

Chemical Techniques Manual



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Technical Report
P261**



ENVIRONMENT AGENCY

Chemical Techniques Manual

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Research Contractor:
HTS Consultants

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Statement of use

This report is intended to act as a Manual providing a source of guidance for Agency staff when dealing with chemical incidents.

Research Contractor

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CONTROL SHEET

This Manual is issued for internal use by Environment Agency personnel. Any comments on useful additions or corrections should be passed to Paul Greaves, Thames Region.

Amendment Record

Date	Issue	Revision
30/11/99	1	First issue of complete Manual

SECTION 1

INTRODUCTION

1.0 PURPOSE, SCOPE & LIMITATIONS

1.1 Purpose of the Manual

The purpose of this Manual is to provide Environment Agency personnel with information to enable them to take effective and safe action to ameliorate the effects of water pollution by a range of hazardous chemicals.

In the first instance, the range of chemicals covered by the Manual has been limited to:

- **Chlorinated solvents**
- **Timber treatment chemicals**
- **Cyanide**
- **Ammonia**

These chemicals have been identified by the Agency as ones which have been frequently found to give rise to pollution problems, and for which the impact might be lessened by the implementation of appropriate amelioration techniques. Further chemical groups and techniques may be added at a later stage.

1.2 Scope of the Manual

The information provided in this Manual assumes that traditional containment measures have failed, and that the contaminant has entered the drainage system or watercourse.

The amelioration techniques proposed are therefore intended to reduce the concentration of the contaminant in rivers, lakes, streams or discharges to acceptable levels, thereby minimising the environmental damage which might otherwise have been caused if no action had been taken.

In order to use the information provided in this Manual, it is assumed that the contaminant has been identified either by

analysis or from other sources of information relating to the incident.

It is strongly advised that contact is made with ETAS - Environmental Toxicological Advisory Service (See Section 5 for contact details), to obtain toxicological and other relevant data relating to the contaminant, prior to the commencement of amelioration operations.

1.3 Limitations of amelioration techniques

All of the treatment techniques covered in this Manual have relatively limited treatment capacities due to the size restrictions associated with readily transportable equipment.

The maximum flow rate which is likely to be achieved by any of the treatment techniques is around 5 litres per second (18 m³ per hour). None of the techniques is therefore likely to be able to treat significantly more contaminated water than can be removed by conventional vacuum tankers.

The use of the amelioration techniques using transportable equipment is therefore restricted to the treatment of effluent discharges or where the contaminant is confined to relatively small streams or rivers. None of the treatment techniques is likely to be effective where the contaminant has reached a main river and has become diluted with large volumes of water from other sources.

1.4 Complementary remediation techniques

1.4.1 Containment and adsorbents

Many substances covered by the Manual are only partially soluble in water; for example, many chlorinated solvents and white spirit based Lindane/TBTO formulations. Attempts should therefore be made to remove any free product using

conventional booms and adsorbents before implementing any of the amelioration techniques covered in this Manual. Manufacturer's specifications should be consulted to select the most suitable adsorbent material for the pollutant in question.

Many chlorinated solvents are of similar density or are denser than water, and can therefore float or sink depending on conditions. Care should therefore be taken to identify and remove any free product which might accumulate on the riverbed. In these circumstances it may be necessary to construct a flooded dam wall with sandbags or excavate a sump to trap the substance for removal by pumping or vacuum tanker.

1.4.2 Vacuum tankers

None of the amelioration techniques can be considered an automatic replacement for the use of vacuum tankers. All of the techniques suffer from a number of restrictions or disadvantages which could favour the use of vacuum tankers in certain situations, including:

- The maximum flow rates that are likely to be effectively treated by any of the techniques is of the order of 5 litres per second which is comparable to the removal rate of a vacuum tanker.
- All of the techniques require a certain amount of supervision, and some are labour intensive. There can also be a certain amount of risk to staff and members of the public if procedures are not followed correctly. A full Health & Safety Risk Assessment should be carried out prior to the commencement of any works.
- There can be significant costs associated with the acquisition, maintenance and operation of appropriate equipment and chemicals.

- With the exception of the treatment of cyanide by PCS, none of the treatment techniques actually destroy the contaminant; they merely remove it from the water, either by adsorption or mass transfer processes. There are therefore additional costs associated with waste disposal or regeneration.
- The performance of amelioration techniques require monitoring to ensure that they are operating effectively. This can be difficult if there are no suitable portable test kits for the analysis of the contaminant, for example, pesticides and chlorinated solvents.
- There is a high degree of confidence associated with the use of vacuum tankers, because the contaminant is totally removed from the site and therefore no longer poses a threat. No monitoring or control systems are required to ensure that the contaminant treatment process is functioning correctly.

However, there may be circumstances where the use of vacuum tankers may not be appropriate, for example:

- In circumstances where there are large quantities of contaminated water which require disposal, or where action needs to be taken over an extended period which would make the use of vacuum tankers prohibitively expensive.
- Where vacuum tankers may not be available due to access restrictions or logistical difficulties.
- Where the location of the incident is remote from any suitable disposal point thereby preventing the effective use of vacuum tankers.

It can be seen therefore that the amelioration techniques covered in this Manual cannot be considered as a direct replacement for the use of vacuum tankers. Instead they should be thought of as a complementary technique. The merits and disadvantages

associated with the use of each method should be considered in individual situations to arrive at the most appropriate solution given the circumstances at the time.

1.4.3 Spray and land irrigation

For many years the impact of many agricultural pollutants has been successfully minimised by the use of spray and land irrigation techniques. Spray irrigation is likely to result in a reduction in the ammonia concentration of very strong effluents whilst land irrigation can be used where there is sufficient land available for the treatment of large quantities of contaminated water.

1.4.4 pH adjustment

The toxicity of ammonia is dependent on the equilibrium between unionised ammonia (NH_3) and the less toxic ammonium ion (NH_4^+). This equilibrium is dependent on pH, temperature, total dissolved solids and salinity. It is possible to significantly reduce the toxicity of ammonia by decreasing the pH of the water by one pH unit.

1.5 Health & Safety implications

All of the amelioration techniques covered in this Manual have potential Health & Safety implications for Agency staff, contractors and members of the public. It is essential that a full Risk Assessment is carried out using the 5-Step procedure, as detailed in the Agency's Health & Safety Risk Assessment Manual, prior the commencement of any operations.

1.6 Potential legal implications

In considering potential amelioration techniques for inclusion in the Manual, care was taken to ensure that the techniques proposed were, as far as was reasonably practicable, free from any potential adverse environmental impact. However, it should be remembered that under the terms of Section 85 of the Water Resources Act, 1990, “it is an offence to cause or knowingly permit poisonous, noxious or polluting matter, or any solid waste, to enter controlled waters.” The possibility exists that the addition of any material to controlled waters to ameliorate the effects of a pollution incident could be argued to constitute an offence under the terms of the Act. Care should therefore be taken to ensure that adequate consideration is given to any potential adverse effects which might occur on organisms in the receiving water, either directly or indirectly, through reactions of the added chemical in the waterbody. If in any doubt, consult with the Legal Department.

2.0 HOW TO USE THE MANUAL

2.1 Structure of the Manual

- ***Section 1 - INTRODUCTION***

Provides background information concerning the purpose and scope of the Manual. It discusses limitations and implications of amelioration techniques, and considers their use in conjunction with other remediation methods.

- ***Section 2 - GLOSSARY***

Lists chemical names, synonyms and trade names alongside the heading under which information concerning that particular substance will be found in the Manual.

- ***Section 3 - CHEMICALS COVERED BY THE MANUAL***

Lists the chemicals covered by the Manual alphabetically. For each chemical there is information about the character and its sources. Basic Health & Safety information is provided as well as details relating to environmental effects. Possible amelioration techniques are listed.

- ***Section 4 - AMELIORATION TECHNIQUES***

Provides detailed descriptions of the amelioration techniques available to deal with the range of chemicals listed in Section 3.

- ***Section 5 - USEFUL ADDRESSES***

Provides useful addresses where further information concerning the contaminant and amelioration techniques can be found as well as suppliers of chemicals or equipment.

- ***Section 6 - HEALTH & SAFETY DATA SHEETS***

Contains Health & Safety data sheets for chemicals used.

2.2 How to find a Manual entry

For example, to find information and details of amelioration techniques for dealing with an incident involving a substance with the trade name 'Perklone';

- Look up 'Perklone' in the **Section 2** (Glossary). This shows that information relating to 'Perklone' can be found in **Section 3** (Chemicals covered by the Manual) under the heading 'tetrachloroethylene'.
- Refer to **Section 3** (Chemicals covered by the Manual) which lists chemicals alphabetically. Under 'tetrachloroethylene', amelioration techniques are found to be 'Air Stripping' and 'GAC Adsorption'.
- Look up 'Air Stripping' and 'GAC Adsorption' in **Section 4** for detailed information concerning application of the techniques. Having reviewed the information relating to the amelioration techniques in relation to the contaminant involved in the incident, taking particular note of medical effects and environmental effects select the most appropriate technique.
- Consult **Section 6** (Health & Safety Data Sheets) for information concerning any chemicals used in the amelioration process.
- Obtain additional information concerning Health & Safety and Ecotoxicity implications of the substances involved in the incident from the addresses shown in **Section 5** (Useful Addresses). Information concerning suppliers of equipment and chemicals can also be found here.

2.3 Information contained in the Manual

2.3.1 Registry numbers

The UN number is an international system used for the classification of dangerous goods in transit and is used by the emergency services to help in the identification of substances and to advise on precautions which should be taken in the event of an incident.

The CAS (Chemical Abstract Service) number provides a referencing system for the identification of additional information concerning the substance.

2.3.2 Medical effects

The Health & Safety information summarised in this Manual is intended only as a general guide to the Health & Safety implications associated with the chemicals covered by the Manual. It is not intended to act as a detailed description of the Health & Safety precautions and procedures which should be adopted when dealing with incidents involving the chemicals concerned. Personnel are therefore advised to ensure that all relevant Health & Safety issues are adequately considered before embarking on any of the procedures detailed in this Manual.

2.3.3 Environmental effects

The Aquatic Toxicity classification is an estimate based on the assessment of acute toxicity data for a range of freshwater fish, invertebrates, macrophytes and algae. The following broad classes have been used as an indication of overall aquatic toxicity:

- High aquatic toxicity - Less than 1 mg/l
- Moderate aquatic toxicity - 1 - 100 mg/l
- Low aquatic toxicity - Greater than 100 mg/l

2.3.4 Indicative water quality standards

The standard to which the river or stream should be cleaned-up will depend on a variety of local circumstances, including the nature of the contaminant and the use of the water.

Where standards are available for a particular chemical, they have been quoted to assist with the decision making process. Standards referred to in this Manual, include:

- EC Dangerous Substances Directive List I (76/464/EEC)
- EC Surface Water Abstraction Directive (75/440/EEC)
- EC Freshwater Fish Directive (78/659/EEC)
- Water Supply (Water Quality) Regulations
- WHO Drinking Water Guidelines
- EQSs for the protection of freshwater life (EC List II)

Unless otherwise stated the standards quoted are for the Maximum Acceptable Concentration (MAC). The standards are of an indicative nature only. They are intended only to assist with development of appropriate amelioration plans and the determination of adequate clean-up levels for specific pollution incident situations. They should not be considered to be a full and definitive list of water quality standards for use in any other circumstances. For further information concerning water quality standards, consult ETAS, Section 5 (Useful Addresses).

2.3.5 Costs

All costs quoted in this Manual are the best available estimates based on 1999 data. They are intended only as a guide and should not be used to carry out accurate costings for budgetary purposes. The cost for the supply of chemicals mentioned in this Manual varies greatly depending on the quantity required and the delivery location.

SECTION 2

GLOSSARY OF CHEMICAL NAMES, SYNONYMS AND TRADE NAMES

Name	Manual Entry
Abluton-T30	Chlorobenzene
Acetylene tetrachloride	Tetrachloroethane
Acypetacs zinc	Zinc soaps
Aerothene	Dichloromethane
Ammonia	Ammonia
Altene DG	Trichloroethylene
Antisol 1	Tetrachloroethylene
Benzene chloride	Chlorobenzene
Benzinoform	Carbon tetrachloride
γ -BHC	Lindane
Carbona	Carbon tetrachloride
Carbon bichloride	Dichloromethane
Carbon nitride	Cyanide
Carbon tet	Carbon tetrachloride
Carbon tetrachloride	Carbon tetrachloride
CCA	Copper/Chrome/Arsenic
Chlorobenzene	Chlorobenzene
Chloroform	Chloroform
Chloromethane	Methyl chloride
Chlorylen	Trichloroethylene
Copper acypetacs	Copper salts

Name	Manual Entry
Copper/Chrome/Arsenic	Copper/Chrome/Arsenic
Copper naphthenate	Copper salts
Creosote	Creosote
Cyanide	Cyanide
1,1 Dichloroethane	1,1 Dichloroethane
1,2 Dichloroethane	1,2 Dichloroethane
α,β Dichloroethane	1,2 Dichloroethane
1,2 Dichloroethene	1,2 Dichloroethylene
1,2 Dichloroethylene	1,2 Dichloroethylene
Dichloromethane	Methylene chloride
Dichloromethylmethane	1,1 Dichloroethane
Disparit	Trichloroethylene
Distillex DS2	Trichloroethylene
Distillex DS4	Tetrachloroethylene
Dowper	Tetrachloroethylene
Driversit	Dichloromethane
EDC	1,2 Dichloroethane
Ethynyl trichloride	Trichloroethylene
Ethylene dichloride	1,1 or 1,2 Dichloroethane
Ethylene tetrachloride	Tetrachloroethylene
Ethylene trichloride	Trichloroethylene
Freon 10	Carbon tetrachloride

Name	Manual Entry
Freon 20	Chloroform
Freon 30	Dichloromethane
Formyl trichloride	Chloroform
Glycol dichloride	1,2 Dichloroethane
γ -HCH	Lindane
Hexachlorocyclohexane	Lindane
Katharin	Carbon tetrachloride
Lindane	Lindane
MCB	Chlorobenzene
Methane trichloride	Chloroform
Methenyl trichloride	Chloroform
Methoklone	Dichloromethane
Methyl chloride	Methyl chloride
Methyl chloroform	1,1,1 Trichloroethane
Methylene chloride	Methylene chloride
Methylene dichloride	Dichloromethane
Methyl trichloride	Chloroform
M-Clean D	Dichloromethane
Mono chlorobenzene	Chlorobenzene
Nema	Tetrachloroethylene
Nevolin	Dichloromethane
Perclene	Tetrachloroethylene

Name	Manual Entry
Percosolve	Tetrachloroethylene
Perchloroethylene	Tetrachloroethylene
Perchloromethane	Carbon tetrachloride
Perklone	Tetrachloroethylene
Permethrin	Permethrin
Phenyl chloride	Chlorobenzene
Propiconazole	Propiconazole
Solvethane	1,1,1 Trichloroethane
Tanalising solution	CCA
TBTN	Tributyl tin oxide
TBTO	Tributyl tin oxide
Tributyl tin naphthenate	Tributyl tin oxide
Tributyl tin oxide	Tributyl tin oxide
Tetracap	Tetrachloroethylene
Tetrachloroethane	Tetrachloroethane
Tetrachloroethene	Tetrachloroethylene
Tetrachloroethylene	Tetrachloroethylene
Tetrachloroethyleneum	Tetrachloroethylene
Tetrachloromethane	Carbon tetrachloride
Tetralex	Tetrachloroethylene
Tetropil	Tetrachloroethylene
Thawpit	Carbon tetrachloride

Name	Manual Entry
Tributyl tin	Tributyl tin
Trichlorobenzene	Trichlorobenzene
1,1,1 Trichloroethane	1,1,1 Trichloroethane
1,1,2 Trichloroethane	1,1,2 Trichloroethane
Trichloroethene	Trichloroethylene
Trichloroethylene	Trichloroethylene
Trichloroform	Chloroform
Trichloromethane	Chloroform
Triclene	Trichloroethylene
Tri-ethane	1,1,1 Trichloroethane
Trike	Trichloroethylene
Triklone	Trichloroethylene
Westrosol	Trichloroethylene
VDC	1,2 Dichloroethylene
Vinylidene chloride	1,2 Dichloroethylene
Vinyl trichloride	Trichloroethane
Zinc octoate	Zinc soaps
Zinc soaps	Zinc soaps
Zinc versatate	Zinc soaps

SECTION 3

CHEMICALS COVERED BY THE MANUAL

Ammonia	NH₄
Classification: Ammonia Synonyms: Ammonium Registry Nos: UN: Various CAS: Various	
Characteristics Frequently encountered pollutant, often associated with a wide range of oxygen depleting substances. Unionised ammonia (NH ₃) is the main toxic species, which is in equilibrium with the ammonium ion (NH ₄) ⁺ . The equilibrium is dependent on pH, temperature and total dissolved solids.	
Principal sources Sewage, sewage sludge, landfill leachates, silage liquor, farm slurries, fertilisers, refrigerants, coke ovens, gas works, ammonium salts, ammonia bleaches, liquid ammonia (0.880 Ammonia)	
Medical Effects Highly dependent on source, e.g. liquid ammonia is very hazardous and is harmful by skin contact, by inhalation and if swallowed.	
Control Measures Wear suitable protective clothing, including eye/face protection, gloves, footwear and overalls. Respiratory equip. may be required.	
Environmental Effects <u>High aquatic toxicity (<1 mg/l).</u> No potential for bioaccumulation	
Indicative Water Quality Standards	
EC Freshwater Fish Dir:	Unionised (I) sal/cyp 0.021 / 0.021 mgN/l Unionised (G) sal/cyp 0.004 / 0.004 mgN/l Total (I) sal/cyp 0.78 / 0.78 mgN/l Total (G) sal/cyp 0.031 / 0.155 mgN/l
EC Surface Water Abstraction Directive	0.05-4.0 mgNH ₄ /l
Amelioration techniques Zeolite Adsorption pH adjustment to shift the NH ₄ ⁺ /NH ₃ equilibrium Spray / land irrigation	

Carbon Tetrachloride	CCl₄
Classification: Chlorinated Solvent Synonyms: Tetrachloromethane, Perchloromethane, Freon 10 Registry Nos: UN: 1846 CAS: 56-23-5	
Characteristics Colourless liquid with sweet distinctive odour. Vapour much heavier than air. Decomposes to highly toxic phosgene gas at high temperature. Non combustible. Quite soluble in water. Denser than water.	
Principal sources Industrial and laboratory solvent. Synthesis of fluorocarbons. Former dry cleaning solvent. Fire extinguishers. Grain fumigant	
Medical Effects <u>High toxicity.</u> Possible systemic effects. Possible long-term effects. Animal carcinogen. Suspected human carcinogen. Harmful by inhalation, by skin contact and if swallowed.	
Control Measures Do not breathe vapour. Wear safety glasses, protective clothing and gloves. Respiratory equipment may be required.	
Environmental Effects <u>Moderate aquatic toxicity (1-100 mg/l).</u> Low potential for bioaccumulation. Readily volatilises from surface waters.	
Indicative Water Quality Standards	
EC Dangerous Substances Directive List I EQS	12 µg/l (AA)
Water Supply (Water Quality) Regs	3 µg/l
WHO Drinking Water Guideline	2 µg/l
Amelioration techniques Remove free product by; dam / boom / adsorbent / tanker / etc. Air stripping GAC Adsorption (Moderate adsorbability)	

Chlorobenzene	C₆H₅Cl
Classification: Chlorinated Solvent Synonyms: Phenyl chloride, MCB, benzene chloride Registry Nos: UN: 1134 CAS: 108-90-7	
Characteristics Clear volatile liquid. Highly flammable. Above 29°C explosive vapour-air mixtures may be formed. Quite soluble in water. Slightly denser than water.	
Principal sources Paint solvent. Manufacture of phenol, dyestuffs, herbicides and pesticides. Heat transfer medium.	
Medical Effects <u>Moderate toxicity.</u> Mild irritant. Possible systemic effects. Possible long-term effects. Harmful by inhalation, by skin contact and if swallowed.	
Control Measures Do not breathe vapour. Wear safety glasses, protective clothing and gloves. Respiratory protection may be required.	
Environmental Effects <u>Moderate aquatic toxicity (1-100 mg/l).</u> Low potential for bioaccumulation. Readily volatilises from surface waters.	
Indicative Water Quality Standards WHO Drinking Water Guideline 10-120 µg/l	
Amelioration techniques Remove free product by: dam / boom / adsorbents / tanker / etc. Air stripping GAC Adsorption (High adsorbability)	

Chloroform	CHCl₃
Classification: Chlorinated Solvent Synonyms: Trichloromethane, methyl trichloride, Freon 20 Registry Nos: UN: 1888 CAS: 67-66-3	
Characteristics Colourless highly refractive heavy, volatile liquid with characteristic odour. Schedule 1 poison but no genotoxic activity. Non-combustible. Very soluble in water, denser than water.	
Principal sources Anaesthetic. Industrial and laboratory solvent. Synthesis of fluorocarbons and PTFE.	
Medical Effects <u>High toxicity.</u> Moderate irritant. Possible systemic effect. Animal carcinogen. Suspected human carcinogen. Harmful by inhalation, by skin contact and if swallowed.	
Control Measures Do not breathe vapour. Wear safety glasses, protective clothing and gloves. Respiratory protection may be required.	
Environmental Effects <u>Moderate aquatic toxicity (1-100 mg/l).</u> Low potential for bioaccumulation. Readily volatilises from surface waters.	
Indicative Water Quality Standards	
EC Dangerous Substances Directive List I EQS	12 µg/l (AA)
Water Supply (Water Quality) Regs	1 mg/l
WHO Drinking Water Guideline	200 µg/l
Amelioration techniques Remove free product by: dam / boom / adsorbents / tanker / etc. Air stripping GAC Adsorption (Low adsorbability)	

Copper/Chrome/Arsenic		Cu/Cr/As
Classification:	Timber Treatment Chemical	
Synonyms:	CCA	
Registry Nos:	UN: 2902	CAS:
Characteristics		
Aqueous solution of copper, chrome and arsenic salts. Red/brown liquid (concentrated), yellow/green (dilute). Soluble in water. Non-flammable.		
Principal sources		
Timber treatment formulations.		
Medical Effects		
High toxicity. Harmful by inhalation, in contact with skin and if swallowed. Causes severe burns. May cause cancer.		
Control Measures		
Wear suitable protective clothing, including eye/face protection, gloves, footwear and overalls.		
Environmental Effects		
High aquatic toxicity (<1 mg/l). Some potential for bioaccumulation.		
Indicative Water Quality Standards		
EC Surface Water Abstract Dir	Copper	50 µg/l
	Chromium	50 µg/l
	Arsenic	50-100 µg/l
EQS for protect. freshwater life*	Copper	1-28 / 1-28 µg/l
	Chromium	5-50 / 150-250 µg/l
	Arsenic	50 / 50 µg/l
EC Freshwater Fish Directive	Copper	5-112 µg/l (dis.)
*salmonid / cyprinid (AA/dissolved - dependent on water hardness)		
Amelioration techniques		
GAC Adsorption (Low adsorbability)		

Copper Salts	Cu
Classification: Timber Treatment Chemical Synonyms: Copper naphthenate, copper acypetacs Registry Nos: UN: CAS:	
Characteristics Normally used in conjunction with permethrin.	
Principal sources Timber treatment formulations.	
Medical Effects -	
Control Measures Wear suitable protective clothing, including eye/face protection, gloves, footwear and overalls.	
Environmental Effects Moderate aquatic toxicity (1-100 mg/l).	
Indicative Water Quality Standards	
EC Surface Water Abstract Dir	Copper 50 µg/l
EQS for protect. freshwater life*	Copper 1-28 / 1-28 µg/l
EC Freshwater Fish Directive*	Copper 40 / 40 µg/l (dis.)
*salmonid / cyprinid (dependent on water hardness)	
Amelioration techniques GAC Adsorption (Low adsorbability)	

Creosote	
Classification:	Timber Treatment Chemical
Synonyms:	Coal tar oil / distillate
Registry Nos:	UN: 1136 CAS: 8001-58-9
Characteristics	
Brown liquid with characteristic odour. Typically consists of 85% polyaromatic hydrocarbons (PAH), 10% phenols (tar acids) and 5% nitrogen and sulphur heterocycles (tar bases). Low solubility in water. Less dense than water.	
Principal sources	
Timber treatment formulations, gas works.	
Medical Effects	
Harmful in contact with skin and if swallowed. Irritating to eyes, skin and respiratory system.	
Control Measures	
Wear suitable protective clothing, including eye/face protection, gloves, footwear and overalls.	
Environmental Effects	
<u>Moderate Aquatic toxicity (1-100 mg/l).</u> Low potential for bioaccumulation. Low concentrations can lead to water taste problems after chlorination.	
Indicative Water Quality Standards	
Water Supply (Water Quality) Regs	Phenol 0.5 µg/l
	PAH 0.2-1.0 µg/l
EC Surface Water Abstraction Directive	Phenol 1 µg/l
	PAH 0.2 µg/l
EQS for protect. freshwater life	Phenol 300 µg/l
Amelioration techniques	
Remove free product by: dam / boom / adsorbents / tanker / etc. GAC Adsorption (High adsorbability)	

Cyanide	CN								
Classification: Cyanides Synonyms: Carbon nitride, isocyanide Registry Nos: UN: 1935 / 1588 CAS: 57-12-5									
Characteristics Compounds formed by the alkali and alkaline earth metals. Tend to be white crystalline solids soluble in water. <u>Reaction with acid forms toxic and flammable hydrogen cyanide gas.</u>									
Principal sources Metal plating and heat treatment operations, pesticides, coke oven effluents, gas works, gold and silver extraction.									
Medical Effects <u>VERY HIGH TOXICITY.</u> Severe irritant. Possible systemic effects.									
Control Measures Wear suitable protective clothing, including eye/face protection, gloves, footwear and overalls. Respiratory equipment may be required.									
Environmental Effects <u>High aquatic toxicity (<1 mg/l).</u> No potential for bioaccumulation. At pH less than 8 the highly toxic HCN species predominates.									
Indicative Water Quality Standards <table style="width: 100%; border: none;"> <tr> <td style="width: 70%;">Water Supply (Water Quality) Regs</td> <td style="text-align: right;">0.05 mg/l</td> </tr> <tr> <td>EC Surface Water Abstraction Directive</td> <td style="text-align: right;">0.05 mg/l</td> </tr> <tr> <td>EQS for protect. freshwater life (Free CN)</td> <td style="text-align: right;">0.005 mg/l</td> </tr> <tr> <td>WHO Drinking Water Guideline</td> <td style="text-align: right;">0.07 mg/l</td> </tr> </table>		Water Supply (Water Quality) Regs	0.05 mg/l	EC Surface Water Abstraction Directive	0.05 mg/l	EQS for protect. freshwater life (Free CN)	0.005 mg/l	WHO Drinking Water Guideline	0.07 mg/l
Water Supply (Water Quality) Regs	0.05 mg/l								
EC Surface Water Abstraction Directive	0.05 mg/l								
EQS for protect. freshwater life (Free CN)	0.005 mg/l								
WHO Drinking Water Guideline	0.07 mg/l								
Amelioration techniques GAC Adsorption (Moderate Adsorbability) PCS Oxidation (Slow oxidation rate)									

1,1 Dichloroethane	CH₃CHCl₂
Classification: Chlorinated solvent Synonyms: Ethylidene chloride, dichloromethylmethane Registry Nos: UN: 2362 CAS: 75-34-3	
Characteristics Highly flammable. Very soluble in water. Slightly denser than water.	
Principal sources Industrial solvent and intermediate.	
Medical Effects High toxicity. Harmful by inhalation, by skin contact and if swallowed.	
Control Measures Do not breathe vapour. Wear safety glasses, protective clothing and gloves. Respiratory equipment may be required.	
Environmental Effects Low aquatic toxicity (>100 mg/l). Low potential for bioaccumulation. Readily volatilises from surface waters.	
Indicative Water Quality Standards None.	
Amelioration techniques Remove free product by: dam / boom / adsorbents / tanker / etc. Air stripping GAC Adsorption (Low adsorbability)	

1,2 Dichloroethane	CH₂ClCH₂Cl
Classification: Chlorinated solvent Synonyms: Ethylene dichloride, EDC, α,β-dichloroethane Registry Nos: UN: 2362 CAS: 107-06-02	
Characteristics Highly flammable. Very soluble in water. Denser than water.	
Principal sources Chemical intermediate. Solvent. Gasoline lead scavenger. Fumigant for grain. Former carpet cleaner.	
Medical Effects <u>High toxicity.</u> Suspected human carcinogen. Harmful by inhalation, by skin contact and if swallowed.	
Control Measures Do not breathe vapour. Wear safety glasses, protective clothing and gloves. Respiratory equipment may be required.	
Environmental Effects Low aquatic toxicity (>100 mg/l). Low potential for bioaccumulation. Readily volatilises from surface waters.	
Indicative Water Quality Standards EC Dangerous Substances Directive List I EQS 10µg/l (AA)	
Amelioration techniques Remove free product by: dam / boom / adsorbents / tanker / etc. Air stripping GAC Adsorption (Moderate adsorbability)	

1,1 Dichloroethylene	Cl₂C=CH₂
Classification: Chlorinated solvent Synonyms: Vinylidene chloride, VDC, 1,2 dichloroethene Registry Nos: UN: 1303 CAS: 75-35-4	
Characteristics Extremely flammable colourless liquid with sweet characteristic odour. Slightly soluble in water. Denser than water.	
Principal sources Plastic manufacture.	
Medical Effects <u>High Toxicity.</u> Harmful by inhalation. Continued or high exposure by inhalation will cause anaesthetic effects. This may result in a loss of consciousness and could prove fatal	
Control Measures Do not breathe vapour. Wear safety glasses, protective clothing and gloves. Respiratory equipment may be required.	
Environmental Effects Low aquatic toxicity (>100 mg/l). Low potential for bioaccumulation. Readily volatilises from surface waters.	
Indicative Water Quality Standards None.	
Amelioration techniques Remove free product by: dam / boom / adsorbents / tanker / etc. Air stripping GAC Adsorption (Low adsorbability)	

Lindane	C₆H₆Cl₆
Classification: Timber Treatment Chemical Synonyms: γ -BHC, γ -HCH, hexachlorocyclohexane Registry Nos: UN: 2761 CAS: 58-89-9	
Characteristics White crystalline, non-combustible powder. A powerful insecticide which may cause dermatitis. Heat causes decomposition; products include phosgene.	
Principal sources Insecticide. Lindane/TBTO timber treatment formulations (usually dissolved in white spirit).	
Medical Effects <u>High toxicity.</u> Moderate irritant. Possible systemic effects. Animal carcinogen.	
Control Measures Wear suitable protective clothing, including eye/face protection, gloves, footwear and overalls.	
Environmental Effects <u>High aquatic toxicity (<1 mg/l).</u> High potential for bioaccumulation.	
Indicative Water Quality Standards	
EC Dangerous Substances Directive List I EQS	0.1 μ g/l (AA)
Water Supply (Water Quality) Regs	0.1 μ g/l
WHO Drinking Water Guideline	2 μ g/l
Amelioration techniques Remove free product by: dam / boom / adsorbents / tanker / etc. (white spirit base) GAC Adsorption (High adsorbability)	

Methyl chloride	CH₃Cl
Classification: Chlorinated solvent Synonyms: Chloromethane Registry Nos: UN: 1063 CAS: 74-87-3	
Characteristics Extremely flammable, forms explosive mixtures with air. Heat causes decomposition, forming toxic phosgene gas and corrosive hydrochloric acid mists. Slightly soluble in water. Slightly less dense than water.	
Principal sources Formerly used as a local anaesthetic. Refrigerant.	
Medical Effects <u>High Toxicity.</u> Harmful by inhalation. Continued or high exposure by inhalation will cause anaesthetic effects. This may result in a loss of consciousness and could prove fatal. Liquid splashes or spray may cause freeze burns to eyes and skin.	
Control Measures Do not breathe vapour. Wear safety glasses, protective clothing and gloves. Respiratory equipment may be required.	
Environmental Effects Low aquatic toxicity (>100 mg/l). Low potential for bioaccumulation. Readily volatilises from surface waters.	
Indicative Water Quality Standards None.	
Amelioration techniques Remove free product by: dam / boom / adsorbents / tanker / etc. Air stripping (<u>only in well ventilated areas due to high flammability</u>) GAC Adsorption (Very low adsorbability)	

Pentachlorophenol	C₆HCl₅O
Classification: Timber Treatment Chemical Synonyms: PCP Registry Nos UN: 3155 CAS: 87-86-5	
Characteristics Soluble in water.	
Principal sources Insecticide. Timber treatment formulations	
Medical Effects <u>High toxicity.</u> Harmful by inhalation, in contact with skin and if swallowed.	
Control Measures Wear suitable protective clothing, including eye/face protection, gloves, footwear and overalls.	
Environmental Effects <u>High aquatic toxicity (<1 mg/l).</u> Low potential for bioaccumulation. Low concentrations can lead to drinking water taste problems after chlorination.	
Indicative Water Quality Standards	
EC Dangerous Substances Directive List I EQS	2 µg/l (AA)
Water Supply (Water Quality) Regs	0.1 µg/l
WHO Drinking Water Guideline	9 µg/l
Amelioration techniques GAC Adsorption (Very high adsorbability)	

Permethrin	C₂₁H₂₀Cl₂O₃
Classification: Timber Treatment Chemical Synonyms: Cyclopropanecarboxylic acid Registry Nos: UN: 2902 CAS: 52645-53-1	
Characteristics Clear liquid. Soluble in water.	
Principal sources Insecticide. Timber treatment formulations	
Medical Effects High toxicity. Harmful if swallowed. Irritating to eyes and skin.	
Control Measures Wear suitable protective clothing, including eye/face protection, gloves, footwear and overalls.	
Environmental Effects High aquatic toxicity (<1 mg/l). Low potential for bioaccumulation.	
Indicative Water Quality Standards Water Supply (Water Quality) Regs 0.1 µg/l EQS for protection of freshwater life 0.01 µg/l (95%ile) WHO Drinking Water Guideline 20 µg/l	
Amelioration techniques GAC Adsorption (High adsorbability)	

Propiconazole		C₁₅H₁₇Cl₂N₃O₂
Classification:	Timber Treatment Chemical	
Synonyms:	-	
Registry Nos	UN: 3082	CAS: 60207-90-1
Characteristics		
Soluble in water.		
Principal sources		
Agricultural fungicide. Timber treatment formulations		
Medical Effects		
High toxicity. Harmful by inhalation, in contact with skin and if swallowed.		
Control Measures		
Wear suitable protective clothing, including eye/face protection, gloves, footwear and overalls.		
Environmental Effects		
Low aquatic toxicity (>100 mg/l). Low potential for bioaccumulation.		
Indicative Water Quality Standards		
Water Supply (Water Quality) Regs	0.1 µg/l	
Amelioration techniques		
GAC Adsorption (High adsorbability)		

Tetrachloroethane	CHCl₂CHCl₂
Classification: Chlorinated Solvent Synonyms: Acetylene tetrachloride Registry Nos: UN: 1702 CAS: 79-34-5	
Characteristics Colourless heavy liquid with suffocating odour. Non-flammable. Miscible with common organic solvents; slightly miscible with water. Denser than water.	
Principal sources Industrial solvent.	
Medical Effects <u>High toxicity.</u> Mild irritant. Possible systemic effects. Possible long-term effects. Animal carcinogen. Harmful by inhalation, by skin contact and if swallowed.	
Control Measures Do not breathe vapour. Wear safety glasses, protective clothing and gloves. Respiratory protection may be required.	
Environmental Effects <u>Moderate aquatic toxicity (1-100 mg/l).</u> Low potential for bioaccumulation. Readily volatilises from surface waters.	
Indicative Water Quality Standards None	
Amelioration techniques Remove free product by: dam / boom / adsorbents / tanker / etc. Air stripping GAC Adsorption (Moderate adsorbability)	

Tetrachloroethylene	CCl₂=CCl₂
Classification: Chlorinated Solvent Synonyms: Tetrachloroethene, perchloroethylene Registry Nos: UN: 1897 CAS: 127-18-4	
Characteristics Colourless, extremely stable liquid with ether-like odour. Non-combustible. Above 150°C decomposition occurs forming toxic phosgene gas and corrosive hydrogen chloride. Very soluble in water. Very slightly denser than water.	
Principal sources Metal degreasing solvent. Industrial dry cleaning agent. Paint remover and printing inks. Industrial and laboratory solvent.	
Medical Effects <u>High toxicity.</u> Mild irritant. Possible systemic effects. Possible long-term effects. Animal carcinogen. Harmful by inhalation, by skin contact and if swallowed.	
Control Measures <u>Do not breathe vapour.</u> Wear safety glasses, protective clothing and gloves. Respiratory protection may be required.	
Environmental Effects <u>Moderate aquatic toxicity (1-100 mg/l).</u> Low to moderate potential for bioaccumulation. Readily volatilises from surface waters.	
Indicative Water Quality Standards	
EC Dangerous Substances Directive List I EQS	10 µg/l (AA)
Water Supply (Water Quality) Regs	10 µg/l
WHO Drinking Water Guideline	40 µg/l
Amelioration techniques Remove free product by booms / adsorbents etc. Air stripping GAC Adsorption (High adsorbability)	

Tributyl tin oxide	C₂₄H₅₄OSn₂
Classification: Timber Treatment Chemical Synonyms: TBTO, organotin compounds Registry Nos: UN: 2788 CAS: 56-35-9	
Characteristics Colourless to pale yellow liquid. Soluble in common organic solvents, practically insoluble in water. Used as a fungicide and bactericide.	
Principal sources Antifouling agent. Lindane/TBTO timber treatment formulations usually dissolved in a white spirit base).	
Medical Effects <u>High toxicity.</u> Severe irritant. Possible systemic effects.	
Control Measures Wear suitable protective clothing, including eye/face protection, gloves, footwear and overalls.	
Environmental Effects <u>High aquatic toxicity (<1 mg/l).</u> High potential for bioaccumulation.	
Indicative Water Quality Standards	
WHO Drinking Water Guideline	2 µg/l
EQS for protection of freshwater life	0.02 µg/l
Amelioration techniques Remove free product by: dam / boom / adsorbents / tanker / etc. (white spirit base) GAC Adsorption (High adsorbability)	

Trichlorobenzene	C₆H₃Cl₃
Classification: Chlorinated Solvent Synonyms: None Registry Nos: UN: 2321 CAS: 120-82-1	
Characteristics Stable colourless liquid. Combustible. Miscible with common industrial solvents. Insoluble in water. Denser than water.	
Principal sources Industrial solvent for manufacture of dyes.	
Medical Effects <u>Moderate toxicity.</u> Severe irritant. Harmful by inhalation, by skin contact and if swallowed.	
Control Measures Do not breathe vapour. Wear safety glasses, protective clothing and gloves. Respiratory protection may be required.	
Environmental Effects <u>High aquatic toxicity (<1 mg/l).</u> High potential for bioaccumulation. Volatilises from surface waters but also adsorption onto sediments	
Indicative Water Quality Standards	
EC Dangerous Substances Directive List I EQS	0.4 µg/l (AA)
WHO Drinking Water Guideline	20 µg/l
Amelioration techniques Remove free product by: dam / boom / adsorbents / tanker / etc. Air stripping GAC Adsorption	

1,1,1 Trichloroethane	CH₃CCl₃
Classification: Chlorinated Solvent Synonyms: Methyl chloroform Registry Nos: UN: 2831 CAS: 71-55-6	
Characteristics Colourless liquid. Heat causes decomposition, forming toxic phosgene gas and corrosive hydrochloric acid vapours. Insoluble in water. Not combustible. Denser than water.	
Principal sources Industrial solvent. Metal degreasing. Chemical intermediate.	
Medical Effects <u>Moderate toxicity.</u> Mild irritant. Possible systemic effects. Harmful by inhalation, by skin contact and if swallowed.	
Control Measures Do not breathe vapour. Wear safety glasses, protective clothing and gloves. Respiratory protection may be required.	
Environmental Effects <u>Moderate aquatic toxicity (1-100 mg/l).</u> Low potential for bioaccumulation. Readily volatilises from surface waters.	
Indicative Water Quality Standards Proposed EQS for protection of freshwater life 1.0 mg/l	
Amelioration techniques Remove free product by: dam / boom / adsorbents / tanker / etc. Air stripping GAC Adsorption (Moderate adsorbability)	

1,1,2 Trichloroethane	CH₂ClCHCl₂
Classification: Chlorinated Solvent Synonyms: vinyl trichloride Registry Nos: UN: 2810 CAS: 79-00-5	
Characteristics Clear colourless liquid with characteristic sweet odour. Heat causes decomposition, forming toxic phosgene and corrosive hydrogen chloride gases. Non combustible. Harmful by inhalation, by skin contact and if swallowed. Denser than water.	
Principal sources Industrial solvent.	
Medical Effects <u>High Toxicity</u> . Moderate irritant. Animal carcinogen. Possible systemic effects.	
Control Measures Do not breathe vapour. Wear safety glasses, protective clothing and gloves. Respiratory protection may be required.	
Environmental Effects <u>Moderate aquatic toxicity (1-100 mg/l)</u> . Low potential for bioaccumulation. Readily volatilises from surface waters.	
Indicative Water Quality Standards Proposed EQS for protection of freshwater life 1.0 mg/l	
Amelioration techniques Remove free product by: dam / boom / adsorbents / tanker / etc. Air stripping GAC Adsorption (Low adsorbability)	

Trichloroethylene	CCl₂=CHCl						
Classification: Chlorinated Solvent Synonyms: Ethylene trichloride, trichloroethene, Trike Registry Nos: UN: 1710 CAS: 79-01-6							
Characteristics Stable, colourless liquid with chloroform-like odour. Non-combustible. Heat causes decomposition, forming toxic phosgene gas and corrosive hydrochloric acid vapours. Insoluble in water. Denser than water.							
Principal sources Degreasing and industrial solvent							
Medical Effects <u>High toxicity.</u> Moderate irritant. Possible systemic effects. Possible long-term effects. Animal carcinogen. Harmful by inhalation, by skin contact and if swallowed.							
Control Measures Do not breathe vapour. Wear safety glasses, protective clothing and gloves. Respiratory protection may be required.							
Environmental Effects <u>Moderate aquatic toxicity (1-100 mg/l).</u> Low potential for bioaccumulation. Readily volatilises from surface waters.							
Indicative Water Quality Standards <table style="width: 100%; border: none;"> <tr> <td style="width: 60%;">EC Dangerous Substances Directive List I EQS</td> <td style="text-align: right;">10 µg/l (AA)</td> </tr> <tr> <td>Water Supply (Water Quality) Regs</td> <td style="text-align: right;">30 µg/l</td> </tr> <tr> <td>WHO Drinking Water Guideline</td> <td style="text-align: right;">70 µg/l</td> </tr> </table>		EC Dangerous Substances Directive List I EQS	10 µg/l (AA)	Water Supply (Water Quality) Regs	30 µg/l	WHO Drinking Water Guideline	70 µg/l
EC Dangerous Substances Directive List I EQS	10 µg/l (AA)						
Water Supply (Water Quality) Regs	30 µg/l						
WHO Drinking Water Guideline	70 µg/l						
Amelioration techniques Remove free product by: dam / boom / adsorbents / tanker / etc. Air stripping GAC Adsorption (High adsorbability)							

Zinc Soaps	Zn
Classification: Timber Treatment Chemical Synonyms: Zinc versatate, zinc octoate, acypetacs zinc Registry Nos: UN: CAS:	
Characteristics	
Often used in conjunction with permethrin.	
Principal sources	
Timber treatment formulations	
Medical Effects	
-	
Control Measures	
Wear suitable protective clothing, including eye/face protection, gloves, footwear and overalls.	
Environmental Effects	
<u>Moderate aquatic toxicity (1-100 mg/l).</u> Toxic species based on concentration of zinc	
Indicative Water Quality Standards	
EC Surface Water Abstraction Dir.	0.5-5 mg/l
EQS for protect. freshwater life*	8-125 / 75-500 µg/l
EC Freshwater Fish Directive*	0.03-0.5 / 0.3-2.0 mg/l
*salmonid / cyprinid (dependant on water hardness)	
Amelioration techniques	
GAC Adsorption (Low adsorbability)	

SECTION 4

AMELIORATION TECHNIQUES

1.0 AIR STRIPPING

1.1 SUMMARY

- Air stripping can be used for the removal of chlorinated solvents from water by transferring them into a stream of air passed through the water.
- Treatment can be i) ex-situ, by pumping the contaminated water through a packed tower, or ii) in-situ, using conventional aeration equipment such as leaky pipe diffusers or air stones connected to an air blower.
- Prefabricated portable air stripping units are available which can treat flows from around 2 lps up to a maximum of 10 lps. Additional pumping and generating equipment is also needed.
- Contaminant removal efficiencies for packed towers are around 99% with achievable effluent concentrations approx 1 mg/l or less.
- Chlorinated solvents can be flammable, can have adverse Health & Safety implications and may be ozone-depleting materials. Where possible, off-gases from packed towers should be passed through a GAC adsorption unit.
- In-situ treatment using diffused air systems should be used only where there is high natural ventilation and there are no possible adverse Health & Safety implications associated with emissions of solvent vapour to the atmosphere.
- Treatment efficiencies for leaky pipe diffusers are lower than packed towers being in the region of 50% removal after one hour, but it uses readily available equipment and it can be used where the flow is too high for ex-situ treatment.

- Removal rate increases with greater air flows and increasing temperature
- In-situ air sparging works best in deep, slow flowing water

1.2 Applications

Air stripping techniques can be used for the treatment of the following substances:

- Chlorinated solvents

1.3 Introduction

1.3.1 Process description

There are two methods of treatment by air stripping. Treatment can be carried out ex-situ by pumping the contaminated water through a packed tower (Section 1.4) or in-situ using conventional aeration equipment such as leaky pipe diffusers or air stones connected to an air blower (Section 1.5).

1.3.2 Treatment principle

Volatile contaminants in water will eventually be lost by evaporation to the atmosphere. Air stripping techniques aim to accelerate this natural process by creating conditions which facilitate close contact between the contaminated water and a current of air which enables volatile compounds in the water to evaporate. Stripping is a mass transfer process in which volatile components are transferred from the aqueous phase to the gaseous phase.

1.4 Scope for use / limitations

1.4.1 Henry's Law

The distribution of a volatile compound between air and water under equilibrium conditions can be expressed by Henry's Law. As a general rule, air stripping is practical for compounds having a Henry's Law constant of greater than 10^{-3} atm-m³/mole. Very soluble compounds tend to have low Henry's Law constants and can therefore be difficult to remove. However, chlorinated solvents generally have high enough Henry's Law constants to make them suitable for removal by air stripping.

1.4.2 Effect of temperature

Stripping efficiency increases dramatically with increasing temperature. The use of air stripping on a warm summer day is therefore more likely to be effective than during the cold winter months.

1.5 Packed tower aeration (ex-situ treatment)

1.5.1 Description of packed tower aeration treatment

Contaminated water is pumped to the top of the stripping tower, which is filled with packing material designed to maximise the contact with air which is blown up through the tower. As the contaminated water passes down the tower it is brought into intimate contact with the air being blown up from the bottom. Volatile contaminants transfer from the water to the air stream where they are exhausted at the top of the tower. The exhaust gasses are either vented to atmosphere or directed to a GAC adsorption unit for recovery of volatile contaminants. Purified water from the bottom of the tower can be returned to the river or discharged to foul sewer depending on local circumstances.

1.5.2 Treatment capacity

Prefabricated air stripping towers constructed from GRP which are capable of being trailer mounted are commercially available from suppliers as detailed in Section 5 (Useful Addresses).

Prefabricated portable units are available which can treat flows from around 2 lps up to a maximum of 10 lps.

1.5.3 Contaminant removal efficiency

Factors which govern the efficiency of the stripping operation for specific contaminants include: tower dimensions, temperature, air/water ratio and the internal construction of the tower.

Contaminant removal efficiencies of 99% for most chlorinated solvents can be expected under operational conditions, giving effluent concentrations in the low mg/l range or less.

1.6 Diffused -air aeration (in-situ treatment)

1.6.1 Description of diffused-air aeration treatment

Air is sparged or bubbled through the water using a blower connected to some form of diffusion device, such as a leaky pipe diffuser or an air stone

1.6.2 Air blowers

The more air that can be sparged through the water, the greater the removal efficiency is likely to be. Conventional blowers used for reaeration operations, which are available throughout the Agency, are suitable for air stripping operations. Towable diesel engined compressors capable of delivering up to 125 cubic feet per minute (approximately 200 m³/hour) are readily available for hire from national and local hire centres.

Smaller units capable of being transported to an incident site in a van or estate car are available in a range of capacities from 7 to 25 cfm (12 to 40 m³/hour).

1.6.3 Diffusers

For sparging operations, a diffuser which is capable of passing large volumes of air is required. Suitable diffusers for air sparging operations are high volume leaky pipe diffusers which are available in 1.0 and 1.5 metre lengths, from suppliers detailed in Section 5 (Useful Addresses).

Up to 20 m³/hour of air can be sparged per metre length of leaky pipe. The pipes cannot be joined together, but can be run off a manifold.

Large towable diesel compressors will therefore need to be provided with manifolds feeding to six or more lengths of leaky pipe to maximise stripping efficiency

1.6.4 Contaminant removal efficiency

Contaminant removal efficiencies in specific situations is difficult to predict because of the number of influences, including; type of contaminant, air flow, water depth, flow rate and temperature.

However, given situations where leaky pipe diffusers can be laid across the width of the channel, with a water depth of approximately 1 metre and sufficiently low water flow rate to allow a contact time of 60 minutes, it may be possible to achieve reductions of around 50% in chlorinated solvent concentration.

1.6.5 Sparging location

Where possible, sparging should be carried out in areas of relatively deep, slow flowing water to increase stripping

efficiencies, rather than shallow fast flowing streams, where efficiencies will be lower.

1.7 Risks involved

1.7.1 Risk assessment

The nature and severity of any risks to Agency staff, contractors and members of the public is dependent both on the location as well as the nature of the activity. It is essential that a full Risk Assessment is carried out using the 5-Step procedure, as detailed in the Agency's Health & Safety Risk Assessment Manual, prior to the commencement of any operations

1.7.2 Evolution of off-gases

Volatile compounds driven off from the water by sparging or stripping will enter the atmosphere if no GAC adsorption is provided to trap them. Many of these materials can lead to local occupational exposure problems as well as global effects for substances which have high ozone depleting potentials.

Particular care should be taken when dealing with potentially flammable substances to ensure that operations are carried out only in areas of high natural dispersion well away from any sources of ignition.

1.7.3 Resuspension of sediments

When choosing a potential sparging location, care should be taken to ensure that excessive quantities of bottom deposits are not resuspended by the turbulent action of the air bubbles, which could lead to oxygen depletion or siltation problems.

1.7.4 Electrical safety

The blowers used in air stripping towers have a high electrical power requirement. Extreme caution should be exercised to

ensure that all precautions associated with electrical safety when working near water are observed.

1.8 Pros and cons

1.8.1 Advantages

- Air stripping can be used to remove a wide range of volatile chlorinated solvents from water.
- Air sparging using blowers and diffusers relies on relatively inexpensive straightforward technology using equipment which is readily available through the Agency.
- Air stripping does not rely on the addition of any chemicals or materials to the river. There are therefore no problems associated with the potential legal implications of adding materials to controlled waters or possible concerns over impeding river flows which might lead to flooding.
- Depending on conditions, chlorinated solvents can either float on the water surface or sink to the bottom. Diffused-air aeration will tend to resuspend any non aqueous phase free product thereby facilitating its removal.

1.8.2 Disadvantages

- Unless stripping towers equipped with GAC filters are used, volatile components will be transferred from the water to air. Many of these substances are either flammable, hazardous or are ozone depleting chemicals and are consequently the potential implications of releasing such materials to the air requires careful consideration.
- Stripping towers capable of treating significant flows are relatively large and expensive with high power requirements.

- All air stripping techniques rely on some form of power supply to power the blowers to pass air through the water. Treatment operations could not normally be left unattended.
- The efficiency of removal of volatile solvents by air stripping techniques is temperature dependent and therefore may not work very effectively on cold winter days.

1.8.3 Packed tower stripping vs Diffused-air aeration

- Ex-situ packed tower techniques are much more efficient than diffused-air aeration and can be fitted with GAC adsorption equipment to prevent volatile compounds being released to the atmosphere. However, they require additional pumping equipment and the blowers used to force air through the packed tower have large power requirements and therefore require the provision of large generators, even in situations where mains power is available.
- In-situ diffused-air aeration has the advantage that it can be performed using conventional aeration equipment which is relatively easy to deploy and is readily available within the Agency. However, it is less efficient than either packed tower aeration or GAC adsorption techniques. Also, volatile compounds driven off from the water cannot be trapped and therefore will be released into the atmosphere.

1.8.4 Air stripping vs GAC adsorption

- Air stripping or sparging is not as efficient as GAC adsorption for the removal of chlorinated solvents.
- Air stripping can however be significantly cheaper if suitable equipment is available within the Agency. Provided that off-gases can be safely vented to atmosphere, then the only costs are for fuel, compared with the large chemical and disposal costs for GAC adsorption.

2.0 GRANULAR ACTIVATED CARBON (GAC)

2.1 SUMMARY

- GAC adsorption can be used for the removal of a wide range of organic and inorganic compounds, including: chlorinated solvents, timber treatment chemicals and cyanide (as well as many other organic substances).
- Treatment can be i) ex-situ, by pumping the contaminated water through towers packed with GAC, or ii) in-situ, by placing GAC filled sandbags in the water to be treated.
- GAC adsorption is most effective for high molecular weight, low solubility compounds, e.g. pesticides.
- Use good quality, virgin GAC for maximum efficiency.
- Minimum recommended superficial contact time of effluent with GAC is 10 minutes. Lower contact times can be used but contaminant breakthrough can occur with very low contact times.
- Contaminant removal efficiency is very high (up to 99+%).
- GAC lifetime can be from several hours up to many days depending on concentration and adsorbability.
- Prefabricated portable GAC adsorption units are available which can treat flows up to 4 lps. Additional pumping and pre-filtration equipment will also be needed.
- For in-situ treatment, 50 x 12 kg GAC filled sandbags needed for every 1 lps of flow.
- Care must be taken to avoid flooding with sandbag treatment.

- GAC cost approx. £1,000 per tonne.
- Used GAC must be disposed of at suitably licensed facility after use.

2.2 Applications

Granular Activated Carbon techniques can be used for the treatment of the following substances:

- Chlorinated solvents
- Timber treatment chemicals
- Cyanide

2.3 Introduction

2.3.1 Process description

There are two methods of treatment by GAC. Treatment can be carried out ex-situ by pumping the contaminated water through a GAC adsorption tower (Section 2.4) or in-situ using GAC filled sandbags which are placed in the water to be treated (Section 2.5).

2.3.2 Treatment principle

Granular Activated Carbon (GAC) has an open pore structure with a very large surface area. Contaminants are removed from solution and fixed onto the activated carbon surface by adsorption forces.

Eventually all available adsorption sites will become occupied by contaminant species and the GAC will need to be regenerated or disposed of.

2.3.2 Sources of GAC

GAC can be produced from coal, wood or coconut shells. Coal based GAC is preferred for water pollution incident applications because their structure makes them suitable for the adsorption of a wide range of organic compounds.

2.3.3 Grades of GAC

High quality virgin GAC should be used rather than reactivated material to achieve the highest possible efficiencies of contaminant removal in pollution incident situations.

2.3.4 GAC granule size

In general, the smaller the size of the activated carbon granule, the better the adsorption performance will be. However, hydraulic problems can occur if the granule becomes too small. The optimum size is 1.70-0.425 mm (US Mesh 12x40).

2.3.5 Factors affecting contaminant removal performance

GAC can be used to treat an extremely wide range of organic compounds as well as a number of metallic contaminants. The performance of GAC for the removal of organic compounds depends on a variety of factors, including:

- The molecular weight and solubility of the contaminant. Adsorbability increases with increasing molecular weight and decreasing solubility and polarity. This means that soluble low molecular weight compounds, for example ethanol, are poorly adsorbed, while high molecular weight compounds with low solubility such as most pesticides are very well adsorbed.
- The concentration of the contaminant. Carbon consumption increases significantly with higher contaminant concentrations.

- The presence of other organic material in the water which will compete with the target contaminant for available adsorption sites.
- The pH of the water. Adsorption of acidic compounds is better at lower pH.

2.4 Scope for use / limitations

2.4.1 Superficial contact time

The removal efficiency for a specific contaminant depends primarily on its initial concentration and the contact time between the GAC and water. The greater the contact time, the greater the removal efficiency is likely to be.

A minimum superficial contact time of 10 minutes should be aimed for, although good removal efficiencies can often be achieved at lower superficial contact times.

2.4.2 Contaminant removal efficiency

Effluent concentrations in the low $\mu\text{g/l}$ region can be expected from a properly functioning GAC plant. Typical removal efficiencies for 10 minute superficial contact time are as follows:

Chlorinated solvents	99-100%
Timber treatment chemicals (metals)	90-95%
Timber treatment chemicals (organics)	99-100%
Cyanide	95-99%

Adsorbability estimates for a range of compounds covered in this Manual are summarised in Table 2.1. Substances with high adsorbabilities can be readily removed by GAC treatment, whilst those with very low adsorbabilities are not commonly removed by GAC.

Table 2.1: Adsorbability estimates

Substance	Adsorbability
Carbon tetrachloride	Moderate
Chlorobenzene	High
Chloroform	Low
1,1 Dichloroethane	Low
1,2 Dichloroethane	Low
1,1 Dichloroethylene	Low
Methyl chloride	Very low
Methylene chloride	Very low
Pentachlorophenol	Very high
Tetrachloroethane	Moderate
Tetrachloroethylene	High
1,1,1-Trichloroethane	Moderate
1,1,2-Trichloroethane	Low
Trichloroethylene	High

The adsorbability estimates shown in Table 2.1 are for a contaminant concentration of 1 mg/l, and correspond to the weight of contaminant adsorbed compared with GAC:

Very high	>10%
High	>5%
Moderate	>1%
Low	>0.1%
Very low	<0.1%

2.4.3 GAC adsorption capacity

Contaminant break-through will occur when all available adsorption sites become occupied. It is dependent on numerous factors, including: the nature and concentration of the contaminant species, the flow rate and the length of operation. It is therefore difficult to predict with any degree of certainty when break-through is likely to occur. Care will therefore be needed to carry out adequate monitoring of effluent quality to ensure that contaminant break through does not occur either as a result of the use of excessive flow rates or due to saturation of the GAC.

2.4.4 GAC bed life

It is very difficult to estimate the length of time that a GAC plant will operate before becoming saturated in a pollution incident situation because of the large number of variables involved. However an attempt to provide the user with some estimate of theoretical lifetimes is shown in Table 2.2. The total possible days of operation are shown for various contaminant concentrations, based on carbon usage rates calculated by computer simulations.

The estimated bed life shown in Table 2.2 are based on a GAC plant sized to give a superficial contact time of 10 minutes at its maximum flow rate (e.g. 0.25 lps for 150 litres GAC, or 1.67 lps for 1,000 litres GAC). It must be remembered that they are unlikely to be achieved in real life situations due to the presence of other contaminants which will compete for available adsorption sites.

Table 2.2: Estimated length of GAC plant operation (days) for different influent contaminant concentrations

Substance	Max length of operation (days)		
	1 mg/l	10 mg/l	100 mg/l
Carbon tetrachloride	50	17	3.9
Chlorobenzene	126	20	2.6
Chloroform	15	5.0	1.4
1,1 Dichloroethane	13	4.0	1.0
1,2 Dichloroethane	13	3.8	1.0
1,1 Dichloroethylene	20	4.4	0.7
Methyl chloride	0.7	0.5	0.4
Methylene chloride	1.7	1.0	0.5
Pentachlorophenol	650	69	7.1
Tetrachloroethane	41	14	3.8
Tetrachloroethylene	200	40	5.7
1,1,1-Trichloroethane	44	15	3.9
1,1,2-Trichloroethane	15	6.8	2.4
Trichloroethylene	75	16	2.9

2.5 GAC Adsorption tower treatment

2.5.1 Description of GAC adsorption tower treatment

The greatest contaminant removal efficiencies can be obtained using adsorption towers packed with GAC. Contaminated water is pumped to the top of the tower and filters through the

GAC where the contaminants are adsorbed. Purified water is removed at the bottom of the tower and returned to the river or foul sewer depending on local conditions. Pre-fabricated treatment plants are available from a number of suppliers, as detailed in Section 4 (Useful Addresses).

2.5.2 Size of GAC adsorption towers

In order to achieve superficial contact times of at least 10 minutes, the GAC adsorption towers need to be quite large to treat the sort of flow rates that are likely to be necessary in pollution incident situations.

Adsorption units of up to 2 tonnes can be transported on a suitable trailer pulled by a 4-Wheel Drive vehicle. Larger units would require delivery by lorry, which will tend to limit their use in emergency call out situations due to restrictions on possible operational locations and time delays associated with mobilisation of specialist transport arrangements.

2.5.3 Maximum flow rates

The physical size of the adsorption towers effectively limits the maximum flow of water which can be treated by a single portable GAC adsorption unit to approximately 4 litres per second at the minimum recommended superficial contact time of 10 minutes. It may be possible to treat greater flows involving low concentrations of contaminants with high adsorbabilities but care should be taken to ensure that satisfactory effluent quality is maintained.

This can be compared with removal by vacuum tanker which might typically remove around 12,000 litres of liquid in an hour (i.e. 3.3 litres per second).

2.5.4 Parallel operation

Greater flows can be treated by operating two or more adsorption towers in parallel. For example, two units operating in parallel will be capable of treating twice the flow of a single unit.

2.5.5 Series operation

For longer term situations, more efficient usage of GAC and greater security of operation can be obtained by operating two GAC adsorption units connected in series. Effluent quality should be monitored after the first adsorption unit. When break-through is detected or suspected, the first unit should be taken out of service and a replacement unit fitted after the second unit, in the final 'polishing' position.

2.5.6 Pumping requirements

Contaminated water should be pumped through the treatment unit using an appropriate portable pump.

Flow rates of between 0.25 and 2 lps are required for portable adsorption units. These flows can be comfortably achieved at reasonable heads by conventional portable petrol driven 1" or 2" centrifugal pumps which are readily available throughout the Agency or from hire shops.

2.5.7 Water pre-treatment

Precautions should be taken to minimise the intake of suspended matter to the GAC adsorption tower as this can blind the surface of the GAC causing the unit to become blocked. The effects of blinding can be reduced by the use of pre-filters or through regular backwashing of the GAC unit.

The frequency of backwashing will depend on the amount of solids in the water and the flow rate. Backwashing can be achieved by reversing the inlet and outlet connections on the

adsorption tower and pumping water up through the tower to remove accumulated solids from the GAC surface. Suitable arrangements should be provided for the collection and disposal of backwashing effluent.

Suitable pre-filters which can be installed in the inlet pipework include sand filters or bag filters. Sandfilters are efficient but are likely to prove too heavy for easy deployment in pollution incident situations. Bag filters constructed from plastic are capable of treating adequate flows for portable adsorption towers, and are light and readily portable. Disposable polypropylene or reusable nylon mesh filtration bags are available in a range of pore sizes from 5-100 micron. The chosen filter grade for a given situation will depend on the nature and amount of suspended matter encountered. Operational experience will determine the smallest pore size which can be used whilst maintaining sufficient flow.

Where possible filters should be installed in parallel with suitable isolation valves to enable the filter medium to be changed without having to interrupt the flow to the treatment plant.

2.6 GAC-filled sandbag treatment

2.6.1 Description of GAC sandbag treatment

Standard 13x30" hessian 7.5 ounce sandbags can be filled with GAC and packed in a stream or outfall channel. The contaminated water filters through the GAC being purified in the process. When the need for treatment has passed, the sandbags are removed for regeneration or disposal.

2.6.2 Amount of GAC per sandbag

Each sandbag should be packed with approximately 12 litres of GAC (Approximately 5 kg). Care should be taken not to overpack the sandbags as this will prevent the bags being packed closely together, resulting in short-circuiting of the flow through spaces between the bags.

After use, the weight of the sandbags will double to around 10 kg. The use of larger quantities of GAC should be avoided to minimise possible handling problems when trying to remove the sandbags when wet.

2.6.3 Number of sandbags required

In order to achieve an optimum superficial contact time of 10 minutes, 50 sacks (600 litres GAC in total) will be required for every 1 lps of flow. The sandbags are relatively porous and will permit a reasonable flow of water through them. The greater the number of rows of sandbags the smaller the flow which will be able to flow through them.

The approximate porosity of a GAC filled sandbag wall comprising 4 rows of sandbags is in the region of 5 lps per m² of cross sectional area. The flow rate will increase for walls with less than 4 rows of sandbags and decrease for walls with more than 4 rows. The flow rate will also increase with increasing head of water behind the wall.

In pollution incident situations there will be numerous complicating factors which require consideration and it is likely that some degree of trial and error will be required to arrive at the most satisfactory arrangement of sandbags in any given situation. Too few sandbags may not have sufficient structural stability to withstand the flow, whilst too many sandbags may restrict the flow too much, preventing adequate treatment and giving rise to possible flooding risks.

The theoretical number of sandbags, and corresponding volume and weight of GAC for a range of river flows to give a superficial contact time of 10 minutes is summarised in Table 2.3

Table 2.3: Theoretical number of GAC sandbags required to give a superficial contact time of 10 minutes

Flow rate (lps)	GAC volume (litres)	GAC weight (kgs)	Sandbags (No.)
1	600	250	50
2	1,200	500	100
5	3,000	1,250	250
10	6,000	2,500	500

2.6.4 Installation of sandbags

Where possible, sandbags should be laid in a conventional overlapping bricklaying fashion to minimise short-circuiting. A minimum of 3 rows of sandbags should be used to ensure adequate structural stability. In situations where there is limited or difficult access to the river bed or channel, the sandbags should be thrown into the water to form a randomly oriented structure.

In most situations, the sandbags should have sufficient mass to remain in place by virtue of their own mass. In fast flowing streams it may be necessary to weigh down the GAC with conventional sandbags.

2.6.5 Removal and disposal of sandbags

After use, the weight of the sandbags will double to around 10 kg, which should not give rise to any particular handling problems.

After use the sandbags can either be returned to the supplier for regeneration or deposited at a suitably licensed disposal facility in accordance with the requirements of the Duty of Care provisions of the Environmental Protection Act, 1990.

2.7 Risks involved

2.7.1 Risk assessment

The nature and severity of any risks to Agency staff, contractors and members of the public is dependent both on the location as well as the nature of the activity. It is essential that a full Risk Assessment is carried out using the 5-Step procedure, as detailed in the Agency's Health & Safety Risk Assessment Manual, prior to the commencement of any operations

2.7.2 GAC dust

Suitable protective clothing, including goggles, dust masks, gloves and overalls should be worn when handling loose GAC or GAC filled sandbags.

2.7.3 Wet weight of GAC

Used GAC weighs about twice as much as raw material. Care should be taken to ensure that adequate facilities exist for removal of GAC after use.

Operational GAC adsorption towers weigh considerably more than new unused units. Care should be taken when installing units or positioning trailers that they are located on hard

surfaces to prevent them sinking into the ground or toppling over.

Even after use when they are fully drained, GAC adsorption towers weigh approximately twice as much as unused units. Care must be taken to ensure that the lifting capacity of lifting equipment or the towing capacity of trailers is not exceeded when removing used equipment from site.

Wet sandbags containing 12 litres of GAC should weigh no more than 10 kg and should not therefore pose any particular handling problems providing sensible lifting precautions are taken.

2.7.4 Danger of flooding

Care must also be taken to ensure that the use of sandbags does not impede the flow of the river or outfall channel sufficiently to result in flooding.

Particular care should be taken when constructing barriers consisting of more than 5 rows of sandbags to consider the possibility of excessive restriction of flow.

2.7.5 Contaminant breakthrough

Contaminant breakthrough can occur at very low superficial contact times, and also after extended use when all available GAC adsorption sites become occupied. Care must be taken that the treated effluent is monitored frequently enough to detect any deterioration in performance as the treatment process continues.

2.8 Pros and cons

2.8.1 Advantages

GAC is particularly attractive for ameliorating the effects of pollution incidents, because:

- It can almost completely remove an extremely wide range of contaminants over a wide range of concentrations.
- It has a broad spectrum approach, and is therefore very useful in situations where a cocktail of contaminants is encountered or where there is limited information concerning the precise nature of the contamination.
- It is easy to store, transport and handle, and the risks to personnel and the environment are minimal.

The use of GAC sandbags has a number of advantages over adsorption towers in certain situations, because:

- The technique does not rely on pumps or generators or other mechanical equipment. Once installed, the treatment system can be left unattended for extended periods.
- It is relatively simple to replace saturated sacks or to alter the treatment capacity to account for changing circumstances.
- The sandbags can be transported to remote sites using vans or small trailers.

Adsorption towers are however more efficient than sandbags, and can have advantages over sandbags in specific circumstances, including:

- Where sandbags might be unsuitable because of excessive water depths or high flow velocities

- Where the nature of the river or banks make it difficult or unsafe to place sandbags in the directly in the water.
- Where it is thought that there may be a risk of flooding when using sandbags.

2.8.2 Disadvantages

GAC does however have a number of disadvantages which might limit its applicability in certain situations, including:

- GAC is quite expensive at around £1,000 per tonne. 600 kg of GAC is required to provide the optimum superficial contact time of 10 minutes for a water flow rate of 1 lps. This equates to approximately £600 for each 1 litre per second of water treated. It will be necessary to consider Cost/Benefit principals in deciding on the use of GAC in situations where the environmental impact of an incident is not severe.
- After use, GAC can contain high concentrations of contaminants which have been adsorbed. There are therefore further costs associated with regeneration or disposal of the GAC after use. Used GAC should only be disposed of in accordance with operating instructions. For example, return to the supplier for regeneration or disposal at a suitably licensed disposal facility in accordance with the Duty of Care provisions of the Environmental Protection Act, 1990.

2.8.3 GAC adsorption vs air stripping

GAC adsorption is more efficient than air stripping or sparging for the removal of chlorinated solvents. However air stripping can be considerably cheaper if suitable equipment is available at a convenient location within the Agency. GAC adsorption

treatment has significant costs associated with purchase and disposal of materials.

3.0 ZEOLITE

3.1 SUMMARY

- The natural granular zeolite material, Clinoptilolite can be used to remove ammonia from water by ion exchange.
- Treatment can be i) ex situ, by pumping contaminated water through towers packed with zeolite, or ii) in-situ, by placing zeolite filled sandbags in the water to be treated.
- Minimum recommended superficial contact time of effluent with zeolite is 10 minutes. Reduced treatment efficiencies are likely at lower contact times.
- Ammonia removal efficiency approx 75-90%.
- Maximum flow rate for transportable units approx 4 lps. Additional pumping equipment will also be needed
- 50 x 12 kg filled sandbags needed for every 1 lps of flow.
- Care must be taken to avoid flooding with sandbag treatment.
- Zeolite costs approx £1,000 per tonne.
- Used zeolite can be regenerated or disposed of at suitably licensed facility.
- Regeneration produces a high strength effluent which requires suitable disposal facilities.
- Very low potential for adverse effects.

3.2 Applications

Zeolite techniques can be used for the treatment of the following substances

- Ammonia

3.3 Introduction

3.3.1 Process description

There are two methods of treatment by zeolite. Treatment can be carried out ex-situ by pumping the contaminated water through a zeolite contact tower (Section 3.4) or in-situ using zeolite filled sandbags which are placed in the water to be treated (Section 3.5).

3.3.2 Treatment principle

Zeolites are a group of natural and synthetic crystalline aluminosilicate materials with ion exchange properties, replacing ammonia and other contaminating ions in the water with harmless sodium ions.

Eventually the zeolite becomes saturated with ammonia and can be regenerated by washing with sodium chloride solution

3.3.3 Types of zeolite

The zeolite most often associated with the removal of ammonia from waste waters is Clinoptilolite. It is a naturally occurring mineral of volcanic origin, and is a highly complex calcium magnesium sodium potassium aluminosilicate. It has the ability to absorb ammonia, heavy metals and hydrocarbons.

Synthetic zeolites are not generally suitable for waste water treatment applications because they tend to have a powdery structure which tends to become clogged in filtration

applications, rather than the granular structure of natural Clinoptilolite.

3.3.4 Factors which influence contaminant removal performance

Zeolite can be used to remove ammonia from a range of sources, including sewage, silage, slurry and ammonium nitrate fertilisers.

Ammonia reduction is more efficient for the removal of ammonia from inorganic sources, such as ammonium nitrate, than from organic sources such as sewage.

3.4 Scope for use / limitations

3.4.1 Superficial contact time

Ammonia removal efficiency depends primarily on its initial concentration and the contact time between the zeolite and water. The greater the contact time, the greater the removal efficiency is likely to be. A minimum superficial contact time of 10 minutes should be aimed for, although good removal efficiencies can often be achieved at lower superficial contact times.

3.4.2 Contaminant removal efficiency

Ammonia reduction efficiencies of around 75% have been achieved for diluted raw sewage using a superficial contact time of 10 minutes. In comparison, ammonium nitrate concentrations can be reduced by over 90% under similar conditions.

3.4.3 Zeolite adsorption capacity

Clinoptilolite can theoretically adsorb about 4 g NH₄-N per litre of bed before regeneration with sodium chloride is required.

3.4.4 Zeolite bed life

Table 3.1 shows the maximum theoretical operational periods, at an optimum superficial contact time of 10 minutes, which are achievable before regeneration is required.

Table 3.1: Maximum theoretical Clinoptilolite bed life for different influent concentrations of ammonia

Influent conc. NH ₄ -N (mg/l)	Estimated bed life (hours)
5	133
10	66
25	26
50	13

3.5 Zeolite adsorption tower treatment

3.5.1 Description of zeolite adsorption tower treatment

The greatest contaminant removal efficiencies can be obtained using adsorption towers packed with zeolite. Contaminated water is pumped to the top of the tower and filters through the zeolite where the ammonia is adsorbed. Purified water is removed at the bottom of the tower and returned to the river or foul sewer depending on local conditions.

3.5.2 Construction of a treatment plant

No pre-fabricated treatment plants were available at the time of preparation of this Manual. However, a suitable unit could be constructed in much the same way as a GAC adsorption tower.

A suitable small temporary treatment plant could be constructed using a 200 litre drum fitted with a drainage tap at the base for the effluent discharge.

A drainage layer of approximately 20 mm of coarse stones is first placed at the base, followed by approximately 100 litres of zeolite. Water to be treated is pumped into the top of the drum. The drainage tap is adjusted to give a flow rate of 0.17 lps (10 minute superficial contact time) and the pump flow rate into the drum adjusted to maintain a constant head.

For larger flows, several small units can be operated in parallel or the plant can be scaled up if larger tanks are available.

3.5.3 Size of zeolite adsorption tower

In order to achieve superficial contact times of at least 10 minutes, the zeolite towers need to be quite large to treat the sort of flow rates that are likely to be necessary in pollution incident situations.

Adsorption units of up to 2 tonnes can be transported on a suitable trailer pulled by a Land Rover. Larger units would require delivery by lorry, which will tend to limit their use in emergency call out situations due to restrictions on possible operational locations and time delays associated with mobilisation of specialist transport arrangements.

3.5.4 Maximum flow rates

The physical size of the adsorption towers effectively limits the maximum flow of water which can be treated by a single portable zeolite adsorption unit to approximately 4 litres per second at the minimum recommended superficial contact time of 10 minutes. It may be possible to treat greater flows involving low concentrations of ammonia but care should be taken to ensure that satisfactory effluent quality is maintained.

This can be compared with removal by vacuum tanker which might typically remove around 12,000 litres of liquid in an hour (i.e. 3.3 litres per second).

3.5.5 Parallel operation

Greater flows can be treated by operating two or more adsorption towers in parallel. For example, two units operating in parallel will be capable of treating twice the flow of a single unit.

3.5.6 Pumping requirements

Contaminated water should be pumped through the treatment unit using an appropriate portable pump.

Flow rates of between 0.25 and 4 lps are required for portable adsorption units. These flows can be comfortably achieved at reasonable heads by conventional portable petrol driven 1" or 2" centrifugal pumps which are readily available throughout the Agency or from hire shops.

3.5.7 Water pre-treatment

Precautions should be taken to minimise the intake of suspended matter to the zeolite adsorption tower as this can blind the surface of the zeolite causing the unit to become blocked. The effects of blinding can be reduced by the use of pre-filters or through regular backwashing of the zeolite unit.

The frequency of backwashing will depend on the amount of solids in the water and the flow rate. Backwashing can be achieved by reversing the inlet and outlet connections on the adsorption tower and pumping water up through the tower to remove accumulated solids from the zeolite surface. Suitable arrangements should be provided for the collection and disposal of backwashing effluent.

Suitable pre-filters which can be installed in the inlet pipework include sand filters or bag filters. Sandfilters are efficient but are likely to prove to heavy for easy deployment in pollution incident situations. Bag filters constructed from plastic are capable of treating adequate flows for portable adsorption towers, and are light and readily portable. Disposable polypropylene or reusable nylon mesh filtration bags are available in a range of pore sizes from 5-100 micron. The chosen filter grade for a given situation will depend on the nature and amount of suspended matter encountered. Operational experience will determine the smallest pore size which can be used whilst maintaining sufficient flow.

Where possible filters should be installed in parallel with suitable isolation valves to enable the filter medium to be changed without having to interrupt the flow to the treatment plant.

3.5.8 Regeneration

After a period of use, the zeolite will require regeneration with sodium chloride to exchange the adsorbed ammonia ions with sodium ions. The unit should be backwashed with concentrated sodium chloride solution. Regeneration produces an effluent with high concentrations of ammonia which will require appropriate disposal facilities and may not be suitable for disposal to foul sewer.

3.6 Zeolite-filled sandbags (in-site treatment)

3.6.1 Description of zeolite sandbag treatment

Standard 13x30" hessian 7.5 ounce sandbags can be filled with Clinoptilolite and packed in a stream or outfall channel. The contaminated water filters through the Clinoptilolite being

purified in the process. When the need for treatment has passed, the sandbags are removed for regeneration or disposal.

3.6.2 Amount of zeolite per sandbag

Each sandbag should be packed with approximately 12 litres of Clinoptilolite (Approximately 10 kg). Care should be taken not to overpack the sandbags as this will prevent the bags being packed closely together, resulting in short-circuiting of the flow through spaces between the bags.

After use, the weight of the sandbags will increase slightly to around 12 kg. The use of larger quantities of Clinoptilolite should be avoided to minimise possible handling problems when trying to remove the sandbags when wet.

3.6.3 Number of sandbags required

In order to achieve an optimum superficial contact time of 10 minutes, 50 sacks (600 litres zeolite in total) will be required for every 1 lps of flow. The sandbags are relatively porous and will permit a reasonable flow of water through them. The greater the number of rows of sandbags the smaller the flow which will be able to flow through them.

The approximate porosity of a zeolite filled sandbag wall comprising 4 rows of sandbags is in the region of 10 lps per m² of cross sectional area. The flow rate will increase for walls with less than 4 rows of sandbags and decrease for walls with more than 4 rows. The flow rate will also increase with increasing head of water behind the wall.

In order to achieve optimum superficial contact times of 10 minutes it may be necessary to construct zeolite sandbag walls comprising of 6 or more rows because of its relatively high porosity.

In pollution incident situations there will be numerous complicating factors which require consideration and it is likely that some degree of trial and error will be required to arrive at the most satisfactory arrangement of sandbags in any given situation. Too few sandbags may not have sufficient structural stability to withstand the flow, whilst too many sandbags may restrict the flow too much, preventing adequate treatment and giving rise to possible flooding risks.

The theoretical number of sandbags, and corresponding volume and weight of zeolite for a range of river flows to give a superficial contact time of 10 minutes is summarised in Table 3.2.

Table 3.2: Theoretical number of zeolite sandbags required to give a superficial contact time of 10 minutes

Flow Rate (lps)	Zeolite volume (litres)	Zeolite weight (kgs)	Sandbags (No.)
1	600	500	50
2	1,200	1,000	100
5	3,000	2,500	250
10	6,000	5,000	500

3.6.4 Installation of sandbags

Where possible, sandbags should be laid in a conventional overlapping bricklaying fashion to minimise short-circuiting. A minimum of 3 rows of sandbags should be used to ensure adequate structural stability. In situations where there is limited

or difficult access to the river bed or channel, the sandbags should be thrown into the water to form a randomly oriented structure.

In most situations, the sandbags should have sufficient mass to remain in place by virtue of their own mass. In fast flowing streams it may be necessary to weigh down the zeolite with conventional sandbags.

3.6.5 Removal and disposal of sandbags

After use, the weight of the sandbags will increase slightly to around 12 kg, which should not give rise to any particular handling problems.

After use the sandbags can either be returned to the supplier for regeneration or deposited at a suitably licensed disposal facility in accordance with the requirements of the Duty of Care provisions of the Environmental Protection Act, 1990.

3.7 Risks involved

3.7.1 Risk assessment

The nature and severity of any risks to Agency staff, contractors and members of the public is dependent both on the location as well as the activity. It is essential that a full Risk Assessment is carried out using the 5-Step procedure, as detailed in the Agency's Health & Safety Risk Assessment Manual, prior the commencement of any operations

3.7.2 Clinoptilolite dust

Suitable protective clothing, including goggles, dust masks, gloves and overalls should be worn when handling loose Clinoptilolite or Clinoptilolite filled sandbags.

3.7.3 Clinoptilolite regeneration

Ammonia and other contaminants, such as heavy metals, which are absorbed by the Clinoptilolite can be removed by regeneration with sodium chloride producing a concentrated effluent stream which must be disposed of in an appropriate manner. It may be possible to discharge regeneration effluent to a suitable foul sewer subject to Trade Effluent approval or alternatively it could be removed from the site for disposal at a suitable licensed disposal facility.

3.8 Pros and cons

3.8.1 Advantages

Clinoptilolite is easy to store, transport and handle, and the risks to personnel and the environment are minimal.

The use of zeolite sandbags has a number of advantages over adsorption towers in certain situations, because:

- The technique does not rely on pumps or generators or other mechanical equipment. Once installed, the treatment system can be left unattended for extended periods.
- It is relatively simple to replace saturated sandbags or to alter the treatment capacity to account for changing circumstances.
- The sandbags can be transported to remote sites using vans or small trailers.

Adsorption towers are however more efficient than sandbags, and can have advantages over sandbags in specific circumstances, including:

- Where sandbags might be unsuitable because of excessive water depths or high flow velocities

- Where the nature of the river or banks make it difficult or unsafe to place sandbags in the directly in the water.
- Where it is thought that there may be a risk of flooding when using sandbags.

3.8.2 Disadvantages

Zeolite does however have a number of disadvantages which might limit its applicability in certain situations, including:

- Clinoptilolite is quite expensive at around £1,000 per tonne. 600 kg of Clinoptilolite is required to provide the optimum superficial contact time of 10 minutes for a water flow rate of 1 lps. This equates to approximately £600 for each 1 litre per second of water treated. It will be necessary to consider Cost/Benefit principals in deciding on the use of Clinoptilolite in situations where the environmental impact of an incident is not severe.
- After use, Clinoptilolite can contain high concentrations of contaminants which have been adsorbed. There are therefore further costs associated with regeneration or disposal of the Clinoptilolite after use. Used Clinoptilolite should only be disposed of in accordance with operating instructions. For example, return to the supplier for regeneration or disposal at a suitably licensed disposal facility in accordance with the Duty of Care provisions of the Environmental Protection Act, 1990.

4.0 SODIUM PERCARBONATE (PCS)

4.1 SUMMARY

- PCS (sodium percarbonate) is the solid form of hydrogen peroxide, which decomposes in water to give oxygen and water.
- The oxygen liberated oxidises the highly toxic CN species to less harmful cyanate.
- PCS is dosed at a controlled rate directly into the effluent flow or affected stretch of river
- CN concentration is reduced by approx 50% in 24 hours.
- $\text{PCS dosing rate (kg/h)} = \text{CN (mg/l)} \times \text{River flow (lps)} \times 0.12.$
- Care must be taken to ensure that no adverse environmental effects due to high pH or elevated residual peroxide are caused by overdosing.
- Residual peroxide should be kept less than 20 mg/l.
- Care must be taken to ensure that adequate Health & Safety precautions are taken when handling PCS. Extra care is needed where there is public access.
- PCS not as efficient as GAC for CN removal but it is not subject to the same flow limitations. PCS can be therefore be used in high flow situations.
- PCS cost approx £1,000 per tonne.
- PCS is also use as a source of oxygen for raising dissolved oxygen levels.
- Highly toxic HCN gas can be liberated in acidic conditions. Extreme care should be taken to ensure that all necessary Health & Safety precautions are observed.

4.2 Applications

PCS techniques can be used for the treatment of the following substances:

- Cyanide

4.3 Introduction

4.3.1 Process description

Cyanide treatment with PCS (sodium percarbonate) involves the direct dosing of an affected section of river or effluent with solid PCS at a controlled rate.

4.3.2 Treatment principle

The treatment of cyanide with Sodium percarbonate (PCS) involves the oxidation of the highly toxic free cyanide ion to the much less harmful cyanate species, which then slowly hydrolyses to ammonia and bicarbonate.

4.3.3 PCS

PCS is a white powdery solid which decomposes on contact with water to liberate an alkaline solution of hydrogen peroxide and sodium carbonate.

4.3.4 Hydrogen peroxide

Both hydrogen peroxide solutions and PCS have been used frequently by the Agency as sources of oxygen to deal with the effects of deoxygenation following pollution incidents.

However, hydrogen peroxide solution is not considered suitable for cyanide treatment because the reaction is dependent on an elevated pH to proceed at a reasonable rate and also to prevent the formation of the highly toxic HCN gas.

Treatment with hydrogen peroxide solution would therefore also require the addition of alkali to increase the pH whereas the use of PCS gives rise to an automatic increase in pH due to the formation of sodium carbonate., which is more convenient and safe in pollution incident situations.

4.4 Scope for use / limitations

4.4.1 Rate of reaction

PCS is a relatively slow method of treatment of cyanide. Reaction rates will depend on specific conditions, but typically, cyanide concentrations can be expected to reduced by 50% in 24 hours.

The rate of the reaction is considerably enhanced by the presence of a number of metal catalysts, such as copper. The addition of these metals is not considered appropriate in the aqueous environment. However, it is likely that many incidents involving cyanide may well also be accompanied by elevated concentrations of a range of metals which would catalyse the reaction.

4.5 PCS treatment

4.5.1 Description of PCS treatment

PCS is a white powdery solid which is commercially available in 25 kg sacks which can be added directly to the river or effluent at a controlled rate.

When dosing into the river, the PCS should be added to the main plug of contamination. The PCS will move downstream with the contaminant plug, slowly oxidising the cyanide as it goes.

4.5.2 PCS dosing rate

The optimum dosing rate for PCS to achieve treatment without incurring undue chemical costs or risking adverse effects in the river due to overdosing is 33:1 compared with cyanide concentration.

The required PCS dose rate in kg/hour to achieve a 33:1 ratio for a particular situation can be calculated using the following formula:

$$\text{CN (mg/l)} \times \text{River flow (lps)} \times 0.12 = \text{PCS dose rate (kg/hour)}$$

Example

River flow rate 0.05 cumecs (50 lps)

CN concentration 5 mg/l

$$\text{PCS dose rate} = 5 \times 50 \times 0.12 = 30 \text{ kg/hour}$$

4.6 Risks involved

4.6.1 Risk assessment

The nature and severity of any risks to Agency staff, contractors and members of the public is dependent both on the location as well as the activity. It is essential that a full Risk Assessment is carried out using the 5-Step procedure, as detailed in the Agency's Health & Safety Risk Assessment Manual, prior the commencement of any operations

4.6.2 HCN gas evolution

Highly toxic HCN gas can be liberated in acidic conditions. Extreme care should therefore be taken to ensure that all necessary Health & Safety precautions are observed.

4.6.3 PCS dust

Suitable protective clothing, including goggles, dust masks, gloves and overalls should be worn when handling loose PCS.

Dosing is best carried out at locations where there is limited or no public access to avoid potential risks associated with exposure to PCS dusts.

4.6.4 Potential damage to aquatic organisms

Treatment with PCS involves the addition of a substance to the river which has the potential to cause damage to the environment if not properly controlled (unlike the other techniques in this Manual which are extremely unlikely to result in environmental impairment). Careful consideration therefore needs to be given to all potential consequences of PCS use.

4.6.5 Potential for by-product formation

PCS should only be used in circumstances where the pollutant has been positively identified to ensure that any adverse effects due to the formation of undesirable by-products can be fully considered.

4.6.6 Effects of overdosing

The use of excessive quantities of PCS can lead to elevated concentrations of residual hydrogen peroxide and high pH levels which could be toxic to aquatic organisms. Care should therefore be taken to ensure that recommended PCS dosing rates are not significantly exceeded.

Residual hydrogen peroxide concentrations downstream of the dosing site should be maintained below 20 mg/l. Hydrogen peroxide concentrations can be conveniently monitored using portable colourometric instrumentation.

It is recommended that frequent checks are made to ensure that pH levels are also maintained within acceptable limits downstream of the dosing site.

4.7 Pros and cons

4.7.1 Advantages

- PCS has the advantage that no special equipment is required. If the main plug of cyanide contamination can be identified, PCS can be added at that point and left to react slowly as the plug moves downriver.
- Although PCS is not as efficient as GAC, it is not subject to the same flow limitations and can therefore be used in high flow situations, for example, where the contaminant has moved downstream and become diluted with large volumes of water in a larger river or stream.

4.7.2 Disadvantages

- Highly toxic HCN gas can be liberated in acidic conditions. Extreme care should therefore be taken to ensure that all necessary Health & Safety precautions are observed.
- Treatment with PCS involves the addition of a substance to the river which has the potential to cause damage to the environment if not properly controlled (unlike the other techniques in this Manual which are extremely unlikely to result in environmental impairment). Careful consideration therefore needs to be given to all potential consequences of PCS use.
- Although PCS can be used safely provided suitable precautions are taken, there are potential Health & Safety implications associated with its use which must be fully

- considered. Particular care should be taken where there is a possibility of public access to the dosing site.
- Oxidation of cyanide with PCS is quite slow and not as effective as GAC adsorption, but may be suitable in situations where treatment by GAC is not available.
 - PCS is quite expensive at around £1,000 per tonne. Therefore, in situations where the use of PCS might be considered, the chemical costs for dosing operations could be in the region of several hundred pounds.

SECTION 5

USEFUL ADDRESSES

1.0 TECHNICAL ASSISTANCE

Further information concerning toxicological and environmental implications of contaminants can be obtained from the following sources:

OFFICE HOURS

*During office hours, Agency staff should contact their **ETAS Regional Representative** in the first instance.*

Anglian	Selena Randall	7 50 4491
Midlands	James Carron	7 22 4661
North East	Gail Hammond	7 28 4672
North West	Richard Deighton	7 21 2620
Southern	Michael Mandeville	7 23 2166
South West	Rob Moore	7 24 2622
Thames	Sam Fishwick	7 25 5447
Wales	Kate Cameron	7 26 2094

*If the regional contact is unavailable, then escalate the enquiry to the **ETAS National Centre***

Environmental Toxicology Advisory Service (ETAS)

Tel: 01491 828544

Fax: 01491 828427

N.B. **ETAS** can provide information for Agency staff concerning the environmental effects of *any* chemical contaminant, not just those covered by this Manual.

24 HOURS

WRC Medmenham

Tel: 01491 571531

2.0 REFERENCES WHERE FURTHER INFORMATION CAN BE FOUND

2.1 Amelioration techniques

Effluent Treatment Techniques, Guidance for Operators and Inspectors of IPC Processes. Technical Guidance Note A4. Environment Agency. 1997.

Emergency Management Manual for Dealing with Pollution Incidents. Environment Agency Report 081/22/T. WRC plc. 1997

Evaluation of Peroxygens for the Amelioration of River Pollution. Environment Agency, Thames Region. Hunting Technical Services. 1997

Granular Activated Carbon for drinking water treatment. Chemviron Carbon Limited. 1998

Review and Appraisal of Water Pollution Control Equipment. Environment Agency Technical Report P212. AEA Technology Environment. 1999.

2.2 Health & Safety and Environmental Effects

Health & Safety Risk Management Manual. Environment Agency. 1998.

Health & Safety Management Procedures Manual. Environment Agency. 1999.

Dictionary of Substances and their Effects (DOSE). Royal Society of Chemistry. Ed. M L Richardson. 1993

Timber Treatment Chemicals; Priorities for Environmental Quality Standard Development. NRA R&D Note 340. WRC plc. 1994

Pesticides 1999. Pesticides Safety Directorate / Health & Safety Executive. HMSO. 1999

Substances Hazardous to Health. Croners. 1999

3.0 EQUIPMENT

This list is not intended to represent a complete list of potential suppliers. Staff are advised to seek further information concerning the existence of local or national suppliers.

3.1 Aeration equipment suppliers

3.1.1 Air Stripping Units

Georemediation
Sovereign House
Queensway
Leamington Spa
CV31 3JR

Tel: 01926 314700

Fax: 01926 338100

3.1.2 Leaky Pipe diffusers

NCC Supplies Limited
Middlewich Road
Byley
Middlewich
Cheshire
CW10 9NX

Tel: 01606 836811

Fax: 01606 836088

Leaky pipe for air stripping ref LP45VHA

3.2 GAC Manufactures and suppliers

Chemviron Carbon

Number One

Southlink

Oldham

OL4 1DE

Tel: 0161 628 5000

Fax: 0161 628 5111

Portable GAC adsorption tower specifications

Model No.	Minisorb	Disposorb	Cyclosorb
Max flow (lps)	0.25	1.67	3.8
GAC vol. (litres)	150	1,000	2,000
Height (m)	1.00	1.76	2.20
Diameter (m)	0.60	1.10	1.64
Gross weight (kg)	500	500	1,900
Max press. (barg)	-	-	-
Material	Polythene	Polythene	Steel
Connections	3/4" BSP	3/4" BSP	DN50

Carbon Link
Sterling House
2 Park Street
Wigan
WN3 5HE

Tel: 01942 824240
Fax: 01942 824133

Portable GAC adsorption tower specifications

Model No.	Clean-flo HY 1	Clean-flo HY 5	Clean-flo HY 10
Max flow (lps)	0.3	1.5	3.3
GAC vol. (litres)	190	900	2000
Height (m)	0.93	1.60	2.12
Diameter (m)	0.58	1.32	1.50
Gross weight (kg)	-	-	-
Max press. (barg)	-	-	-
Material	-	-	-
Connections	3/4" BSP	2" ANSI 150	2" ANSI 150

Jacobi Carbons

Niord House
Kelvin Park
Dock Road
Seacombe
Wirral
L41 1LT

Tel: 0151 649 8344

Fax: 0151 649 8345

Portable GAC adsorption tower specifications

Model No.	Aquaflow AF 200	Aquaflow AF2000
Max flow (lps)	0.33 lps	200
GAC vol. (litres)	3.3 lps	2,000
Height (m)	0.93	
Diameter (m)	0.58	
Gross weight (kg)	-	
Max press. (barg)	0.5	
Material	Polythene	Steel
Connections	3/4" BSP	2" ASA 150

Protect

Sutcliffe Croftshaw Limited

Antler Court

Lockett Road

Ashton-in-Makerfield

Lancashire

Tel: 01942 275400

Fax: 01942 275600

Portable GAC adsorption tower specifications

Model No.	L200	L1000	L2000
Max flow (lps)	0.39	2.8	5.6
GAC vol. (litres)	200	1,000	2,000
Height (m)	0.90	1.85	2.60
Diameter (m)	0.58	1.30	1.30
Gross weight (kg)	120	850	1,450
Max press. (barg)	0.3	0.5	0.5
Connections	2" BSP	4or6" flange	4or6" flange

CPL Carbons Ltd.

PO Box 23

Mill Lane

Wingerworth

Chesterfield

Derbyshire

S42 6YK

Tel: 01246 221221

Fax: 01246 222000

3.3 Filtration equipment and suppliers

Fielder Filter Systems

Orchard Business Centre

20/20

Maidstone

Kent

ME16 OJ2

Tel: 01622 691886

Fax: 01622 683507

3.4 Hydrogen peroxide and PCS Suppliers

Solvay Interox Ltd

P O Box 7
Warrington
Cheshire
WA4 6HB

Tel: 01925 651277
Fax: 01925 655856

Ellis & Everard

46 Peckover Street
Bradford
West Yorkshire
BD1 5BD

Tel: 01274 377000
Fax: 01274 737058

3.5 Zeolite suppliers

Universal Mineral Suppliers

Unit 14a
Firmin Coates Industrial Estate
Middlewich Road
Byley
Middlewich
Cheshire
CW10 9NT

Tel: 01606 834723
Fax: 01606 834732

SECTION 6

HEALTH & SAFETY DATA SHEETS FOR CHEMICALS USED

HEALTH & SAFETY DATA SHEET

Granular Activated Carbon (GAC)

HEALTH & SAFETY DATA SHEET

Clinolite (Zeolite)

HEALTH & SAFETY DATA SHEET

SodiumPercarbonate (PCS)

