravels and fractured rock, less dense petroleum-based liquids, such as engine oil, will move slowly down to groundwater level and then spread out on the groundwater surface. Over time, bacteria will destroy some of these liquids, while some will dissolve into the groundwater (some of these liquids are partially soluble in water). Some denser petroleum-based liquids will move further downwards into the groundwater until they meet an impermeable barrier, such as a horizontal layer of clay. Petroleum-based liquids are more easily degraded (i.e. destroyed) in aerated soils than in groundwater.

The risk of well water or borehole water being contaminated is increased when:

- Petroleum-based liquids, solvents, brake fluids, used wash-water, and chemical additives are disposed of near or in the water table, or near or in a water source. This reduces the time in which the soils and the geological sub-surface material can help remove potential contaminants before they reach the groundwater.
- Petroleum-based liquids, solvents, brake fluids, used wash-water, and chemical additives are disposed of on highly permeable soils, or where fractured bedrock lies close to the ground surface. These conditions shorten the travel time to groundwater.
- There is high loading over a relatively small area. The greater the volume of contaminants disposed of over a small area, the greater the quantity of contaminants that are likely to move down to the groundwater. There will also be limited treatment of contaminants as a result of overloaded conditions and lack of aeration, so the contaminants will not have been reduced much by the time they reach the groundwater.
- The threat of groundwater contamination from spillage of contaminants in rural communities is generally small. However, exceptions include informal repair workshops and where borehole / well pumps are equipped with engines.
- In cases where borehole / well pumps are equipped with engines, a potential groundwater contamination threat occurs when used oil, fuel, brake fluid, radiator water, paint residues, solvents, cleaning fluids or used wash-water are disposed of, or spilled, onto the ground in the immediate vicinity of the borehole or well. When servicing pump engines and servicing vehicles at informal vehicle repair workshops, the disposal of used engine oil presents a particular problem as it is usually disposed to ground. Used engine oil contains contaminants such as acids, additives, detergents and sometimes heavy metals and these can be carried down with the oil into groundwater.
- Spilled oil and diesel fuel presents a particular contamination risk when engines are used to pump groundwater. This is because oils and fuels are spilled or disposed of in a relatively small area over a long period of time. As these sites are located on, or in the immediate vicinity of a borehole or well, oils and fuels could easily reach the groundwater directly when the well or borehole is being pumped.

Impact on health

Many oils, fuels and solvents are potentially toxic (poisonous) or carcinogenic (causing cancer) to humans and animals if contaminated water is used for drinking purposes, or when strong fumes are breathed in. When spilled on vegetation, they can cause vegetation to die off. When spilled on the ground, oil and diesel can seal off soil pores so that the soil becomes impermeable, which prevents plant roots from breathing. This results in a die off of vegetation or no plant growth. Solvents spilled into streams can kill aquatic life.
Brake fluid, radiator water additives and engine oil additives are mostly toxic to humans, animals and plants, and some are corrosive (i.e. they eat into metals). Some petroleum products cause the water that they come into contact with to have a bad taste and smell.

Guidelines

For groundwater protection, every effort should be made to avoid disposal and spillage of oils, fuels, solvents, brake fluids, radiator water, cleansing agents and chemical additives in the following areas:

- Close to boreholes, well heads and springs.
- Where highly permeable soils and exposed bedrock exist.

The disposal and spillage of engine oil, fuels and solvents at informal (back-yard) workshops, and in motorised pump houses, should be prevented wherever possible. To reduce the likelihood of groundwater contamination as a result of oil spillage, individuals and companies should ensure that:

- They do not allow engine oil, fuels or solvents to be used or stored in the vicinity, or upslope, of a borehole, well head or spring, except where they are required for pumping purposes (for example, when filling the fuel tank of a diesel pump motor). If they are needed for pumping purposes, special protective measures should be in place.
- No workshops that handle oils, fuels, solvents, brake fluids, radiator water, cleansing agents and chemical additives should be located close to, or upslope of a borehole, well, or spring.
- Oils, fuels, solvents, brake fluids, radiator water, cleansing agents and chemicals should not be disposed of into pit latrines or into places where water can collect.
- In the case of engine-driven pumps care should be taken that no spilled fuel or oil lies on the floor of the pump house, or on the ground in its immediate vicinity. The source of such spillage should be located, and measures should be taken to prevent further spillage or leakage.
- If a site is needed for disposal of oils, fuels, solvents, brake fluids, radiator water, cleansing agents, chemicals (including paint) or batteries, it is important to consult a hydrogeologist and other specialists for advice. If an area is to be zoned for disposal of such wastes, the site should be treated as a landfill site and the Minimum requirements for waste disposal by landfill (DWAF, 1998) should be adhered to.

General protective measures for informal workshops

Where a vehicle servicing, parts washing and spray painting facility is unprotected from rain or else the floor of the facility is at risk of being inundated by runoff water from adjacent areas, the potential for contamination of both surface water and groundwater resources can be significantly increased.

It is important to ensure that rainfall and surface runoff from adjacent areas does not come into contact with oils, solvents and other potential contaminants, and that any contaminated water at a site does not present a contamination threat to groundwater or surface water resources. Precautionary measures include:

- Ensure that leakproof roofs adequately cover a service site.
- Ensure that lined diversion ditches and berms upslope of a site effectively lead uncontaminated runoff water away from site.
- Ensure that impermeable floors are designed to direct spilt liquids and oil towards a sealed sump.
- Ensure that liquids collected in the sump are not left there, but are transferred to storage containers for removal to, for example, a treatment facility.
- Where contaminated runoff could occur downslope of a service site, ensure that ditches or berms are in place on the downslope side to divert contaminated runoff to a lined treatment pond.

2 Tools for dealing with the contamination threat

Decision aids in the form of a checklist and flowcharts are presented to guide decision makers on the most appropriate courses of action to follow.

Checklist

The checklist is to be filled in is:

- **Checklist:** ***Sites used or proposed as informal vehicle servicing sites, or sites where solvents are regularly used in spray painting and solvents/detergents are regularly used for cleaning vehicles, engines and mechanical parts.***

The checklist asks some simple questions, as a first step to guide decision makers on the suitability of sites or practices for informal vehicle servicing, spray painting and parts washing. The questions are numbered, with options of possible answers (YES, NO or UNSURE). Tick the most appropriate box as you proceed through the checklist.

In this way, the checklist will serve as a "record of decision". The complete checklist should be answered, irrespective of whether an answer recommends a particular course of action. Recommendations on an appropriate course of action and occasional references to other sections of this document series are presented next to the YES tick box.

In most instances a YES answer would indicate the need to consult a specialist (waste management specialist or hydrogeologist) on the suitability of the informal vehicle servicing, spray painting and parts washing activities followed at the site. In the box for COMMENTS the reader should provide background on how a decision on the most appropriate answer to the question was arrived at. Justification of the answer given may include personal observation.

The questions should be answered before moving to the **Flowchart: On-site Test** sheet, though the user may choose to move between sections when necessary. The user may choose to revisit and / or redo this questionnaire after completion of the **Flowchart: On-site Test** sheets.

Flowcharts - On-site Test

The purpose of the flowcharts are to help the user judge the existence and depth to the seasonal high water table from inspecting a pit dug at the site being evaluated.
Two flowcharts are presented:

- **Flowchart 1: On-site Test** ***Informal vehicle servicing facilities***
- **Flowchart 2: On-Site Test** ***Parts washing and spray painting facilities***

The flowcharts end in advice to the decision maker and give further directions.

Checklist:
Sites used or proposed as informal vehicle servicing sites, or sites where solvents are regularly used in spray painting and solvents/detergents are regularly used for cleaning vehicles, engines and mechanical parts.

Checklist: Sites used or proposed as informal vehicle servicing, vehicle or engine cleaning or spray painting sites

Questions	Yes	No	Unsure	Comment
1 Does the seasonal high groundwater table come to within 2m of the ground surface?	☐ Groundwater pollution is more likely in high water table areas. Steps should be taken to relocate the activity site to a more favourable location. A specialist should be consulted on appropriate locations.	☐	☐ See the flowcharts **On-site Test 1** and **On-site Test 2** for information on how to establish the seasonal-high depth to the water table.	
2 Does the slope of the site or surrounding terrain result in rapid surface runoff, or does it make rapid surface runoff and erosion likely?	☐ Relatively steep slopes may result in the rapid transport of contaminants or contaminated surface soils in runoff to a surface water body or else to a landscape depression, quarry, borrow pit, borehole or well where they can enter the groundwater. A specialist should be consulted.	☐	☐ At no time should by-products from vehicle servicing (e.g. used oil, radiator fluid) be allowed to contaminate a drinking water source. See the runoff manangement guidelines for more information.	
3 Does informal vehicle servicing occur fairly close to a borehole, well, spring or surface water source being used for domestic supply?	☐ Where water sources and informal vehicle servicing occur in close proximity, contamination of a water source by vehicle serivicing by-products is possible. Consider relocating the vehicle servicing facility, especially if there are any leaking containers, areas used for disposing of fluid wastes, or contaminated soils at the site. Consult a specialist.	☐	☐ See the guidelines on how to conduct a hydrocensus.	
4 Is the vehicle servicing facility upslope of a borehole, well, spring (including disused boreholes or wells)?	☐ Surface runoff and contaminated seepage have the potential to pollute water sources located down slope of the facility, especially if there are any pits / trenches or areas used for disposing fluid wastes, and any leaking containers or containinated soils at the site. Test the water sources in question for containination. Consult a specialist.	☐	☐ See the guidelines on runoff management for more information.	
5 Is the site underlain by fractured / fissured bedrock, by gravels or coarse sandy soils?	☐ Highly permeable soils like sands and gravel, and the presence of fissues / fractures in shallow bedrock, increases the likelihood of contamination of groundwater by disposed or leaking vehicle servicing by-products. A specialist should be consulted on the suitability of the site.	☐	☐ See the **Introduction to Groundwater Protection** document for a background to aquifer types. Seek expert advice.	
6 Is part or all of the topsoil stained or discoloured in the area of the informal vehicle servicing facility?	☐ Continuous contamination of this soil layer by oils and solvents will lead to contamination of deeper soils and then the rest of the geology below. Regularly remove this contaminated soil layer, and replace with clean soil or absorbent material. Collect contaminated soils and materials in a storable container for later disposal.	☐	☐ Visit the site and take samples of any dis-coloured surface soils, especially where these smell of oils or chemicals, and seek expert advice.	
7 Are containers for new and / or used servicing fluids at the site showing signs of leaking, or are they stored in the open?	☐ Leaking or corroding storage facilities could have a negative impact on the quality of water resources. Make sure that appropriate water resource protection measures are in place at informal vehicle servicing storage facilities. See the "Why and What" part of these guidelines for information on the management of informal vehicle servicing facilities.	☐	☐ Visit the facility and take samples of any discoloured surface soild, especially where these smell of oils or chemicals, and seek expert advice.	
8 Is runoff from the vehicle servicing facility channelled or directed to flow into a stream or the area surrounding a spring, borehole or well?	☐ This practice should be stopped. Surface run-off from the site should instead be directed to a sump (a sealed pit) where contaminants can be separated off for later disposal. Consult a specialist.	☐	☐ See the guidelines on runoff management for more information.	

Flowchart 1: On-site Test for Informal Vehicle Servicing Facilities

Flowchart 1: On-site Test for Informal vehicle and servicing facilities

Critical Components
- Geological formation
- Depth to seasonal high water table
- Signs of spillage of oil, fuel, etc. (depth of discoloration)
- Topography (i.e. to determine if spilled liquids and / or rainfall are likely to accumulate on the site, flow rapidly off site, etc.)

1 Make a pit or excavation of at lease 2m deep in the area of the vehicle servicing, parts washing or panel beating site.
2 Note whether the water table is intersected during the excavation work.
3 Note changes in the texture and colour of the soil profile.

Pit is dry

Wet season

A depth of at least 2m to the seasonal high water table is required to help protect groundwater from contamination. → BOX 1

Dry season

Consider that the water table will be higher at the end of the wet season. If it is not possible to make a reliable judgement on the height to which the water table rises in the dry season, the excavation test should be repeated in the wet season. → BOX 2

Pit is wet

Wet season

Check to ensure that neither runoff nor subsoil seepage is entering the pit. If the gound is permeable, the wetness may be the result of a seasonal high groundwater table, while in areas underlain by low permeable* soils and rock this may an indication of interflow (subsurface seepage from rainwater infiltration). → BOX 3

Dry season

Groundwater is likely to occur near the surface. Check for supporting evidence, e.g. is the site next to a river, vlei or the coast, or near a groundwater seepage area (e.g. a spring)? Check water levels in any quarries, boreholes or wells in the area. → BOX 4

* The rate at which water drains away reflects the permeability of the soil. Permeable soils are typically sandy or gravelly. Impermeable soils typically have a high clay content. The relative clay content of soil is often reflected by its ability to be formed into a small ball.

BOX 1

To protect groundwater from pollution generated through spillage and disposal of used oils and solvents at a vehicle service site, a separation of at least 2m in clay soils is recommended between the surface and the water table at its seasonal highest level. Shallow groundwater in areas where the ground is highly permeable from the surface down to the water table, is vulnerable to contamination from spillage or disposal of oils, paints and solvents.

At least 5m is recommended where the ground is highly permeable from the surface down to the water table. Where such conditions are suspected, the excavation pit should be deepened, if possible, in order to establish (i) the permeable nature of the ground deeper down, (ii) whether fissured or fractured bedrock is present, and (iii) that the water table does not rise to within at least 5m of the surface. If it is not feasible to dig deeper than two metres, there may be other ways of confirming the depth to the water table, such as by investigating water levels in nearby boreholes, wells and quarries.

If on digging deeper, water flows into the pit and starts to pond, then repeat the flowchart test for a wet pit.

For a dry pit, proceed to BOX 2

BOX 2

Examine the side walls of the pit. Note should be taken of colour changes in the profile that are not related to soil mineralogy or texture, as this probably indicates the level to which the water table rises at the end of the wet season.

If possible, consider taking photographs and samples of the soil in the pit walls for expert interpretation.

BOX 3

Shallow groundwater in areas where the ground is highly permeable from the surface down to the water table is vulnerable to contamination from spillage or disposal of oils and solvents.

Decision makers may wish to validate whether the water observed in the excavation does represent the actual water table. This can be done by referring to the hydrogeological reports, and / or by checking water levels in nearby boreholes and / or excavations (such as quarries). If there is still uncertainty, a specialist should be consulted.

If the water in the pit does not represent the water table, then the seepage water may not present a threat to a local groundwater resource, but contaminated seepage could present a threat to water resources further down slope of the site, and this should be investigated. A hydrogeologist or suitably qualified engineer should be consulted on this.

BOX 4

High water table areas are generally unsuitable for the location of informal vehicle servicing sites. In permeable soils, contaminants may get easy access to the groundwater resource, with little or no natural removal of contaminants. The possibility of moving the vehicle servicing activity to a location where such an activity would present less of a threat to water resources should be investigated. Consult a hydrogeologist or suitably qualified engineer on this.

Flowchart 2: On-site Test for Parts Washing and Spray Painting Facilites

Flowchart 2: On-site Test for Parts washing and spray painting

Critical Components
- Geological formation
- Depth to water table
- Signs of spillage (i.e. volume of oils and solvents being generated / handled)
- Topography (i.e. does water and / or waste accumulate at one point; flow to a water source)

1 Where oil, solvents, paints and detergents occur at a location not designed for the handling of such waste, e.g. a lined sump or storage dam, etc.) then an examination of soil conditions should be done to the excavation of a 2m pit.
2 Note whether the water table is intersected during the excavation work.
3 Note changes in the texture and colour of the soil profile.

Where there is evidence of significant disposal or spillage of oils / solvents / paint on site ground, collect a soil sample for analysis and seek expert advice.

Where there is only slight spillage of oils / solvents / paint on site ground, then contaminated soil may be small enough to be collected and removed.

* The rate at which water drains away reflects the permeability of the soil. Permeable soils are typically sandy or gravelly. Impermeable soils typically have a high clay content. The relative clay content of soil is often reflected by its ability to be formed into a small ball.

Pit is dry

Wet season: A depth of at least 2m to the seasonal high water table is required to help protect groundwater from contamination. → BOX 1

Dry season: Consider that the water table will be higher at the end of the wet season. If it is not possible to make a reliable judgement on the height to which the water table rises in the dry season, the excavation test should be repeated in the wet season. → BOX 2

Pit is wet

Wet season: Under permeable soils and rock conditions this may be the result of a high water table, while in areas underlain by low permeability* soils and rock this may an indication of interflow or slow infiltration rates. → BOX 3

Dry season: Groundwater could occur near the surface. Check for supporting evidence, e.g. is the site next to a river, vlei or the coast, or near a groundwater seepage area (e.g. a spring)? Check water levels in any quarries, boreholes or wells in the area. → BOX 4

BOX 1

To protect groundwater from pollution generated through spillage and disposal of used oils and solvents at a vehicle service site, a separation of at least 2m in clay soils is recommended between the surface and the water table at its seasonal highest level. Shallow groundwater in areas where the ground is highly permeable from the surface down to the water table, is vulnerable to contamination from spillage or disposal of oils, paints and solvents.

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BOX 4

High water table areas are generally unsuitable for the location of informal vehicle servicing sites. In permeable soils, contaminants may get easy access to the groundwater resource, with little or no natural removal of contaminants. The possibility of moving the vehicle servicing activity to a location where spray painting and parts washing activities present less of a threat to water resources should be investigated. Consult a hydrogeologist or suitably qualified engineer on this.

3 References and additional reading

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Protecting Groundwater from Contamination by

Pit latrines

TOOLKIT for WATER SERVICES: Number 3.4.4

This document provides guidelines and tools to help protect groundwater from contamination. It will be useful to Environmental Health Officers, environmental planners, health and hygiene educators, sanitation planners and pollution control officers working in Water Services Authorities, Water Services Providers, the Department of Health, the Department of Water Affairs and Forestry and Catchment Management Agencies.

Protecting Groundwater from Contamination by Pit Latrines

Published by
Department of Water Affairs and Forestry
Directorate: Information Programmes
Private Bag X313
PRETORIA 0001
Republic of South Africa
Tel: (012) 336 7500

Implemented by
CSIR

Written by
Freeternity Rusinga

Editing
Anthea Josias and Kerry Harris

Artwork
Vusi Malindi

Layout and design
Gill McDowell

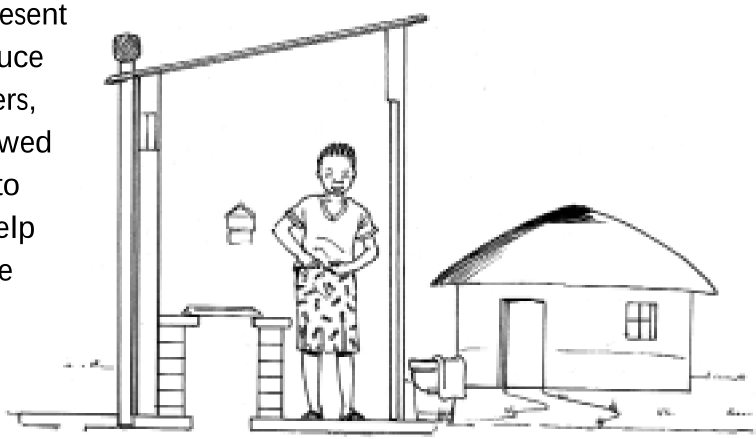
Inputs
Irené Saayman, Oliver Sililo, Pannie Engelbrecht,
Kerry O'H Murphy

Pit latrines

1 Background to the contamination threat

Introduction

Human excreta is characterised by a high, rapidly biodegradable organic content, a high concentration of nutrients, and a large number of potential disease-causing organisms (pathogens). Faeces typically contain a very high number of pathogens like germs (bacteria) and viruses. Although these pathogens present no risk of disease to the people who produce them, they do present a health risk to others, especially if they are ingested (e.g. swallowed with food). The disposal of faeces needs to be carefully managed, not only so as to help prevent the outbreak and spread of disease in a community, but also to protect the general health of the people.



Groundwater vulnerability

Water resources can be contaminated both directly and indirectly by the disposal of excreta in a rural environment. Germs, viruses and other substances from excreta in pit latrines can move through the sub-surface soils and contaminate groundwater.

Groundwater in areas with high rainfall and shallow water tables is more vulnerable to contamination from pit latrines. Groundwater vulnerability is also high in fractured rock and other high permeability environments, such as sandy or gravelly soils. The risk of groundwater being contaminated by pit latrines is increased where:

- The base of the pit occurs near the water table or the pit latrine is located too close to a water source. The separation distance then does not give enough time for the geological sub-surface material to remove potential contaminants before they reach the water table or the water source.
- The bottom part of the pit is unlined. Impermeable linings act as a barrier to contamination, helping to prevent contaminants finding a short cut from the lower part of the pit to the water table.
- High loading occurs. The more people who use a pit latrine (e.g. in a school environment) then the greater the amount of contaminants that will be produced, resulting in a higher risk of groundwater contamination.
- High numbers of infective pathogens are produced. Where pit latrines serve a community that is suffering from an epidemic or else serve a group of people who are sick (e.g. at a clinic), the groundwater contamination risk is much higher.

Impact on health

Faeces can contain very dangerous disease-causing protozoa such as amoebic dysentry and giardia; bacteria such as typhoid and other salmonellas, shigella, and vibriocholerae; dangerous viruses such as polio, hepatitis A and rota; and worms (hook and round).

Although viruses and germs can move through soil, they are seldom able to survive in soils for more than 50 days. They are generally filtered out by soil, and most are killed off or rendered inactive by soil microbes. If water is added to a pit latrine, they can be transported by percolating water from the pit into groundwater. This is especially true of a permeable environment (e.g. fractured rock, course sands and gravels). Once in groundwater, viruses and germs can travel for more than one kilometre.

Germs and viruses move through the sub-surface mostly attached to suspended particles in water. Although normally associated with a host, germs are able to survive and multiply in the environment if the proper conditions and nutrients are present. Viruses have also been found to survive for long periods in the environment, although they do not multiply outside their host (e.g. humans).

The sub-surface environment (soils and rock) is not the natural habitat of germs and viruses. Germs and viruses may die off as a result of starvation, competition from other microbes, or direct attack by other microbes. Viruses on the other hand, do not require a food source to survive. Instead, the inactivation of viruses results from the harsh physical conditions encountered in the sub-surface environment and also from attack by enzymes produced by soil microbes.

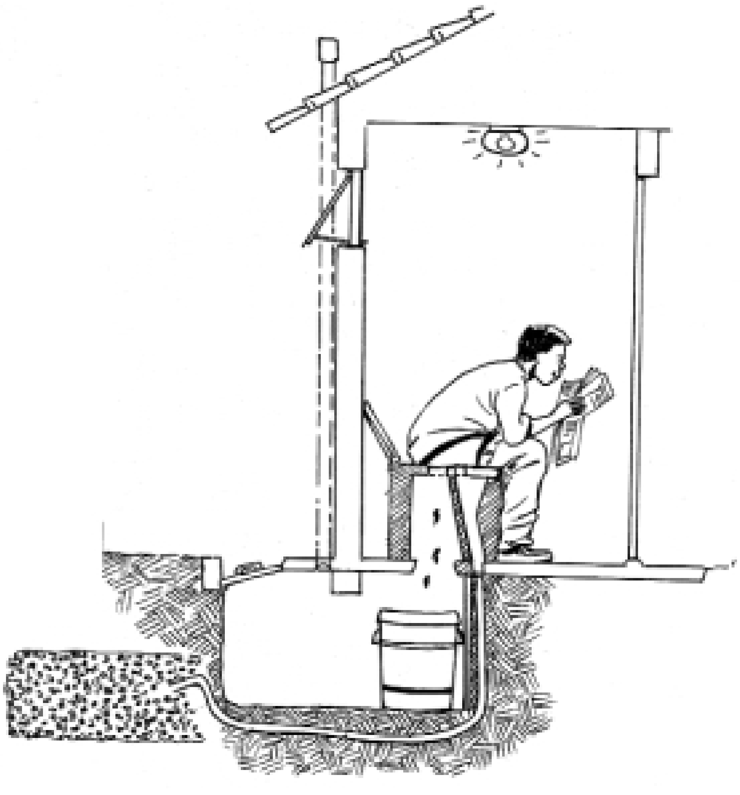
Research shows that germ and virus die-off / inactivation rates are much higher in the unsaturated soils above groundwater than in the groundwater itself. In one study, it was found that bacteria were not removed during passage through one metre of soil that was saturated with water. It was, however, found that 95% of the bacteria were filtered out or died during passage through a similar column of unsaturated soil. This is partly due to an increase in the length of time that pathogens reside in the unsaturated zone. These studies show the value of unsaturated soils in protecting groundwater resources. The greater the depth of unsaturated soil below a contaminant source, the more protected the underlying groundwater is likely to be.

The ability of bacteria to move through soils is dependent on the filtration capability of the soils. Fine silty soils are far better at removing bacteria than coarse sandy soils. The ability of viruses to move through unsaturated soils is dependent mostly on the adsorption capacity of the soils.

Where disease-carrying substances pass into groundwater and reach an abstraction point (e.g. a borehole), they render the abstracted water potentially harmful to users. Typical sicknesses resulting from contaminated water include diarrhoea, typhoid fever and cholera.

Guidelines

- When siting and designing sanitation facilities, every effort should be made to ensure that faecal wastes or seepage from such wastes will not enter the water table directly.
- Wherever possible, pit latrines should not be located up slope of a water abstraction point (or an abandoned borehole / well) (See **Pit Latrine Distance Chart**).
- Pit latrines should not be located in the vicinity of a borehole, well, or spring (See **Pit Latrine Distance Chart** for recommended minimum setback distances). Where it is not possible to adhere to a prescribed distance, it is important to consult a hydrogeologist and sanitary engineer.
- Ensure that the base of the pit latrine is at least two metres, but preferably not less than five metres, above the seasonal high water table (See Groundwater Protocol, Version 2). If it is not, the sanitation option should be reconsidered. Alternatives include raised pit latrines, carefully lined pit latrines, pour flush or urine diversion latrines (See ***Introductory Guide to Appropriate Solutions for Water and Sanitation***, Toolkit for Water Services, Number 7.2); or a hydrogeologist and sanitary engineer should be consulted.
- It is important to note that where many pit latrines are provided in the same location (e.g. for schools and hospitals), the prescribed minimum set-back distance from a water source should be increased by 50% or more than that recommended in the **Pit Latrine Distance Chart**.
- Ensure that pit latrines are properly sealed at the surface to help prevent ingress of runoff water into the pit.
- Do not allow or promote ingress or direct addition of used water to the pit, whether by design (handwashing facilities) or where wash-water can be thrown into the pit.



Urine diversion system – one of many appropriate solutions detailed in the **Introductory Guide to Appropriate Solutions for Water and Sanitation**

2 Tools for dealing with the contamination threat

Decision aids in the form of a checklist, a flowchart, set-back distance decision tables and decision charts are presented to guide decision makers on the most appropriate courses of action to follow.

Checklist

The checklist to be filled in is:

- **Checklist: *Pit latrines.***

The checklist serves as a first step to guide decision makers on the suitability of sites for the location of pit latrines. The questions should be answered before moving to the **Flowchart: On-site Test** sheet, though the user may choose to move between sections when necessary. The questions are numbered, with options of possible answers (YES, NO, UNSURE or NOT APPLICABLE (N/A). Tick the most appropriate box as you proceed through the checklist. In this way the checklist will serve as a "record of decision". The complete checklist should be answered, irrespective of whether an answer recommends a particular course of action. Some of the questions may refer the user to the **Flowchart: On-site Test**. The user may choose to revisit and / or redo the checklist after completion of the **Flowchart: On-site Test**.

Decision Table

After the questions in the **Checklist** have been answered, go to the **Decision Table**. Look for the combination of answers that matches yours. The last column of the **Decision Table** presents the name of the **Set-back Distance Chart** that is to be used to determine the appropriate set-back distance.

Flowchart - On-site Test

The **Flowchart: On-site Test** provides a step-by-step procedure for establishing the major contaminant contributing factors. The user may choose to revisit and / or redo the checklist after completion of the **Flowchart: On-site Test**.

Set-back Distance Charts

There are three set-back distance charts, applicable only for pit latrines:

- **Chart PL-DL**: lightly loaded pit latrines - for deep unconfined aquifers with boreholes and wells fitted with motorised pumps.

- **Chart PL-S&DH**: heavily loaded pit latrines - for shallow and deep unconfined aquifers with boreholes and wells fitted with motorised pumps.

- **Chart PL-SL**: lightly loaded pit latrines - for shallow unconfined aquifers with boreholes and wells fitted with motorised pumps.

It should be known whether the users of the pit latrine are private household users or public users. If the public uses it, the hydraulic and the pathogenic loading loads are assumed to be heavy. In this case **Chart PL-S&DH** will be applicable.

If a private household uses it, then the the hydraulic and the pathogenic loading loads are assumed to be light. In order to choose the appropriate decision chart, further information on the depth to the water table is needed. Since it is virtually impossible or difficult to determine the depth of the pit for a pit latrine, the assumption is made that the depth of pits is 2m. If the depth to the expected high seasonal water table is less than or equal to 12m below the ground surface, the aquifer is classified as a shallow aquifer and vice-versa.

Checklist: Pit latrines

Checklist: Pit latrines

Questions	Yes	No	Unsure or N/A	Comment
1 Is the aquifer formation material known?	☐ Classify it as one of the following: - sand - sandstone - limestone - fractured dolomite - weathered granite - sand and gravel - shale and / or clay - fractured limestone - fractured granite	☐ Use thehydro-geological map to identify the aquifer materi-al, or consult a hydrogeologist	☐ Use the hydrogeological map to identify the aquifer material, or consult a hydrogeologist	
2 What sanitation option is currently being used in the area?	Dry on-site systems A Ventilated improved pit (VIP) toilet B Ventilated improved double pit (VIDP) toilet C Pour-flush toilet D Urine diversion toilet Go to the next srep. Wet systems E Aqua-privy and soakaway; or septic tank and soakaway F Conveyance tank; or full waterborne sewerage Go to step 4. For more information on different sanitation options see Intoductory Guide to Appropriate Solutions for Water and Sanitation (Toolkit for Water Services Number 7.2)		☐ Go to the appendix to establish the sanitation option being used in comparison with the sanitation drawings.	
3 For pit latrines only: Is the water content of the material in the pit very high?	☐ Establish the source of water from one of the following: - Ingress of runoff water - Toilet area being used for washing. - High water table. Consult the flowchart for recommended actions.	☐ Consult the flowchart for recommended actions.	☐ Consult the flowchart for the recommended procedures to establish the water content of the excreta and the actions to be taken or N / A - Not a pit latrine.	
4 Is the aquifer a shallow aquifer? In this context it means that the depth of the water table below the ground level is 12m and less, and for depths greater than 12m the aquifer is classified as a deep aquifer.	☐ Proceed to the next step.	☐ Proceed to the next step.	☐ Use a dip meter to establish the depth to the water table during the rainy season or N / A - Not a pit latrine.	
5 For pit latrines only: Is the pit latrine up gradient of the water supply well or borehole?	☐ Measure the separation distance.	☐ Measure the separation distance.	☐ In a rough sketch, mark the direction the streams and runoff water in the area drain. Locate drainage ditches to establish the ground surface slope. The water table generally follows the slope of the topography. Establish if the latrine is upslope (up gradient) of the borehole or well, or down gradient and consult the Introduction. or N / A - Not a pit latrine.	
6 For pit latrines only: Is the latrine used by the general public or by a private household?	☐ A It is a public latrine. B It is a private latrine. Consult the Decison Table below.	☐	☐ Not a pit latrine.	

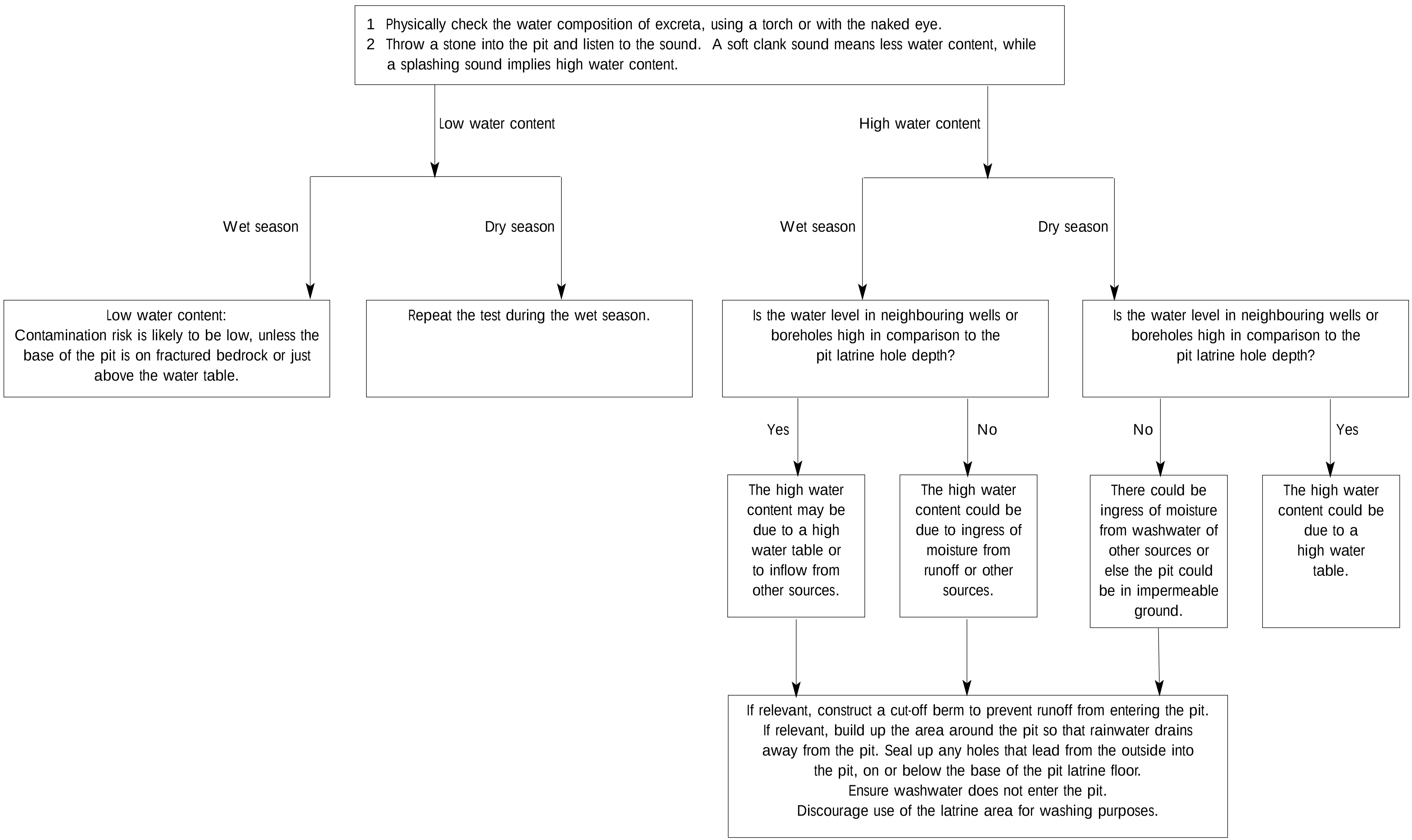
Decision Table: Pit latrines

Decision Table: Pit latrines

Comination number	Q. No. 2	Q. No. 3	Q. No. 4	Q. No. 5	Q. No. 6	Action
1	A or B or C	Yes	Yes		B	Use the aquifer material for question 1 to enter the Distance Chart PL-SL
2	A or B or C	Yes	No		B	Use the aquifer material for question 1 to enter the Distance Chart PL-DL
3	A or B or C	No	Yes		B	Use the aquifer material for question 1 to enter the Distance Chart PL-SL
4	A or B or C	No	No		B	Use the aquifer material for question 1 to enter the Distance Chart PL-DL
5	D		Yes		B	Use the aquifer material for question 1 to enter the Distance Chart PL-SL
6	D		No		B	Use the aquifer material for question 1 to enter the Distance Chart PL-DL
7	E					Go to next document on guidelines
8	A or B or C	Yes	Yes		A	Use the aquifer material for question 1 to enter the Distance Chart PL-S&DH
9	A or B or C	Yes	No		A	Use the aquifer material for question 1 to enter the Distance Chart PL-S&DH
10	A or B or C	No	Yes		A	Use the aquifer material for question 1 to enter the Distance Chart PL-S&DH
11	A or B or C	No	No		A	Use the aquifer material for question 1 to enter the Distance Chart PL-S&DH
12	D		Yes		A	Use the aquifer material for question 1 to enter the Distance Chart PL-S&DH
13	D		Yes		A	Use the aquifer material for question 1 to enter the Distance Chart PL-S&DH
14	E					Go to next document on guidelines

Flowchart On-site Test: Pit latrines

Flowchart On-site Test: Pit latrines



Set-Back Distance Charts for Pit Latrines:

1. **Chart PL-DL**
2. **Chart PL-S&DH**
3. **Chart PL-SL**

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Protecting Groundwater from Contamination by

Runoff water

TOOLKIT for WATER SERVICES: Number 3.4.5

This document provides guidelines and tools to help protect groundwater from contamination. It will be useful to Environmental Health Officers, environmental planners, health and hygiene educators, sanitation planners and pollution control officers working in Water Services Authorities, Water Services Providers, the Department of Health, the Department of Water Affairs and Forestry and Catchment Management Agencies.

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Published by
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Private Bag X313
PRETORIA 0001
Republic of South Africa
Tel: (012) 336 7500

Implemented by
CSIR

Written by
Kerry O'H Murphy

Editing
Anthea Josias and Kerry Harris

Artwork
Vusi Malindi

Layout and design
Gill McDowell

Inputs
Irené Saayman

Runoff water

1 Background to the contamination threat

Introduction

Runoff water refers to water that runs off the land as a result of rainfall, irrigation or spillage from leaking water supply facilities.

In rural communities, runoff water from sloping bare ground or from sloping ground used for agriculture, carries with it sediment, and is often contaminated by wastes. It carries this material into low-lying areas such as pits, trenches and hollows, and also deposits it where steep slopes even out to more gentle gradients. Sometimes runoff water gains access to pits used for waste disposal (including pit latrines) and sometimes gains access to boreholes, wells or springs that are not properly protected. Runoff water from animal kraals and stock watering points is of particular concern because it is usually heavily contaminated by faecal material and can pose a serious contamination threat to water resources.

The different types of contamination sources and concentrations of waste that occur depend on the characteristics of a particular community. This includes the population density, sanitation arrangements and sanitation / waste management practices.

Groundwater vulnerability

Groundwater is particularly vulnerable to contamination during and shortly after it rains. Runoff water from contaminated land and bare ground is usually contaminated by the wastes it comes into contact with, and by suspended particles that carry microbes, some of which can cause disease.

Factors affecting groundwater contamination

Factors that influence a potential contaminant's movement into groundwater include its relative mobility (the speed at which it moves in the ground), its solubility (i.e. whether it dissolves easily in water), its concentration or total load (i.e. the total amount of the contaminant), its ability to degrade naturally (i.e. the extent to which the contaminant can be destroyed naturally), the presence of "carriers" and the "ease of access" to groundwater.

A potential contaminant that is present in large amounts, can move through soils easily, and can dissolve easily in water is a much greater contamination risk to groundwater than a contaminant that does not move through soils easily and does not dissolve easily in water.

The presence of a substance such as a detergent or solvent promotes suspension of contaminants in water, and promotes movement of pathogens (germs and viruses) and certain contaminants into the ground. Such substances are known as "carriers". Carriers include decomposed / decayed substances normally found in dry, dead vegetation (this causes water to become tea-coloured). The pathogens and contaminants bind to the carriers, and are transported into the soil in this way. Carriers also promote the movement of contaminants in surface water over long distances, and in cases of peak flow rates, promote the re-suspension of sediments and other contaminants buried with those sediments, and thus the cycle of contamination by carriers starts once again.

Contamination by runoff water

When runoff water lies in thin sheets over the land, it generally sinks slowly (percolates) through the ground surface. If this water is contaminated, pathogens and other contaminants are normally rapidly removed by aerobic soils. When runoff waters combine to form deeper flows, they have a greater ability to pick up particles and lighter materials (such as litter and decomposing wastes) from the ground surface, and to carry them off. This type of runoff is often called "storm water runoff". In low-lying areas, these flows collect to form puddles and small pools. Most of the sediments and wastes are deposited here, along with many pathogens. Organic waste materials deposited in the puddles and pools tend to accumulate and they decay, becoming anoxic (i.e. lack oxygen) and give off unpleasant smells. These decaying waste materials release nutrients such as ammonia, while providing an ideal environment for pathogenic bacteria (germs) to grow, as well as providing a breeding environment for insect pests.

Hydraulic pressure is exerted on the bottom of these puddles and pools, promoting rapid movement of contaminated water into the underlying soils. In these conditions, pathogens and other contaminants are able to infiltrate deep into the underlying soils, presenting an increased contamination risk to groundwater resources. Because the water table tends to lie closer to the ground surface in low-lying areas, the time of travel of the contaminated water to the water table is relatively short, and this results in less time for contaminants to be removed effectively by the soils.

Runoff water, especially from public water supply taps, livestock watering points and storm water from bare ground and paved areas, can end up as stagnant water that persists in low-lying areas or in partially blocked gullies for long periods of time. Such stagnant water may represent a significant contamination risk to groundwater if the stagnant water is contaminated or if animals such as pigs, goats and cattle gain access to the water. Faecal material and associated nutrients can enter the water and thus present a potential health risk, both as result of direct use of the water by humans, but also through possible contamination of groundwater and nearby surface water resources.

A well-designed soakaway means that water will not stagnate around pumps or standpipes

Contamination risk to groundwater can be significantly increased when contaminated water gains access to groundwater via preferential flow pathways (short cuts), such as via an insufficiently protected borehole or well. If there is a borehole in the immediate vicinity of a potential pollution source, and contaminated runoff comes into contact with an unsealed borehole casing, it is likely to find its way into the groundwater by flowing down the outer side of the pipe. It may also gain access to the inside of an older casing that has rusted through in places, and so enter the groundwater directly. Where an uncapped borehole casing does not extend above ground, runoff water in the vicinity could flow straight into the borehole, with the potential of contaminating the aquifer directly. Exposed fractured rock (e.g. in a quarry) can present a preferential flow pathway (short cut), as can sinkholes and mine shafts. A storm water channel or road culvert can present a similar "short cut" to a surface water resource (such as a river or dam).

A high contamination risk is possible when very permeable soils (e.g. sands and gravel), or when fissures in underlying bedrock, allow contaminated runoff water to move down to the groundwater in a short time and with little or no treatment.

Contaminated stagnant water that is located next to, or upslope of boreholes, wells and springs has the potential to contaminate the water source. Even an uncontaminated body of stagnant water lying upslope of a pit latrine can cause water to collect in the pit and so become contaminated. This will promote transport of contaminants from the pit latrine into the surrounding soils, increasing the contamination risk to local groundwater resources.

Effects of vegetation cover

Vegetation cover (e.g. grass) helps to protect soils from erosion, and helps prevent sediment, wastes and microbes (e.g. pathogens) from being carried away by runoff water into low-lying areas and finally into water resources. Vegetation helps to reduce peak runoff flow rates, thus reducing the carrying ability of the runoff water, and reducing the potential for soil erosion. Removal of vegetation cover results in increased runoff and increased potential for soil erosion.

Ammonia, nitrates and phosphates are among the plant nutrients released from decaying faecal material and decaying organic wastes. If they are carried off in large quantities by runoff water, these plant nutrients have the potential to significantly contaminate water resources. Vegetation cover helps to prevent this from happening by not only reducing the carrying capacity of runoff water, but also by taking up nutrients from the water as it percolates into the soil.

Vegetation cover, especially grass, often does not exist in and around rural communities. The lack of protective soil cover helps to cause soil erosion and to cause waste and faecal material, along with pathogens and nutrients, to be carried off by runoff, into lower-lying areas (where stagnant puddles and muddy areas form). This contaminated water then moves into the soil under hydraulic pressure and can present a serious contamination risk to groundwater resources.

The risk of contamination of groundwater resources by faecal pathogens from free ranging livestock is generally low. This is because of the complete natural degradation / removal of faeces and urine by soil microbes when wastes are deposited over a wide area. However, the problem could become serious where animals are gathered in large numbers, for example around water holes or in kraals. In these situations, large amounts of liquid (urine and spilled water) and semi-solid faecal matter are concentrated in a small area. Under such conditions, urine and faecal matter may easily access water sources in the vicinity and move through the ground surface to enter the water table.

In some rural areas there is a tendency to increase stock numbers in wetter years when more vegetation grows. Therefore, in drier years, the large number of stock results in over-grazing and soil erosion. Any heavy rainfall then causes rapid runoff, which carries silt and faeces with it to lower-lying areas.

The risk of groundwater being contaminated by runoff water is increased when:

- There is high loading. The more faecal material and other wastes that there are in an area where runoff and erosion occur, the greater the quantity of contaminants that can be carried off in runoff water. These contaminants can be deposited, in large amounts, in low-lying areas, where they present a contamination risk to groundwater and surface water resources.
- There are heavy storms. Short-duration, high-flow-rate storm water runoff carries far greater loads of contaminants and sediments with it, than do lighter rains that last for a long period of time.
- There is little or no vegetation cover. Vegetation helps trap contaminants and the roots help take up nutrients from the ground before the nutrients (especially nitrates) can present a threat to groundwater.
- There is a shallow water table. Where the water table is close to the ground sur face, there is little depth of aerobic soil available that can treat contaminants in the water that sinks into the ground (i.e. in percolating water).

- There are high permeability soils and rocks. Where soils consist of sand or gravel, or where there is only rock at (or close to) the ground surface, there is an increased risk of groundwater being contaminated. Where contaminated runoff water sinks into the ground or enters fissures in the rock, it is less likely that contaminants will be removed from the percolating water before it reaches the water table.
- There are preferential flow pathways (short cuts to groundwater). These are often found in relation to unprotected boreholes, wells, sinkholes, mines, quarries, and exposed fractured bedrock.
- There are bodies of stagnant water, especially upslope or close to boreholes, wells, pit latrines and waste disposal pits.

Impact on health

Faeces contain very high numbers of pathogens, and if present in water supplies can represent a significant risk to human health. Runoff from areas specifically used for defecation by animals or humans can carry with it large quantities of faecal material and also nutrients into relatively low-lying areas, where these pathogens and nutrients can represent a significant contamination risk to groundwater and surface water resources, and where they also present a health risk to humans and animals who have direct contact with the water (e.g. if children play in it).

Pathogens tend to die off quickly in dry conditions, in sunlight or where there is lots of oxygen. When runoff water contaminated by pathogens slowly percolates into the soil surface, the pathogens are usually held back by filtration and adsorption. When the topsoil dries out, they tend to die off as result of:

- aeration and desiccation; and
- competition with, and predation by aerobic microbes.

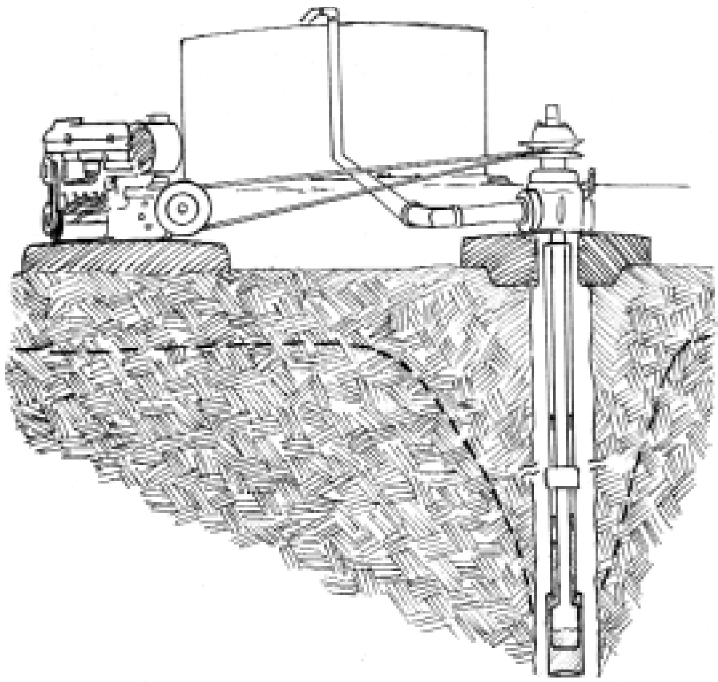
Some pathogens on the soil surface are killed by sunlight, while certain pathogens, in the form of spores and eggs, can remain viable within the soil for several years.

When contaminated runoff water is distributed over the ground surface so that it infiltrates the ground slowly over a large area, and where ponds or puddles rapidly dry out, the pathogens in the water tend to get trapped in the topsoil, and slowly die off.

Guidelines

For groundwater protection, it is important that faecal material and wastes do not collect in confined, unprotected areas, and that they do not come into contact with rainfall runoff. Where this does occur, relevant prevention measures need to be implemented.

- Do not allow stagnant runoff water (such as a puddle) to exist upslope of, or close to, a borehole, well, spring, pit latrine or a pit used for disposing of waste.
- Do not allow animal and human faeces or other wastes to come into direct contact with surface water or groundwater. Also, do not allow wastes or faeces to collect in drainage channels or puddles. Do not allow runoff water to enter pit latrines or pits used for waste disposal.
- Do not allow runoff water from areas where animal or human faeces are concentrated (or stockpiled), to enter any water source, drainage channel for natural runoff or an unsealed pit. Such wastes or water should not be upslope of, or close to a bore hole, well, spring, sinkhole, mine, quarry, exposed fractured bedrock, or storm water channel.
- When choosing a site where contaminated runoff water can soak away:
  - Choose areas that do not have a shallow water table.
  - Ensure that no boreholes (used or disused), wells, springs, pit latrines, pits used for disposal of wastes, sinkholes, mines, quarries, borrow pits, or exposed fractured bedrock are down-slope of the site, and that otherwise they are not close to the site or any places where contaminated water could flow.
  - Avoid areas with deep coarse sands, gravel or areas underlain by fractured rock.
  - Boreholes and wells need to be properly sealed off and, together with springs, protected from the entrance of runoff water from the surrounding areas. Runoff diversion ditches and berms should be established upslope of such water sources. This ruling should also apply to disused boreholes and wells.



2 Tools for dealing with the contamination threat

A decision aid in the form of a checklist is presented to guide decision makers on the most appropriate courses of action to follow in managing runoff water.

Checklist

The checklist presents some simple questions. Three or four possible answers are presented, each which recommends a particular course of action. The questions are numbered, with options of possible answers: YES, NO, UNSURE or N/A (NOT APPLICABLE). Tick the most appropriate box as you proceed through the checklist. In this way the checklist will serve as a "record of decision". The complete checklist should be answered, irrespective of whether an answer recommends a particular course of action.

Recommendations on an appropriate course of action and occasional references to other sections of this document series are presented next to the YES tick box. In some instances, a YES answer would indicate the need to seek expert input, such as that of a hydrological practitioner. In the box for COMMENTS, the user should provide background on how a decision on the appropriate answer to the question was reached. Justification of the answer given may include personal observation.

Checklist:

Runoff water (for areas with non-sandy soils if there is evidence of, or potential problems with, contaminated runoff, runoff erosion and sediment deposits)

Checklist: Runoff water (for areas with non-sandy soils if there is evidence of, or potential problems with, contaminated runoff, runoff erosion and sediment deposits)

Questions	Yes	No	Unsure or N/A	Comment
1 For slopng sites: Does the terrain and the lack of vegetation cover make rapid surface runoff likely?	☐ Relatively steep slopes and the lack of vegetation can result in the rapid runoff of rainwater or irrigation water, especially at the start of the rainfall or irrigation season. Stimulating the rapid growth of vegetation can help to prevent soil, nutrient and runoff water loss over the longer term. Dig holes or trenches (in parallel to the land surface contours) in the ground, replace the soil to just below ground level, and plant new vegetation. Add mulch to the soil surface, and ensure there is still space to add water. Mulching with dead grass, leaves, bark, small twigs and branches should also help to prevent soil erosion.	☐	☐ If the vegetation cover is scarce and the ground is not sandy, gravelly, stony or rocky, and soil slopes are steeper that 6 degrees, then assume the answer is YES ☐ N / A: Ground is not sloping.	
2 For sloping sites: Are erosion channels in evidence?	☐ There are various ways of combating erosion channels: Impale stakes into or across the channel. Close up or block the channel with dead branches, old tyres, logs and stones. Plant new vegetation with strong root systems at / along the sections to be rehabilitated. Just upstream of each dammed section, construct a diversion berm and / or ditch, away from the erosion channels towards vegetated or stable land. Ensure people or stock animals do not interfere with the sections being rehabilitated.	☐	☐ Unsure: Check with people who know the area, or conduct a site visit. ☐ N / A: Site does not slope.	
3 Are there any places where concentrated storm water flows are likely to exist?	☐ Down slope sections of paved or bare areas, road culverts, footpaths and large roofs are likely to produce concentrated storm water flows. These flows should be controlled so that they don't cause upslope flooding or down slope erosion. Where suitable, construct diversion berms or drainage to lead the water to stable land, to vegetated areas, or to stable (paved) storm water channels or drains. Where possible, paths, roads and paved areas should allow for runoff to be led off at frequent intervals. Storage facilities for roof runoff should be promoted, for household use. Storm water runoff retardation basins should be considered for areas subjected to heavy, short-duration rainfall, especially where such basins can be located over permeable soils.	☐	☐ Unsure: Check with people who know the area, or conduct a site visit.	
4 Does storm water lead to an area in close proximity to a borehole, well or spring?	☐ Storm water and irrigation runoff has the potential to contaminate groundwater if it comes close to boreholes or wells, and it has the potential to contaminate source water at abstraction points if it gains direct access to the water source. Storm water should be kept away by using diversion berms and ditches. Boreholes, wells and springs should be protected using measures described in the guidelines. Please consult the guidelines for applicable protective measures for boreholes, wells and springs.	☐	☐ Unsure: Check with people who know the area, or conduct a site visit.	
5 Does storm water lead to an area in close proximity to a contaminated source?	☐ Storm water and irrigation runoff has the potential to increase groundwater contamination threats posed by pit latrines, waste dispostal sites or animal kraals in the vicinity, if it gains access to them or forms stagnant puddles in the direct vicinity (a result of increased contaminant transport stimulated by hydraulic loading). This threat is substantially increased if groundwater abstraction points are also located in the vicinity. Construct diversion berms and ditches to divert runoff water away from contaminant sources. If this is still likely to be a problem, then assume a high contaminant loading for the contaminant source in question and consult the relevant guidelines, or consult a specialist.	☐	☐ Unsure: Check with people who know the area, or conduct a site visit.	
6 For sloping land, does storm water lead to an area in close proximity and upslope of a contaminant source?	☐ Storm water and irrigation runoff has the potential to increase groundwater contamination threats posed by down slope souces (for example, a pit latrine located downslope could trap some of the water, increasing its contamination threat). This threat is substantially increased if groundwater abstration points are located further down slope of the contaminant sources. As an interim measure, construct diversion berms and ditches so as to divert runoff water away from contaminant sources. If in doubt, consult the relevant guidelines, or preferably consult an expert.	☐	☐ Unsure: Check with people who know the area, or conduct a site visit.	

Checklist (continued):

Runoff water (for areas with non-sandy soils if there is evidence of, or potential problems with, contaminated runoff, runoff erosion and sediment deposits)

Checklist: Runoff water (cont)

Questions	Yes	No	Unsure or N/A	Comment
6 Does rainfall runoff flow directly off a site where contaminating activities occur?	☐ Rainfall runoff from an animal kraal, a stock watering point, a contaminated informal workshop area, or a "bush toilet" area presents the potential to contaminate water resources, especially if they are located in the vicinity of a water source or if contaminated runoff enters a channel used by storm water (e.g. a road culvert). Where possible, such contaminated water should be intercepted and led off to a wastewater treatment pond.	☐	☐ Ask the owner, or conduct a site visit.	

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Protecting Groundwater
from Contamination by

Subsistence agriculture

TOOLKIT for WATER SERVICES: Number 3.4.6

This document provides guidelines and tools to help protect groundwater from contamination. It will be useful to Environmental Health Officers, environmental planners, health and hygiene educators, sanitation planners and pollution control officers working in Water Services Authorities, Water Services Providers, the Department of Health, the Department of Water Affairs and Forestry and Catchment Management Agencies.

How to Protect Groundwater from Contamination by Subsistence Agriculture

Published by
Department of Water Affairs and Forestry
Directorate: Information Programmes
Private Bag X313
PRETORIA 0001
Republic of South Africa
Tel: (012) 336 7500

Implemented by
CSIR

Written by
Kerry O'H Murphy

Editing
Anthea Josias and Kerry Harris

Artwork
Vusi Malindi

Layout and design
Gill McDowell

Inputs
Irené Saayman

Subsistence agriculture

1 Background to the contamination threat

Groundwater for irrigation

In semi-arid and arid (dry) climates, and during periods of drought, groundwater presents a reliable, low-cost option to surface water for both drinking and irrigation purposes. Groundwater is also of a more consistent quality than surface water and, if it is not brackish, should be easier to manage once it is pumped out of the ground.

Subsidisation and development-aid for water supply schemes often means that the price paid for water over a project lifetime is less than the initial cost of developing the water resource. The true cost of the water being supplied is therefore higher than the price being paid for it. An example relating to groundwater supply is where the initial costs of installing and equipping a supply borehole are borne by government or a non-governmental organisation (NGO). Cheaper groundwater supplies may promote the growth of irrigation and the installation of piped water supply (to bring the water supply closer to individual households) in rural communities. This would lead to a significant increase in the use of a groundwater resource. Easy access to low-cost water supplies enables rural communities to achieve food security, increase agricultural and livestock productivity, and to alleviate poverty.

Extensive use of a groundwater resource for irrigation can lead to an over-exploitation of the water resource, and to deterioration in groundwater quality. Therefore, the more a groundwater resource is used for irrigation, the more careful management would be needed, not only for the resource itself, but also in terms of crop irrigation.

Management is likely to relate to the impact of brackish groundwater on crops, the need to drain accumulating salts out of the crop root zone, the impact of leached salts and nutrients on the quality of the groundwater resource, and the impact of over-abstraction on the aquifer and on base-flows in streams and rivers.

Impact of brackish water on crops

Brackish water is water that contains a noticeable level of dissolved salts, but that can still be used for drinking and for irrigating certain crops. Some crops are more sensitive to dissolved salts in irrigation water than others. Fruit trees are very sensitive, as are strawberries, beans, carrots and onions. Most of the other vegetable crops are moderately sensitive to brackish water, as is maize, millet, sugarcane and sunflower. Grain and grass crops are generally less sensitive to brackish water than other crops.

High chloride ion concentrations (part of what makes water brackish) in irrigation water can be toxic to many plants, especially when plant leaves become wet during irrigation.

Besides presenting a potential problem to plants when sprayed directly onto their leaves, dissolved salts in irrigation water become a problem to crops if salt accumulates in the crop root zone to levels, which can:

- Prevent the crop from extracting sufficient water due to an imbalance in osmotic pressure between the water in the soil and the water in the plant roots, resulting in a reduced growth rate.
- Become toxic (poisonous) to a crop as result of too much chloride or sodium being taken up into the plants.
- Prevent oxygen reaching the plant roots as a result of the reduced permeability of clayey soils caused by a high sodium ion concentration in relation to the concentrations of calcium, magnesium and other ions in the irrigation water.

To help prevent a build-up of salts in agricultural soils, and to keep crops growing healthily, extra irrigation water is normally required to leach (drain) the salts out. In clayey soils and soils that are not well-drained, over-irrigation can cause soils to become waterlogged, and evaporation will then increase. This causes salts to be drawn up from the deeper soils and to become concentrated at the soil surface. In waterlogged soils, oxygen is stopped from reaching plant roots, often with the result that plants die. Methods used to help overcome these problems include: Putting in drainage systems, mulching the soils, adding gypsum to soil, irrigating crops less frequently, irrigating at night using less water, and switching to more salt-tolerant crops in order to reduce leaching requirements.

During hot, dry weather the concentration of salts at the surface of irrigated soils can be four times or more than that of the irrigation water. While adding extra irrigation water to well-drained soils helps to keep salt concentrations in the soil relatively low, it has the following disadvantages:

- Some water has to be wasted. This excess can range between 10% and 50% of the amount of water normally required for irrigation.
- Nutrients are rapidly drained from the plant root zone, requiring an increased application of manure or other fertilisers.
- Some of the drained water may move down into the groundwater resource, taking with it salts, nutrients and sometimes herbicides or pesticides.
- Drained water sometimes moves downwards to an impermeable soil barrier and then travels down-slope, underground, on top of this impermeable layer. This water sometimes can have a negative impact on down-slope crops, vegetation and water resources.

Groundwater vulnerability

Groundwater may be vulnerable to leached (drained) salts and nutrients from irrigated agriculture, and from liquids generated by stockpiles of manure. Using excess groundwater irrigation to leach out accumulated salts in soils in some areas (e.g. groundwater recharge areas) could result in an increase in salinity of the groundwater resource.

Generally, nitrates do not degrade (that is, are not removed) in shallow groundwater. Hand-dug wells and protected springs normally draw from shallow groundwater, and these are particularly vulnerable to nitrate contamination from irrigated agriculture, cattle kraals, pit latrines and septic tanks. In these situations, usually the most effective way of reducing nitrate concentrations to safe levels is to dilute the water with other water (from another source) that has a low nitrate concentration.

The vulnerability of an aquifer to contamination by agriculture irrigated with groundwater is generally high in fractured rock with shallow soils, or when the aquifer is a shallow one located in sandy or gravelly soils. Vulnerability is increased where an excess of nitrate fertiliser or manure is being applied, and when a significant amount of irrigation water is lost to leaching.

Impact on health

High nitrate concentrations in groundwater used for drinking water can lead to health problems in humans and in cattle. For example, high nitrate concentrations in drinking water can lead to methaemoglobinaemia in babies (blue baby syndrome).

Herbicides and pesticides could present a risk to groundwater resources if these are applied in sufficient quantities to crops. Herbicides tend to be more mobile in soils than pesticides are, and so present a greater contamination risk to groundwater. For subsistence agriculture the use of herbicides is limited due to the cost or the need for them.

Germs (pathogenic bacteria) from manure can move through the soil. They can survive and multiply in moist soil for many days. Nitrates, nitrogenous compounds, potassium and other nutrients from manure, together with moisture from irrigation and rainfall, are needed by germs to stay alive. Pathogens and nitrates can be carried down to the water table by excess irrigation water, and may eventually be pumped up at a nearby abstraction point. If the abstracted groundwater is used for drinking, this would present a risk to human health.

Where manure is applied to land for crop growth purposes, the risk of pathogen or nitrate contamination of groundwater resources is likely to be small, due to the complete natural degradation (removal) of manure by soil bacteria, and the uptake of nitrates by crops. However, contamination risk could be significant if manure is applied in excessive amounts to cropland, or if it is stockpiled in the open on the land for a long period of time before it is applied to crops.

Where irrigated land or a manure stockpile is located close to, or upslope of, a borehole, well or spring, contaminated run off water could enter the water source. The contamination risk is likely to be high if there is inadequate protection around the borehole, well or spring. Pathogens and nitrates that enter the water source may then be immediately available for abstraction, and if the abstracted water is used for drinking, it could present a significant risk to human and / or animal health.

Higher salinities resulting from irrigation return flows to groundwater would make the groundwater less palatable to drink (giving it a bad taste), and in some cases could present a risk to individuals who need to be on a low-salt diet for health reasons.

Guidelines

For groundwater protection, it is important that manure, compost, fertilisers, pesticides and herbicides are not stockpiled in the vicinity of a borehole, well or spring.

Where motorised pumps are used for irrigation, it is important to assess the impact of pumping on a borehole and an aquifer. Where irrigation water is likely to find its way back into the aquifer, and a significant amount of water is needed for leaching (above 10%), groundwater should be monitored for salinity. If the groundwater resource is used for drinking purposes, groundwater should also be monitored for pathogens and nitrates.

The following steps should be taken to protect groundwater resources from degradation as a result of subsistence agriculture:

- Do not allow stockpiles of manure, compost or fertilisers to be located close to or upslope of a borehole, well or spring.
- Do not allow irrigation run off to come anywhere near a borehole, well or spring.

When choosing a site for storing manure or fertilisers:

- Choose areas that do not have a shallow water table and that do not or will not contain stagnant water.
- Choose an area with low permeability soils.
- Avoid areas with coarse sands or gravels, areas with exposed bedrock, or areas where shallow soils overlie bedrock.
- Take measures to protect the manure pile and fertilisers from getting wet, especially if there is doubt about the suitability of the site.

2 Tools for dealing with the contamination threat

A series of checklists are presented, which serve to guide decision makers on the most appropriate courses of action to follow in terms of:

1. soil infiltration problems,
2. the potential for groundwater / surface water contamination, and
3. irrigating sensitive crops with brackish water.

Checklists

- **Checklist A1:** ***Irrigation water.*** The checklist presents questions on how irrigation water sinks into the soil, the condition of the ground surface and underlying soil, and when fertilizer is applied.
- **Checklist A2:** ***Irrigation methods.*** The checklist asks basic questions on irrigation methods used, and then directs the user to one of the following three checklists: B1, B2 or B3.

- **Checklist B1:** ***Crops with no irrigation.*** This checklist is for crops that are grown without irrigation.
- **Checklist B2:** ***Crops irrigated by hand.*** This checklist is for crops that are grown with irrigation done by hand with a watering can, bucket or other container.
- **Checklist B3:** ***Crops irrigated by hose pipe or water supply furrow.*** This checklist is for crops that are grown with irrigation using a hose pipe or from a water supply furrow.

- **Checklist C:** ***Crops irrigated with brackish water.*** This checklist is meant to guide a decision maker on irrigating crops with brackish water (TDS greater than 250ppm), and is applicable to both groundwater and surface water. The advice relates to crops from the late seeding stage onwards (young seedlings are more sensitive to salinity). Crops are categorised according to sensitivity to salinity in soil water, and soil water is related to the salinity (units: EC or TDS) of irrigation water, assuming the application of certain irrigation management practices. Irrigation management practices that are presented in each EC/TDS category in **Checklist C** relate to the irrigation of crops that are categorised as being sensitive, moderately sensitive, moderately tolerant or tolerant of salinity in soil water. Once the salinity tolerance category of the crop together with the associated irrigation management method has been selected from **Checklist C**, the user should proceed to the final section.

The questions in the checklists serve as the first steps to identifying potential issues and prevention measures, in order to help reduce the potential for impact on groundwater resources from informal agriculture. The questions are numbered, with options of possible answers: YES, NO, UNSURE or NOT APPLICABLE (N/A). Tick the most appropriate box as you proceed through the checklist. In this way, the checklist will serve as a “record of decision”.

Recommendations on an appropriate course of action and occasional references to other sections of this document series are presented next to the YES tick box. In the box for COMMENTS, the user should provide background notes on how a decision on the appropriate answer to the question was reached. Justification of the answer given may include personal observation.

Tabulated lists

In the final section tabulated lists of crops are presented together with each crop's salinity tolerance category. This list can be used to identify potentially suitable crops once the salinity tolerance category of the crop, together with the associated irrigation management method, has been selected from **Checklist C**.

- **Table 1:** ***Salt tolerance of herbaceous crops***
- **Table 2:** ***Salt tolerance of woody crops.***

Checklist A1:
Irrigation water (to gauge how irrigation water sinks into the soil and the condition of the ground surface and underlying soil)

Checklist A2:
Irrigation methods

Checklist A1: Irrigation water (to gauge how irrigation water sinks into the soil and the condition of the ground surface and underlying soil)

Questions	Yes	No	Unsure or N/A	Comment
1 Does rain or irrigation water tend to run off the cropland, with only a small portion sinking in?	☐ Loosen and level the soil, or else use a garden fork to make holes in the soil. Fill the holes with loose sand or fine mulch. Add gypsum to topsoil. Apply organic mulch, then dig lightly into surface soil.	☐	☐	
2 Even though rain or irrigation water sinks into the ground, do large portions of the soil, in the plant root zone, remain dry?	☐ Loosen and level the soil. Use mulches. Modify irrigation system or method.	☐	☐	
3 Does the ground become hard, and very difficult to dig, once the surface dries out?	☐ Add compost. Use mulches. Add gypsum. Install drains and increase leaching fraction.	☐	☐	
4 Is manure or fertilizer applied to the ground prior to planting or after crops are harvested?	☐ Potential problem in terms of contaminant / nutrient transport. Apply during growing season.	☐	☐	

Checklist A2: Irrigation methods

Questions	Yes	No	Unsure or N/A	Comment
1 Are the crops dependent on rainfall, with no supplementary irrigation?	☐ Go to **Checklist B1**.	☐	☐	
2 Are the crops irrigated by hand (e.g. bucket) or by using a handpump from a water source?	☐ Go to **Checklist B2**.	☐	☐	
3 Are crops irrigated with water supplied by hose, pipeline or furrow from a public water supply, or else with water supplied from a source equipped with a motorised pump?	☐ Go to **Checklist B3**.	☐	☐	

Checklist B1:
Crops with no irrigation

Checklist B1: Crops with no irrigation

Questions	Yes	No	Unsure or N/A	Comment
1 Does the slope of the terrain make rapid surface runoff and erosion likely?	☐ Relatively sleep slopes may result in the rapid runoff of rainwater, especially in heavy rain during the sowing and crop sprouting stages. This runoff can carry topsoil and nutrients with it, into surface water bodies or towards groundwater abstraction points, presenting a contamination threat to them. Terracing the land can help to prevent soil, nutrient and runoff water loss, and this also helps to prevent contamination of water sources in the area. Mulching also helps.	☐	☐ If the slopes are steeper than 6 degrees then assume the answer is YES.	
2 For sloping sites: Is there a borehole, well or spring being used for community domestic supply down slope of the cultivated land?	☐ Surface runoff from cultivated land has the potential to pollute water resources down slope. Terrace the land and / or construct diversion berms and ditches down slope to divert rainfall runoff water away from groundwater sources. Please consult the guidelines for applicable setback distances and protective measures for boreholes, wells and springs.	☐	☐ Check with people who know the area, with maps or orthophotos, or conduct a site visit. ☐ N / A. Site does not slope.	
3 Is there a borehole, well or spring being used for community domestic supply in the vicinity?	☐ Do not cultivate crops fthat require fertilizer or manure application, close to a groundwater abstraction point. Please consult the guidelines for applicable setback distances and protective measures for boreholes, wells and springs.	☐	☐ Check with peolple who know the area, with maps or orthophotos, or conduct a site visit.	
4 Is fertilizer added during the seed or seedling planting stage?	☐ Fertilizer and manure applications release nutrients that are not taken up effectively by seedlings, and a large portion of the nutrients (in particular nitrates) are leached downwards out of reach of the root zone of the plants before they grow big. It is preferable to apply nitrate and liquid fertilizers after the seedling stage, during the rapid growth phase of plants, so that the nutrients can be utilized more effectively by crops.	☐	☐ Ask the owner.	
5 Is manure being stored at the site prior to application?	☐ Large stores of animal manure could have a significant impact on the quality of groundwater or surface water resources. See also the guidelines documents for animal kraals on the management of manure storage sites.	☐	☐ Conduct a site visit or ask the owner.	

Checklist B2:
Crops irrigated by hand

Checklist B2: Crops irrigated by hand

Questions	Yes	No	Unsure or N / A	Comment
1 For sloping sites: Does the slope of the terrain make rapid surface runoff and erosion likely?	☐ Relatively steep slopes may result in the rapid runoff of irrigation water and rainwater, especially during the sowing and crop sprouting stages. This runoff can carry topsoil and nutrients with it, into surface water bodies or towards groundwater abstraction points, presenting a contamination threat to these. Terracing the land can help to prevent soil, nutrient and runoff water loss, and this also helps prevent contamination of water sources in the area. An alternative to terracing is to plant the crops along ridges and furrows dug in parallel to the land contours (the ridges should not slope). Mulching with dead grass, leaves, bark and small twigs should also help to prevent erosion.	☐	☐ If the slopes are steeper than 6 degrees, then assume the answer is YES. ☐ N / A: Site does not slope.	
2 For sloping sites: Is there a borehole, well or spring being used for community domestic supply down slope of the cultivated land?	☐ Surface runoff and sub-soil seepage has the potential to pollute groundwater abstraction points located down slope. Do not cultivate crops that require fertilizer or manure application upslope and close to the groundwater source. Construct diversion berms and ditches down slope of cultivated land to divert runoff water away from a borehole, well or spring. See the borehole / well / spring protection guidelines. If in doubt, consult a specialist.	☐	☐ Check with people who know the area, with maps or ortho-photos, or conduct a site visit. ☐ N / A: Site does not slope.	
3 Is there a borehole, well or spring being used for community domestic supply in the vicinity?	☐ Surface runoff and sub-soil seepage have the potential to pollute groundwater abstraction points in the vicinity. Do not cultivate crops that require fertilizer or manure application, close to a groundwater abstraction point. Construct diversion berms and ditches to divert runoff water away from a borehole, well or spring. See the borehole / well / spring protection guidelines. If in doubt, consult a specialist.	☐	☐ Check with people who know the area, with maps or orthophotos, or conduct a site visit.	
4 Is fertilizer of manure added before or during the seed or seedling planting stage?	☐ Fertilizer and manure applications release nutrients that are not taken up effectively by seedlings, and a large portion of the nutrients (in particular nitrates) is leached downwards, out of reach of the root zone of plants before they grow big. It is preferable to apply nitrate and liquid fertilizers after the seedling stage, during the rapid growth phase of plants, so that the nutrients can be utilized more effectively by crops.	☐	☐ Ask the owner.	
5 Is brackish water with TDS>250ppm being used to irrigate the crops?	☐ Most groundwater, greywater or washwater contains dissolved salts (mostly sodium and chloride ions), at concentrations making it unsuitable for use on certain crops. When irrigating sensitive crops with brackish water, it is preferable to irrigate more than what is needed (taking into account evaporation losses), so as to leach out salts from the soil. Consult **Checklist C** for advice on irrigating with brackish water.	☐	☐ Conduct a site visit or ask the owner.	
6 Is washwater being used to irrigate crops?	☐ The topsoil layer is an important zone of bacteria activity, which plays an important roll in the protection of groundwater by removing pathogens, greases, ammonia, phosphates and a portion of the nitrates from contaminating water. Nutrients are then released gradually over time, allowing the crops to make effective use of them. Consult the guidelines on greywater for advice on the impact on health and groundwater.	☐	☐ Conduct a site visit or ask the owner.	
7 For brackish water: In dry weather, does the ground surface remain moist for more than two days after watering the plants?	☐ Salt build-up in soils is likely when brackish water is used for irrigation and the surface soils remain moist for too long in drier weather and in full sunshine. Mulching helps to prevent loss of water to evaporation and runoff: leaves, bark, compost, dead grass or even small stones laid evenly on top of the ground can help. Probably the best way is to loosen the top soil with a hoe or rake after rain or irrigation, and then add an organic mulch (leaves, bark, etc.). Plastic sheeting laid on the soil surface can effectively reduce evaporation, but this needs careful management and may be costly.	☐	☐ An alternative is to take a soil sample for testing. Ask a soil expert. ☐ N / A: Not brackish water.	
8 Is manure being stored at the site prior to application?	☐ Large stores of animal manure could have a significant impact on the quality of groundwater resources. See the guidelines documents for animal kraals on the management of manure storage sites.	☐	☐	

Checklist B3:
Crops irrigated by hose pipe or water supply furrow

(from a water source equipped with a motorised pump or from a mains water supply)

Checklist B3: Crops irrigated by hose pipe or water supply furrow (from a water source with a motorised pump or a mains supply)

Questions	Yes	No	Unsure or N/A	Comment
1 For sloping sites: Does the slope of the terrain make rapid surface runoff and erosion likely?	☐ Relatively steep slopes can result in the rapid runoff of irrigation water and rainwater, especially during the sowing and crop sprouting stages. This runoff can carry topsoil and nutrients with it, into surface water bodies or towards groundwater abstraction points, presenting a contamination threat to them. Terracing the land can help to prevent soil, nutrient and runoff water loss. This also helps prevent contamination of water sources in the area. Alternatively, plant crops along ridges and furrows dug in parallel to the land contours (i.e. the ridges should not slope). Mulching helps to prevent soil erosion.	☐	☐ If the slopes are steeper than 6 degrees, then assume the answer is YES. ☐ N / A: Ground is not sloping.	
2 For sloping sites: Is there a borehole, well or spring down slope of the cultivated land?	☐ Surface runoff and sub-soil seepage can pollute groundwater abstraction points located down slope, especially if irrigation is excessive. Do not cultivate crops that require fertilizer or manure application close to, or upslope, of a groundwater source. Construct diversion berms and ditches down slope to divert runoff water away from a borehole well or spring. If in doubt, consult a specialist. Consult the guidelines for setback distances and protective measures for boreholes, wells and springs.	☐	☐ Check with people who know the area, with maps or ortho-photos, or conduct a site visit. ☐ N / A: Site does not slope.	
3 Is there a borehole, well or spring in the vicinity?	☐ Surface runoff and sub-soil seepage has the potential to pollute groundwater abstraction points in the vicinity, especially if excess irrigation is applied. Do not cultivate crops that require fertilizer or manure application close to a groundwater source. Consult the guidelines for applicable setback distances and protective measures for boreholes, wells and springs.	☐	☐ Check with people who know the area, with maps or ortho-photos, or conduct a site visit.	
4 Is there a contaminant source, e.g. a pit latrine, waste disposal site, animal kraal in the vicinity?	☐ Surface runoff and sub-soil seepage has the potential to greatly increase groundwater contamination threats posed by sources in the vicinity, especially if there is excess irrigation because of the increased movement of contaminants promoted by hydraulic loading. This threat increases if groundwater abstraction points are also located in the vicinity. Do not cultivate crops that require excessive irrigation requirements, close to the contaminant source. If in doubt, assume a high contaminant loading for the contaminant source in question and consult the relevant guidelines, or preferably consult a specialist.	☐	☐ Check with people who know the area, with maps or ortho-photos, or conduct a site visit.	
5 Is there a contaminant source, e.g. a pit latrine, waste disposal site, animal kraal down slope of the irrigated land?	☐ Surface runoff and sub-soil seepage can greatly increase groundwater contamination threats posed by down slope contaminant sources, as a result of the increased movement of contaminants promoted by hydraulic loading. This threat increases if irrigation is excessive, or if groundwater abstraction points are located down slope of the contaminant sources. An interim measure is to construct diversion berms and ditches down slope to divert runoff or seepage water away from contaminant sources. If in doubt, assume a high contaminant loading for the contaminant source. Consult the relevant guidelines, or consult a specialist.	☐	☐ Check with people who know the area, with maps or ortho-photos, or conduct a site visit.	
6 Is fertilizer or manure added before or during the seed or seedling planting stage?	☐ Fertilizer and manure applications release nutrients that are not taken up effectively by seedlings. Many nutrients (especially nitrates) are leached downwards out of reach of the root zone of the plants before they grow big. Preferably apply nitrate and liquid fertilizers after the seedling stage, during the rapid growth phase of plants, so nutrients can be utilized more effectively by	☐	☐ Ask the owner.	
7 Is the manure being stored at the site prior to application?	☐ Large stores of animal manure could have a significant impact on the quality of groundwater or surface water resources, especially if they are located close to and down slope of land that is subject to excess irrigation. See also the guideline documents for animal kraals, on the management of manure storage sites.	☐	☐ Conduct a site visit or ask the owner.	
8 Is groundwater or brackish water with TDS>250 ppm being used to irrigate the crops?	☐ When irrigating sensitive crops with brackish water, apply the water in excess of crop needs (take into account evaporation losses), so as to leach accumulated salts out from the soil. The drawback is that the mobile nutrients are rapidly leached out along with the salts, and some water is lost. To reduce these losses, several measures can be applied, including changing to crops that are less sensitive to brackish water irrrigation. Consult Checklist C for advice on irrigating with brackish water.	☐	☐ Ask the owner.	
9 For brackish water: Does the ground surface remain moist for more than two days after watering?	☐ Water is wasted through evaporation when the top soil remains moist too long in dry weather and in full sunshine. Salt build-up in soils is also likely when brackish water is used for irrigation. Mulching helps to prevent loss of water. Loosen the top soil with a hoe or rake after rain or irrigation, then add an organic mulch (leaves, bark, etc,). Plastic sheeting laid on the soil surface can effectively reduce evaporation, but this needs careful management and may be costly.	☐	☐ An alternative is to take a soil sample for testing. Ask a soil expert.	

Checklist C:
Crops irrigated with brackish water

The following refers to crops from the late seedling stage onwards (young seedlings are more sensitive to salinity). Crops are categorised according to sensitivity to salinity in soil water. Soil water salinity is related to salinity (units: EC or TDS) of irrigation water, assuming the application of certain irrigation management practices.

1 The leaching fraction (LF) is the amount of water applied to a crop in excess of the crop needs. All irrigation water must percolate into the ground (there should be no runoff).
2 Prevention measures to reduce water losses and prevent salinity build-up in the soils are:
    - (i) Mulching
    - (ii) For spray irrigation: irrigate when the wind does not blow, preferably in lower temperatures, when sunshine is minimal (before 10am, after 4pm, or in cloudy weather)
    - (iii) Use low-frequency irrigation.
3 To protect relatively vulnerable crops:
    - (i) Minimise leaf wetting
    - (ii) Increase the leaching fraction (LF).
4 If the soil surface does not dry out within two days of being irrigated in warm dry weather, consider:
    - (i) Mulching
    - (ii) Installing drains
    - (iii) Reducing the LF and if required, switching to a more salt-tolerant crop.
5 Irrigate taking rainfall into account. (The more it rains, the less irrigation is needed, and the less the effect of salinity). Use simple rain gauges (e.g. empty jam tins) to estimate rainfall and the amount spray irrigated.
6. Potential salinity problems:
    - (i) If crop leaves start to go brown at the tips, a build-up of soil salinity or else leaf wetting could be the problem
    - (ii) If a crop shows signs of wilting under normal irrigation practices, a build-up of soil salinity could be the problem.

Checklist C: Crops irrigated with brackish water

Water salinity *	Yes (Select the row for which a positive answer can be given and tick this box. Leave all other boxes unticked.)	Comment
1 Is EC above 40 mS/m? or Is TDS above 260 ppm?	☐ Most crops can be grown with this water. For **sensitive crops** (**S**): Ensure prevention measures are applied, and use a LF of about 10%, and don't wet crop leaves. For **other crops**, ensure that sufficient water is supplied to meet crop needs.	
2 Is EC above 40 and less than 90 mS/m? or Is TDS above 260 and less than 590 ppm?	☐ Don't irrigate **sensitive crops** (S) with this water unless prevention measures are applied and a LF of between 15% to 30% is used, and wetting of crop leaves is avoided. (Note that higher leaching fractions may require additional measures to reduce evaporative water losses.) For **moderately sensitive crops** (**MS**) ensure prevention measures are applied, use a LF of between 10% and 15% and avoid wetting crop leaves. For **moderately tolerant crops** (**MT**) and **tolerant crops** (**T**), apply a LF of between 3% and 5%.	
3 Is EC above 90 and less than 270mS/m? or Is TDS above 590 and less than 1760 ppm?	☐ Don't irrigate **sensitive crops** (**S**) with this water. In exceptional circumstances irrigation may be considered under expert advice: where prevention measures are applied and a LF of between 30% and 100% is considered viable. Note that higher leaching fractions witll probably require additional measures (e.g. drainage) to reduce evaporative water losses. For **moderately sensitive crops** (**MS**) ensure prevention measures are applied, and use a LF of between 15% and 40%. Avoid wetting crop leaves. Note that higher leaching fractions may require additional measures to reduce evaporative water losses and also, may not be feasible. Seek the advice of a specialist. For **moderately tolerant crops** (**MT**) , ensure prevention measures are applied, use a LF of between 10% and 20%, and avoid wetting crop leaves. For **tolerant crops** (**T**), ensure prevention measures are applied. Use a LF of between 5% and 15%.	
4 Is EC above 270 and less than 540 mS/m? or Is TDS above 1760 and less than 3510 ppm?	☐ Don't irrigate **sensitive crops** (**S**) or **moderately sensitive crops** (**MS**) except under expert advice. For **moderately tolerant crops** (**MT**) , ensure prevention measures are applied, use a LF of between 15% and 30%, and avoid wetting crop leaves. Higher leaching fractions may require additional measures to reduce evaporative water losses. For **tolerant crops** (**T**), ensure prevention measures are applied. Use a leaching fraction of between 10% and 25%, and avoid wetting crop leaves.	
8 Is EC above 540 mS/m? or Is TDS above 3510 ppm?	☐ Certain **ttolerant crops** (**T**) could be irrigated. The advice of a specialist should be sought.	

* South African Water Quality Guidelines, 1996

3 Crop tolerance rates to soil salinity

The ability of plants to absorb water through their roots is dependent on the concentration of salts in the water. The more saline the water is, the less available it is to the plant. For each plant type, there is a salinity threshold above which the plant's growth becomes restricted. The extent to which the growth is restricted then depends on the salinity of the soil water above this threshold. Some plant species are able to extract water from saline moisture in soils more effectively than others. The sensitivity of crops to salinity can therefore be expressed as a function of the concentration of total soluble salts in the soil moisture.

To ease decision making, crops have been rated for tolerance to salinity and placed in four categories:

S **Sensitive**
MS **Moderately Sensitive**
MT **Moderately Tolerant**
T **Tolerant**

These categories, referred to in **Checklist C** (above), are used to indicate the salinity tolerance of the crops listed in **Table 1** (herbaceous crops) and **Table 2** (perennial/woody crops). To make use of these tables, first have the irrigation water analysed for total dissolved solids by measuring its electrical conductivity (EC). Then go to **Checklist C** and answer the most relevant question in the second column by placing a tick in the box next to the question.

Then, EITHER

- Select the relevant salinity sensitivity category to the right of the ticked box, and proceed to **Table 1**and **Table 2**. Identify particular crop types that are in the selected salinity sensitivity category, and then select from these the crops that can be grown in the area of concern.

OR

- If a crop is already growing under irrigation in the area, go to **Table 1** and **Table 2** and identify the salinity sensitivity category of the crop in question. Then return to **Checklist C** and determine the requirements for effective irrigation management to the right of the ticked box.

Herbaceous crops

Herbaceous crops are generally annual. The following table refers to the salt tolerance of these crops.

Table 1: Salt tolerance of herbaceous crops † (after Maas and Grattan, 1999)

Common name	Botanical name ‡	Rating §
Artichoke	*Cynara scolymus* L.	MT
Artichoke, Jerusalem	*Helianthus tuberosus* L.	MS
Asparagus	*Asparagus officinalis* L.	T
Bean, common	*Phaseolus vulgaris* L.	S
Bean, lima	*P. lunatus* L.	MT*
Bean, mung	*Vigna radiata* (L.) R. Wilcz	S
Beet, red	*Beta vulgaris* L.	MT
Broad bean	*Vicia faba* L.	MS
Broccoli	*Brassica oleracea* L. (Botrytis Group)	MS
Brussels sprouts	*B. oleracea* L. (Gemmifera Group)	MS*
Cabbage	*B. oleracea* L. (Capitata Group)	MS
Carrot	*Daucus carota* L.	S
Cassava	*Manihot esculenta* Crantz	MS
Cauliflower	*Brassica oleracea* L. (Botrytis Group)	MS*
Celery	*Apium graveolens* L. var dulce (Mill.) Pers.	MS
Corn / Maize	*Zea mays* L.	MS
Cowpea	*Vigna unguiculata* (L.) Walp.	MT
Cucumber	*Cucumis sativus* L.	MS
Eggplant	*Solanum melongena* L. var *esculentum* Nees.	MS
Garlic	*Allium sativum* L.	MS
Gram, black or Urd bean	*Vigna mungo* (L.) Hepper [syn. *Phaseolus mungo* L.]	S
Kale	*Brassica oleracea* L. (Acephala Group)	MS*
Kohlrabi	*Brassica oleracea* L. (Gongylodes Group)	MS*
Lettuce	*Lactuca sativa* L.	MS
Millet, channel	*Echinochloa turnerana* (Domin) J.M. Black	T
Muskmelon	*Cucumis melo* L. (Reticulatus Group)	MS
Oats	*Avena sativa* L.	T
Okra	*Abelmoschus esculentus* (L.) Moench	MS
Onion (bulb)	*Allium cepa* L.	S
Onion (seed)		MS
Parsnip	*Pastinaca sativa* L.	S*
Pea	*Pisum sativum* L.	MS
Peanut	*Arachis hypogaea* L.	MS
Pepper	*Capsicum annuum* L.	MS
Pigeon pea	*Cajanus cajan* (L.) Huth [syn. C. indicus (K.) Spreng.]	S
Potato	*Solanum tuberosum* L.	MS
Pumpkin	*Cucurbita pepo* L. var Pepo	MS*
Purslane	*Portulaca oleracea* L.	MT
Radish	*Raphanus sativus* L.	MS
Sorghum	*Sorghum bicolor* (L.) Moench	MT
Spinach	*Spinacia oleracea* L.	MS
Squash, scallop	*Cucurbita pepo* L. var *melopepo* (L.) Alef.	MS
Strawberry	*Fragaria x Ananassa* Duch.	S
Squash, zucchini	*C. pepo* L. var *melopepo* (L.) Alef.	MT
Sugar cane	*Saccharum officinarum* L.	MS
Sunflower	*Helianthus annuus* L.	MT
Sweet potato	*Ipomoea batatas* (L.) Lam.	MS
Tepary bean	*Phaseolus acutifolius* Gray	MS*
Tomato	*Lycopersicon lycopersicum* (L.) Karst. ex Farw. [syn. *Lycopersicon esculentum* Mill.]	MS
Tomato, cherry	*L. lycopersicum* var. *Cerasiforme* (Dunal) Alef.	MS
Turnip root/ Turnip top	*Brassica rapa* L. (Rapifera Group)	MS / MT
Watermelon	*Citrullus lanatus* (Thunb.) Matsum. & Nakai	MS*
Winged bean	*Psophocarpus tetragonolobus* L. DC	MT

Key to Table 1 and Table 2

† These data serve only as a guideline to relative tolerances among crops. Absolute tolerances vary, depending upon climate, soil conditions, and cultural practices.

‡ Botanical and common names follow the convention of Hortus Third (Liberty Hyde Bailey Hortorium Staff, 1976) where possible.

§ **Ratings:**

S	Sensitive
MS	Moderately Sensitive
MT	Moderately tolerant
T	Tolerant

Ratings with an * are estimates

Perennial / woody crops

The tolerance of trees, vines and other perennial / woody crops to salinity is complicated by the sensitivity of these plants to the toxic effects of high concentrations of chloride, sodium and boron ions. Many of the perennial crop types are susceptible to injury from the build-up of chloride and sodium ions in the leaves, when irrigated with brackish water containing these ions.

The salinity ratings for perennial / woody crops are given in **Table 2**. Specific ion toxicity is not accounted for. However, for irrigation water containing high proportions of sodium and chloride ions in comparison with other ions, the sensitivity categories are similar to the ones shown in the table.

In the absence of specific-ion effects, the tolerance of perennial / woody crops, like that of herbaceous crops, can be expressed as a function of the concentration of total soluble salts in the soil solution. In contrast to other crop groups, most woody fruit and nut crops tend to be salt sensitive. Only a few well-known ones, such as date palm, olive and fig, are tolerant or moderately tolerant.

Table 2: Salt tolerance of perennial / woody crops † (after Maas and Grattan, 1999)

Common name	Botanical name ‡	Rating §
Almond	*Prunus duclis* (Mill.) D.A. Webb	S
Apple	*Malus sylvestris* Mill.	S
Apricot	*Prunus armeniaca* L.	S
Avocado	*Persea americana* Mill.	S
Banana	*Musa acuminata* Colla	S
Blackberry	*Rubus macropetalus* Doug. ex Hook	S
Boysenberry	*Rubus ursinus* Cham. and Schlechtend	S
Cherry, sweet	*Prunus avium* L.	S*
Cherry, sand	*Prunus besseyi* L., H. Baley	S*
Coconut	*Cocos nucifera* L.	MT*
Date-palm	*Phoenix dactylifera* L.	T
Fig	*Ficus carica* L.	MT*
Gooseberry	*Ribes sp.* L.	S*
Grape	*Vitis vinifera* L.	MS
Grapefruit	*Citrus x paradisi* Macfady.	S
Guava	*Psidium guajava* L.	MT
Guayule	*Parthenium argentatum A.* Gray	T
Jambolan plum	*Syzygium cumini* L.	MT
Jojoba	*Simmondsia chinensis* (Link) C. K. Schneid	T
Jujube, Indian	*Ziziphus mauritiana* Lam.	MT
Lemon	*Citrus limon* (L.) Burm. f.	S
Lime	*Citrus aurantiifolia* (Christm.) Swingle	S*
Loquat	*Eriobotrya japonica* (Thunb). Lindl.	S*
Macadamia	*Macadamia integrifolia* Maiden & Betche	MS*
Mandarin orange; tangerine / naartjie	*Citrus reticulata* Blanco	S*
Mango	*Mangifera indica* L.	S
Natal plum	*Carissa grandiflora* (E.H. Mey.) A. DC.	T
Olive	*Olea europaea* L.	MT
Orange	*Citrus sinensis* (L.) Osbeck	S
Papaya	*Carica papaya* L.	MS
Peach	*Prunus persica* (L.) Batsch	S
Pear	*Pyrus communis* L.	S*
Pecan	*Carya illinoinensis* (Wangenh.) C. Koch	MS
Persimmon	*Diospyros virginiana* L.	S*
Pineapple	*Ananas comosus* (L.) Merrill	MT
Pistachio	*Pistacia vera* L.	MS
Plum; Prune	*Prunus domestica* L.	MS
Pomegranate	*Punica granatum* L.	MS
Pummelo	*Citrus maxima* (Burm.)	S*
Raspberry	*Rubus idaeus* L.	S
Tamarugo	*Prosopis tamarugo* Phil.	T
Walnut	*Juglans* spp.	S*

Example of using Tables 1 and 2 in relation to Checklist C:

Suppose pineapples are to be irrigated with brackish water of EC of 240 mS/m.
Table 2 has pineapple listed as a moderately tolerant (MT) crop. **Table 1** shows that, for moderately tolerant crops, prevention measures (mulching, low-frequency irrigation, etc.) should be applied, and that a leaching fraction (LF) of between 10% and 20% should be used. The salinity of the irrigation water places it close to the next higher salinity category where greater leaching fractions may be required. Therefore it is probably safer to assume that a leaching fraction of 20% would be required to keep soil salinities down.

If irrigation is to be carried out during the rainy season, then the leaching fraction can be reduced in proportion to the contribution of the irrigation water to the total seasonal crop requirements (e.g. If the seasonal rainfall thus far is sufficient for 70% of the crop needs, then the contribution of irrigation water is 30%, so the leaching fraction of supplementary irrigation water can be reduced to 30% of the original, that is, 6%).

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How to Protect Groundwater from Contamination by

Informal waste disposal

TOOLKIT for WATER SERVICES: Number 3.4.7

This document provides guidelines and tools to help protect groundwater from contamination. It will be useful to Environmental Health Officers, environmental planners, health and hygiene educators, sanitation planners and pollution control officers working in Water Services Authorities, Water Services Providers, the Department of Health, the Department of Water Affairs and Forestry and Catchment Management Agencies.

Protecting Groundwater from Contamination by Informal Waste Disposal

Published by
Department of Water Affairs and Forestry
Directorate: Information Programmes
Private Bag X313
PRETORIA 0001
Republic of South Africa
Tel: (012) 336 7500

Implemented by
CSIR

Written by
Irené Saayman and Kerry O'H Murphy

Editing
Anthea Josias and Kerry Harris

Artwork
Vusi Malindi

Layout and design
Gill McDowell

Informal waste disposal

1 Background to the contamination threat

Introduction

Waste generated in rural communities typically includes household items as well as products generated outside the house, like crop residues, used oil, fertiliser, insecticide containers and animal droppings. The composition of household waste can be quite varied and may include food waste, paper, cans, cardboard, plastics, textiles; rubber, leather, wood, glass, dirt, ash, brick and bones. Pathogens (infectious germs and viruses) may also be present as a result of the disposal of soiled tissues and rags, contaminated food and floor sweepings.

Moisture helps waste to decompose, and decomposing waste produces moisture. Common sources of moisture are rainfall, liquids disposed with the waste, and the decomposing waste itself. Excess moisture leaves the waste as a smelly, toxic and infectious fluid called leachate. Waste decomposition products such as organic acids, ammonia, sulphides and potentially toxic trace elements (such as zinc, cadmium and lead) are carried off in the leachate as it moves through the waste. The potentially toxic trace elements come from chemicals and metals in the waste.

Groundwater vulnerability

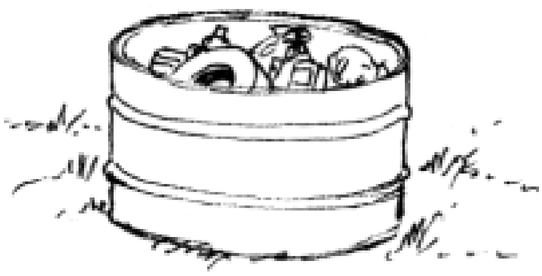
If waste is disposed of directly into standing water, the decomposing waste will rapidly contaminate the water. Waste can contaminate water resources indirectly, as a result of leachate entering the water resources. Leachate can flow directly overland into surface water resources, or move through soils and enter groundwater or surface water resources. If water is contaminated by leachate, the taste and odour of the water can be objectionable. Pathogens and potentially toxic trace elements from leachate pose a health risk if the water is used for drinking purposes.

When leachate moves through aerated soil, the concentration of potential contaminants in the percolating leachate becomes progressively diminished, until the leachate reaches groundwater. This means that the soil removes some of the potential contaminants, but that once leachate reaches water, this natural treatment process effectively stops. Leachate from waste is normally acidic because of dissolved organic acids. These organic acids are able to carry contaminants, such as heavy metals, ammonia, and certain pathogens deep into the ground, and thus represent a contamination risk to groundwater.

The vulnerability of groundwater to pollution from informal waste sites increases in areas with high rainfall and shallow water tables. Groundwater vulnerability will also be high in fractured rock and other high permeability environments, such as sandy or gravelly soils. The risk of groundwater being contaminated is increased under conditions where:

- Waste is disposed near or in the water table, or near or in a water source. This reduces or removes the ability of soils to reduce or remove potential contaminants from the leachate.
- A high waste loading occurs. The more waste in a disposal site, the greater the quantity of contaminants that are generated.
- The bedrock is highly fractured, lies close to the ground surface, and the overlying soils are highly permeable.

The threat of groundwater contamination from personal littering (for example, a person dropping one or two items of rubbish on the ground) activities in rural communities is usually comparatively low. This is mainly because the contaminant loading is low, and the soil can effectively remove potential contaminants. However, the direct threat of such waste to personal health can be significant, and so it is better to dispose of such waste in other ways. Litter and refuse should rather be collected and then disposed of at specially selected designated waste disposal sites.



Impact on health

Water that is used for drinking, that has become contaminated by household waste or by leachate from such waste, can cause disease like diarrhoea and other health problems over the longer-term. The longer-term effects relate to the impairment of nerves, eyes, liver, kidney and other organs of the body. Poor taste and a bad odour may be early warning signs that a water resource has become contaminated by leachate from waste. If contamination is suspected, the advice of health professionals, waste management experts and hydrogeologists should be sought.

Managing informal waste disposal

For groundwater contamination to occur, leachate from waste needs to be able to move downwards to the water table. It is important, therefore, that liquids are not disposed of onto or with waste, or that rain water does not enter it. In addition, waste (e.g. rubbish) should not be dumped into water or a place where water can collect.

Unfavourable conditions include:

- Areas of high rainfall. This makes the accumulation of water in waste more likely.
- Areas with shallow water tables. This means that the separation between the disposed waste and the water table is small, which limits the opportunity for treatment of the leachate.
- Areas underlain by high permeability soils and rock. This means that leachate can move rapidly from the waste to the water table, with limited opportunity for treatment of the leachate.
- Large-scale dumping in one place, especially a pit or hollow, where water can collect.

If waste disposed at an informal site exceeds about half a ton per month (or serves more than 30 people), it is recommended that a departmental official be consulted, as the ***Minimum requirements regulations for waste disposal by landfill*** (DWAF, 1994) may be applicable.

Issues to consider in the disposal of informal waste

- It is important that liquids are not disposed of onto or with waste.
- Do not dump waste in the vicinity of a borehole, well or spring. (See **Set-back Distance Charts** for appropriate setback distances).
- Where never possible, do not dump waste upslope of a borehole, well or spring (See **Set-back Distance Charts**).
- Do not dispose of waste in any water source.
- Do not dispose of waste in a place where water can collect.
- Do not dispose waste in a quarry, borrow pit, sinkhole, mine shaft or storm water channel.
- Do not dispose waste in a fault zone, on a dyke or on fractured rock.

Include the following steps in the selection of an informal waste disposal site

- Conduct a hydrocensus beforehand, in order to pinpoint the location of water sources in the area and their level of use (see ***Involving community members in a hydrocensus*** – Toolkit for Water Services Number 3.1).
- Ensure that the proposed site is kept sufficiently far away from water resources. To this end, ensure that the minimum separation distances from water sources and groundwater resources, as specified in the DWAF's *Minimum requirements regulations for waste disposal by landfill*, are adhered to. The **Set-back Distance Charts** provide guidelines on setback distances for informal waste disposal sites from water sources.
- Choose an area that does not have a shallow water table and that does not contain any surface water.
- Choose areas with deep, low permeability soils (e.g. clays). Avoid areas with coarse sands, gravel or areas with exposed bedrock, or areas that have fissured bedrock near the ground surface.
- If an informal site is to be used for disposal of a large volume of waste, such as more than half a ton per month (that is, to serve more than 30 people), a departmental official should be consulted.

2 Tools for dealing with the contamination threat

The decomposition of waste produces a highly contaminated liquid known as **leachate**. It is therefore important that waste disposal sites are not located where leachate may enter and contaminate water resources.

The following two sections serve to guide decision makers on actions that are required to protect groundwater resources in their unique settings. The link between waste disposal practices and physical and hydrological conditions of the area is also highlighted. In the first section, the reader is presented with **Informal Waste Disposal Sites Checklists**, in which some simple questions are asked. Three possible answers are presented, each of which recommends a particular course of action.

Where waste produced by rural communities is disposed to formal waste disposal sites, such sites come under the minimum requirements legislation and are not covered by these guidelines. These guidelines are for small informal sites in a rural community environment, where waste disposal is typically less than half a ton of waste per month.

Checklists

The checklists serve as a first step to guide decision makers on the suitability of sites for the disposal of solid waste. It should be noted that the recommendations contained here apply only to informal waste disposal, and do not apply to formal sites that are classified as communal or larger in the minimum requirements for waste disposal (DWAF, 1998).

The two checklists for waste disposal sites are:

- **Checklist 1:** ***Existing informal waste disposal site.***
- **Checklist 2:** ***Proposed informal waste disposal site.***

The following questions should be answered before moving to the **Flowchart: On-Site Test** sheet, though the reader may choose to move between sections where necessary.
The questions are numbered, with options of possible answers (YES, NO or UNSURE) presented in subsequent columns of the same row. Tick the most appropriate box as you proceed through the test sheet. The complete test sheet should be answered, irrespective of whether an answer recommends a particular course of action. The reader may choose to revisit and /or redo this questionnaire after completion of the test sheet.

Recommendations on an appropriate course of action and occasional references to other sections of this document series, is presented next to the YES tick box. In most instances a YES answer would indicate the need to consult a specialist (waste management specialist or hydrogeologist) on the suitability of the waste disposal site and the practices to be followed at the site.

In the box for COMMENTS, the reader should provide background information on how the most appropriate answer to the question was arrived at, and provide references to supporting documentation (if available). Justification of the answer given may include personal observation, or the results obtained through the attached **Flowchart: On-Site Test** sheet. This documentation, once completed, may be kept as a record of the decisions taken.

If the site is currently being used, answer the questions in **Checklist 1**. If the site is being proposed for future waste disposal, answer the questions in **Checklist 2**.

Flowchart: On-Site Test

The second section contains a **Flowchart: On-Site Test** sheet which is designed to help the user to judge the existence and depth to the seasonal high water table from inspecting a pit dug at the site being evaluated. The **Flowchart: On-Site Test** ends in advice to the decision maker and gives further directions.

Set-back Distance Charts

The threat that solid waste poses to local groundwater supplies should be evaluated in terms of the hydrogeological setting within which the waste is deposited, the volume of waste deposited at this location, the moisture content of the waste, and the design, operation and management practices adopted at the site. The reader is referred to DWAF's *Minimum requirements for waste disposal by landfill* (1998) for guidelines on the siting, design, operation and management of landfill sites.

This section provides decision makers with guidelines on the minimum set-back distances that should exist between small informal waste disposal sites and a community groundwater supply source. Community groundwater supply sources typically include boreholes, dug wells, and springs, the former equipped with motorised pumps. The **Set-back Distance Charts** are meant to provide a simplified, easy to follow guide on the suitability of set-back distances for informal waste disposal. The information is presented in table form, and considers the hydrogeological setting and the depth to the water table, in order to derive set-back distances. The hydrogeological settings evaluated are those that are typically exploited for water supply. These are: unconsolidated sedimentary deposists (silt, fine silty sand, medium sand, and gravel), fractured hard rock environments and limestone.

Minimum Requirements regulations on the disposal of waste to small landfills require a minimum (vertical) separation of 2 metres between the waste and the top of the water table at its highest elevation in silty soils (DWAF, 1994). In other soil and rock type settings, different minimum vertical separation distances are recommended.

The **Set-back Distance Charts** do not account for sites that are:

- excluded because of legislative requirements (e.g. the requirement for a minimum vertical separation distance of 2 metres in silty soils)
- excluded in the checklists or flowcharts and
- excluded by criteria in the first section of this guideline in the text box entitled ***Issues to consider in the disposal of informal waste*** (e.g. water sources, quarries, mine shafts, fault zones, dykes, etc.)

Only two vertical separation classes are considered in the decision charts: 0 to 10 metres separation, and more than 10 metres separation (depth to water table).

The volume of waste deposited is not among the variables considered in the decision charts. DWAF's *Minimum requirements for waste disposal by landfill* (1998) uses a classification system for waste disposal sites. This is based on the quantity of waste (in tons per day) handled at a particular site, and the likely moisture content of the waste (the latter relates to the potential of waste at a site to generate significant volumes of leachate).

Guidelines are then given for the operation and management of waste disposal sites for each class. In terms of the waste volumes disposed, most rural waste disposal sites are expected to fall at the lower end of the Communal Class. The Communal Class includes sites where less than 1 ton of waste is deposited per day (or less than 30 tons per month). For comparison purposes; A rural community of thirty people will dispose half a ton of waste per month. (Formal waste disposal sites used by rural communities come under the Minimum Requirements legislation and are not covered by these guidelines.)

There are three decision charts applicable to these guidelines, for identifying suitable separation distances (between informal waste disposal sites and groundwater abstraction points) and associated protective measures:

- **Chart DML**: light contaminant load - for deep unconfined aquifers with boreholes and wells fitted with motorised pumps.

- **Chart S&DMH**: heavy contaminant load - for shallow and deep unconfined aquifers with boreholes and wells fitted with motorised pumps.

- **Chart SML**: light contaminant load - for shallow unconfined aquifers with boreholes and wells fitted with motorised pumps.

Summary of information needed to use the decision charts:

In terms of informal waste disposal sites, heavy loading is applicable to sites where there is standing water, or where moist wastes and liquids are disposed of together with solid waste. The loading category applies to sites used by a community of up to 30 people would depend on the extent to which the waste will produce leachates, and this partly dependent on climatic and site factors. Expert advice will probably be needed here.

Light loading is applicable to waste disposal sites used by a family (no co-disposal of moist wastes or liquids). In order to choose the applicable decision chart, further information on the depth to the water table from the base of the waste disposal site (e.g. base of a pit) is needed. If the depth to the expected highest seasonal water table is less than or equal to 10 metres below the base of the waste pile, the aquifer is classified as a shallow aquifer. Otherwise it is a deep aquifer.

Checklist 1:
Existing informal waste disposal sites

Checklist 1: Existing informal waste disposal sites

Questions	Yes	No	Unsure	Comment
1 Are chemicals, pesticides or any other toxic or harmful substances being disposed of at the site?	☐ This activity should be stopped until a specialist has been consulted and his / her recommendations followed.	☐	☐ Indications of this activity should be revealed during a site visit. Get specialist input.	
2 Is the site being used for disposing liquids (e.g. wastewater, vehicle oil, etc.)?	☐ This activity should be strictly controlled or else stopped. Consult a specialist.	☐	☐ Indications of this activity should be revealed during a site visit. Get specialist input.	
3 Is the site being used for disposing human or animal wastes (e.g. animal carcasses, faeces, manure)?	☐ This activity should be stopped or else strictly controlled. Consult a specialist.	☐	☐ See the guidelines for burial sites, pit latrines and animal kraals, watering points and dipping tanks. Get specialist input.	
4 Is waste being disposed into standing water or into a place where water may flow (e.g. erosion channel)?	☐ This activity should be stopped or else strictly controlled. Consult a specialist.	☐	☐ Indications of this activity should be revealed during a site visit. Get specialist input.	
5 Is waste disposed into / onto bedrock, onto ground consisting of gravels or coarse sandy soils, over a fault or dyke, in a sinkhole, mineshaft or quarry?	☐ This activity should be stopped until a specialist has been consulted and his / her recommendations followed.	☐	☐ See the **Introduction to Groundwater Protection** and the "Why and What guide-lines for waste disposal". Get specialist input.	
6 Does the seasonal high groundwater table come to within 2 metres of the base of the pit where the waste is disposed?	☐ For guidance on the management of wate disposal sites and the appropriate disposal of waste, the user is referred to the Minimum Requirements guidelines on Waste Disposal. Consult a specialist. (See the *Minimum Requirements for Waste Disposal*, DWAF, 1998.)	☐	☐ See the **Flowchart: On-Site Test** sheet on how to identify the existence of a shallow water table. Get specialist input.	
7 Does a river or stream flow within 100 metres of the waste site? (See the *Minimum Requirements for Waste Disposal*, DWAF, 1998)	☐ A waste disposal site should not be located within 100 metres of a river, stream, dam or natural pond, where these are downslope of the site, or where run off water could reach them. Consult a specialist.	☐	☐ The existence of a river or stream close to the site should be revealed during a site visit. Otherwise consult a map or obtain a hydrocensus report.	
8 Does the waste site occur upslope of, or close, to a borehole, well or spring (including disused boreholes or wells)?	☐ See the **Waste Disposal Decision Chart** for guidance on the appropriate set-back distance. Consult a specialist.	☐	☐ The existence of a borehole, well or spring close to or downslope of the site should be revealed during a site visit. Otherwise consult a map or obtain a hydrocensus report.	

Checklist 2:
Proposed informal waste disposal sites

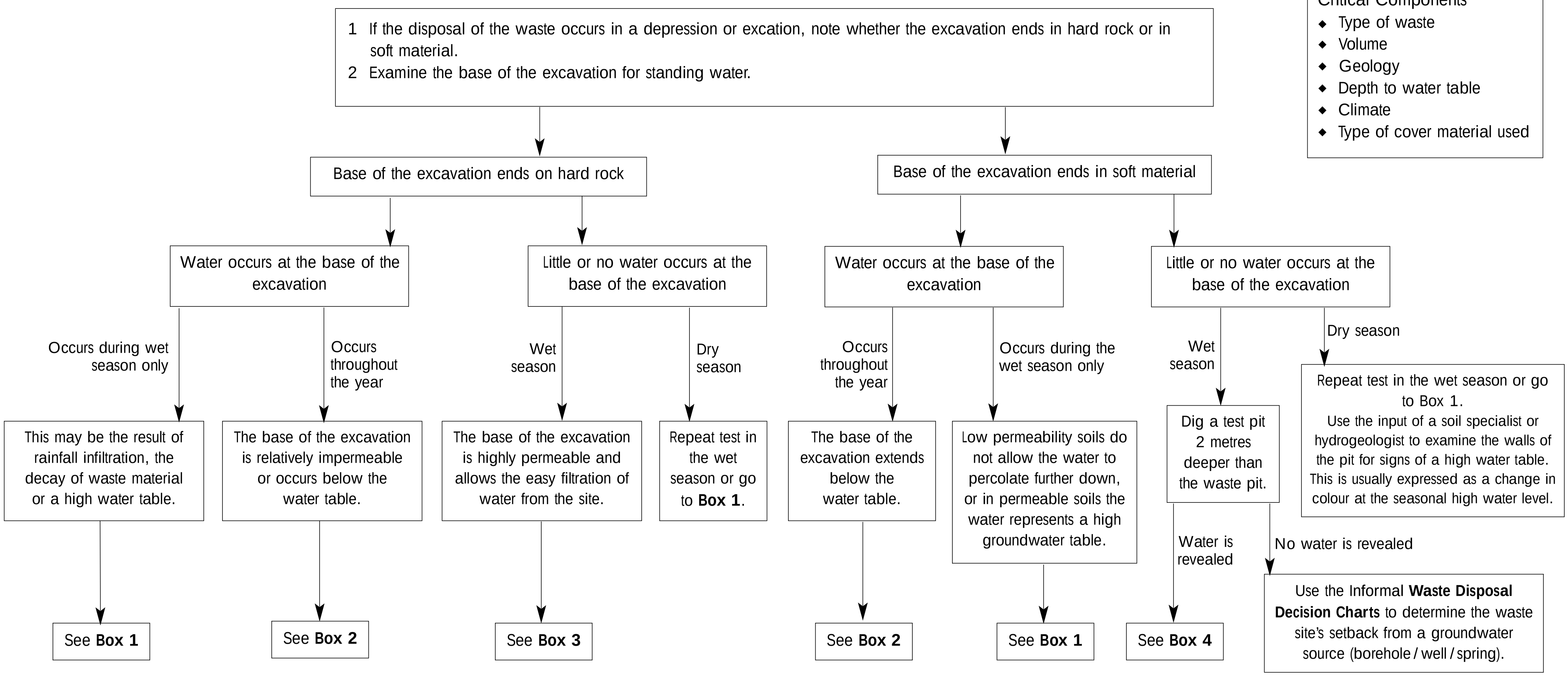
Checklist 2: Proposed informal waste disposal sites

Questions	Yes	No	Unsure	Comment
1 Will chemicals, pesticides or any other toxic or harmful substances be disposed of at the site?	☐ Exclude this proposed activity, or else consult a specialist.	☐	☐ Investigate this further, unless the question is not applicable.	
2 Will the site be used for disposing liquids (e.g. wastewater, vehicle oil, etc.)?	☐ Exclude this proposed activity. Only under strict circumstances could the disposal of liquids be allowed. Consult a specialist.	☐	☐ Investigate this further, unless the question is not applicable. Get specialist input.	
3 Will the site be used for disposing human or animal wastes (e.g. animal carcasses, faeces, manure)?	☐ Exclude this proposed activity. Only under special circumstances and strict supervision could this activity be allowed. Consult a specialist.	☐	☐ Investigate this further, unless the question is not applicable. Get specialist input.	
4 Will waste be disposed into standing water or into a place where water may flow (e.g. erosion channel)?	☐ Ensure this does not happen. Consider excluding the site from further consideration, or consult a specialist.	☐	☐ Investigate this further, unless the question is not applicable. Get specialist input.	
5 Will waste be disposed into / onto bedrock, onto ground consisting of gravels or coarse sandy soils, over a fault or dyke, in a sinkhole, mineshaft or quarry?	☐ This should not happen. Exlude the site from further consideration or consult a specialist.	☐	☐ See **Introduction to Groundwater Protection** and the why and what guidelines for waste disposal". Investigate this further, unless the question isn't applicable. Get specialist input.	
6 Does the seasonal high groundwater table come to within 2 metres of the base of the proposed pit where the waste will be disposed of?	☐ Two metres is the minimum depth for low-permeability soils. Five metres or more is preferable for permeable soils. If this cannot be achieved, exclude the site from further consideration, or consult a specialist.	☐	☐ See the **Flowchart: On-site Test** sheet on how to identify the existence of a shallow water table. Get specialist input.	
7 Does a river or stream flow within 100 metres of the proposed waste disposal site? (See the *Minimum Requirements for Waste Disposal*, DWAF, 1998)	☐ A waste site should not be located closer than 100 metres from a river, stream, dam or natural pond, where these are downslope of the site, or where runoff water could reach them. Exclude the site or consult a specialist.	☐	☐ The existence of a river or stream close to the site should be revealed during a site visit. Otherwise consult a map or obtain a hydrocensus report.	
8 Will the waste disposal site occur upslope of, or close to, a borehole, well or spring (including disused boreholes or wells)?	☐ See the Waste Disposal Decision Chart for guidance on the appropriate set-back distance. Consult a specialist.	☐	☐ The existence of a borehole, well or spring close to or downslope of the site should be revealed during a site visit. Otherwise consult a map or obtain a hydrocensus report.	

Flowchart: On-site Test
Informal waste disposal

The on-site test presented here is designed to provide decision makers with information on the minimum depth to the seasonal high groundwater table at the site being evaluated for informal waste disposal. This test is meant to provide input to the decision making process, and should not be viewed in isolation of the Minimum Requirements guidelines and the other documents that make up this series.

Flowchart On-site Test: Informal waste disposal



BOX 1
If it is suspected that the presence of water is related to a rise in water levels in an aquifer during the wet season, the input of a hydrogeologist or suitably qualified engineer should be sought, (See **Box 2**)
For exposed bedrock, if there is a possibility that the rock is fractured, see **Box 2** and **Box 3**.
For an existing informal wastes site; Control the amount of water entering the site. Do this through the construction of a cut-off trench to reduce the inflow of surface run off, and cover the waste with low permeability soil. The cover should be designed so that rainfall runoff is directed away from the waste pile. This reduces the generation and mobility of contaminants in the waste pile, while the cover soil reduces the occurrence of flies and bad odours.

BOX 2
Areas with high water tables are generally unsuitable for the dumping of wastes, as exposure to water hastens the decay of waste material, while the location of waste near or below the water table allows access to the groundwater resource of potenially lethal and toxic waste decay products (leachate). A separation of at least 2 metres should exist between the base of the waste pile and the water table in impermeable soils, whereas at least 5 metres is preferable for highly permeable ground.
Investigate the possibility of moving the waste site to a location where the waste represents less of a threat to water resources. Consult a hydrogeoligist or suitably qualified engineer on this.

BOX 3
Waste material should not be disposed of in settings where high permeability hard rock occurs close to the surface, or is exposed in the waste pit. The high flow rates that are typical of hard rock aquifers means nearby boreholes and surface water resources could be easily contaminated by potentially toxic waste decay products (leachate).
Investigate the possibility of moving the waste site to a location where the leachate from waste represents less of a threat to water resources.
Consult a hydrogeologist or suitably qualified engineer on this.

BOX 4
The vulnerability of water resources to contamination generated by the decay of solid wastes depends onsite specific conditions, such as the depth of the water table and topography. Exposure to moisture (e.g. rainfall) hastens the decay of waste, and results in the increased generation of leachate. The rate at which contaminants are generated can be limited by preventing the access of surface runoff by constructing a cut-off trench on the upslope sides of the site and by covering the waste pit with clayey soil in such a manner that rainfall runoff runs away from the site. Where the ground is highly permeable, a hydrogeologist or suitably qualified engineer should be consulted on the extent to which such a site poses a threat to groundwater resources (See also Box 2).

Set-Back Distance Charts for Informal Waste Disposal Sites:

1. **Chart DML**
2. **Chart S&DMH**
3. **Chart SML**

3 References and additional reading

Albaiges, J., Casado, F. & Ventura, F. (1986) *Organic Indicators of Groundwater Pollution by a Sanitary Landfill*, Water Research, Vol. 20, Pp. 1153-1159

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