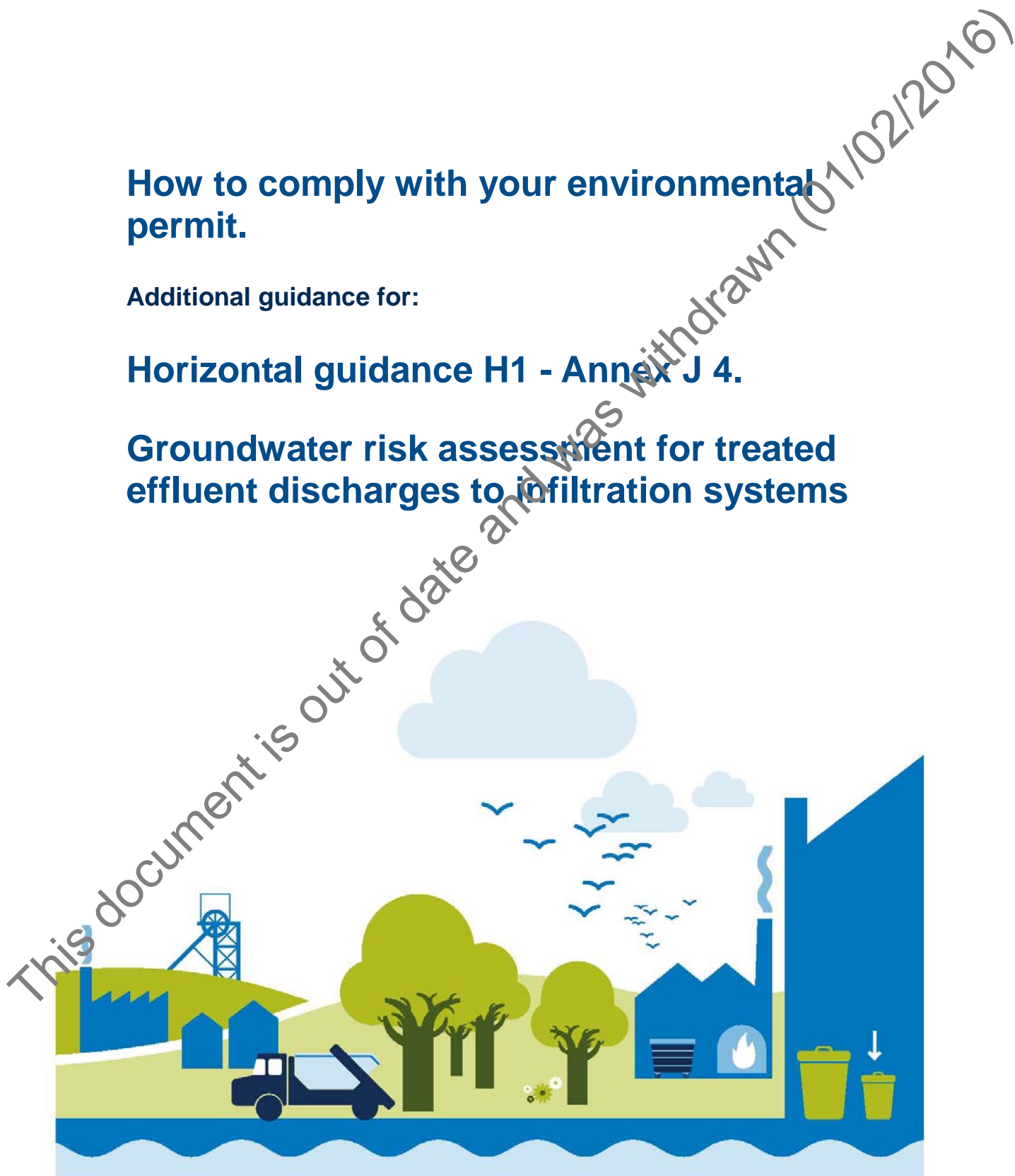Environment Agency

How to comply with your environmental permit.

Additional guidance for:

Horizontal guidance H1 - Annex J 4.

Groundwater risk assessment for treated effluent discharges to infiltration systems

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Content

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Summary of changes

Below is a summary of changes made to this Annex since the launch in February 2011.

Annex version	Date	Change	Template version
Issue 1.1	November 2011	Reformatting to respond to general issues raised in the 2010 consultation. Minor change to text and layout	H1 April 2011

Introduction

Introduction

This document provides specific guidance on how to undertake a groundwater risk assessment to support permit applications for the discharge of treated effluent to subsurface infiltration systems under the Environmental Permitting (England and Wales) Regulations 2010 (EPR).

This new guidance document is a technical annex to our H1 Environment Risk Assessment *Annex (j) Groundwater* (Environment Agency, 2011a). *Annex (j) Groundwater* sets out the broad concepts, terminology and approaches to assessing the risks to groundwater and readers will need to be familiar with this before using this document.

How this document fits in with our H1 environmental risk assessment framework is illustrated in Figure A.

This guidance is primarily focussed on discharges of treated sewage effluent (domestic and non-domestic) and trade effluent to constructed infiltration systems (drainage fields). We will undertake all initial risk assessments for discharges of up to 15 m^3/day of treated effluent. For volumes over this and for trade effluents or where our in house risk assessment has indicated the need for further information and we have requested this, you will need to read this guidance (see Figure B).

The document, although new, does not represent any fundamental change in the way we will assess permit applications. EPR has given us the opportunity to consolidate existing guidance and produce this suite of groundwater risk assessment documents.

Discharge of liquid effluents to the ground

Our overall approach to the permitting of discharges of liquid effluents to the ground is set out in our Groundwater Protection: Policy and Practice (GP3), Part 4 - Legislation and Policies, (Environment Agency, 2008 or as updated)[1] and further guidance is provided in our Pollution Prevention Guidelines Note 4 (PPG4): Treatment and disposal of sewerage where no foul sewer is available, (Environment Agency/SEPA/EHS 2001, update 2006). We recommend that you check these documents before starting a risk assessment and contact us if any of our position statements affect you.

Risk assessment can, in some cases, become a lengthy and costly process and, therefore, we would recommend that you read the "Things to consider before you start" of our main groundwater risk assessment document: *Annex (j) Groundwater,* Environment Agency, (2011a).

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[1] Groundwater Protection: Principles and Practice (GP3) Part 4 and Part 5 due for launch in 2012

Introduction

Figure A   How the HI Framework is structured with respect to this guidance
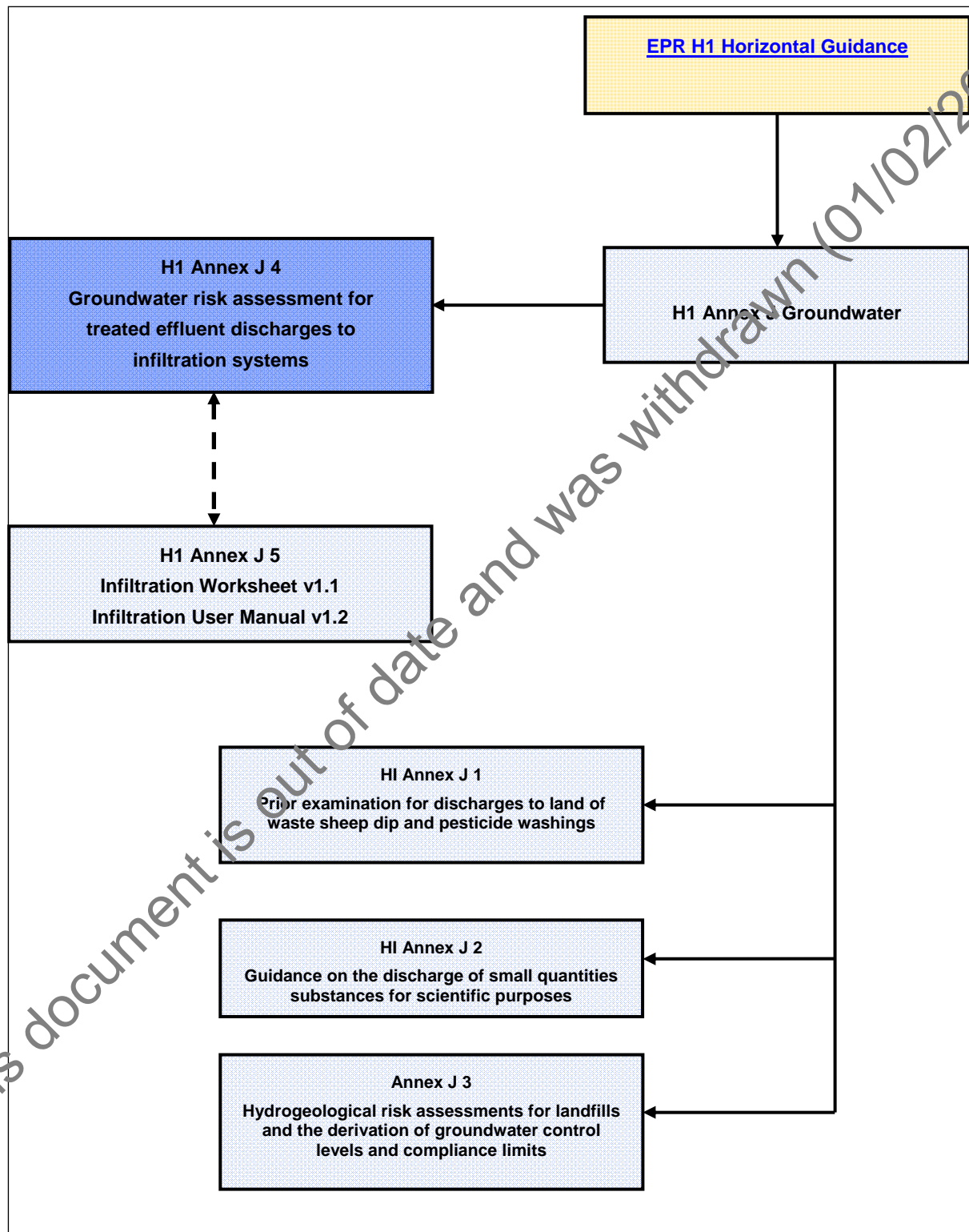
Main focus of this guidance

This guidance is primarily focussed on discharges of treated sewage effluent (domestic and non-domestic) and trade effluent to constructed drainage fields (infiltration systems) that comply with the requirements of BS6297:2007 (+ A1:2008). To permit these discharges we need to be satisfied that the rate of infiltration will not exceed the attenuation capacity of the soil and/or substrata and therefore, will not result in an unacceptable impact on groundwater quality. This document does not consider discharges to surface waters although this is mentioned where relevant.

It is possible for polluting effluents to fall outside the categories of sewage or trade, for example, contaminated surface run-off or recirculation of abstracted water in domestic cooling systems. If such circumstances lead to the requirement for a permit you should, for the purposes of applying this document, treat them as if they were trade effluents (see Section 1.1 and Box 1.1).

Our guidance[2] requires that for sewage and trade effluents we will only consider granting an environmental permit for a discharge to ground if it can first be demonstrated that is it not reasonable to connect to mains sewer. This is because of the higher levels of treatment and management that are associated with sewage treatment works. Criteria for assessing reasonableness include distance from existing foul sewer, cost, and sustainability, geology, and river / rail / road crossings.

The discharge of raw sewage directly to the ground or to sub surface drainage systems will not be permitted and therefore will require an appropriate level of pre-treatment. Depending on the environmental risk these may comprise the following levels (see Box 1.2):

- **Primary** treatment such as a septic tank system;

- **Primary** + **Secondary** treatment such as a biological treatment. For example, a package treatment plant

- **Primary** + **Secondary** + **Tertiary** treatment (such as a reed bed).

This guidance is not directly intended to apply to discharges to the land surface (for example unlined reed beds or grass plots).[3] In the case of discharges of contaminated surface water run-off (such as run-off from lorry parks) use of this guidance may be difficult due to the likely variability of flow and water quality. However in either case, the principles described

will be relevant. Dealing with such discharges requires site specific consideration in consultation with our local staff.

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[2] Refer to our Pollution Prevention Guidance Note No. 4 and EPR 7.01:How to comply with your environmental permit - additional guidance for water discharge and groundwater activity permits

[3] Disposal of liquid wastes onto the surface of land is not permitted by the Landfill Directive (1999/31/EC) although there are some limited circumstances where use of the land surface may be accepted as part of an infiltration and treatment system for sewage effluent. For example, unlined reed beds or grass plots.

An infiltration system is defined by BS6297:2007 (+ A1:2008) as "a series of infiltration pipes, placed in either single trenches or one large bed, used to discharge effluent in such a way that it percolates into the disposal area".

Cesspools, cesspits or boreholes are not classed as infiltration systems and pose a higher risk of groundwater pollution. You should not normally make discharges to soakage pits because they concentrate the discharge in one place and bypass the soil layers limiting the potential for attenuation of contaminants. Therefore we are likely to refuse an environmental permit for such discharges. Discharging effluents into boreholes is generally only acceptable in cases where there is no other alternative and where there is adequate evidence of sufficient unsaturated zone beneath the base of the borehole to allow for effective attenuation of the contaminants (see Environment Agency 2008 or as updated).

Regulatory requirements

Our regulatory requirements under EPR for groundwater risk assessment and environmental permits are summarised in Box A. Please also refer to *Annex (j) Groundwater* (Environment Agency, 2011a) and government statutory guidance on Groundwater Activities (Defra 2010).

Hazardous substances

For hazardous substances (Appendix 7) it will be necessary to demonstrate:

- There is no discernible concentration of a hazardous substance in the discharge. This would also clearly come within the exclusion under Paragraph 3 (3)(b) of Schedule 22 of EPR (2010)4, with only limited assessment needed to make this judgement.

Or,

- There are no discernible concentrations of hazardous substances attributable to the discharge in groundwater immediately down-gradient of the discharge zone, subject to adequate monitoring (or in the case of new discharges a detailed predictive hydrogeological impact assessment).

Or

- There are (or are predicted to be) discernible concentrations of hazardous substances in the groundwater down-gradient of the discharge zone attributable to the discharge but all of the following conditions apply:

- concentrations will not result in any actual pollution or a significant risk of pollution in the future;

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[4] The input of pollutants "is or would be of a quantity and concentration so small as to obviate any present or future danger of deterioration in the quality of the receiving groundwater".

- there should be no progressive increase in the concentration of hazardous substances outside the immediate discharge zone. This means, there will be no statistically and environmentally significant and sustained upward trend or significant increasing frequency in pollutant 'spikes';
- all necessary and reasonable measures to avoid the entry of hazardous substances into groundwater have been taken (see below).

Notes:

1. More data and assessment are needed as you progress down this list. The ideal situation is to ensure that there are no discernible concentrations of hazardous substances in the discharge.

2. The immediate discharge zone is the boundary of the activity giving rise to the input into the groundwater (for example, the limits of a drainage field). If concentrations are being assessed by monitoring boreholes, these should be as near as reasonably possible to the point of input within the uppermost flow horizon.

Necessary and reasonable measures

Assessment of necessary measures must be preceded by investigation to determine pathways and is a site-specific judgement.

A reasonable measure would be one where the necessary technical precautions to prevent inputs to groundwater are technically feasible, not disproportionately costly and are within the control of the operator. Such measures could include: source control, alteration of discharge mechanism, treatment of the discharge, interception or diversion of contaminated groundwater, and diversion of the discharge to another disposal route. For new developments this could include simply not conducting the activity in a location where valuable groundwater resources would be particularly vulnerable to inputs of hazardous substances. Any measures taken should not result in a net environmental disbenefit.

If there is actual pollution, or a substantial risk of such pollution, remedial measures must be taken. Cost-benefit assessment is not a factor in deciding whether to take action in such cases but may be a consideration in determining which precautions are necessary.

Non-hazardous pollutants

Our objective is to limit the input of non-hazardous pollutants to avoid pollution. This relates to both direct and indirect inputs to groundwater. We must be satisfied that pollution of groundwater will not be caused (which includes avoiding deterioration in the status of a groundwater body or causing an environmentally significant and sustained upward trend in

the concentration of pollutants). Therefore, we must ensure that the proposal and any conditions necessary to achieve this objective are attached to the permit.

More general requirements when considering an application for a permit which might lead to the discharge of a pollutant include the requirement for prior investigation of the circumstances of such applications. As a minimum requirement a permit may not be granted unless hydrogeological conditions, the purifying powers of the soil and subsoil and the risk of pollution and alteration of the quality of the groundwater have been examined. Where a permit is granted, conditions on the permit must require any necessary technical precautions to be observed to prevent inputs of hazardous substances, and to limit the input of non-hazardous pollutants, to groundwater so as to ensure that such inputs do not cause pollution of groundwater.

Box A   Schedule 22 Groundwater activities (EPR, 2010)

Exercise of relevant functions

6. For the purposes of implementing the Groundwater Directive, the Water Framework Directive and the Groundwater Daughter Directive, the regulator must, in exercising its relevant functions, take all necessary measures—

(a) to prevent the input of any hazardous substance to groundwater; and

(b) to limit the input of non-hazardous pollutants to groundwater so as to ensure that such inputs do not cause pollution of groundwater.

Applications for grant of environmental permit

7.—(1) This paragraph applies to an application for the grant of an environmental permit

relating to—

(a) a discharge mentioned in paragraph 3(1)(a), (b) or (c); or

(b) an activity that might lead to such a discharge

(2) When the regulator receives an application, it must ensure that all necessary investigations have been carried out to ensure that it grants any permit in accordance with paragraph 6.

(3) If it grants the permit, it must include conditions requiring all necessary technical

precautions to be observed to ensure the objectives of paragraph 6 are achieved.

(4) A permit may not be granted—

(a) without examination of—

(i) the hydrogeological conditions of the area concerned,

(ii) the possible purifying powers of the soil and subsoil, and

(iii) the risk of pollution and alteration of the quality of the groundwater from the

discharge, and

(b) without establishing whether the input of pollutants to groundwater is a satisfactory

solution from the point of view of the environment.

(5) A permit may only be granted if the regulator has checked that the groundwater (and, in particular, its quality) will undergo the requisite surveillance.

Who this guidance is aimed at and the level of assessment that is likely to be required

This document is mainly aimed at larger, complex discharges or discharges within sensitive locations. It only applies to discharges to ground (not surface waters). Our risk based assessment framework aims to ensure that the effort of assessment is proportionate to the level of environmental risk as follows (see also Figure B):

- **New[5] discharges in SPZ1:** We will not permit new discharges in SPZ1 (see Environment Agency 2008 or see our web site for further information).

- **2 m³/day or less** (domestic sewage only): Most small sewage effluent discharges to ground of 2 m³/day or less may be eligible to be exempt from the requirement for an environmental permit. Such discharges will have to satisfy certain criteria. Please refer to our web site for further information.

- **Discharges to ground of greater than 2 m³/day and less than 15 m³/day, and small sewage effluent discharges that cannot comply with the specified criteria for exemption:** We will carry out an initial risk assessment for you. If this initial assessment fails we may ask you to undertake further assessment in accordance with this guidance or advise you that the proposed discharge is unacceptable.

- **Discharge to ground of over 15 m³/day** (or if the discharge warrants further assessment from the previous step): You need to undertake the risk assessment in accordance with this guidance.

- **Combined sewage/trade or trade effluents:** You need to undertake the risk assessment in accordance with this guidance.

- **Intermittent or seasonal discharges:** We would use the maximum daily discharge rate when applying the 2 m³/day or 15 m³/day thresholds to decide responsibility for undertaking the risk assessment. Whether or not the frequency and cumulative volume of the discharge should be a factor in deciding overall risk and acceptability will be a matter for the risk assessment itself.

- **If you already have a permit for a discharge to ground but the circumstances have changed** or a review in line with the requirements of EPR reveals that a modification to the permit may be required, this guidance will support decisions on the approach to providing additional risk assessment.

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[5] In the case of small sewage effluent discharges to ground: A new discharge is one that was made after the 6 April 2010. An existing discharge is one that was made before the 6 April 2010. For an existing discharge: if the point of discharge has been modified since the 6 April 2010 it is classed as a new discharge. These dates relate to the implementation of the Environmental Permitting (England and Wales) Regulations 2010.

Figure B **Illustrative flow chart indicating the level of assessment that is likely to be required for an application for a new permit**
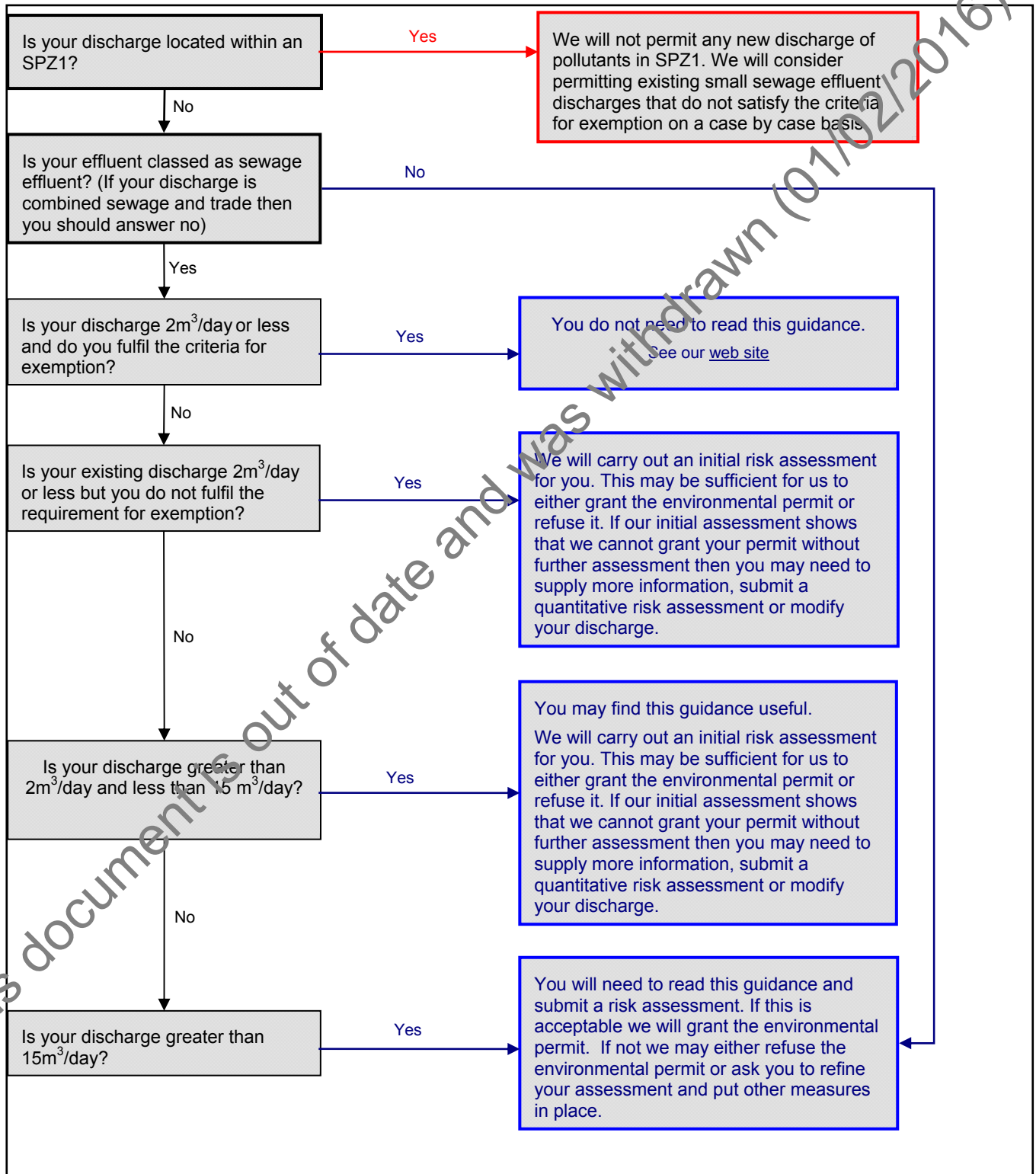
This guidance sets out the requirements for additional assessments arising from the above steps. Throughout the assessment the overall aim should be to minimise the risk to groundwater through appropriate location, design and operation of liquid effluent treatment and disposal.

We are likely to require a detailed quantitative groundwater[6] risk assessment (see Chapter 3) wherever the presence of polluting substances are of concern. You will need to support all such assessments with adequate site specific data. The scale of the assessment and the amount of information required will depend on the volume of the discharge, the substances present, the complexity and the environmental sensitivity of the site.

By following this guidance, and providing the appropriate information and analysis, we will have the necessary information against which to decide whether the activity can be permitted and if so what permit conditions we need to give you to ensure that groundwater is adequately protected and that the risks remain low during the operation of the activity.

However, a permit cannot be granted if we do not have the relevant information necessary for permit determination, or it is clear there would be an unacceptable impact on groundwater.

Layout of this document

Chapter 1 - **Background information** on the discharge of treated effluent to infiltration systems.

Chapter 2 – **The Activity and its setting** includes guidance on describing the site's environmental setting and identifying source-pathway-receptor (S-P-R) linkages within a conceptual model.

Chapter 3 – **Risk assessment approach** includes guidance on methods and approaches to quantifying risks for the protection of groundwater from the disposal of treated effluent.

Chapter 4 – **Monitoring** provides guidance on any potential monitoring requirements to demonstrate that the disposal is being operated in accordance with permit conditions and that groundwater is adequately protected.

Appendices

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[6] The terms 'groundwater risk assessment' and 'hydrogeological risk assessment' have identical meanings.

Groundwater risk assessment for treated effluent discharges to infiltration systems

Chapter 1 Background information

1.0 Introduction

This chapter provides background information on treated effluent discharges and the associated risks to groundwater. The emphasis is on discharges to constructed sub-surface drainage fields (infiltration systems[7]), but the general principles can also be applied to discharges to the land surface (for example, infiltration sustainable drainage systems - SuDS). A classification of the effluent types (domestic or trade) covered by this guidance is given in Box 1.1.

1.1 Revised interpretations of domestic sewage and trade effluent

EPR has allowed us to look again at our definition of 'domestic sewage' and change to the one based on the Urban Waste Water Treatment Directive (UWWTD) definition and in the case of the Water Industry Act 1991 (WIA), case law.

Domestic sewage includes wastes arising from normal domestic activities wherever these are carried out. Therefore, sewage from schools, restaurants, takeaways, holiday parks and nursing homes is domestic. Determining whether a discharge contains trade effluent should not involve a detailed audit of the substances used by an applicant on a particular site. If the effluent is broadly of a domestic nature it is domestic sewage. If a significant proportion of the waste generated by a commercial enterprise is different from that found in a normal home then it becomes a mixture of domestic sewage and trade effluent.

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[7] An infiltration system is defined by BS6297:2007 (+A1:2008) as "a series of infiltration pipes, placed in either single trenches or one large bed, used to discharge effluent in such a way that it percolates into the disposal area".

Groundwater risk assessment for treated effluent discharges to infiltration systems

Box 1.1 Domestic or Trade activity analysis

Activity	Trade or Domestic
Toilet waste	Domestic
Chemical toilet waste (regardless of whether site is commercial or residential)	Trade (Note 1)
Personal washing, showering and bathing	Domestic
Domestic cooking for family and friends	Domestic
Household washing of clothes, bedding, etc. using domestic detergents, etc	Domestic
Washing of dishes and cooking utensils after use on the premises	Domestic
Commercial cooking - for sale directly to consumers and consumption on or off the site (for example, restaurant, pub, fast food outlet, sandwich bar)	Domestic (Note 2)
Commercial cooking - for sale off the site (for example, manufacture of ready meals or jams, preparation of sandwiches for sale at petrol stations, canteens, etc.)	Trade
Washing at commercial premises of clothes or linen from activities or residents on the site (for example, camp site launderette)	Domestic
Washing at commercial premises of clothes or linen received from off the site bedding, tablecloths, towels, etc solely for use on the site (for example, camp site launderette open to non-residents, high street launderette or centralised laundry for hotel chain)	Trade
Swimming pool filter backwash water	Domestic or Trade (Note 3)
Hospitals, vets, schools and universities	Domestic or Trade (Note 4)

Notes on Box 1.1

Note 1 – It is recommended that chemical toilet waste is not discharged to a package treatment plant, as the chemicals may poison the treatment system and cause pollution.

Note 2 - The definition of 'domestic activity' goes beyond basic activity definitions, such as 'cooking'. It also takes in the nature of the activity. Thus, cooking food to serve as a meal is a normal domestic activity, even if the meal is sold to a customer. Cooking meals in quantity for sale elsewhere, or cooking food to put in cans is not a normal domestic activity. Where a commercial enterprise generates effluent that is different to that of a normal home, then it will cease to be a domestic only activity and will be a combination of domestic sewage and trade effluent.

Note 3 – Depends on the nature of the swimming pool. Pools at houses or hotels where they are provided free for the use of residents are domestic. Municipal or commercial pools, where the pool is a major part of a commercial activity are trade. Note that small package plants and septic tanks are unsuitable for the treatment of pool filter backwash, as it contains bactericidal chemicals that can damage the treatment process. They should only be

discharged to treatment plants if they will be substantially diluted by other waste components, which is unlikely to be the case for smaller package plants. If a public sewer or large private treatment plant is not available, then the backwash should be discharged to a properly designed infiltration system.

Note 4 – Depends on the nature of the discharge and how waste and drainage is managed. For example, larger hospitals are likely to discharge trade effluent due to the kind of activities taking place on site, but a smaller hospital may well discharge solely domestic sewage. Where the discharge includes animal wastes or clinical wastes that would not be expected to occur in domestic sewage that part of the discharge will be trade effluent.

For more information please refer to:

Annex 1 - Definition of "Domestic Sewage" and "Trade Effluent" for permitting (EPR 7.01)

1.2 Liquid effluent disposal

The main components of a liquid effluent disposal system to the sub-surface are shown on Figure 1.1 and are summarised below:

- Collection and treatment of raw effluent. Examples of systems for domestic sewage can include septic tanks (Primary treatment) and additional treatment via a package treatment plants (Secondary treatment). In some cases, the effluent may also be routed through a reed bed and undergo Tertiary treatment before discharge; (Box 1.2).

- Collection and distribution of treated effluent to the infiltration system.

- Discharge to ground via the infiltration system or drainage field.

The drainage field is an important component of the system, as significant attenuation processes can take place there and in the underlying unsaturated strata.

1.3 Effluent treatment

Liquid effluent discharges to infiltration systems occur largely from septic tank systems, package treatment plants, and sewage treatment works. Non-sewage related effluents (for example, from the treatment of industrial wastewaters), may come from a variety of other treatment plants. Further information on sewage treatment systems is provided in Box 1.2. A description of the range of treatment processes and systems for other wastewaters is beyond the scope of this guidance.

Groundwater risk assessment for treated effluent discharges to infiltration systems
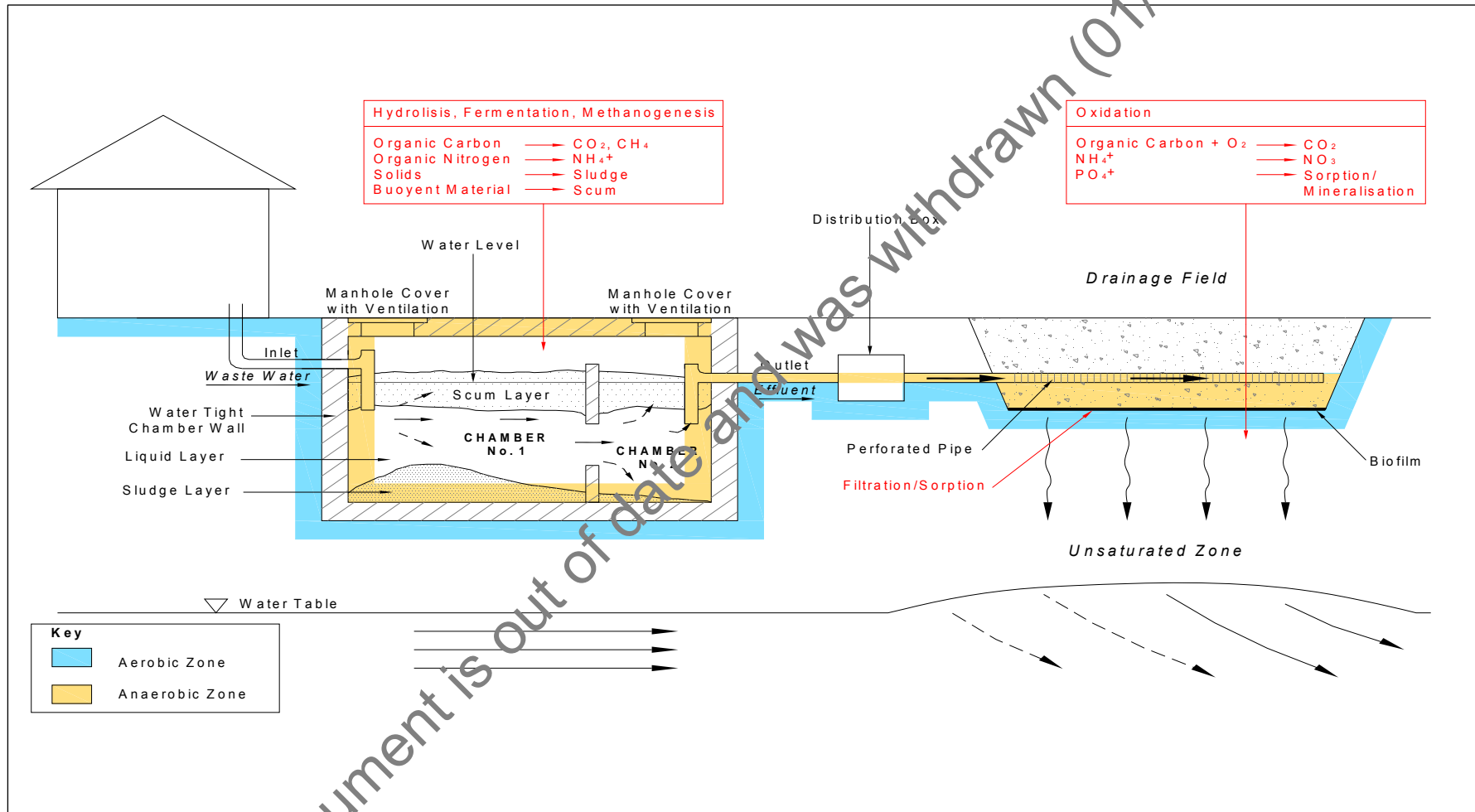
Figure 1.1   Septic tank system and discharge to an infiltration system (also shown are <u>some</u> of the key attenuation processes).

Groundwater risk assessment for treated effluent discharges to infiltration systems

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Box 1.2   Types of Primary, Secondary and Tertiary treatment

Septic tank systems (compulsory Primary treatment) consist of a tank, a subsurface drainage field (the infiltration system or 'soakaway') and connecting pipe work as illustrated on Figure 1.1. On modern systems a distribution chamber is typically located between the septic tank and the drainage field to allow sampling of the effluent and visual inspection of fluid levels.

The raw sewage will undergo settlement or floatation (physical separation) of the solids, storage and partial decomposition (anaerobic digestion) in the tank, whilst the liquid component is released via the inspection chamber and distribution box to the drainage field.

A correctly operated septic tank and drainage field system can result in a reasonable standard of treatment and produce an effluent similar to that resulting from conventional sewage treatment. This will require the septic tank to be emptied periodically to prevent it filling with solid materials and overflowing or the drainage field clogging as a result of the carryover of solids normally held within the tank. Under poor operating conditions, the quality of the discharge is likely to deteriorate with time and the hydraulic performance of the drainage field will also deteriorate.

The Building Regulations Approved Document H (2002 version as amended, Building Regulations 2010) sets out design criteria for the tank, drainage field and pipe work.

Package treatment plants (PTPs) (additional Secondary treatment) are small scale sewage treatment works. They treat effluent to a higher standard than septic tank systems. Note: a discharge to surface water is not allowed without Secondary treatment.

Reed Beds (further Tertiary treatment). A reed-bed or wetland system should improve the quality of effluent discharges from septic tanks, a settlement tank or package treatment plants. This enhanced level of treatment might be required before a discharge is allowed into for example a sensitive or small watercourse, a watercourse that receives many discharges, or a drainage field where groundwater is vulnerable.

Reed-beds are specially designed and constructed plots with a granular medium and an impermeable base which can be used to improve effluent quality. They have the advantage of having no moving parts and require less maintenance than package treatment plants. Reed-beds rely on the ability of certain plants to absorb and transport oxygen through their stem system to the root zone, which supports micro-organisms capable of breaking down the effluent where it can be taken up by the organic material present in the sewage and so purify the effluent.

Groundwater risk assessment for treated effluent discharges to infiltration systems

Many package sewage treatment plants and septic tanks available within the UK market are designed, manufactured and pre-constructed as modular units in accordance with British or European design Standards. The current design and construction British Standard (BSEN12566) incorporates the minimum European requirements for package treatment plants and septic tanks for up to 50 persons. From April 2010 (Environment Agency 2010b), we will require new or replacement units to comply with BSEN 12566: 2000.

1.4 Liquid effluent composition

The chemical composition of liquid effluent will depend on the effluent source (for example, domestic or trade), the type of treatment system and the state/condition of the treatment system. Sewage effluent is likely to be more consistent than the potentially large range in compositions from the treatment of other wastewaters (such as trade effluent). Most of the following subsection is focussed on treated sewage effluent.

1.4.1 Sewage effluent

A summary of the main chemical and biological substances of concern is given in Box 1.3. The chemical composition of a typical septic tank and package treatment plant is given in Table 2.3. Non-domestic sources of sewage effluent may have distinct characteristics that produce higher or lower strength effluent. The effluent from a sewage treatment works will usually be of a higher quality as a result of a higher standard of treatment.

For domestic and non-domestic systems it will be important to prevent the disposal of pharmaceutical, chemicals (pesticides, solvents), oils and greases. You should be aware that bleaches and household cleaners may affect the treatment process or may result ultimately in the risk of an unacceptable input to groundwater. Good practice for the design, operation and maintenance of septic tank and package treatment plant systems has been published by CIRIA (1993) and we strongly recommend that this is followed. British Water has also produced a series of useful guides (see Section 2.10).

1.4.2 Trade effluent

The chemical composition of trade effluent will be dependent on the activities which produce waste water and the type of treatment process. Some trade effluents may also vary though the year. Therefore its chemical composition will need to be characterised (for example, minimum, average, maximum or 90 / 95%-ile concentrations) by chemical analysis to determine the absence or presence of hazardous substances and non-hazardous pollutants. In our guidance notes for the application form for a permit, a list is provided of the substances for analysis that should be considered, but this list is not exhaustive and the analysis should be based on knowledge of the activities feeding the waste water stream.

Groundwater risk assessment for treated effluent discharges to infiltration systems

Box 1.3   Key contaminants of concern for sewage effluent

Ammoniacal nitrogen (predominantly the ammonium ion NH_4^+), is a non-hazardous pollutant and likely to be a primary contaminant of concern with respect to groundwater as it is present in sewage at concentrations that are significantly in excess of drinking water (0.39 mg/l N or 0.5 mg/l as NH_4^+) or environmental quality standards. The environmental quality standard for total ammonia ($NH_3 + NH_4^+$) is 0.3 or 0.6 mg/l as N depending on the alkalinity of the water course.

Ammoniacal nitrogen can be expressed as mg/l as N or mg/l as NH_4^+ where:

1 mg/l as N = 1.28 mg/l as NH_4^+

The conversion is based on the molecular ratio of NH_4^+ to N (18/14 = 1.28)

Ammonium may be transformed (nitrified) to nitrate. Nitrate may be an issue if concentrations in groundwater are close to or exceed 50 mg/l as NO_3, or if the groundwater body is at poor status as a result of nitrate. This may require additional treatment (such as denitrification of nitrate) prior to discharge.

Ammonia (NH_3) (also referred to as free ammonia or unionized ammonia) may also be present in effluent, although concentrations are likely to be lower than ammonium, except under higher pH (alkaline conditions). There is no drinking water standard for ammonia, but there is an environmental quality standard (EQS) of 0.015 mg/l as N.

The chemical equation that drives the relationship between ammonia and ammonium is:

$$NH_3 + H_2O \leftrightarrow NH_4^+ + OH^-$$

When the pH is low, the reaction is driven to the right, and when the pH is high, the reaction is driven to the left. The activity of aqueous ammonia also is much lower at low temperatures and higher at warm temperatures. This means that at low temperatures and low pH the activity as NH_3 is lower, and as NH_4^+ is higher. Therefore, sensitive aquatic organisms can tolerate a higher total "ammonium-N plus ammonia-N" at low temperatures than at high temperatures due to much less aqueous NH_3 being present in the water.

Microbiological contaminants. Microbiological contaminants are neither hazardous substances nor non-hazardous pollutants (so are not covered by EPR, 2010). Precautionary measures may be necessary to protect soil functions. Sewage effluent contains large numbers of micro-organisms (for example, bacteria, viruses and protozoa), some of which can cause infectious disease if ingested. The term '*pathogens*' is used here to group these harmful organisms. Routine testing of drinking water supplies often takes place for micro-organisms that are indicative of the presence of raw sewage, rather than for the pathogens themselves. The tests then indicate whether a pathway exists that poses a risk to water quality.

Groundwater risk assessment for treated effluent discharges to infiltration systems

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Box 1.3 continued

Phosphorus and phosphates. These are non-hazardous pollutants. Concentrations of phosphate in sewage effluent are typically in the range 10 to 20 mg/l as P. Phosphate may be a particular issue where there is a discharge to surface water for which low (0.04 to 0.12 mg/l as P) environmental quality standards may be set. Phosphate will readily sorb to particulates to the soil and to the rock and in many cases phosphate from the discharge will be sorbed within the drainage field / unsaturated zone. However for high discharge rates there is a potential for the attenuation capacity to be exceeded or bypassed. Some phosphate will also be taken up by microbes, and potentially plant roots, as it is a nutrient.

Other Contaminants. Organic compounds (including hazardous substances) may be present at low concentrations, but the available data (for example, Environment Agency, 2002, BGS, 2007) indicates that their occurrence is sporadic and the compounds present vary over time.

Other chemicals (including hazardous substances) used in household products / equipment may also be present, such as the metals cadmium and mercury, which are both hazardous substances. Medical products (pharmaceuticals) and their metabolites may also be present in trace concentrations. Due to the likely variability, it is not possible to characterise the discharge in terms of organic pollutants and for larger or more complex discharges, chemical analysis will be required.

For domestic systems the presence of hazardous substances can be avoided by ensuring that chemicals are disposed of appropriately (CIRIA 1993).

1.5 Discharges to ground surface and infiltration systems

1.5.1 Discharges to the ground surface

Groundwater risk assessment for treated effluent discharges to infiltration systems

The methodology described in this document can also be applied to discharges of effluent to the ground (for example, irrigation of grass plots and woodland). The information requirements will be similar and the overall objective of a risk assessment will be to demonstrate that the activity is acceptable.

1.5.2 Infiltration systems

Requirements for the design and installation of drainage fields and infiltration systems for domestic properties are set out in BS6297:2007 (+ A1:2008). Further guidance is contained in Part H of the Building Regulations (2002 edition)[8] on drainage and waste disposal.

Infiltration systems typically comprise a network of below surface perforated pipes which sit in gravel filled trenches. Unless properly designed and operated, infiltration systems can cause excess hydraulic loading. This may mean:

- the underlying ground is unable to accept the rate of discharge, resulting in surface breakouts;

- rapid travel times through the unsaturated zone or by-pass flow resulting in limited attenuation of the effluent;

- groundwater mounding below the drainage field, resulting in a reduced unsaturated zone thickness.

To minimise the risk to groundwater you should ensure that the size of the drainage field is appropriate to the rate of discharge and the infiltration capacity of the ground. In addition, you should ascertain that there is a sufficient depth to the water table (minimum of 1.2 m) to ensure attenuation of the effluent. You should also consider the proximity to receptors such as water supplies and surface water courses. Good practice for the location of drainage fields is set out in BS 6297:2007 (+ A1:2008) Code of practice for the design and installation of drainage fields for use in wastewater treatment - Amended 2008 and Pollution Prevention Guidelines Note 4 (PPG4 Environment Agency/SEPA/EHS 2001 update 2006). The Building Regulations (Part H 2002) also prescribe certain criteria. Key requirements to protect water arising from these standards are summarised in Box 1.4.

Box 1.4   Location of infiltration systems or drainage fields

Discharge to a drainage field should not take place on land:

- within 10 m of the nearest watercourse;

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[8] The Building Regulations have been updated for 2010

- within 50 m of a well, spring or borehole or other source of water intended for human consumption;

- that is steeply sloping or waterlogged;

- where there is less than 1.2 m depth to water table below the invert of the drainage pipes;

- where percolation rates fall outside an upper and lower range of values (see Percolation tests).

Reference should also be made to Environment Agency (2006-2008)

Both BS6297:2007 (+ A1:2008) and the Building Regulations (Part H 2002; 2010) require you to carry out a percolation test to determine whether the rate of percolation is suitable. If it is too low the effluent will not infiltrate, if it is too high infiltration will be too rapid and important attenuation mechanisms will not occur.

BS6297:2007 (+ A1:2008) also requires you to dig a trial hole to determine the minimum depth to water table. The recommended minimum depth in the Standard is 1.5 m below the base of the proposed trench.

Information on the depth to water table, soil description and percolation tests will need to be provided as part of the application for a permit.

Depending on the circumstances, you may need to demonstrate a greater depth to the water table to provide confidence that attenuation will occur; otherwise you may need to consider modifying the infiltration system or reduce the risk in other ways such as increasing the level of treatment. This might be the case for larger discharges, or where the effluent contains hazardous substances, or where the underlying strata are characterised by rapid flow (for example, fissured aquifers).

STAY SAFE. Standing adjacent to or entering even shallow excavations is potentially dangerous if they are unsupported and it is very important that you comply with relevant health and safety legislation and guidance. If it is necessary to excavate deeper than recommended it may be more appropriate to consider the use of an auger or small drilling rig. Do not work alone.

Groundwater risk assessment for treated effluent discharges to infiltration systems

Drainage fields are frequently located at a lower level than the building/treatment plant that they serve so that drainage is gravity driven. However, surface or groundwater flooding of drainage fields and tanks is a potential problem and generally, you should not locate them in areas that are known to suffer from flooding. Flooding of the tank and/or drainage field (but not the property it serves) will mean that the contents will result in environmental pollution and human health issues.

The drainage field may also need occasional maintenance to remove any clogging as a result of biofouling and in the long-term may need to be replaced when performance falls. Drainage fields with subsoil infiltration systems are typically maintained as grassed areas to prevent penetration of the distribution pipes by the roots of larger plants (shrubs and trees).

1.6 Percolation tests

Percolation test procedure is given in British Standard BS6297:2007 (+A1:2008). We have provided an overview of this in Appendix E.

The percolation test allows you to assess the drainage characteristics of the soil and to calculate the floor area of the drainage field (see Box 1.5). The test must be carried out to the current British Standard BS6297:2007 (+A1:2008). The results of this test will give you a percolation value (Vp) figure which should be provided as part of the supporting information of the permit. Vp relates to the permeability of the soil/drainage field. Vp is measured in seconds per mm. The results of a percolation test should be within the range Vp = 15 – 100 sec/mm.

The minimum value of 15 allows sufficient attenuation (the effluent cannot percolate too rapidly into the ground), potentially resulting in the pollution of groundwater. The higher the value for Vp the more attenuation will take place but values over 100 may result in effluent ponding.

If the Vp is between 1-15, or greater than 100, you will need to discuss alternative options with us.

Where soils are too permeable (Vp = 1-15), the rate of downward movement can be slowed and contaminants attenuated through the use of constructed drainage mounds or sand filters.

Where soils are insufficiently permeable (Vp = 100+), then an alternative disposal method in place of an infiltration system will be needed.

Groundwater risk assessment for treated effluent discharges to infiltration systems

You will need a value for Vp in order to calculate the floor area of the drainage field (Box 1.5). The Infiltration Worksheet (Environment Agency 2011c) can also be used to calculate the area of the drainage field.

Box 1.5   **Floor area of drainage field**

Floor area of drainage field

For domestic properties the floor area of the drainage field required can be calculated as follows

For septic tanks (Primary treatment): A = p x Vp × 0.25

Where,

A = required drainage field floor area in square metres (m^2).

p = number of people served by the tank (for domestic applications (this should be the maximum number of people that could live in the dwelling).

Vp = percolation value.

For effluents which have received additional Secondary treatment (such as a Package Treatment Plant), the area should be reduced by 20% as follows:

A = p x Vp x 0.20

Example calculations:

The calculation for the floor area of drainage field required for a septic tank serving 12 people with a percolation value of 20 seconds/mm would be:

A = p x Vp × 0.25

A = 12 x 20 x 0.25 = 60 m^2

The calculation for the floor area of drainage field required for a septic tank and secondary treatment serving 12 people with a percolation value of 20 seconds/mm would be:

A = p x Vp x 0.20 (reduced by 20% due to Secondary treatment)

A = 12 x 20 x 0.20 = 48 m^2

Floor area conversion

The floor area "A" should be converted to a linear trench based on the width of the trench

Drainage trench widths should be between 0.3 m to 0.9 m. Examples of conversions for different trench widths are given in Table 4 of BS6297:2007 (+A1:2008).

For example, for a trench of 0.9 m in width and for a calculated floor area of 60 m^2 then from Table 4 (BS6297:2007 (+A1:2008) the linear trench length is given as 66 m.

Reference: British Standards (BS6297:2007 (+A1:2008). *Code of practice for the design and installation of drainage fields for use in wastewater treatment,* ICS 13.060.30, BSI 2008

1.7 Dilution and attenuation processes

1.7.1 Key processes

The key processes likely to reduce the impact on groundwater of liquid effluent discharges to a drainage field are given below and some of these processes are illustrated in Figure 1.1. The key processes of sorption, retardation, biodegradation, abiotic degradation, volatilisation, dispersion and diffusion are considered in Box 1.6.

Box 1.6	Key attenuation processes dependencies and effect		
Process	**Description**	**Dependencies**	**Effect**
Sorption	Reaction between aquifer matrix and solute whereby contaminants become sorbed on organic carbon or clay minerals. Sorption can be represented by linear or non-linear equations.	Dependent on aquifer properties (organic carbon, clay mineral content, bulk density, specific surface area and porosity) and the hydrophobicity of the pollutant.	Removes solutes from groundwater via sorption to the aquifer matrix. Reduces apparent rate of solute movement (retards contaminants relative to groundwater). Contaminants can desorp back into groundwater from the aquifer matrix.
Retardation	Reduction in rate of contaminant migration to processes including sorption, ion exchange, precipitation/dissolution and fissure/pore water diffusion.	Dependent on aquifer and contaminant properties.	Reduction in apparent rate of solute movement.
Biodegradation	Microbial degradation of contaminants.	Dependent on: • contaminant concentration (degradation may be inhibited at high concentration – toxicity effect); • supply of electron acceptors (oxygen, nitrate, sulphate). If insufficient supply, then degradation will be inhibited; • geochemical environment. For example, some compounds will degrade at faster rate under aerobic conditions.	Results in a loss of contaminant mass and reduction in contaminant concentration.

Groundwater risk assessment for treated effluent discharges to infiltration systems

Box 1.6	Key attenuation processes dependencies and effect		
Process	**Description**	**Dependencies**	**Effect**
Abiotic degradation	Chemical transformations (for example, hydrolysis) that degrade contaminants.	Dependent on contaminant properties and groundwater geochemistry.	Results in a loss of contaminant mass and reduction in contaminant concentration. Rates typically much slower than biodegradation.
Volatilisation	Volatilisation of contaminants dissolved in groundwater into the vapour phase (soil gas).	Dependent on the vapour pressure (Henry's Law constant) and air-filled porosity of the chemical.	Removes contaminants from groundwater and transfers them to soil gas.
Dispersion	Spreading of a contaminant plume as a result of groundwater moving at different rates/following different pathways through the aquifer. Dispersion is typically represented by empirical equations (derived from analysis of plume dimensions).	Dependent on aquifer properties and scale of observation. Independent of contaminant properties.	Results in longitudinal, transverse and vertical spreading of the contaminant plume as it moves through the aquifer. Reduces contaminant concentrations.
Diffusion	Spreading of contaminant due to molecular diffusion.	Dependent on contaminant properties and concentration gradients. Generally unimportant relative to dispersion except at very low groundwater velocities. Diffusion significant in dual porosity systems in controlling contaminant movement between fissure water and pore water.	Diffusion of contaminant from area of relatively higher concentration to areas of lower concentration. Reduces contaminant concentrations. For dual porosity aquifers, can result in a decrease in the rate at which a contaminant can migrate through the aquifer.

1.7.2 Degradation[9]

For degradable contaminants such as ammonium (Environment Agency 2003a), the calculation of an attenuation factor is sensitive to the assumed rate of degradation. Evidence must be provided for the use of degradation. Any values used must be justified. Thus it is essential that:

- the conceptual model for the site provides evidence that degradation is likely to occur;

- a realistic or conservative value is used and, where possible, this is based on field data (Environment Agency, 2000).

For ammonium it will also be necessary to consider whether its transformation to nitrate could result in nitrate concentrations in groundwater that exceed 50 mg/l as NO_3 as discussed in the following section.

The conceptual model should also consider the factors that may influence the rate of degradation. These include contaminant concentration, the geochemical environment (for example, aerobic or anaerobic) and, in the case of degradation of oxidisable contaminants, the availability of oxidants such as dissolved oxygen, nitrate and sulphate (Environment Agency 2002b).

If you use a literature-based decay rate this should be:

- based upon a field observation from a natural system similar to the one in question;

- reviewed and agreed upon by the appropriate parties.

This is to safeguard against the use of too rapid a rate of biodegradation, which may result in an underestimate of the impact on groundwater quality and hence insufficient aquifer protection. In the absence of validated degradation rates, degradation should be assumed to be negligible.

Guidance on assessing degradation due to natural attenuation is given in Environment Agency (2000). Rates of degradation for some contaminants are published in other Environment Agency reports for a range of geochemical environments and aquifer settings (Environment Agency 2002b, 2003a).

The degradation rates given in these reports mainly relate to the groundwater environment (saturated zone). The unsaturated zone may be characterised by higher degradation rates as it may contain higher bacteria populations, higher levels of oxygen and a higher proportion of organic material.

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[9] Reference should also be made to Enviroment Agency 2011c

Groundwater risk assessment for treated effluent discharges to infiltration systems

Most analytical models assume that degradation can be represented as a first order reaction (for example, exponential decay of contaminant degradation). This assumption will need to be justified based on the conceptual understanding of the site and particularly where degradation may be inhibited due to the geochemical environment. In some cases, a first order reaction is not appropriate for representing the degradation of organics as degradation may be rate-limited and dependent on contaminant concentration and/or the availability of electron acceptors.

1.7.3 Filtration of particulate matter and microbial contaminants

Within infiltration systems, the process of filtration is aided by the development of a bio-mat beneath the effluent discharge. Filtration is also likely to be important within the unsaturated zone where flow is intergranular. Highly fissured unsaturated zone material is likely to be poor at filtering any particulate contaminants which pass through the bio-mat.

Pathogens are typically only viable within a host organism and therefore, will show a decline in numbers over time as a result of die-off. It is typically assumed that micro-organisms remain viable in the subsurface for 50 to 70 days (though some viruses can survive much longer than this). Pathogens (and other micro-organisms) will be attenuated by firstly attaching to solid materials and then being filtered out. They are then prone to predation. Some micro-organisms, notably cryptosporidium, form cysts that are resistant to die-off and predation and hence can be long lived in the environment. Transport of pathogens is therefore, most likely to occur where flow beneath the drainage field is via a fractured and fissured unsaturated zone. Pathogens will be filtered out by more sandy, intergranular material and die off. Unsaturated zones with large fractures would be unlikely to pass the percolation test in any case.

1.7.4 Sorption and precipitation of metals and phosphate

Sorption of metals onto clays and precipitation of metals under oxygenated and / or alkaline pH conditions is likely to render the already low concentrations of metals below concentrations which would cause an unacceptable impact.

The fate of phosphates in sewage effluent discharges is an area of active investigation. Most conceptual models suggest that phosphate is rapidly mineralised (precipitated as calcium phosphate) within a short distance of the point of discharge. This is likely to be the case where calcium carbonate is present. However, in some groundwater environments, notably in areas of hard rock, this may not occur.

Groundwater risk assessment for treated effluent discharges to infiltration systems

1.7.5 Sorption, retardation, degradation of organic contaminants

The large organic loading and microbial activity within the treatment system and the presence of a biofilm beneath the pipe work of the infiltration system are likely to promote sorption and degradation of most organic contaminants before discharge to the infiltration system.

1.7.6 Sorption, retardation and nitrification of ammoniacal nitrogen

Within sewage, nitrogen starts off in an organic form (for example, urea), but is converted to ammoniacal nitrogen (predominantly present as the ammonium ion – $NH4+$) as it passes through the treatment system and drainage field. Within and beneath the drainage field, ammoniacal nitrogen is oxidised by microbially mediated reactions (nitrification), first to nitrite (NO_2) and then to nitrate (NO_3) in the presence of oxygen. The rate of reaction is temperature dependent and is very slow below $7^{o}C$. Some denitrification (reduction of nitrate to nitrite, nitrous oxide (NO) and then nitrogen (N_2)) may also occur within the saturated pockets in the unsaturated zone.

1.7.7 Soil water partition coefficient K_d

The critical importance of the sorption characteristics of soils/aquifer materials and the K_d values used in these equations should be emphasised. Literature based K_d values can vary by several orders of magnitude for the same substance and great care must be exercised in selecting the most appropriate value(s) or mean and standard deviation for probabilistic calculations. For larger, complex or hydrogeologically sensitive discharges it might be preferable to undertake batch testing to determine site specific K_d values. Although it should be noted that the presence of other substances competing for sorption sites in the soil / aquifer matrix will lead to lower actual K_d values. Thus, multi-element batch testing for Kd values would be preferable and more realistic to single element testing. The estimation of the most appropriate K_d value and degradation coefficient if applicable is a key aspect of the whole risk assessment process.

1.7.8 Cation Exchange Capacity

Cation Exchange Capacity (CEC) is the capacity of the soil / sub-surface matrix for ion exchange of cations between the matrix and the solution. Under certain conditions, CEC may be used to calculate the partition coefficient of a solute, usually a trace metal. The formulation is presented in detail in Domenico and Schwartz (1998) and Appelo and Postma (1993). However, the assumptions behind this calculation mean that it often may not be appropriate for assessing partition coefficients in typical contaminant plumes. In such cases more complex geochemical modelling would be required. Therefore, we will accept CEC as

a viable attenuation process, but only when robust supporting evidence is provided (for example, geochemical modelling such as PHREEQC).

Other processes include:

- **uptake of nutrients** (nitrogen and phosphorus) by microbes and plants

- **volatilisation** where the discharge is to the land surface

- **dilution** at the water table.

1.8 Recent research on attenuation

The available information on attenuation processes in the unsaturated zone below infiltration areas for discharges from septic tanks (BGS 2007, IEPA 2006) suggests high rates of transformation of ammonium for these particular scenarios (see Appendix C). Therefore, it is important to properly look after the system.

1.9 Risk reduction

In designing the effluent disposal system the overall aim should be to minimise the risk to the environment.

A range of measures are available to reduce the risk to groundwater. These include:

- Locating the drainage field in accordance with relevant British Standards (BS6297 2007 (+A1:2008)) to minimise the risk to groundwater (and surface water) receptors.

- Ensuring efficient drainage by providing adequate surface area to the infiltration trenches based on percolation tests and ensuring infiltration rates are not too fast resulting in rapid movement through to the water table with limited attenuation.

- Ensuring there is at least the minimum thickness of 1.2 m[10] of dry subsoil (unsaturated zone) below the infiltration trench. In some cases, you may need to demonstrate a greater depth to the water table to allow attenuation processes to occur.

- Being vigilant about what goes into raw effluent. For example, not pouring paint thinners down a domestic sink (see CIRIA 1993 and Britsh Water guides).

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[10] The minimum depth of 1.2 m must not be subject to seasonal fluctuations where the water table could rise above this depth.

- Designing and operating the system according to best practice; desludging and other maintenance in accordance with manufacturer's recommendations.

Chapter 2 The activity and its setting

2.0 Introduction

This chapter outlines the information that you will need to provide as part of a detailed quantitative risk assessment. In summary you will need to:

- Characterise the discharge in terms of quantity and quality based on adequate understanding of the discharge mechanisms and infrastructure (for example, infiltration system layout), the volumes, concentrations and chemical nature of the discharge.

- Demonstrate a conceptual understanding of the relationship of the discharge, pathways and receptors within their wider hydrogeological setting including the likely fate and transport processes, particularly within the unsaturated zone.

- Describe the local soil conditions and hydrogeology, where necessary supported by site investigations; and in particular describe the strata (soils, rock) below the drainage field, the depth to water table and the permeability of the strata (for example, from percolation tests).

You should refer to our H1 Environmental Risk Assessment Annex (j) Groundwater (Environment Agency, 2011a) for the key principles in describing an activity and its potential impact on groundwater. This section provides further details on the information that will be needed to support a groundwater risk assessment.

If we are not confident in the description of the activity, its site setting and the conceptual model, we will need to be conservative in how we review your environmental permit application. This could lead us to ask you to undertake further work or refuse your application. The amount of work and the sophistication of the risk assessment will depend on the nature of the discharge and the environmental sensitivity of the site.

A general guide to the typical levels of information (basic, extended, comprehensive) needed for different discharges is given in Table 2.1 and in Table D1 in Appendix D. Basic data requirements covers information required in the application for a permit. Groundwater vulnerability, the constituents of trade effluent and the level of treatment involved must also be taken into account when deciding what data are needed for an individual site. Reference should also be made to Box 1.1.

Groundwater risk assessment for treated effluent discharges to infiltration systems

The applicant / permit holder is responsible for providing us with this and any other relevant information. Site investigation may be required for large disposals or where the proposed discharge is located in a sensitive setting.

Table 2.1   Guidance on data requirements

Discharge	Volume m³/d	Data requirements for assessment (refer also to Table D1 (Appendix D) for a description of basic, extended and comprehensive data needs)
Sewage effluent	0 - 15	Basic information. For discharges that do not comply with the exemption criteria or those that fail our in-house risk assessment, you may need to supply an extended set of information
	>15 - <50	Extended or comprehensive set of information may be needed
	>50	Comprehensive set of information needed
Trade Effluent	0 - 25	Extended or comprehensive set of information may be needed
	>25	Comprehensive set of information needed
Combined sewage overflows (CSO) and Emergency overflows (EO)		Extended or comprehensive set of information may be needed

Groundwater risk assessment for treated effluent discharges to infiltration systems

2.1 Construction, operation and management

We will need you to provide the following information in support of your application and to demonstrate that the necessary construction or engineering will be or has been put in place to control the discharge:

- details of the type and source of effluent (for example, domestic sewage);
- details of the discharge rate, frequency and duration;
- details of the treatment process;
- details (plans and cross sections) of the infiltration system;
- results of the percolation tests;
- a description of how the quality of the construction or engineering has been or is to be controlled. Examples of quality controls include Building Regulations certificates;
- a detail of proposed operation and maintenance to ensure the system continues to perform to design (for example, de-sludging of septic tanks, servicing of package sewage treatment plants, etc.).

2.2 Discharge rate, frequency and duration

2.2.1 Overview

You need to provide details of the discharge rate, its frequency and duration. For many discharges, the discharge rate will be relatively constant throughout the year. Variations to this may occur for discharges of treated sewage effluent from some premises (i.e. holiday cottages, hotels) and for sewage treatment works where summer or dry weather flows[11] (Box 2.2) are likely to be lower and more concentrated than winter flows. The assessment should consider the range of discharges.

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[11] DWF is only needed for water company STW which receive sewage and rainwater from combined sewers - private STPs should avoid allowing rainwater into the plant

Groundwater risk assessment for treated effluent discharges to infiltration systems

2.2.2 Discharge rates for sewage effluent discharges

The discharge rate for treated sewage effluent can be estimated based on the type of premise (Table 2.2) or estimated (sewage treatment works) based on population equivalents (Box 2.1). For large discharges, it will be generally necessary to measure the discharge.

2.2.3 Discharge rates for trade effluent

For trade effluent discharges you will need to estimate the quantities of treated effluent (minimum, maximum and average) that will be discharged to the ground throughout the year and whether this might change. For larger discharges, typically greater than 50 m^3/d, we may require actual measurements. This may include for example, constant flow monitoring subject to conditions in the environmental permit.

Groundwater risk assessment for treated effluent discharges to infiltration systems

Table 2.2   **Typical rates of sewage generation (from British Water, 2009a)**

Premise	Sewage Generation Rate person/litres/day	Premise	Sewage Generation Rate person/litres/day
Domestic	180	**Hotels, pubs and clubs**	
Industrial		Prestige hotel	300
Office/factory without canteen	50	3* or 4* hotel	250
Office/factory with canteen	100	Bedroom only	80
Open industrial site for example, construction, quarry, without canteen	60	Residential conference/training	350
Schools		Non-residential conference/training	60
Non-residential without canteen	50	Holiday camp	227
Non-residential with canteen	90	Restaurants (per customer)	30
Residential	200	Public House (per customer)	12
Hospitals and residential care homes		**Amenity Sites**	
Residential old peoples/ nursing home	350	Local community sports club	40
Small hospitals	350	Health club/sports centre	50
Large hospitals	450	Golf club	20
		Caravans (touring) not serviced	100
		Caravans (static) serviced	180
		Campsites	75

http://www.britishwater.co.uk/publications/Publications_and_Technical_Guides.aspx

Groundwater risk assessment for treated effluent discharges to infiltration systems

Box 2.1   How to calculate the discharge

Example 1: Single 3 bed roomed house

The sewage generation rate per person per day for a domestic property is 180 litres/person/day (Table 2.2)

The total sewage output can be calculated as 180 x P then divided by 1000, where P is the minimum recommended population load based on the number of bedrooms in each property **plus 2**.

For example, a house with 3 bedrooms is considered to be a 5 P (3 + 2) system with a total sewage output of 180 x (5 P)/1000 = **0.90 m³/day**

Note: This approach would apply to **groups** of small 1 or 2 bedroom houses or apartments. (For example, a one bed roomed house is (1+2) = 3 P), but a **single** dwelling with up to 3 bedrooms is treated as a 5 P system. A five bedroom house would be (5 + 2) = 7 P.

Example 2: For a group of domestic properties comprising a two, a three, a four and a five bed roomed house:

Calculate the P value for each property (as above), then add together:

2 bed roomed house = (2 **+ 2**) = 4 P

3 bed roomed house = (3 **+ 2**) = 5 P

4 bed roomed house = (4 **+ 2**) = 6 P

5 bed roomed house = (5 **+ 2**) = 7 P

= 22 P

If the calculated total P for a group of houses is between 12 to 25 then some reduction may be made to allow for the balancing effects on daily flow:

For P values of 12 to 25 multiply by a factor of 0.9

22 x 0.9 = 19.8 which should always be rounded up so in this example P = 20

= (180 x 20)/1000 = **3.60 m³/d**

For P values of 26 to 50 multiply by a factor of 0.8. For a P value of 36:

36 x 0.8 = 28.8; so P would equal 29

= (180 x 29)/1000 = **5.22 m³/d**

Where there are larger groups of houses, the P value should be estimated using both the expected total load and the flow, considering both peak and total flow.

Groundwater risk assessment for treated effluent discharges to infiltration systems

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Box 2.1 continued

Calculations for non-domestic properties are more straightforward:

Example 3: 75 persons within a four star hotel

The sewage generation rate for a 3 or 4 star hotel = 250 litres/person/day (Table 2.2)

Number of persons = 75

Therefore discharge = 75 x 250 = 18 750 litres/day or **18.75 m³/d**

Example 4: 150 persons on a static serviced caravan park

The sewage generation rate for a serviced caravan park = 180 litres/person/day (Table 2.2)

Number of persons = 150

Therefore discharge = 150 x 180 = 27 000 litres/d or **27.0 m³/day**

For more information please refer to Flows and Loads 3 – *Sizing criteria, treatment capacity for sewage treatment systems*, British Water, BW-COP (2009a).

2.3 Area of drainage field and percolation tests

You will need to provide details of the drainage field including:

- a map showing location and layout of the drainage field;

- the design of drainage system;

- the area of drainage field and how this has been determined;

- the results of infiltration or percolation tests.

The hydraulic loading rate (area averaged volumetric rate, for example, m³/ha/d) will be also need to be provided, although this can simply be calculated by dividing the discharge (the volume Q in Box 2.3) by the area (A = ha) of the drainage field (Box 2.3). For discharges from septic tanks and package treatment plants the area of the drainage field can be calculated as set out in Box 1.5 and 2.3. The Infiltration Worksheet v1.1 (Environment Agency, 2011) can also be used to undertake these calculations.

Groundwater risk assessment for treated effluent discharges to infiltration systems

2.3.1 Dry weather flow

Box 2.2 provides additional information on Dry Weather Flow (DWF)

DWF is only needed for water company STW which receive sewage and rainwater from combined sewers - private sewage treatment systems should avoid allowing rainwater into the plant

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Box 2.2	Dry Weather Flow (DWF)

Dry Weather Flow is the average daily flow to a sewage treatment works during a period without rain.

An estimate of DWF can be obtained using the following formula:

DWF = PG + I + E

where:

P = Population served by the works

G = Domestic water consumption (typically 180 litres per head per day)

I = Infiltration of groundwater into the sewer (typically 50% of PG)

E = Trade effluent flows.

Example calculation:

Population served (*P*) = 4 000

Domestic water consumption (*G*) = 180 litres/day

Groundwater infiltration (*I*) = 0 (Assuming sewer above groundwater table and therefore no infiltration)

Trade effluent inflow (*E*) = 16 000 litres/day

DWF = PG + I + E

DWF = 4 000 x 180 + 0 + 16 000 = 736 000 litres/day or **736 m³/d**

Groundwater risk assessment for treated effluent discharges to infiltration systems

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Box 2.3   Standard equations for infiltration systems

For an infiltration system the **hydraulic loading or infiltration rate (Inf)** can be calculated from:

$$Inf = \frac{Q}{A}$$
(Equation 1)

where:

Inf = Infiltration rate through the infiltration system (m/d)

Q = discharge rate to drainage field (m³/d). The discharge rate can be measured or estimated using the information provided in Table 2.2.

A = area of drainage field (m²) (see below)

Note: The infiltration rate (*Inf*) should not exceed the maximum infiltration rate determined from percolation tests. This would indicate re-design of the drainage field was necessary. For some infiltration systems (for example, where the discharge includes surface water run-off) the design may include for storage to deal with peak flows, in these cases the infiltration rate should be set as the maximum infiltration rate.

Example calculation: Infiltration rate and area of drainage field required for septic tank serving 12 people

Number of people served by septic tank (*p*) = 12

Calculated percolation rate (*V_p*) = 20 seconds/mm (see Section 1.6 and Appendix E)

Therefore:

Area of drainage field *(A)* =   A = 0.25 (see Box 2.1) x p x V

                    = 0.25 x 12 x 20 = 60 m²

Discharge rate (Q)   = 12 x 180 litres/day = 2 160 litres/day or 2.16 m³/d
                    (based on generation rate of 180 litres/day from Table 2.2)

Infiltration rate *(Inf)*   = 2.16/60 = **0.036 m/d**

Groundwater risk assessment for treated effluent discharges to infiltration systems

2.4 Effluent quality

2.4.1 Overview

The chemical composition of effluent will depend on effluent source (domestic or trade), type of treatment and operation and maintenance of the treatment system (see Section 1.4).

You should consider the concentration (or range and variability of concentrations) of all hazardous substances and non-hazardous pollutants that may be released as a result of the activity. Where there is a wide range of substances present you will need to identify representative substances or groups of substances. The risk assessment will need to focus on:

- whether or not there is likely to be an input of hazardous substances to groundwater;
- whether any input of non-hazardous pollutants to groundwater will be sufficient to cause pollution.

(See also Introduction, Defra (2010) and Environment Agency (2011a).

2.4.2 Treated sewage effluent discharges

The main substances which are of concern for sewage effluent discharges are described in Box 1.3. A key contaminant of concern will be ammonium (Table 2.3). For septic tank and package treatment plant effluent discharges, where the quality of the discharge is unlikely to vary significantly or contain unusual substances, it should be possible in many cases to use published information from studies which have characterised the key substances and their concentration variability. Table 2.3 provides a summary of the chemical composition of a typical septic tank and package treatment plant. Where this is not appropriate or where the discharge is >50m³/day, analysis of the effluent is likely to be needed as a basis of any quantified risk assessment.

Groundwater risk assessment for treated effluent discharges to infiltration systems

Table 2.3 **Contaminants in septic tank and package treatment plant liquid effluent and their typical concentrations**

Contaminant	Sewage (mg/l)[1]	Septic Tank Discharge (mg/l)[2]	Package Treatment Plant (mg/l)[2]	Domestic waste water from single property (mg/l)[3]
BOD (5 day ATU)	~380 (residential properties)	368	55	300
COD		677	210	400
Ammonium (as NH_4^+)[4]	~50 (residential properties)	104	89	50
Chloride		68.6	88.1	
Phosphorous		15.8	10.5	10
Boron		0.84	0.37	
Lead			<0.005	
Zinc		0.03	0.01	
Copper		0.015	0.007	
Iron		0.13	0.04	
Cadmium		<0.002	<0.002	
Arsenic		<0.015	<0.015	
Pharmaceuticals		No information	No information	
Other organic products		Sporadic: mineral oil, quintozene, methoxychlor, permethrin, phenol, 4-methyl-phenol, toluene, phthalates	Sporadic: mineral oil, quintozene, 4-methyl-phenol, toluene, phthalates	

1 British Water (2009).

2 BGS (2007). For package treatment plants effluent quality will depend on the type of plant and treatment process.

3 IEPA (2007).

4 Ammonium may be transformed to nitrate in the drainage blanket and/or unsaturated zone and the assessment (Section 4) may need to consider the impact of nitrate on groundwater quality. In theory 50 mg/l of ammonium (NH_4^+) could be converted to 172 mg/l of nitrate (NO_3^-) if there were no losses of nitrogen.

Groundwater risk assessment for treated effluent discharges to infiltration systems

2.4.3 Quality of trade effluent discharges

For trade effluent discharges, we will require an assessment of the likely quality of the effluent based on analysis of the effluent. We may also require information on the treatment system and what substances it has been designed to treat (for example, BOD rather than pesticides / herbicides which may represent the main risk to groundwater).

Analytical data should be reviewed to identify substances which are above the relevant environmental standards applicable for the receptors at risk. If time series data are available it is often helpful to graph the key parameters to show how they change through the year and whether this can be related to changes in waste streams and treatment processes.

2.4.4 Thickness and nature of the unsaturated zone

Depending on the constituents of the effluent to be discharged and the characteristics of the site, attenuation processes in the unsaturated zone below the infiltration system may play an important role in preventing the input of hazardous substances to groundwater and reducing concentrations of non-hazardous pollutants to acceptable levels.

For sewage effluent discharges from septic tanks and package treatment plants BS6297:2007 (+ A1:2008) requires that the base of the trench shall have a minimum 1.2 m of unsaturated soil present above the seasonally highest groundwater level.

Sufficient information (refer to Appendix D) should be provided on the depth to the water table and the lithology of the strata underlying the drainage field to allow this assessment (note that BS6297:2007 (+ A1:2008) requires a trial hole investigation).

2.5 The potential for mounding of the water table

Where infiltration rates are high, but the capacity of the saturated aquifer to transmit this water away is limited, the discharge may lead to an increase in water levels and so reduce the thickness of the unsaturated zone. We may therefore, require additional assessment of this, especially for larger discharges, leading to modification of the drainage field (for example, use of drainage mounds as described in BS 6297:2007 + (A1:2008). You can estimate the extent of mounding of the water table by calculation or for an existing operation by measurement of groundwater levels in boreholes adjacent to the field.

2.6 Rapid pathways

In fractured and weathered rocks, fissures may provide preferential pathways for water or effluent movement through the unsaturated zone. This can occur in any strata, but is of particular concern in limestone aquifers (such as the Carboniferous Limestone and in places, chalk) where solution of the rock renders it karstic due to the enlargement of fractures (see also Section 3.7.1)

We may require an investigation to demonstrate that karst features (such as sink holes, swallow holes or dolines) or other preferential pathways are not present in the vicinity of the drainage field and / or that there is a significant thickness of overlying drift deposits or an appropriate drainage medium. Appropriate investigation should be undertaken by a specialist consultant or contractor. You should discuss the scope of such investigations with us to avoid any unnecessary effort.

2.7 Attenuation properties and groundwater flow

An overview of the attenuation processes which may reduce the impact of treated effluent discharges to the sub-surface is given in Section 1.7.

Risk assessments for large discharges or for infiltration systems located in sensitive areas will require supporting information on the properties of the unsaturated zone (thickness and lithology of soils, sub-soil and rock, moisture content, soil bulk density, fraction of organic carbon) and groundwater flow in the aquifer below the drainage field (flow direction, hydraulic gradient and aquifer properties). Further information is given in our H1 Environmental Risk Assessment Annex (i) Groundwater (Environment Agency, 2011a) This information will be needed to support any detailed risk assessment including calculation of attenuation and dilution factors (Chapter 3 and Appendix F).

2.8 Investigative monitoring

If the effluent discharge is currently being made or has been made historically at the location under investigation we may require monitoring as part of the investigations to determine whether any unacceptable impact has occurred or might occur in the future. This may involve down-gradient and up-gradient monitoring as well as monitoring of the effluent itself. Such information will increase the confidence attached to predictive assessment allowing refinement of the site conceptual model and in some cases may mean that less emphasis on modelling of unsaturated zone processes is needed.

Groundwater risk assessment for treated effluent discharges to infiltration systems

Monitoring data may allow you to estimate site specific dilution and attenuation factors which you can then use to derive discharge limit values and the necessary treatment criteria for the discharge. Monitoring may also help to provide evidence for the use of degradation in the risk assessment model.

Groundwater level monitoring can be used to determine the depth to the water table and/or the direction of groundwater flow. The thickness of the unsaturated zone will have an important influence on attenuation processes and therefore, on the impact of the discharge on groundwater water quality. Groundwater levels can vary seasonally and may be affected by the hydraulic loading from the infiltration system (for example, mounding of groundwater levels see Section 2.5).

For larger, complex discharges and discharges in sensitive locations or where our in house risk assessment has determined that more site specific data is required, you may need to carry out investigations to provide further information as part of the permit application.

2.9 Site investigation

This may involve intrusive site investigation and monitoring to ascertain the depth of the groundwater, the hydraulic gradient[12] and flow regime, hydraulic properties (such as moisture content, effective porosity, hydraulic conductivity, presence of fractures/fissures, etc.) and the background quality along with other site specific data such as the effects of earlier discharges. Evidence for the use of degradation in the detailed quantitative risk assessment will also be required (see Section 1.7.2).

The purpose of the investigation may be twofold:

1. To support the risk assessment and decisions as to whether a proposed or existing discharge is acceptable.

2. To identify requirements for long term monitoring of the discharge

We recommend that where appropriate, you consider whether investigative boreholes should be installed as groundwater monitoring installations (see below). In some cases, these boreholes may be suitable for the ongoing monitoring of the permitted discharge provided they are appropriately located and installed.

Boreholes installed to monitor groundwater quality may not always provide the best information on groundwater levels and so the purpose of the monitoring should be carefully considered when designing investigations.

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[12] To determine the hydraulic gradient, a minimum of three monitoring points in triangular formation is required.

Groundwater risk assessment for treated effluent discharges to infiltration systems

The details of monitoring point location, design and construction will inevitably be site specific taking account the local three-dimensional flow regime.

All construction should be designed so as to prevent any risk of cross contamination between different layers of strata.

Reference should be made to: Guidance on the design and installation of groundwater quality monitoring points, Science Report SC020093. Environment Agency (2006a) ISBN: 1844325342.

Note: Investigation monitoring is for the purpose of providing information to assist in assessing whether a permit can be granted. This differs from monitoring to check on-going compliance with a permit (see Chapter 4).

2.10 Further reading

British Water, 2009b	Code of Practice: A guide for users of small wastewater treatment systems for package sewage treatment plants and septic tanks.
British Water, 2009c	Code of Practice: Guide to the Installation of Sewage Treatment systems.
British Water, 2009d	Code of Practice: Guide to the Desludging of Sewage Treatment systems.
British Water, 2010	Code of Practice: A Guide to the Maintenance Requirements for Sewage Treatment Systems (under development)
BSEN 12566: 2000	Small Wastewater Plants (<50 PT). Part 1 Prefabricated Septic Tanks. Part 2 Soil Infiltration Systems. Part 3 Packaged and or Site Assembled Domestic WW Treatment Plants. Part 4 Septic Tanks Built in situ from prefabricated kits (execution standard). Part 5 Filtration systems (including sand filters). Part 6 On site testing (Notes Parts 2 to 6 in press).
BSEN 12566: 2007	Part IV for Septic Tanks assembled in situ from prefabricated units.

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BSEN 12566:2005   Part III for package or site assembled domestic sewage treatment plants.

BS 6297: 2007 (+A1:2008)   Code of practice for the design and installation of drainage fields for use in wastewater treatment. ICS 13.060.30, BSI 2008 (Amended 2008).

Groundwater risk assessment for treated effluent discharges to infiltration systems

Chapter 3 Risk assessment approach

3.0 Introduction

This chapter provides guidance on the steps in the evaluation of the risks posed by the proposed discharge to groundwater (and the wider water environment). The objective of the risk assessment is to ensure that the proposed discharge meets the requirements of EPR to prevent inputs of hazardous substances to groundwater and to avoid pollution from non-hazardous pollutants. Definitions of the main terms used in this section are given in Box 3.1.

Box 3.1   Standard terms used as part of the risk assessment
Compliance Point: A compliance point is a suitable point along the contaminant pathway between the source and a receptor at which you set a compliance value. The compliance point may be a virtual point (for the purpose of predictive assessments) or it may be a physical monitoring point such as a borehole. In some cases the compliance point may be the receptor itself.
Compliance Value: This is a concentration at the compliance point that should not be exceeded. Depending on the level of assessment, a compliance value may take account of some or all of the dilution and attenuation processes along the contaminant pathway to the receptor(s). The purpose of the selected compliance value is to provide protection to a down-gradient receptor – provided the compliance value is met the relevant environmental standard for the receptor(s) should also be met. In some cases a compliance value may form a condition to the permit in addition to the limit values for the discharge itself.
A **Limit Value** is a value set as a condition in the environmental permit to control a specified parameter in the discharge with the aim of preventing the input of hazardous substances to groundwater or limit pollution due to the input of non-hazardous pollutants.
Dilution Factor describes the amount of dilution of the discharge by groundwater flow and is calculated from the ratio of groundwater below the drainage field and the discharge to the drainage field.
Attenuation Factor (unsaturated zone) describes the amount of attenuation of a substance in the unsaturated zone and can be calculated as the ratio between the effluent concentration and the predicted concentration at the base of the unsaturated zone.
Attenuation Factor (saturated zone) describes the amount of attenuation of a substance in the saturated zone and can be calculated as the ratio between the concentration of the substance in groundwater below the drainage field and the predicted concentration at a point down-gradient of the drainage field.

This document is out of date and was withdrawn (01/02/2016)

Groundwater risk assessment for treated effluent discharges to infiltration systems

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Box 3.1 continued

The **Environmental Standard** used to derive the compliance values will depend on (a) whether the substance is hazardous substance or a non-hazardous pollutant and (b) the use of the receptor (for example, a potable abstraction or surface water). Examples of environmental standards are:

- Limits of detection (LOD) or where applicable a minimum reporting value (MRV). These are typically used to assess the discernibility of hazardous substances as a basis for deciding whether their input has been prevented.

- Natural background (up-gradient) quality. This might be used to assess the discernibility of hazardous substances where background concentrations are higher than detection limits or the MRV. Alternatively it might be used for non-hazardous pollutants where the natural background concentration exceeds the relevant standard such as a drinking water standard (DWS) or environmental quality standard (EQS):

DWS or EQS. In some cases it will be appropriate to use lower concentrations than these to provide satisfactory protection to a receptor. For example, it may be suitable to apply a factor to provide greater security to an existing drinking water supply (for example, 0.75 x DWS). In other cases where the DWS or EQS represents a significantly higher concentration than the natural background quality, use of such values might represent a significant level of deterioration (for example, a DWS of 250mg/l of chloride compared to a background concentration of for example, 30mg/l). You may need to discuss this with us and derive a more suitable value between the MRV or background concentration and the EQS or DWS.

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Before using this section you should consult the guidance provided in Chapter 4 of our main groundwater risk assessment guidance (Annex (j) Groundwater, Environment Agency 2011a). This main guidance also describes how a conceptual model should be formulated and its importance in any risk assessment.

It is assumed in the following paragraphs that basic requirements for water protection as set out in GP3 (Environment Agency 2006-2008) and in Box 1.4 have been complied with.

3.1 Risk assessment approach

In undertaking the risk assessment we advise the following tiered approach as this will avoid unnecessary effort:

- risk screening

- generic quantitative risk assessment

- detailed quantitative risk assessment.

-

The outcome from each stage will be one of the following:

a) There is sufficient information to determine that the discharge does not present an unacceptable risk.

b) Further assessment is required (by moving to the next assessment tier with additional information) or alternatively, modifications need to be made to the activity such as improved treatment of the effluent or changes to the drainage field or its location.

c) The activity presents an unacceptable risk and a permit will not be granted.

This tiered approach to risk assessment should ensure that the effort required is consistent with the complexity of the activity and its setting. The assessment should be as simple as these factors allow and summarised in the conceptual model.

As part of the risk assessment process you will need to set one or more compliance points and to derive an appropriate compliance value. Compliance points and compliance values are defined in Box 3.1 and are described in more detail in section 3.5. . Exceedance of the compliance value would indicate that the discharge is not acceptable and that additional treatment or modifications to the drainage system will be required before we would grant a permit.

The objectives of risk assessment, in terms of regulatory requirements, are noted in Box A. For non-hazardous pollutants the requirement is to assess whether pollution will take place. This is described in the rest of this chapter and follows our standard approach to the assessment of groundwater pollution (see also the Introduction text on hazardous substances and non-hazardous pollutants).

3.2 Risk screening

Risk screening (RS) may identify that the proposed discharge is acceptable and a permit can be granted or that the activity needs more detailed assessment (for example, taking it to the next stage – a generic quantitative risk assessment).

Risk screening should not be confused with an assessment as to whether an activity may be excluded from the definition of 'groundwater activity' under the EPR. You will have reached the stage of risk screening because such exclusions cannot be applied and some level of assessment is needed.

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For treated sewage effluent discharges up to 15 m³/day we will already have undertaken a screening assessment for you based on the information supplied with your application. From this we will identify whether we require you to undertake any further assessment.

For all other discharges (see Introduction) we will want you to include a risk screening section in your own risk assessment which considers factors such as those set out below:

3.2.1 Examples of factors as basis of risk screening

From an initial risk screening of the site, can the discharge be shown to be acceptable based on one or more of the following:

- The discharge has concentrations of hazardous substances sufficiently close to our relevant 'minimum reporting value' (MRV: usually a detection level or agreed minimum practical analytical value) or the natural background level in groundwater (whichever is the higher concentration) for an assessment to be made at a qualitative level that their input will be prevented by virtue of available attenuation processes in the unsaturated zone and/or immediate dilution at the water table[13].

- The discharge has concentrations of non-hazardous pollutants less than the relevant environmental standard or natural background level applicable to the receiving groundwater.

- The presence of unproductive drift or unproductive bedrock strata (there are no aquifers beneath or near the activity – Unproductive Strata) and remoteness from surface waters means that risk to any identified groundwater dependent receptor is very low.

- The volume or hydraulic loading rate of the discharge is very small such that only minimal dilution in underlying groundwater will be required to avoid pollution by non-hazardous pollutants.

The basic information required for a screening assessment (as referred to in Appendix D) would include the size of discharge; the results of percolation tests; depth to water table; geology (soils and strata descriptions and thicknesses from logs from excavations) and details of proximity to receptors.

For existing disposal activities then groundwater monitoring data may be used to support the assessment. This will involve comparison of groundwater quality data in down-gradient boreholes with the relevant environmental standard or MRV. If there are no exceedances then provided the monitoring data are representative then it would be reasonable to conclude that attenuation and dilution is sufficient to reduce the concentrations of hazardous substances and/or non-hazardous pollutants to acceptable levels.

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[13] This would relate to the assessment of your permit application/review and therefore does not relate to the determination of whether or not an exclusion under EPR would apply.

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More detailed quantitative risk assessment will involve an assessment of whether attenuation and dilution will reduce the concentrations of hazardous substances and non-hazardous pollutants to acceptable levels.

3.3 Generic quantitative risk assessment

A generic quantitative risk assessment (GQRA) is used when the source, pathway and receptor terms are sufficiently well understood that they can be confidently represented by conservative assumptions. This includes activities where the source can be well defined and the known properties of the soil are easily sufficient to reduce risks to underlying groundwater to low regardless of uncertainties in the thicknesses and properties of underlying strata.

Basic quantitative risk assessments will typically use these conservative assumptions as input values to relatively simple scoping calculations of for example, dilution, unretarded and retarded travel time, and attenuation factor. Some basic equations and examples are presented in Appendix F:

Box F1   Basic calculations for determining the impact of a discharge on groundwater quality and for determining discharge limit values.

Box F2   Standard equations for calculation of dilution factor.

Box F3   Standard equations for calculation of attenuation factors.

Box F4   Example calculation of attenuation factor for the unsaturated zone.

Box F5   Calculation of dilution and attenuation factors using monitoring data.

Box F6   Example calculation for determining the impact of a discharge on groundwater quality and for determining discharge limit values.

The calculations and examples in Boxes F1 – F6 are provided for illustration. Our Infiltration Worksheet v1.1 (Environment Agency, 2011c) will usually be used to calculate these parameters.

3.4 Detailed quantitative risk assessment

Detailed quantitative risk assessments (DQRA) should be carried out where a potential risk has been identified from the generic risk assessment based on simple calculations and conservative assumptions.

A detailed quantitative risk assessment will require more detailed site specific information supported by investigations and typically use a probabilistic modelling approach to assess

the impact of uncertainties in input data. They may also be needed where the quantity and quality of the activity's discharge may change significantly through time (as potentially the case for trade effluent discharges).

3.5 Compliance points and compliance values

As part of the risk assessment process you will need to set one or more compliance points and to derive an appropriate compliance value. Compliance points and compliance values are defined in Box 3.1.

For discharges to the ground, the following compliance points should be considered:

For **hazardous substances**:

- Groundwater at the point of entry into the saturated zone immediately below the infiltration field.

Or, where borehole monitoring is necessary to validate the assessment:

- As near as practically possible to the point of entry into the saturated zone, if necessary further down-gradient at, or as near as possible to, the boundary of the infiltration field.

The aim is to account only for the instant dilution that occurs as the discharge comes into contact with the groundwater but not attenuation in the saturated zone or dilution by groundwater flow below or outside the mixing zone.

For **non-hazardous pollutants**:

- An existing water use (for example, abstraction borehole, spring, wetland, stream or river) or a suitable point between this receptor and the discharge along the contaminant pathway.

Or, where it is the groundwater resource rather than defined receptors at risk:

- The distance to the compliance point will need to take account the environmental sensitivity of the aquifer. The receptor in this case would be a theoretical abstraction borehole at a point not exceeding 50 metres from the boundary of the discharge (in a Principal or strategically important Secondary Aquifer) or a point up to 250 metres from the boundary of the discharge (in a Secondary Aquifer of local importance).

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Figure 3.1   Compliance points
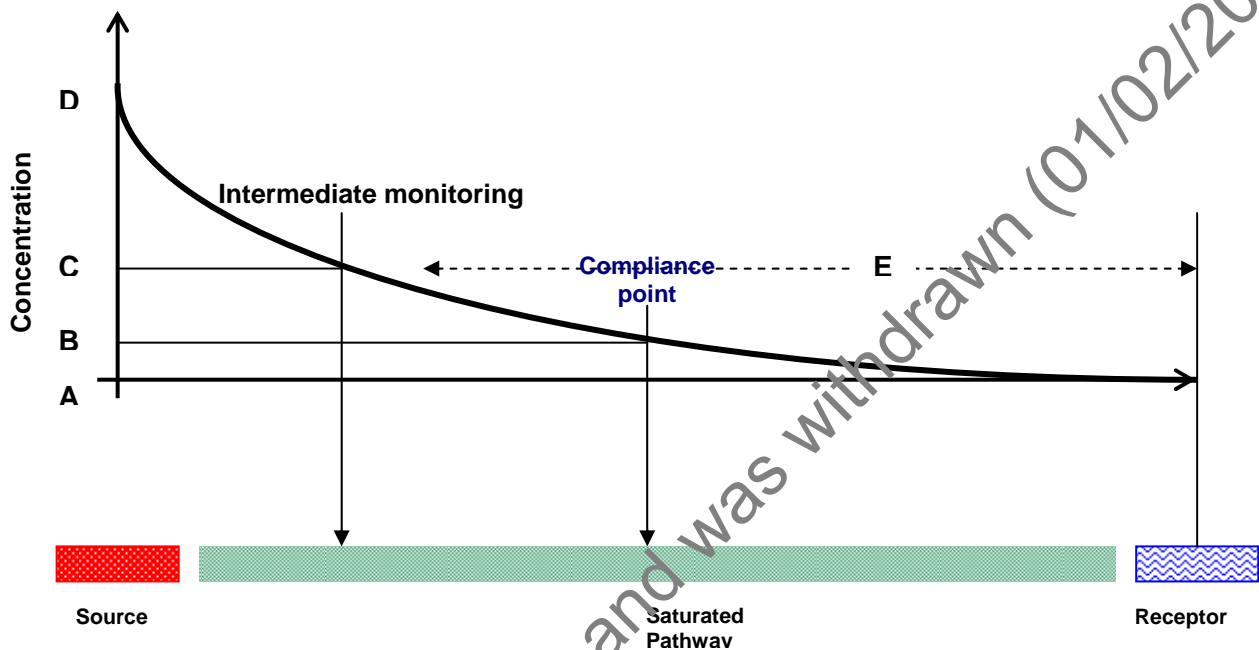
A =   Environmental standard necessary to protect the **receptor**.

B =   Compliance value at a **compliance point**, set to ensure the environmental standard at the receptor is/will be met (may be physical, such as the actual **monitoring point** or a virtual point used for model prediction).

C =   Quality measurement at **intermediate monitoring points** to provide advance information.

D =   Discharge source concentration.

E =   Possible range of compliance point locations according to site specific conditions – could be at the receptor itself, or some other point along the pathway.

Exceedance of the compliance value indicates that the discharge is not acceptable and that additional treatment or modifications to the drainage system will be required before we can grant a permit.

For further guidance on compliance points please refer to our H1 Environmental Risk Assessment *Annex (j) Groundwater* (Environment Agency, 2011a)

Groundwater risk assessment for treated effluent discharges to infiltration systems

3.6 Processes and substances to model

3.6.1 Processes

The main processes that you will need to consider within a generic or detailed risk assessment are:

- Attenuation in the unsaturated zone, including retardation and degradation of substances. It will be important to consider rates of movement through the unsaturated zone - in particular where this is thin or rapid flow occurs (for example, fissured strata).

- Dilution by groundwater flow. For most aquifer settings dilution is likely to be low (dilution factor of 1 to 3). If higher dilution factors have been calculated then this will need to be justified (for example, the value of hydraulic conductivity is plausible).

- Attenuation in the saturated zone (for non-hazardous pollutants only). This process and in particular degradation will typically be slower than in the unsaturated zone, but may be still be significant.

As part of the assessment of degradation, you need to consider transformation products (for example, nitrate derived from the degradation of ammonium) and whether the resulting secondary contamination is significant (for example, exceeds water quality standards).

3.6.2 Substances to model

The risk assessment needs to focus its effort on hazardous substances and non-hazardous pollutants in the discharge which are most likely to have an effect on groundwater or associated sensitive receptors. You need to identify substances to model according to the following criteria:

- Hazardous substances in high concentrations compared to their minimum reporting values (MRVs) and background concentrations in groundwater; and / or

- non-hazardous pollutants in high concentrations compared to their appropriate environmental standards.

From these two groups, consideration should be given to those substances that, during the movement of the discharge down through the subsurface soils, rocks and strata, are:

- least likely to be attenuated (and could be used as a marker substance in monitoring); and

- attenuated by different mechanisms (for example, the metal cadmium being attenuated by sorption / precipitation or ammonium being attenuated due to transformation to nitrate).

The main substances of concern (and most likely) in sewage effluent are identified in Box 1.3. As a minimum the assessment should be undertaken for ammonium and total inorganic nitrogen. For ammonium consideration will need to be given as to whether it transforms [14] to nitrate and whether this could result in groundwater concentrations exceed 50 mg/l as NO_3 (see Box 1.3). For nitrate background concentrations may be elevated due to other sources of nitrogen (for example, fertilisers, atmospheric deposition) and consideration may need to be given as to whether the total nitrogen loading is acceptable. Assessment of total nitrogen may need to be included in future assessments because a complete understanding of the impact from sewage involves the various breakdown products. The extent to which we do this will depend on the scale of the activity and the proximity to water supplies.

The Infiltration Worksheet v1.1 (Environment Agency 2011c) provides an ammonia conversion calculator for the various laboratory analyses. .

For larger discharges the assessment should also include:

- orthophosphate particularly if the receptor is surface water and its falls under the Habitats Directive;
- metals (subject to analysis of the effluent);
- hazardous substances (subject to analysis of the effluent);
- hydrocarbons (subject to analysis of effluent);
- boron (subject to analysis of the effluent);
- other substances may need to be considered (such as pharmaceuticals, chlorinated hydrocarbons, etc.).

For large sewage effluent discharges (>50 m^3/d) and trade effluent chemical analysis will be required. The need for chemical analysis for smaller sewage effluent discharges will be site specific.

3.7 Risk assessment calculations and modelling tools

A quantitative analysis requires the use of calculations or numerical models to assess the impact of a discharge on groundwater and to assess the significance of attenuation and dilution. In Appendix F we have summarised the basic calculations to determine this impact. Supporting calculations for determining dilution and attenuation factors are given in Boxes F4 and F5 together with example calculations. We emphasize that these are relatively simple

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[14] In theory 50 mg/l of ammonium as NH_4^+ could convert to 172 mg/l of nitrate as NO_3^-. This assumes there is no loss of nitrogen as gas (N_2) or through sorption.

equations and more complex numerical approaches may be required. Any calculations need to be consistent with the conceptual understanding of the activity and its potential impact on groundwater and need to be justified as part of the risk assessment.

We have developed a spreadsheet tool (Infiltration Worksheet v1.1, Environment Agency 2011c) to assist in the assessment of discharges to infiltration systems. However, you need to assess whether the use of this spreadsheet tool is appropriate for the site, and if not, an alternative numerical model should be used and justified.

You should only employ the Infiltration Worksheet v1.1 or other risk assessment tools where a robust conceptual model has been developed and you are satisfied that the calculations performed by the worksheet are relevant to the processes described within that conceptual model.

The development of a robust conceptual model is perhaps the most important aspect in the process of successfully estimating and evaluating environmental risks. The use of any mathematical modelling tool without first developing a robust conceptual model is likely to result in meaningless output and poor decision-making.

The Infiltration Worksheet v1.1 or other risk assessment tools should only be used by suitably experienced hydrogeologists or those fully conversant with our approach to groundwater risk assessment and the relevant England and Wales legislation and guidance.

Probabilistic calculations (such as ConSim, Environment Agency 2003b) use ranges of realistic input values, with an informed assumption of the distribution (for example, normal, log normal, etc.) of values within the range, to produce a distribution of output values. Such calculations are typically undertaken in detailed quantitative risk assessments. The Environment Agency ConSim model includes an option to model discharges to soakaways. The soakaway can be treated as an infiltration system by using the area and infiltration rate derived from percolation tests. There are other numerical modelling tools that may also be appropriate.

In undertaking the risk assessment calculations you must either justify the choice of parameter values or demonstrate that they are not important to the outcome of the assessment (for example, through sensitivity analysis).

The ConSim user manual provides further information on assigning values to uncertain parameters.

3.7.1 Fissure and fracture flow systems – use of risk assessment models

Please note our Infiltration Worksheet v1.1 (Environment Agency 2011c) is only applicable to intergranular flow systems

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If the preliminary risk assessment has identified the presence of fissure or fractures the Infiltration Worksheet v1.1 (Environment Agency 2011c) equations for dilution and attenuation factors assume that flow is through the matrix of the soil or rock and that there is no rapid bypass flow (it is intergranular). Most rocks have a degree of fissuring and you can take this into account to some extent by adjusting parameter values such as porosity and permeability to approximate to an intergranular flow system. However, if fissure flow is dominant on a scale where such approximation is unreasonable or if the rock is karstic and rapid bypass flow is more likely, then the assessment may need to be more conservative and limited to simple dilution using the assumption of high permeability. Attenuation is likely to be very limited in fast flow karstic situations. To make such assessment less conservative you would need more detailed field evidence, such as groundwater tracer testing and flow measurement and you may need to adopt a more sophisticated modelling approach.

For highly fissured or karstic limestone systems, any models need to be conservative and allow for dilution only. More detailed investigation may be needed to confirm that the discharge is not over a major fissure / karstic feature (percolation tests should indicate whether there are rapidly draining strata). Drainage fields comprise granular material and there is the potential for significant attenuation to take place in the drainage blanket. The thickness of the drainage blanket may also be increased to enhance attenuation.

For dual porosity systems such as Chalk then an equivalent effective porosity can be assumed (diffusion between fissure and pore water) this needs to be considered on a case by case basis. A key aspect will be the design of system such that discharge rate does not exceed hydraulic capacity of unsaturated zone, leading to rapid bypass.

We will usually ask you to provide us with an electronic copy of the model to allow us to check the approach and undertake our own analysis. Any model submitted should be supported by the relevant site specific data. You should undertake a sensitivity analysis on identified key input parameters (further guidance can be found in Environment Agency 2001a).

Note that the use of any model should be undertaken by a competent person and that a model is just a risk assessment tool that should be based on a good site conceptual model and hydrogeological expertise.

3.7.2 Further information on the use of numerical models

For further information on the use of numerical models you should refer to our guidance on using numerical models and to assigning values to uncertain parameters:

Guidance on the assessment and interrogation of subsurface analytical contaminant fate and transport models, NGWCLC report NC/99/38/1, Environment Agency, June 2001.

Guidance on conceptual models in subsurface contaminant fate and transport modelling, NGWCLC report NC/99/38/2, Environment Agency, June 2001.

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Guidance on assigning values to uncertain parameters in subsurface contaminant fate and transport modelling, NGWCLC report NC/99/38/3, Environment Agency, June 2001.

3.8 Linking risk assessment to permit conditions

Assuming the risk assessment for the activity and its setting has demonstrated an acceptable outcome, then to ensure this is sustained during the operation (and aftercare) of the activity and site, we will set corresponding conditions in the permit to control parameters such as the discharge rate and discharge quality. In addition to limit values, we may require you to monitor the effluent and / or provide down-gradient monitoring. You will be required to manage and operate the discharge in accordance with a management system and be able to show that you are minimising pollution.

Potential post-application monitoring requirements are described in Chapter 4.

3.9 Reporting

The completed environmental permit application should include the following:

- description of the proposed activity including the volume and type of discharge;
- chemical composition of the discharge and identification of hazardous substances and non-hazardous pollutants;
- details of the drainage field (for example, location, area and construction details);
- results of investigations of the disposal area (for example, trial pits, boreholes) and percolation tests;
- maps to define the boundaries to the activity and its regional context (for example, location in relation to water courses, springs and boreholes);
- identification of potential receptors (for example, private wells, surface courses);
- description of unsaturated zone (for example, depth to water table, lithology);
- assessment of attenuation properties of the unsaturated zone;
- assessment of groundwater flow below site (for example, direction of groundwater flow direction, groundwater hydraulic gradient and aquifer properties);
- results of any groundwater level and quality monitoring;

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- conceptual model describing the discharge, pathways and receptors together with an assessment of dilution and attenuation processes. Supporting evidence should be provided where the risk assessment involves the use of degradation rates;

- justifications for the risk approach adopted and for any supporting calculations and numerical modelling;

- results of the risk assessment including proposed limit values and monitoring.

For smaller discharges we will have undertaken the risk assessment for you and this will be placed on file by us.

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Chapter 4 Monitoring

4.0 Introduction

This chapter describes specific elements of monitoring related to discharges of treated effluent for a newly granted or existing environmental permit. Investigative monitoring may be required during the permit application and risk assessment process. Please refer to 'Investigative Monitoring' (Chapter 3) for more details.

For more information on monitoring in general please refer to our H1 Environmental Risk Assessment *Annex (j) Groundwater* (Environment Agency 2011a) where we describe the need and benefits of monitoring and the required approach, with links to relevant guidance. The decision for whether or not you will need to install investigative and/or post-permit monitoring will be assessed on a site specific basis.

4.1 Ongoing monitoring of the activity

We need to make sure that, if permitted, the activity is carried out within any limits assumed in the risk assessment. Monitoring may comprise one or more of the following:

- checks and records;
- measurement of the discharge rate and effluent quality;
- measurement of groundwater levels and groundwater quality in boreholes located around the infiltration system;
- measurement of water quality in related receptors.

Under the current environmental permitting 'charging for discharges' scheme we will normally undertake essential monitoring of the effluent and groundwater (where and if existing boreholes are available) for the purposes of checking compliance with the permit - unless you have entered into an Operator Self Monitoring arrangement whereby you take over some of this responsibility. However, in all cases we will require you to provide the necessary infrastructure and access arrangements.

You will normally be responsible for conducting measurements of discharge flow rate if this is required by the permit.

You should check our EP charging scheme pages for further information.

Groundwater risk assessment for treated effluent discharges to infiltration systems

The extent of monitoring required will be site specific and depend on the size and type of discharge and the sensitivity of the environmental setting. For smaller discharges, monitoring may be limited to checks and records; for larger discharges (typically greater than 50 m^3/day) or where the site is in a particularly sensitive location then we may require monitoring of groundwater levels and quality. We would advise you to discuss this with us at an early stage as this will influence the scope of the risk assessment.

4.1.1 Effluent monitoring

For treated sewage effluent the parameter suite should typically include ammonium and total inorganic nitrogen. For larger discharges, you should set out the recommendations for monitoring of effluent discharge rate and quality including the frequency of measurement and which parameters will be measured.

4.1.2 Recommendations

The proposals should include recommendations for essential monitoring of groundwater. This requires careful planning, usually on a case-by-case basis, to determine parameters to be measured or sampled and analysed, frequency of measurement / sampling and location of monitoring points. Reference should be made to the conceptual model when designing the monitoring system. For more detail on the sampling of groundwater please refer to: British Standard BS ISO 5667-11:2009 (Guidance on Sampling of Groundwaters).

In line with, European Guidance (EC, 2007 – CIS No 17), we recommend that you consider the following points when proposing a groundwater monitoring programme:

- Up-gradient and / or background monitoring: It may be necessary to report on the unaffected / background situation in the subsurface either before a new activity is set up or up-gradient of an existing source of contamination. For the larger discharges, up-gradient compliance monitoring should be outside the zone of influence (that is away from any potential groundwater mounding).

- Monitoring intervals (frequency) should take into account the behaviour (for example, travel times) of the known pollutants and their degradation products.

- Construction (technical) characteristics of the monitoring wells and the depth of monitoring within each observation well should be dependent on the nature of the input and on the seasonal water level fluctuation.

- Sampling methods, sample preservation and analysis methods will be dependent on the nature of the input and its expected pollutant concentration. Commercial analytical laboratories can advise on sample preservation and analysis.

Groundwater risk assessment for treated effluent discharges to infiltration systems

- The parameters monitored at each well should be indicative of the type of pollutant(s) and their expected impact. Possible indicator parameters (redox, pH, electrical conductivity, temperature, salts) could be used to reduce the monitoring effort.

- The cost-benefit of the number of wells versus the level of information that will be obtained.

The details of monitoring point location, design and construction will inevitably be site specific taking account the local three-dimensional flow regime.

Glossary

Glossary of terms

Aquifer	A subsurface layer or layers of rock or other geological strata of sufficient porosity and permeability to allow either a significant flow of groundwater or the abstraction of significant quantities of groundwater (Water Framework Directive, 2000).
Attenuation	A decrease in contaminant concentration or flux through biological, chemical and physical processes, individually or in combination (for example, dispersion, precipitation, ion exchange, biodegradation, oxidation, reduction). See also natural attenuation.
Background	See baseline.
Baseline	In the context of an environmental permit, the measurements that characterise the pre-permit physical, chemical or other distinctive properties of groundwater and surface water beneath / around a site.
Biodegradation	The breakdown of a substance or chemical by biological organisms, usually bacteria.
Cess pit/pool	Sealed tank used to collect sewage. It has no outlet and requires periodic emptying.
Compliance point	A compliance point is a suitable point along the contaminant pathway between the source and a receptor at which you set a compliance value. The compliance point may be a virtual point (for the purpose of predictive assessments) or it may be a physical monitoring point such as a borehole. In some cases the compliance point may be the receptor itself.
Compliance value	This is a concentration at the compliance point that should not be exceeded. Depending on the level of assessment, a compliance value may take account of some or all of the dilution and attenuation processes along the contaminant pathway to the receptor(s).
Conceptual model	A simplified representation or working description of how the real (hydrogeological) system is believed to behave based on qualitative analysis of field data. A quantitative conceptual model includes preliminary calculations for the key processes.
Conservative contaminants	Contaminants which can move readily through a permeable medium with little or no reaction and which are unaffected by biodegradation (for example, chloride).
Contamination / contaminant	The introduction of any substance to water at a concentration exceeding the baseline concentration. A contaminant is any such substance.

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Detection limit	The lowest concentration of a substance that can be reliably measured to be different from zero concentration.
Dilution	Reduction in concentration brought about by mixing (typically with water).
Dilution factor	The dilution factor describes the amount of dilution of the discharge by groundwater flow and is calculated from the ratio of groundwater below the drainage field and the discharge to the drainage field.
Discernibility	The GWD states that all measures necessary to prevent the input of any hazardous substance into groundwater must be taken. One of the criteria that define 'Prevent' is that the substance being discharged is not **discernible** in comparison to either the natural background concentration of groundwater or a minimum reporting value if this is at a higher concentration.
Discharge	A release of effluent to the ground surface or to infiltration system
Dispersion	Groundwater - Irregular spreading of solutes due to heterogeneities in groundwater systems at pore-grain scale (microscopic dispersion) or a field scale (macroscopic dispersion).
Down-gradient	In the direction of decreasing water level (in groundwater this is following the hydraulic gradient).
Drainage field	System of infiltration pipes placed in trenches and arranged so that effluent can be discharged to the ground.
Dry weather flow (DWF)	DWF is the average daily flow to a sewage treatment works (STW) during a period without rain. It only relates to water company STW serving combined sewered area.
Environmental quality standard (EQS)	A water quality and biological standard for a surface watercourse.
Groundwater	In this document the definition used is that given in the Water Framework Directive (2000/60/EC) as "all water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil".
Hazardous substances	Defined in the WFD as: "substances or groups of substances that are toxic, persistent and liable to bio-accumulate, and other substances or groups of substances which give rise to an equivalent level of concern."
Hydraulic conductivity	A coefficient of proportionality describing the rate at which a fluid can move through a medium. The density and kinematic viscosity of the fluid affect the hydraulic conductivity, so that this parameter is dependent on the fluid as well as the medium. Hydraulic conductivity is an expression of the rate of flow of a given fluid through unit area and thickness of the medium, under unit differential pressure at a given temperature. (See also

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	permeability).
Hydraulic gradient	The change in total head (of water) with distance in a given direction. The direction is that which yields a maximum rate of decrease in head.
Infiltration system	An infiltration system is defined by BS6297:2007 (+ A1:2008) as "a series of infiltration pipes, placed in either single trenches or one large bed, used to discharge effluent in such a way that it percolates into the disposal area".
Limit value	A limit value is a compliance value specifically set such that if it is exceeded, the receptor will be at risk of being polluted.
Minimum reporting value (MRV)	The lowest concentration of a substance which is reported in the results of an analysis. It is not necessarily the detection limit.
Natural attenuation	Natural processes which, without human intervention, reduce the concentration, mass, flux or toxicity of contaminants in groundwater and surface water.
Non-hazardous pollutant	Any substance capable of causing pollution that has not been classified as a hazardous substance.
Partition coefficient (K_d)	Soil water partition coefficient (l/kg). In a heterogeneous system of two or more phases in equilibrium, the ratio of activities (or less accurately the concentrations) of the same molecular species in the phases is a constant at constant temperature. The constant is termed the partition coefficient.
Pathway	The route alone which a particle of water, substance or contaminant moves through the environment.
Package treatment plant	Package treatment plants (PTPs) are small scale sewage treatment works
Permeability	A measure of the rate at which a fluid will move through a medium. The permeability of a medium is independent of the properties of the fluid. See also hydraulic conductivity.
Pollutant	Water Framework Directive: "any substance liable to cause pollution, in particular those listed in Annex VIII [of the WFD]".
Pollution	Defined in EPR (2010) as: "the direct or indirect introduction, as a result of human activity, of substances or heat into the air, water or land which may be harmful to human health or the quality of aquatic ecosystems or terrestrial ecosystems directly depending on aquatic ecosystems, which result in damage to material property, or which impair or interfere with amenities or other legitimate uses of the environment."
Porosity	The ratio of the volume of void spaces in a rock or sediment to the total volume of the rock or sediment.

Glossary

Potable water
Water of suitable quality for drinking.

Principal Aquifer
Geological strata that exhibit high permeability and usually provide a high level of water storage. They are capable of supporting water supply on a strategic scale and are often of major importance to river base flow (formerly known as Major Aquifer).

Receptor
An entity / organism, material property or any existing or potential active or passive use of water that is being or could be harmed by a potential pollutant, including groundwater or surface water resources, amenity uses or abstraction points.

Recharge
The amount of water added to the groundwater system by natural or artificial processes.

Retardation
A measure of the reduction in solute velocity relative to the velocity of the flowing groundwater caused by processes such as adsorption.

Risk
A quantitative or qualitative combination of the probability of a defined hazard causing an adverse consequence at a receptor, and the magnitude of that consequence.

Risk assessment
The process of identifying and quantifying a risk, and assessing the significance of that risk in relation to other risks.

Saturated zone
The zone in which the voids of the rock or soil are filled with water at a pressure greater than atmospheric. The water table is the top of the saturated zone in an unconfined groundwater system. In general, flow on a macro scale is horizontal and typically faster than for unsaturated zone flow. Flow rates between different types of strata vary over several orders of magnitude.

Septic tank
Sealed tank receiving and treating sewage by bacteria and settlement of solids from which effluent overflows, usually to a drainage field.

Small sewage effluent discharge
Defined by EPR (2010) as a treated sewage effluent discharge to ground of 2 m^3/day or less.

Soakaway
The former term for an infiltration system. Permeable area of ground, or buried structure, designed to speed the drainage of clean surface water into the ground.

Sorption
Absorption; adsorption, chemisorption and ion exchange considered jointly. Sorption is generally removal of a solute from solution. Can be reversible.

Trade effluent
Effluent derived from commercial process/premises.

Unproductive Strata
These are geological strata with low permeability that have negligible significance for water supply or river base flow (formerly part of the Non-Aquifers).

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Unsaturated zone   The zone between the land surface and the water table. The pore space contains water at less than atmospheric pressure, as well as air and other gases. Saturated bodies, such as perched groundwater may exist in the unsaturated zone. Also called the vadose zone.

Up-gradient   In the direction of increasing hydraulic head (in groundwater this is moving up the hydraulic gradient).

List of abbreviations

List of abbreviations

AF	Attenuation Factor
BGS	British Geological Survey
BOD	Biological oxygen demand
BS	British Standard
COD	Chemical oxygen demand
DF	Dilution Factor
DQRA	Detailed Quantitative Risk Assessment
DWF	Dry Weather Flow
DWS	Drinking Water Standard
EPR	Environmental Permitting Regulations
EQS	Environmental Quality Standard
GP3	Groundwater Protection: Principles and Practice
GQRA	Generic Quantitative Risk Assessment
IEPA	Irish Environmental Protection Agency
LOD	Limit of Detection
MRV	Minimum Reporting Value
PPG	Pollution Prevention Guidelines
PTP	Package Treatment Plant
RS	Risk Screening
S-P-R	Source-Pathway-Receptor
SPZ	Source Protection Zone
STW	Sewage Treatment Works
SuDS	Sustainable Drainage Systems
UWWTD	Urban Waste Water Treatment Directive
WFD	Water Framework Directive
WIA	Water Industry Act 1991

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British Water, 2009b — Code of Practice: A guide for users of small wastewater treatment systems for package sewage treatment plants and septic tanks

British Water, 2009c — Code of Practice: Guide to the Installation of Sewage Treatment systems

British Water, 2009d — Code of Practice: Guide to the Desludging of Sewage Treatment Systems

British Water, 2010 — Code of Practice: A Guide to the Maintenance Requirements for Sewage Treatment Systems (under development)

BS 6297:2007 (+A1:2008) — Code of practice for the design and installation of drainage fields for use in wastewater treatment. ICS 13.060.30, BSI 2008 (Amended 2008).

BS EN 12566: 2000 — Small Wastewater Plants (<50 PT). Part 1 Prefabricated Septic Tanks. Part 2 Soil Infiltration Systems. Part 3 Packaged and or Site Assembled Domestic WW Treatment Plants. Part 4 Septic Tanks Built in situ from prefabricated kits (execution standard). Part 5 Filtration systems (including sand filters). Part 6 On site testing (Notes Parts 2 to 6 in press).

BSEN 12566:2007 — Part IV for Septic Tanks assembled in situ from prefabricated units

References

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Building Regulations, 2002   Part H, Drainage and waste disposal, The Office of the Deputy Prime Minister (ODPM).

Building Regulations, 2010   2010 No. 2214 Building and Buildings, England and Wales, the Building Regulations 2010

CIRIA, 1993   Septic Tanks and Small Sewage Treatment Works: A Guide to Current Practice and Common Problems. CIRIA Technical Note 146.

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Environment Agency, 2001b Guidance on Conceptual Models in Subsurface Contaminant Fate and Transport Modelling, NGWCLC report NC/99/38/2, Environment Agency, June 2001

Environment Agency, 2001c Guidance on Assigning Values to Uncertain Parameters in Subsurface Contaminant Fate and Transport Modelling, NGWCLC report NC/99/38/3, Environment Agency, June 2001

Environment Agency, 2002a Impacts of Sewage Effluent Disposal into Aquifers on Groundwater Quality - Phase 1: Literature Review. P2-229

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Environment Agency, 2006	Pollution Prevention Guidance Note 4 'Disposal of sewage where no mains drainage is available: PPG4' Environment Agency/SEPA/EHS 2001 update 2006
Environment Agency, 2006-2008	Groundwater Protection: Policy and Practice, Parts 1 – 4. Environment Agency 2006 – 2008
Environment Agency, 2006a	Guidance on the design and installation of groundwater quality monitoring points, Science Report SC020093. Environment Agency (2006) ISBN: 1844325342
Environment Agency, 2011a	H1 Environmental Risk Assessment Annex (J) Groundwater (Environment Agency 2011)
Environment Agency, 2011b	Guidance for the registration of small sewage effluent discharges (Environment Agency July 2011)
Environment Agency, 2011c	Infiltration Worksheet v1.1 and User Manual (v1.2)
Environment Agency, 2012	Groundwater Protection: Principles and Practice Part 4 & Part 5 (in preparation)
EPR 7.01	How to comply with your environmental permit Additional guidance for: Water Discharge and Groundwater Activity Permits Environment Agency, 2010
EPR, 2010	The Environmental Permitting (England and Wales) (Amendment) Regulations 2010. SI 2010 No. 675
IEPA, 2004	An investigation into the performance of sub-soils and stratified sand filters for the treatment of wastewater from on-site systems: Literature Review
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IEPA, 2007	Code of Practice: Waste water treatment systems for single houses
Landfill Directive	Council Directive 1999/31/EC on the Landfill of Waste. In England and Wales, the Directive is applied under the Landfill (England and Wales) Regulations 2002

Appendices

Appendix A

Hazardous substances and non-hazardous pollutants

| Box A1 | Schedule 22 Groundwater Activities, EPR (2010) |

Meaning of "hazardous substance"

4.—(1) A hazardous substance is any substance or group of substances that are toxic, persistent and liable to bio-accumulate.

(2) This includes in particular the following when they are toxic, persistent and liable to bioaccumulate—

(a) organohalogen compounds and substances which may form such compounds in the aquatic environment,

(b) organophosphorous compounds,

(c) organotin compounds,

(d) substances and preparations, or the breakdown products of such, which have been proved

to possess carcinogenic or mutagenic properties or properties which may affect

steroidogenic, thyroid, reproduction or other endocrine-related functions in or via the

aquatic environment,

(e) persistent hydrocarbons and persistent and bioaccumulable organic toxic substances,

(f) cyanides,

(g) metals (in particular, cadmium and mercury) and their compounds,

(h) arsenic and its compounds,

(i) biocides and plant protection products.

(3) The regulator must publish a list of substances that it considers to be hazardous substances.

Meaning of "non-hazardous pollutant"

5. A non-hazardous pollutant is any pollutant other than a hazardous substance.

The former Groundwater Directive (80/68/EEC) defined two lists of substances that were deemed to pose the greatest risk to groundwater quality. These were referred to as List 1 and List 2, with substances on List 1 being of most concern. The Water Framework Directive

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(WFD, 2000/60/EC) and its daughter Groundwater Directive (2006/118/EC) consider a wider range of potential pollutants and refer to them as hazardous substances or non hazardous pollutants. This terminology is used in the Environmental Permitting Regulations (2010) and further details are provided below:

Hazardous substances

Hazardous substances are defined in the WFD as "substances or groups of substances that are toxic, persistent and liable to bio-accumulate, and other substances or groups of substances which give rise to an equivalent level of concern"

Under EPR (2010) we are required to publish a list of hazardous substances and the Joint Agencies Groundwater Directive Advisory Group (JAGDAG) is the body that confirms these determinations. All former List I substances are hazardous substances. Due to their nature, it is considered that all radioactive substances are hazardous substances.

Non-hazardous pollutants

A non-hazardous pollutant is any substance capable of causing pollution that has not been classified as a hazardous substance. The non-hazardous list of pollutants does not simply replace the former List II; it is wider, as for example, nitrate is now termed as being non-hazardous whereas before it was not a Listed Substance.

Further information on the list of substances considered to be hazardous, can be found on the UKTAG website

All substances liable to cause pollution that are not considered hazardous are deemed non-hazardous pollutants.

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Appendix B

Assessing discharges of hazardous substances to groundwater. Environment Agency indicative Minimum Reporting Values for selected substances in clean water.

Substance	MRV (µg/l)	Comment
1,1,1-trichloroethane	0.1	
1,1,2-trichloroethane	0.1	
1,2-dichloroethane	1	
2,4 D *ester*	0.1	methyl, ethyl, isopropyl, isobutyl and butyl each to 0.1
2,4-dichlorophenol	0.1	
2-chlorophenol	0.1	
4-chloro-3-methylphenol	0.1	
aldrin	0.003	
atrazine	0.03	
azinphos-ethyl	0.02	
azinphos-methyl	0.001	
benzene	1	
cadmium	0.1	
carbon tetrachloride	0.1	
chlorfenvinphos	0.001	
chloroform	0.1	
chloronitrotoluenes	1	2,6-CNT; 4,2-CNT; 4,3-CNT; 2,4-CNT; 2,5-CNT each to 1µg/l
PCB (individual congeners)	0.001	
demeton	0.05	demeton-s-methyl only
diazinon	0.001	
dieldrin	0.003	
dimethoate	0.01	
endosulfan	0.005	endosulphan a and endosulphan b, each to 0.005µg/l
endrin	0.003	
fenitrothion	0.001	
fenthion	0.01	
hexachlorobenzene	0.001	
hexachlorobutadiene	0.005	

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Substance	MRV (μg/l)	Comment
hexachlorocyclohexanes	0.001	α-HCH, γ-HCH and δ-HCH each to 0.001μg/l β-HCH to 0.005μg/l
isodrin	0.003	
malathion	0.001	
mecoprop	0.04	
mercury	0.01	
mevinphos	0.005	
op DDT	0.002	o = ortho; p = para
pp DDT	0.002	
op DDE	0.002	
pp DDE	0.002	
op TDE	0.002	
pp TDE	0.002	
parathion	0.01	
parathion methyl	0.015	
pentachlorophenol	0.1	
permethrin	0.001	cis and trans-permethrin both to 0.001μg/l
simazine	0.03	
tetrachloroethylene	0.1	
toluene	4	
tributyltin compounds	0.001	
trichlorobenzene	0.01	135 tcb; 124 tcb; 123 tcb each to 0.01
trichloroethylene	0.1	
trifluralin	0.01	
triphenyltin compounds	0.001	
xylenes	3	o-xylene and m/p-xylene each to 3μg/l. May not be possible to separate m- and p-xylene.

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Appendix C

Summary of research on sewage effluent

This appendix provides a summary some recent research of the attenuation processes that may affect sewage effluent in the sub-surface and provides an overall summary of attenuation processes and they can affect contaminant concentrations. Long term substantive evidence must be provided before considering the conclusions given below.

Attenuation of sewage effluent

BGS (2007): The BGS study investigated the impact of sewage effluent disposal on Chalk groundwater beneath drainage fields serving a number of domestic properties. The BGS study did not encounter ammonium (NH4+) in groundwater beneath and down-gradient of the drainage field of a septic tank serving eight domestic properties, suggesting that it had attenuated or been diluted within a short distance of the point of disposal.

IEPA (2006): Irish EPA studies investigated the impact of sewage effluent disposal at 4 domestic properties in typical settings. The more detailed IEPA (2006) studies found that significant ammonium attenuation occurred in the unsaturated zone beneath the drainage field. A significant conclusion from this study was that the majority of the treatment of the septic tank effluent took place in the distribution gravel and first 300 mm of subsoil where there was also a reduction in the total nitrogen load.

Similar results were observed for a package treatment plant. They concluded that the remaining unsaturated zone provided a polishing effect on effluent quality.

Filtration of particulate matter and microbial contaminants.

Studies undertaken by the Irish EPA (2006) into discharges from septic tanks to ground found that:

> *"1.2 m of unsaturated subsoil did not fully remove all enteric bacteria from the septic tank effluent. Isolated incidences of low concentrations of E. coli were found in the subsoil on both septic tank sites."*

However, numbers were substantially reduced with depth.

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Studies conducted by BGS (2007) on effluent discharges to the Chalk found some low-level impact on the aquifer from the effluent discharge. Septic tank and the PTP systems had very similar microbial populations dominated by high numbers of faecal bacteria, particularly coliforms and bacteroides. They concluded that low bacteria numbers, the chemical and physical conditions within the treatment systems, and dilution in the aquifer all contribute to a low or insignificant impact on the aquifer

Sorption, retardation and nitrification of ammoniacal nitrogen.

The IEPA (2006) studies indicated that ammonium concentrations fell from starting concentrations of ~50 mg/l (as N) to ~5 mg/l (as N). They also found that most of the oxidation occurred within the gravel trench fill and the first 300 mm of subsoil, with the remaining unsaturated zone providing limited additional attenuation. Some denitrification may occur, leading to a reduction in the total nitrogen loading due to loss of nitrogen as N2 (gas). Further information on the attenuation of ammonium can be found in the Environment Agency 2003 report 'Review of ammonium attenuation in soil and groundwater'

Further reading

BGS, 2007   *Assessing the impact of sewage effluent disposal on groundwater*. Science Report SC010070/SR (Prepared by BGS [Trick, J K, Lelliott, M, Pickup, R, Heaton, T E and Noy D J] for Environment Agency).

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Appendices

Appendix D

Information requirements (see Table 2.1)

Table D1 Information requirements

Information	Description / Source of Information / Comments	Level of information needed		
		Basic	Extended	Comprehensive
Details of premises	Domestic (single or multiple dwelling), industrial, STW	✓		✓
Location of discharge	12 figure grid reference. Location map (1:10000)	✓	✓	✓
Details of drainage field	Plan area, depth, details of construction and drainage		✓	✓
Number of persons	Where applicable	✓	✓	✓
Type of effluent	Sewage effluent, trade effluent, combined	✓	✓	✓
Details of pre-treatment of effluent	Septic tank, package treatment plant, septic tank, reed bed, other	✓	✓	✓
Soil /subsoil characteristics (where relevant) to 3 m below base of drainage field	Thickness, description (clay, silt etc) below drainage field. Borehole logs and trail pits essential for extended or comprehensive	✓	✓	✓
Geology including solid and drift	Borehole logs and trial pits, geological maps	✓	✓	✓
Presence of karst features	Solution features, large fissures, cave systems	✓	✓	✓
Rate of discharge (m^3/d)	Measured or calculated based on number of persons and type of premise (Table 2.2, Box 2.1) or estimated dry weather flow (Box 2.2) where applicable.	✓	✓	✓
Hydraulic loading	Discharge divided by area of drainage field (Box 2.3)	✓	✓	✓
Details and results of percolation tests	Results of percolation or other infiltration tests	✓	✓	✓
Composition of	Results of chemical analysis	✓	✓	✓

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Information	Description / Source of Information / Comments	Level of information needed		
		Basic	**Extended**	**Comprehensive**
discharge	or published data (for small sewage discharges)			
Groundwater Environment	Principal Aquifer, Secondary A or B, Non-Productive Strata SPZ, Water Protection Zone, Safeguard Zone, etc.	✓	✓	✓
Environment	SSSIs, SPAs, etc	✓	✓	✓
Surface water course(s) and wetlands	Location and distance from drainage field Additional information may need to be obtained on stream flows, water quality, ecological status and use (for example, salmonid fishery, source of potable water supply)	✓	✓	✓
Distance to nearest abstraction(s) (springs, wells, boreholes).	Type, purpose, size of abstraction. Further information may be required on dewatering operation, unlicensed sources, potential or planned water use	✓	✓	✓
Depth to water table/unsaturated zone thickness	Seasonal water level variation Evidence of water logging Details of any water seepage or standing water levels in trial pits	✓	✓	✓
Flood risk	Is site within floodplain	✓	✓	✓
Historical discharge	Details of historical discharges to drainage field	✓	✓	✓
Hydraulic conductivity of the aquifer	Basic can include literature values Extended or comprehensive: site specific data	✓	✓	✓
Historical land use	Industrial site, contaminated land, other		✓	✓
Details of operation and maintenance	Monitoring of discharge rates, effluent quality, liquid levels in distribution chamber		✓	✓

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Information	Description / Source of Information / Comments	Level of information needed		
		Basic	**Extended**	**Comprehensive**
Flow mechanism	Fissure/intergranular flow		✓	✓
Direction of groundwater flow	Groundwater monitoring boreholes		✓	✓
Hydraulic gradient	Groundwater monitoring boreholes		✓	✓
Effective porosity of the aquifer	Literature		✓	✓
Mixing depth	Borehole logs, groundwater quality sampling, theoretical calculation		✓	✓
Soil and rock properties	Lithology, moisture content, fraction of organic carbon content, other factors for retardation			✓
Groundwater quality, up-gradient and down-gradient of discharge field	Groundwater monitoring boreholes			✓

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Appendix E

How to undertake a percolation test

Avoid carrying out this test in extreme weather conditions such as drought, frost and heavy rain.

a) Excavate at least two (three in Northern Ireland) holes 300mm square to a depth 300mm below the proposed invert level (bottom of pipe) of the infiltration pipe and space them evenly along the proposed line of the subsurface irrigation system.

b) Fill each hole with water to a depth of at least 300mm and allow to seep away overnight.

c) Next day, refill each hole with water to a depth of at least 300mm and observe the time in seconds for the water to seep away from 75% full to 25% full i.e. a depth of 150mm).

d) Divide this time by 150. This answer gives the average time in seconds (Vp) required for the water to drop 1mm.

e) The test should be carried out at least three times with at least two trial holes. The average figure from the tests should be taken. This is the percolation value Vp (in seconds).

f) The average figure for the percolation value (Vp) is obtained by summing all the values and dividing by the number of values used.

g) Drainage field disposals should only be used when percolation tests indicate average values of Vp between 15 and 100 and the preliminary assessment of the trial hole tests has been favourable.

h) The minimum value of 15 ensures that untreated effluent cannot percolate too rapidly into ground water.

i) Where Vp is above the limit of 100 effective treatment is unlikely to take place in a drainage field as there will be inefficient soakage in this location which may lead to sewage ponding on the surface.

j) For domestic premises, the floor area of the drainage field (A in square metres) required may be calculated from:

A = p x Vp x 0.25 for septic tanks
A = p x Vp x 0.20 for package sewage treatment plants

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Where:

p is the number of people served by the tank (this should be the maximum number of people that could live in the house).

Vp is the percolation value described above.

If in doubt, consult your professional advisor or local authority building control officer for advice.

Reference: Pollution Prevention Guidelines Note 4 (PPG4 Environment Agency/SEPA/EHS 2001 update 2006).

Appendices

Appendix F Calculations

Box F1 Basic calculations for determining the impact of a discharge on groundwater quality and for determining discharge limit values.

Concentration at compliance point.

The concentration of a substance at different points along the pollutant pathway can be calculated as follows:

(i) Water table (attenuation in unsaturated zone only):

$$C_{cp} = C_e / AF_u.$$

(ii) Borehole adjacent to infiltration system (attenuation in unsaturated zone and dilution)

$$DCL = C_e /(AF_u.DF)$$

(iii) Attenuation in unsaturated and saturated zone and dilution (non-hazardous pollutants only)

$$DCL = C_e / (AF_u. AF_s DF)$$

where,

C_{cp} = Concentration at compliance point (mg/l). Concentration should be below the compliance value

C_e = Effluent concentration (mg/l)

AF_u = Attenuation factor (unsaturated zone) (see Box F3)

DF = Dilution factor (see Box F2)

AF_s = Attenuation factor (saturated zone) (see Box F3)

DCL = Discharge limit values

Discharge limit values.

Discharge limit values (*DCL*) can be calculated as follows:

(i) Attenuation in unsaturated zone only:

$$DCL_1 = AF_u. C_c$$

(ii) Attenuation in unsaturated zone and dilution

$$DCL_2 = AF_u.DF. C_c$$

(ii) Attenuation in unsaturated and saturated zone and dilution (non-hazardous pollutants only)

$$DCL_3 = AF_u. AF_s DF. C_c$$

where,

DCL = Discharge limit value

DF = Dilution factor (see Box F2)

AF_u = Attenuation factor (unsaturated zone) (see Box F3)

AF_s = Attenuation factor (saturated zone) (see Box F3)

C_c = Compliance value set to protect receptor (mg/l) (for example, water quality standard or minimum

reporting value)

Appendices

Box F2   Standard equations for calculation of dilution factor

The **dilution factor (DF)** for groundwater below the drainage field can be calculated from:

(i) DF calculated taking background concentration into account

$$DF = \frac{(G_w + Inf.A).C_t - (G_w.C_u)}{Inf.A.C_t}$$

(i) DF calculated with no allowance for background concentration

$$DF = 1 + \frac{G_w}{Inf.A}$$

(iii) DF calculated taking background concentration into account and using effluent concentration

$$DF = \frac{(G_w + Inf.A).C_e}{G_w.C_u + Inf.A.C_e}$$

and

$$G_w = K.i.w_d.M_z$$

where,

DF = dilution factor

C_t = compliance value (mg/l) (for example, water quality standard or minimum reporting value)

C_u = background concentration (mg/l)

C_e = effluent concentration (mg/l)

K = hydraulic conductivity (m/d)

i = hydraulic gradient

w_d = width of disposal field perpendicular to flow direction (m)

Inf = infiltration rate (m/d)

A = area of drainage field (m^2)

M_z = mixing zone thickness (m). The mixing zone thickness can be calculated using the following equation

$$= (0.0112L^{0.5}+d_a.(1-exp[(-L.Inf/K.i.\,d_a)])$$

Note for shallow aquifers: If $M_z > d_a$, then $M_z = d_a$

L = length of site parallel to groundwater flow (m)

d_a = aquifer thickness (m)

Example calculation of dilution factor

A discharge of 5 m^3/day is applied to a drainage field covering 100 m^2 (10 m by 10m).ay Information on the aquifer thickness, hydraulic gradient and hydraulic conductivity of the underlying aquifer has been obtained from borehole drilling and testing.

The dilution factor can be calculated using the following equation (no allowance made for background concentration):

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$$DF = 1 + \frac{K.i.w_d.M_z}{Inf.A}$$

where

K = 15 m/d

i = 0.01

w_d = 10 m

M_z = 4 m (based on saturated thickness of aquifer)

Inf = 5/100 = 0.05 m/d

A = 100 m^2

Therefore calculated dilution factor (DF) = 1 + (15 x 0.01 x 10 x 4)/(0.05 x 100) = 2.20

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Box F3   Standard equations for calculation of attenuation factors

An **attenuation factor (AF) for the unsaturated zone** can be calculated from the following equation

$$AF = 1/\exp\left[\frac{D}{2a} - \left\{\frac{D}{2a}\sqrt{1+(4a\lambda/\mathrm{u})}\right\}\right]$$

D = unsaturated zone thickness (m)

α = vertical dispersivity in the unsaturated zone (approximately D/10) (m)

λ = unsaturated zone decay constant (d^{-1}) = ln(2)/half life for degradation

u = retarded contaminant velocity in the unsaturated zone (m/d) where $\mathrm{u} = \dfrac{Inf}{R.\theta}$

R = retardation factor where $R = 1 + \dfrac{Kd.\rho}{\theta}$

θ = effective porosity of unsaturated zone

Inf = infiltration rate (m/d)

Kd = partition coefficient (l/kg)

P = soil bulk density

An **attenuation factor (AF) for the saturated zone** *can be calculated from the following equation (no allowance for vertical or lateral dispersion)*

$$AF = 1/\exp\left[\frac{x}{2a} - \sqrt{1+(4a\lambda/u)}\right].erfc\left[\frac{x}{2\sqrt{a.u.t}} - \left(x - ut\sqrt{1+(4a\lambda/u)}\right)\right]$$

x = distance to compliance point down-gradient of the disposal field (m)

α = longitudinal dispersivity in the saturated zone (m)

λ = saturated zone decay constant (d^{-1}) = ln(2)/half life for degradation

u = retarded contaminant velocity in the saturated zone (m/d) where $u = \dfrac{Inf}{R.n}$

K = hydraulic conductivity (m/d)

i = hydraulic gradient

n = effective porosity of the saturated zone

R = retardation factor where $R = 1 + \dfrac{Kd.\rho}{n}$

Kd = partition coefficient (l/kg)

P = aquifer bulk density

NB This equation ignores dispersion in the vertical or lateral direction. Further equations can be found in Environment Agency 2006 and 2011.

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Box F4   Example calculation of attenuation factor for the unsaturated zone

A discharge of 5 m^3/day is applied to a drainage field covering 100 m^2 (10 m by 10m). Ammonium is present in the discharge and is considered to represent a risk of pollution of groundwater. The concentration of ammonium in the discharge is 30 mg/l. Information on the unsaturated zone thickness (15m), soil bulk density (1.8 gm/cm^3) and water filled porosity (25%) was obtained from site investigation boreholes. Evidence for the use of degradation was agreed with us. Literature values indicate a half life for the degradation of ammonium of 1 to 2 years and a partition coefficient of 2 l/kg.

The attenuation factor can be calculated using the following equations:

$$AF = 1/\exp\left[\frac{S}{2a} - \left\{\frac{S}{2a}\sqrt{1+(4a\lambda/v)}\right\}\right]$$

where

Inf = 0.05 m/d

S = 15 m

α = D/10 = 1.5 m

θ = 0.25

λ = ln(2)/365 = 0.0019 d^{-1} (assuming a half life of 365 days)

Kd = 2 l/kg

P = 1.8 gm/cm^3

$$R = 1 + \frac{Kd.\rho}{\theta} \quad = \quad 1 + \frac{2\text{x}1.8}{0.25} = 15.4$$

$$v = \frac{Inf}{R.\theta} \quad = \quad \frac{0.05}{15.4 \times 0.25} = 0.013 \, \text{m/d}$$

Therefore $AF = 1/\exp\left[\frac{15}{2\times1.5} - \left\{\frac{15}{2\times1.5}\sqrt{1+(4\times1.5\times0.0019/0.013)}\right\}\right] = 6.4$

The calculated attenuation factor for ammonium for the unsaturated zone is 6.4. For an effluent concentration of 30 mg/l then the calculated concentration at the base of the unsaturated zone = 30/6.4 = 4.7 mg/l.

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<table>
<tr><td colspan="2">Box F5   Calculation of dilution and attenuation factors using monitoring data</td></tr>
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Dilution and attenuation factors can be calculated from monitoring data for existing discharges as follows

The dilution factor (DF_{cl}) can be calculated for a conservative contaminant such as chloride from:

$$DF_{cl} = (C_e - C_u) / (CB - C_u)$$

where,

CB = mean concentration in monitoring borehole down-gradient of disposal field (mg/l)

C_u = up-gradient or background mean concentration (mg/l)

C_e = mean concentration in effluent (mg/l)

The attenuation factor (AF) can be calculated for a non-conservative contaminant from:

$$AF = ((C_e - C_u)/(CB - C_u))/ DF_{cl}$$

The calculation of dilution and attenuation factors is dependent on:

- Presence of conservative contaminant such as chloride in the discharge;
- The contaminant is present above background in groundwater

Example calculation: Groundwater monitoring data are available for two boreholes, one located up-down-gradient and one located adjacent to a drainage field receiving an effluent discharge. The effluent has an average chloride concentration of 90 mg/l and an ammonium concentration of 20 mg/l. The observed chloride concentration in groundwater up and down-gradient of the drainage field is 24 mg/l and 60 mg/l respectively. The concentrations of ammonium in the two boreholes are 0.1 and 0.4 mg/l respectively.

The dilution factor can be calculated using the following equation:

$$DF_{cl} = (C_e - C_u) / (CB - C_u)$$

where,

CB = 60 mg/l

C_u = 24 mg/l

C_e = 90 mg/l

Therefore DF_{cl} = (90-24)/(60-24) = **1.8**

The attenuation factor (AF) can be calculated for ammonium from:

$$AF = ((C_e - C_u)/(CB - C_u))/ DF_{cl}$$

where,

CB = 0.4 mg/l

C_u = 0.1 mg/l

C_e = 20 mg/l

DF_{cl} = 1.8

Therefore **AF** = ((20-0.1)/(0.4-0.1))/1.8 = **36.85**

This document is out of date and was withdrawn (01/02/2016)

Appendices

Box F6   Example calculation for determining the impact of a discharge on groundwater quality and for determining discharge limit values

Calculation of impact on groundwater

A discharge of 5 m^3/day is to be applied to a drainage field covering 100 m^2 (10 m by 10m). Ammonium is present in the discharge and is considered to represent a risk of pollution of groundwater. The concentration of ammonium in the proposed discharge is 30 mg/l (as NH_4^+).

Information from site investigations together with literature values were used to determine an attenuation factor for the unsaturated zone and a dilution factor. These factors are:

DF = 2.2 (see Box F2)

AF_u = 6.4 (see Box F4)

The concentration of ammonium in groundwater immediately down-gradient of the drainage field can be calculated as follows:

$C_{cp} = C_e / (AF_u.DF)$ *(see Box F1)*

= 30/(6.4 x 2.2)

= 2.13 mg/l

This calculated concentration exceeds the drinking water standard of 0.5 mg/l such that:

- The application should be refused; or

- Further assessment undertaken on attenuation in the unsaturated zone and also on whether attenuation in the saturated zone is significant; or

- Additional treatment of the effluent would be required prior to discharge.

In the latter case a discharge limit value can be calculated as follows:

$DCL = AF_u.DF. C_c$ *(see Box F1)*

= 6.4 x 2.2 x 0.5

= 7 mg/l

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