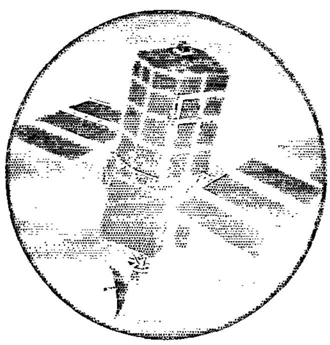
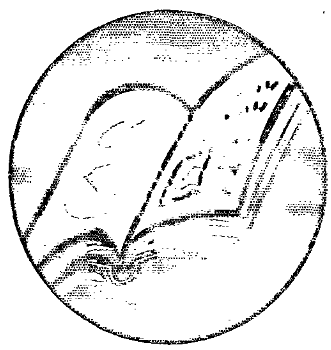
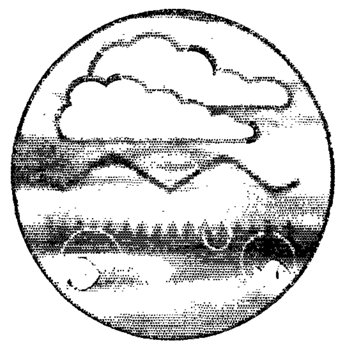
Review and Appraisal of Water Pollution Control Equipment

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P212

ENVIRONMENT AGENCY

Review and Appraisal of Water Pollution Control Equipment

R&D Technical Report P212

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This report summarises the findings of a national project to review and appraise water pollution control equipment. The information within this document is for use by Agency staff and others involved with pollution control, particularly in the event of an oil or chemical spill.

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EXECUTIVE SUMMARY

The Environment Agency deals with over 35,000 reported pollution incidents each year and it is therefore essential that the response to these incidents is effective and efficient in order to minimise the impact on the environment. The Agency has thus commissioned a detailed study to review and appraise the performance of the water pollution control equipment currently used. This is the Technical Report of this review and appraisal.

Sorbents

The Agency should consider identifying a restricted range of sorbent types based on performance, value for money and environmental implications. Whereas organic sorbents are generally reported to be derived from sustainable resources there may be a perceived environmental implication in their use. In contrast, some synthetic sorbents are manufactured from otherwise waste materials that would be disposed of to landfill.

As far as is possible, the Agency should also consider within their purchasing mechanism, the possibility of introducing some standardisation in the colour of sorbents used for particular duties. Ideally, sorbents for application to hydrocarbons should all be the same colour, while those for application to chemicals should all be another colour. It is further recommended that a combination of colour coding and labelling is used: all sorbents that are oil only should be white and bear the word "OIL" in black while all sorbents that are universal, and capable of handling the more aggressive chemicals, should be yellow and bear the word "UNIVERSAL" in black.

Most synthetic oil only sorbents were found to be similar in performance during laboratory tests although, of those tested, Drizit 0140 performed best in many aspects. Liquitrol OPH 4843 also performed well and was rated highly by Agency staff during their evaluation. Sphag Sorb and Peat Sorb were the best organic sorbents tested with oil. However, these materials are probably best suited for use on solid surfaces. Additionally, as their performance does not appear to be better than the best synthetic sorbents, and as there are possible perceived negative environmental implications from the harvesting of the moss used in their manufacture, it is recommended that use be restricted to special applications where oil needs to be recovered from hard surfaces.

Frogmat has potential to protect vulnerable riverbanks although deployment and recovery might be difficult. The removal of oil sheen by sorbents would still appear to be problematical.

Most synthetic universal sorbents are appropriate for many chemicals but most are incompatible with at least some of the more stronger acids, caustics and oxidisers. Organic universal sorbents should be avoided for use on many chemicals. It is therefore recommended that synthetic sorbents only be used for chemicals.

It is recommended that sorbent re-use be confined to the clean-up of solid surfaces.

It is recommended that sorbent disposal by incineration should be the preferred route for both organic and synthetic sorbents although costs will probably be significantly higher than for landfill.

Environment Protection Officer's Kit

A list of kit which should be accessible to an Environment Protection Officer has been developed. The adoption of this list will provide some uniformity across the Regions and thus facilitate any transfer of staff.

Equipment Required by Fire Services

A list of equipment required by Fire Services responding to a spillage has also been developed. The following recommendations for best practice are also made:

- due consideration should be given to the leave alone option
- clay leak sealants should be preferred compared to epoxy based leak sealants
- sheets (or tubs) of clay based material, and inflatable drain seals/pipe blockers should be preferred to water filled plastic bags or polyurethane sheeting for blocking drains. Where appropriate the clay sealant should be used in conjunction with metal sheeting to reduce quantities used
- sorbent booms or other sorbent types should be used in conjunction with containment booms for containment and recovery of liquids on water surfaces.
- wherever possible drums and overdrums or similar vessels should be lined with plastic prior to use, thus enabling potential re-use.

Booms

An evaluation of sorbent boom for use in narrow waterways has resulted in the following recommendations:

- booms without skirts can be used in still water
- booms with skirts should be used where there is any water movement
- sorbent boom should be used in combination with containment boom if there is any appreciable flow, such that the containment boom is downstream of the sorbent boom. Alternatively, the containment boom can be used in conjunction with other sorbent types
- consideration should be given to the use of double booms, more than one single boom or a single boom along with other sorbent types if the boom is to be left unattended.

An evaluation of containment boom for use in narrow waterways has resulted in the following recommendations:

- for low velocity applications - lightweight, high visibility, inflation or permanent buoyancy boom with own brand connectors. (Height, ~200-300 mm; freeboard, minimum of 30 % of height; draft, minimum of 50 % of height.)

- for high velocity applications - heavier high visibility fence boom with standard ASTM or Unicon connectors and which can be easily cleaned. (Height, ~300 mm upwards; freeboard, minimum of 30 % of height; draft, minimum of 50 % of height.).

The review of containment boom for coastal and river use has resulted in the following recommendations:

- high strength, durable inflation boom with standard ASTM or Unicon connectors and multiple anchoring points and which is easily cleanable. (Height, up to 2m; freeboard, minimum of 30% of height; draft, minimum of 55% of height; minimum breaking strain in rivers, 50 kN; minimum breaking strain in coastal area, 100 kN.)

Skimmers

Skimmers that are considered more versatile and of potential use to the Agency include the suction, weir and disc type along with rope mops. However, as usage by the Agency seems to be very low it is recommended that the Agency does not require any permanent pieces of equipment of this type.

Aeration Technologies

Aeration technologies are important to the Agency operations. It is considered that the use of hydrogen peroxide to achieve rapid oxygenation has considerable potential and achieves a more rapid improvement of oxygen levels than aeration alone. Should the ongoing investigation being funded by the Agency confirm the benefits of hydrogen peroxide treatment then the Agency should increase the amount of equipment they hold. This can be readily achieved by either of the following two approaches:

- conversion of existing River Rovers - this equipment would have potential for use in larger and deeper water bodies
- additional pumps and venturi devices - this equipment would have potential for use in both large/deep and small/shallow water bodies. The Oxyjet, for example, would appear to be versatile for these applications and it is recommended that this equipment be trialed and compared to the River Rover.

Spill Detection at Night

An evaluation of low cost methods and equipment for the detection of oil and chemical spills at night has been undertaken. It is concluded that there is no portable and cheap equipment available for this purpose, although oil test papers are available.

Encapsulation

Two encapsulation products, Unisafe and Unibiber, are both suitable for encapsulating a range of chemicals although each had different strengths and weaknesses. With the existing price structure for these two products it would appear that the cost of treatment is significantly less with Unisafe. It is thus recommended that, while this cost differential exists, Unisafe be used rather than Unibiber. However, users need to be informed that there are potential hazards when this product is used with strong oxidisers. When either product is used on unknown chemicals only a small amount should be applied initially.

Drain Seals

Laboratory based investigations suggest that, on clean surfaces, all types of drain seals tested can be expected to perform well although sand bags will probably allow some leakage. With non-clean surfaces, or surfaces with some roughness, clay material and inflatable seals can be expected to perform well. The sand bag is likely to allow significant leakage. The tetrahedral water-filled plastic bag and the polyurethane sheet are likely to result in excessive leakage.

Temporary Storage and Oil-Water Separation

The most appropriate temporary storage containers for immediate emergency use are rigid rectangular collapsible storage units such as Fastank and TroilTank. The TroilTank is the most rapid to deploy. Additionally, a low walled flexible tank such as the Pop-Up Pool is recommended as this has potential for the collection of leaking liquids in restricted spaces.

Oil-water separation procedures would have potential in reducing the quantity of liquids that need to be transported and disposed of. Separation would occur within storage tanks with bottom drawn liquid being discharged to the environment. This should be discharged through a sorbent filter if necessary or with the use of an oil-in-water monitor to ensure water quality. Any discharged liquid should be returned upstream of the collection point. The use of skimmer heads while collecting fluids into vacuum tankers would also assist in reducing volumes to be disposed of.

Proprietary oil-water separators are expected to provide a better performance than separation in ordinary storage units.

(**Key words**: oil, chemical, spills, skimmers, booms, sorbents, aeration, hydrogen peroxide, drain seals, storage vessels.)

1 INTRODUCTION

The National Environmental Technology Centre of AEA Technology Environment has been commissioned by the Environment Agency to undertake a review and appraisal of water pollution control equipment.

The Environment Agency currently deals with over 35,000 reported water pollution incidents annually. The response to such incidents is a core function of the Agency and the effectiveness of its response actions is crucial in mitigating the effects of the pollutant. The response of any field staff must therefore be effective in reducing discharge and containing the damage caused by the pollutant. Recognising this, a study was commissioned in 1993 to review their response to pollution incidents.

The report from that study highlighted a number of differences between the response arrangements and equipment utilised by the various Agency Regions and recommended that further work be conducted to provide a consistent national approach. Consequently, the Agency commissioned the current R&D Project (P2/053/1) "Review and Appraisal of Water Pollution Control Equipment" to examine the equipment used by the Agency and provided by them to Fire Brigades. This is the Technical Report of this review and appraisal.

2 OBJECTIVES

The objectives of R&D Project P2/053/1 were "to review and critically assess the performance of the water pollution control equipment (incident response equipment only) currently used by the Agency, including that supplied to local Fire Brigades, along with the other comparable products on the market, in order to provide a consistent national approach".

Specific objectives were:

- to carry out an assessment and comparison of the water pollution control equipment presently used by the Agency, including that supplied to local Fire Brigades, and review other comparable materials on the market
- to consider factors such as current/likely future utilisation of equipment, its cost and storage, ease of deployment, and environmental impact
- to consider the use of novel methods and equipment
- to look at the possibility/practicability of using standard methods utilising best practice when dealing with pollution incidents
- to take account of the Environment Agency's Environmental Policy.

3 WORK PROGRAMME

The work programme consisted of two stages. Stage 1 of the work programme critically reviewed the current equipment and undertook literature searches, held meetings with water pollution control organisations and issued a user opinion survey to identify the limitations of the current equipment. The information gathered was then used to identify a work programme to be undertaken as Stage 2.

3.1 Proposed Stage 2 Work Programme

The proposed work programme for Stage 2 of the project was developed from the findings of the information gathering and evaluation exercise. A detailed description was included in the First (Stage 1) Progress Report and is summarised below.

3.1.1 Sorbents

A range of selected sorbents, including products for sheen removal, were to be evaluated for use by the Agency. This was to include limited laboratory testing followed by an evaluation of the net environmental benefits, safety implications and purchasing options.

3.1.2 Environment Protection Officer's Kit

The components of the Environment Protection Officer's kit were to be reviewed to determine, as far as possible, a definitive list of equipment that should be included.

3.1.3 Booms

A variety of booms for use in streams and waterways up to 10 m wide were to be examined. This was to include five types of sorbent boom, three types of inflation boom and two types of permanent buoyancy booms. This was to include a discussion on aspects of oil retention, deployment, maintenance, operational constraints and storage.

3.1.4 Coastal and River Booms

The compatibility of Agency stockpiled boom with that held by organisations such as MPCU, SEPA and OSRL Ltd was also to be examined.

3.1.5 Skimmers

A literature review of skimmers was to be undertaken to identify the main types, their limitations and advantages. Additionally, attachments to improve vacuum tanker efficiency by reducing water pick up were to be examined.

3.1.6 Aerators

Work involving aerators was to be concerned mainly with the development of field guidance for their deployment. This was to include an evaluation of the availability and utilisation of aeration equipment throughout the Agency. Additionally, an evaluation of combined aeration and hydrogen peroxide systems was to be undertaken, involving a review of published documentation on hydrogen peroxide use.

3.1.7 Improvised and Novel Techniques

A range of improved and novel techniques was to be evaluated. These include techniques for:

- spill detection at night
- encapsulation
- drain plugging and sealing
- oil:water separation
- temporary storage.

3.2 Project Reports

Full details of both Stage 1 and Stage 2 work programmes and their findings are available in the following project reports:

- Stage 1 Progress Report, July 1997
- Stage 2 Progress Report - Second Quarterly Report, November 1997
- Stage 2 Progress Report - Third Quarterly Report, February 1998
- Stage 2 Progress Report - Fourth Quarterly Report, April 1998
- Stage 2 Report - Aeration, Oxidation and Adsorption Technologies for Water Pollution Control, October 1997
- R&D Project Record P2/053/1, 1998.

4 SORBENTS

Sorbents are currently utilised by the Environment Agency as an initial clean-up response to a spill. Consequently, part of this project was to evaluate different proprietary sorbents to identify any significant difference in their performance and to present a discussion on the broader environmental implications of sorbent use. This evaluation concentrated on the use of sorbents with oil.

This section identifies the major characteristics of sorbents, indicating those that were tested. It also outlines the testing procedures, presents the results and provides a discussion and conclusions.

4.1 Characteristics of Sorbents

Sorbents can be classified in a number of ways although two overall classes are generally recognised according to the liquids that can be sorbed. These two classes are oil only and universal. The universal sorbents (sometimes called chemical sorbents) generally sorb most chemicals, solvents and water, as well as oil.

An ideal sorbent for oil should:

- be oleophilic and hydrophobic i.e. attract oil, reject water
- sorb oil and retain it
- be easy to apply to a spill
- be inert so that it is not harmful to either the handlers or environment
- be buoyant, even when saturated with oil
- be easy to recover and strong enough to be handled without disintegrating
- be easy to dispose of once recovered.

An ideal sorbent for chemicals should:

- sorb the material of concern and retain it
- be easy to apply to a spill
- be inert so that it is not harmful to either the handlers or environment
- be buoyant, even when saturated
- be easy to recover and strong enough to be handled without disintegrating
- be easy to dispose of once recovered.

Universal sorbents are not selective in the material that they will sorb, hence the term universal. Consequently, when used for chemical spills they will also pick up any water or oil that might be present.

Sorbents can also be classified according to the nature of the material that they are manufactured from. Three categories are recognised:

- organic sorbents; those made from naturally occurring carbon compounds. These include straw, peat, wood chips, cork and rags. These materials generally have to be treated to render them oleophilic if they are to be used on oil
- inorganic sorbents; those which are generally mined such as vermiculite, glass wood, volcanic rock, clay and sand
- synthetic sorbents; these are the most common sorbents and include polymeric materials such as polypropylene, polyethylene and polyurethane.

4.1.1 Colour Coding of Sorbents

In an emergency situation it is essential that a particular sorbent material can be readily identified for its use; whether it be for oil only or universal. Additionally, it is important that the universal sorbent is of the more robust grade and specification that can handle the more aggressive chemicals. Many suppliers do colour code their products although there is no agreed standard colour. However, many do use white for oil only products and yellow or pink for universal products. An additional operational problem has been reported by some Fire Services when using the products at night. It is reported that it can be extremely difficult to differentiate any colour difference under the sodium lights that are often used at incidents.

It is therefore recommended that a combination of colour coding and labelling is used to identify sorbent types. All sorbents that are oil only should be white and bear the word "OIL" in black while all sorbents that are universal, and capable of handling the more aggressive chemicals, should be yellow and bear the word "UNIVERSAL" in black.

4.2 Oil Only Sorbents

The sorbents selected for evaluation for use on oil included both organic and synthetic materials. These are summarised in Table 4.1. Some of these products had been previously tested by Environment Canada. Where Environment Canada have undertaken tests on the same products on more than one occasion the most recent results are used in our evaluation. Additionally, an evaluation of Frogmat was made based on earlier work by AEA Technology.

Table 4.1 Sorbents evaluated for use on oil

Type	Manufacturer /Supplier	Name of Product	Form of Sorbent	Tested by
Organic	Perpetual Environment	Oclansorb	Loose	Environment Canada 1991
Organic	Conwed	Conwed	Blanket	Environment Canada 1985
Synthetic	Briggs	Matasorb	Pads	Environment Canada 1991
Synthetic	New Pig	Pig Skimmer	Loose	Environment Canada 1991
Synthetic	Vikoma/ Lubetech	SPC Type 21-1003	Pads	Environment Canada 1985 AEA Technology 1998
Synthetic	3M	3M Type 156	Pads	Environment Canada 1985
Organic		Frogmat		AEA Technology 1992
Organic	Zorbit Technologies	Peat Sorb	Loose	AEA Technology 1998
Organic	Yeo Valley Company Ltd.	Sphag Sorb	Loose	AEA Technology 1998
Organic	Darcy Products	Zorb	Loose	AEA Technology 1998
Synthetic	Darcy Products	Drizit Pad 0140	Pads	AEA Technology 1998
Synthetic	Fosse Liquitrol	Liquitrol OPH 4843	Pads	AEA Technology 1998
Synthetic	New Pig	Pig Pad REZ401	Pads	AEA Technology 1998
Synthetic	OPEC Ltd.	RP18	Pads	AEA Technology 1998

4.2.1 Frogmat

AEA Technology personnel have previously examined Frogmat and deployed it in the field. This has included evaluating its use as an:

- sorbent on hard mud
- sorbent on soft mud
- shoreline barrier/boom.

Frogmat is supplied in large rolls and would generally be deployed in large continuous amounts. It was found that with both the hard and soft mud, Frogmat did remove much of the oil, but also removed a large amount of mud. This made the mat very difficult to recover. However, it should be noted that this was partly due to the extensive quantities of Frogmat that were deployed. If smaller quantities were used then recovery would be easier although the relatively large quantities of mud would still be present. It was also shown that Frogmat was more effective at collecting an oil emulsion rather than oil. However, in an inland spill situation the likelihood for occurrence of an emulsion would be restricted.

When examined as a barrier for shoreline protection it was found that the Frogmat disintegrated where there was any significant wave action but was more successful in more sheltered areas.

The findings suggest that Frogmat would have potential to protect vulnerable riverbanks although deployment and recovery might be difficult. It can also be used to cover access points for vehicles or personnel in order to protect land and avoid the transfer of pollutants on tyres and footwear. Its use as a conventional sorbent for inland spill is restricted.

4.2.2 Sheen Removal

The products Q Bond (Oilsorb Inc) and Oil Snare (Parker Systems Inc) were to have been examined for their ability to remove oil sheen from a water surface. However, it has not be possible to obtain samples of these products from suppliers. Consequently, it was agreed that a general survey on possible sheen removal products would be undertaken.

Environment Canada have undertaken thin film tests in their evaluations of various products which provide a measure of performance in sheen removal. The tests indicate that sorbent oil pick up decreases with decreasing film thickness and that water pick up increases. Consequently the efficiency of products for the removal of sheen is generally going to be low. Additionally, very few products were found to be marketed specifically for sheen removal although rope mops and sweeps are generally regarded by the manufacturers as the most effective.

The ability of a sorbent to remove a sheen is also likely to be strongly influenced by the presence of any current flow. If there is a current carrying the sheen past the collection point then there would be little opportunity for the sheen to be collected as contact time would be minimal.

4.3 Testing Procedure

The tests undertaken by AEA Technology followed the protocol proposed in the Stage 1 Progress Report. This procedure is based on the protocol used by Environment Canada and the ASTM Standard Method of Testing and thus enables some comparison of results. However, some changes from the original protocol did occur and these are discussed in subsequent sections.

The range of tests undertaken were:

- Still Water Test
- Long Term Test
- L Test.

4.3.1 Still Water Test

The Still Water Test also forms the initial stage of the Long Term Test. The procedure allows the water uptake of the sorbent to be calculated in the absence of oil. This is important as the most efficient oil-only sorbent should have a low water pick-up. The test consists of leaving a known weight of the sorbent floating on a deep layer of water for 12 hours. The sorbent is then re-weighed to determine the quantity of water taken in.

The sorbent is then used again in the Long Term Test.

4.3.2 Long Term Test

The Long Term Test undertaken varies slightly from the original protocol in that the oils used were made more representative of potential spilled liquids within the UK. The tests liquids selected were diesel and hydraulic oil.

The Long Term Test provides information on several aspects of sorbent performance:

- oil retention
    - initial oil retention
    - oil retention over 30 minutes
- water uptake
- sorbent degradation.

The test uses the sorbents from the Still Water Test which are placed on a 5 mm layer of oil on top of an excess of water. The sorbents are left for a further 12 hours before being removed and weighed. This provides an indication of the oil initially retained. The pads are then hung up for a period of 30 minutes and weighed periodically. The weight of any oil lost by dripping is thus known giving an indication of the potential of the sorbent to retain oil over 30 minutes. At the end of the 30 minutes the sorbent is squeezed and any liquid that is squeezed out is added to that lost by dripping. This liquid is then allowed to separate out and the ratio of water to oil measured. This provides an indication of water uptake in the presence of oil.

Sorbent degradation was evaluated by examining the integrity of the sorbents during the final weighing of the Long Term Test. After the period of hanging, any weaknesses in the pads become noticeable in the form of stretching or tearing. This gives an indication of the strength of the pad and the ease of retrieval after a long period of time on a spill.

4.3.3 L Test

The L Test also provides information on several aspects of sorbent performance:

- maximum oil uptake from a solid surface
- re-use potential
- adsorption speed.

The sorbents were left on a 5 mm layer of test oil for 15 minutes and, after weighing, are squeezed and placed back on the oil for a further 5 minutes. The first stage gives an indication of maximum oil uptake while the second part provides an indication of re-use potential. Adsorption speed is determined by comparing the oil uptake from this test with the results from the Long Term Test. The test oils were diesel, crude, weathered crude and Heavy Fuel Oil (HFO). However, the loose sorbents were not tested with the HFO.

4.4 Results

4.4.1 Still Water Tests

The results of the Still Water Tests are indicated in Table 4.2. The majority of sorbents show very little affinity to water with the exception of Sphag Sorb which sorbed about 9.5 grams water/gram sorbent. However, in the Long Term Tests described below Sphag Sorb was found to sorb less (0.6 g water/g sorbent). This shows that Sphag Sorb will sorb water or oil, depending on which layer it is in contact with. Sphag Sorb would thus be more useful on solid surfaces rather than water surfaces. RP18 shows the least affinity for water and this is supported by the results from the Long Term Tests.

Table 4.2 Results of the still water tests

Product	**Water content, g water/g sorbent**		
	Test 1	Test 2	Mean
Peat Sorb	0.8	1.8	1.3
Sphag Sorb	9.5	9.8	9.65
Zorb	1.7	1.5	1.6
Drizit Pad 0140	0.2	0.3	0.25
Liquitrol	0.2	0.3	0.25
Pig Pad REZ401	0.7	0.64	0.67
RP18	0.04	0.09	0.065
SPC Type 21-1003	0.1	0.1	0.1

4.4.2 Long Term Tests

Initial Oil Retention

The results for initial oil retention of different sorbents determined during the long term tests with diesel and hydraulic oil are indicated in Table 4.3. This also includes some relevant results obtained by Environment Canada. Note that the similar values obtained by Environment Canada and AEA Technology for SPC Type 21-1003 suggest that the available results are comparable. The initial oil retention is the quantity of oil sorbed during a 12 hour period where the sorbent is left in contact with a layer of oil.

Diesel retention was greatest with Drizit 0140 recording 20.7 grams oil/gram sorbent. The other synthetic sorbents produced similar results from 8-16 grams oil/gram sorbent. Environment Canada (1983) also tested a foam synthetic sorbent (Reichhold Foam) which recorded an adsorption capacity of 67.13 g oil/g sorbent. However, this product was not very practical as it is understood to disintegrate if left for too long in the liquid. The Conwed blanket was the best performing organic material overall. It sorbed 14.0 grams oil/gram sorbent and out performed some of the synthetic materials. Sphag Sorb also performed well, sorbing 11.1 grams oil/ gram sorbent. This is due to the product undergoing specific screening and drying techniques to get the moisture level down to 6-8%. The accompanying literature also states that peat is naturally hydrophobic and oleophilic. Oclansorb is also a modified peat product and performed well at 9.1 grams oil/gram sorbent. This is again down to the drying techniques, this time incorporating chemical drying. Peat Sorb was next at 6.8 g/g with Zorb following at 3.5 g/g.

Table 4.3 Initial retention of diesel and hydraulic oil

Product	Testing Body	Diesel Retained		Hydraulic Oil Retained	
		Weight g oil/g sorbent	Percent	Weight g oil/g sorbent	Percent
Oclansorb	Environment Canada	9.1	*	*	*
Conweb Blanket	Environment Canada	14.0	*	*	*
Matasorb	Environment Canada	8.0	*	*	*
Pig Skimmer	Environment Canada	8.1	*	*	*
3M Type 156	Environment Canada	16.4	*	*	*
SPC Type 21-1003	Environment Canada	11.7	*	*	*
Peat Sorb	AEA Technology	6.8	93.2	6.3	87.7
Sphag Sorb	AEA Technology	11.1	92.0	12.5	90.5
Zorb	AEA Technology	3.5	85.3	3.6	82.9
Drizit Pad 0140	AEA Technology	20.7	77.9	18.8	56.8
Liquitrol	AEA Technology	12.2	75.0	14.8	65.3
Pig Pad REZ401	AEA Technology	11.3	61.2	13.3	51.9
RP18	AEA Technology	10.4	49.9	13.1	37.6
SPC Type 21-1003	AEA Technology	11.9	72.7	10.4	69.5

*Environment Canada results do not include the percentage of diesel retained and any information on hydraulic oil.

The results with the hydraulic oil indicate similar trends. Again Drizit 0140 performs well amongst the synthetic sorbents while Sphag Sorb performs well amongst the organic sorbents. Zorb was the least effective.

These results indicate that the synthetic pads generally out-performed the organic sorbent for the initial retention of both diesel and hydraulic oil. The Drizit Pad 0140 would appear to be the best synthetic product and Sphag Sorb would appear to be the best organic product of those tested. Zorb would appear to be the least effective of those tested.

Oil Retention Over 30 Minutes

The percentage of oil retained over 30 minutes by the various sorbents with both diesel and hydraulic oil was determined. The results were presented as Appendix 1 to the Project Record.

The results show that the organic materials retain a large proportion of their oil compared to the synthetic sorbents. Some of the organic loose material is specifically formulated to minimise leaching of liquids from them. This could have implications for disposal routes and will be discussed in greater detail later.

All of the synthetic sorbents performed to a similar standard with around 60-78 % retention for diesel and 50-65 % for hydraulic oil. RP18 was below these levels for both diesel and hydraulic oil.

Water Uptake

The water uptake in the presence of oil, as determined by the Long Term Tests, are indicated in Table 4.4. These results show that none of the sorbents have a natural tendency to sorb water in the presence of oil. The sorbents tested by Environment Canada tended to have slightly lower water contents. This is due to the sorbents tested by AEA Technology having been previously subjected to the Still Water Test. Note that the water content of Sphag Sorb is considerably less than that determined by the Still Water Test.

Table 4.4 Water Uptake in the Presence of Oil

Products Tested by Environment Canada	Water Content g water/g sorbent	Products Tested by AEA Technology	Water Content g water/g sorbent
Oclansorb	0.1	Peat Sorb	0.4
Conwed Blanket	0.6	Sphag Sorb	0.6
Matasorb	0.03	Zorb	0.4
Pig Skimmer	0.5	Drizit type 0140	0.2
SPC	0.08	Liquitrol OPH 4843	0.1
3M type 156	0.0	Pig Pad REZ 401	0.1
		RP18	0.1
		SPC type 21-2003	0.1

Sorbent Degradation

Observations of the integrity of sorbent pads during the Long Term Tests indicated that all pads remained intact and that there were no signs of fatigue or weakness. Although this test does not simulate the conditions that a sorbent pad may face, it does give an idea of the strength of the pads when saturated. This is important during the recovery of pads.

4.4.3 L Test

Maximum Oil Uptake from a Solid Surface

The results of tests with different oils to determine the maximum oil uptake from a solid surface are shown in Table 4.5. Note that the relative viscosities of the test oils are:

diesel < crude < weathered crude < Heavy Fuel Oil (HFO).

The results with diesel confirm the previous findings from the Long Term Test. That is that Drizit is the most efficient of those tested for diesel. The other synthetic products all show similar sorbencies of around 10 g oil/g sorbent, with SPC being the lowest at 7.6 grams oil/gram sorbent. Again the organic sorbents exhibit the lowest sorbencies, with Sphag Sorb being the most efficient at 5.1 g oil/g sorbent.

Table 4.5 Maximum oil uptake from a solid surface

Product	Maximum oil uptake, g oil/g sorbent			
	Diesel 11 mPa s @ 10 s^{-1}	Crude 54 mPa s @ 10 s^{-1}	Weathered Crude 1200 mPa s @ 10 s^{-1}	HFO 12100 mPa s @ 10 s^{-1}
Peat Sorb	4.5	4.5	10.6	
Sphag Sorb	5.1	3.8	9.3	
Zorb	2.2	0.4	6.9	
Drizit	12.5	14.6	18.2	7.6
Liquitrol	10.2	12.1	15.1	7.4
Pig Pad REZ401	10.5	13.1	17.2	19.1
RP18	9.5	11.9	16.9	4.3
SPC Pad 21-1003	7.6	8.8		

The level of sorbency overall generally increases from diesel to crude to weathered crude. For both the crude and the weathered crude, Drizit is again the best performer overall. The performance of the organic sorbents was generally significantly better with the weathered oil than with either the diesel or the crude.

With HFO, only the synthetic sorbents were tested with Pig Pad REZ401 performing significantly better than the rest.

Re-Use Potential

Table 4.6 shows the percentage of oil lost from a pad as a result of squeezing and also the volume of oil taken up when the squeezed pad is replaced on oil. As the organic sorbents consist of loose material, they were not tested for re-use as this would be impractical in the field.

Table 4.6 Oil lost from pad by squeezing and subsequent oil uptake

Product	Diesel		Crude		Weathered	
	% oil lost	% oil taken up	% oil lost	% oil taken up	% oil lost	% oil taken up
Drizit	71	52	69	51	37	39
Liquitrol	63	55	67	53	39	47
Pig Pad REZ401	58	51	61	35	39	31
RP18	57	47	60	22	52	43

All the sorbents have the potential to be re-used with diesel and similar light oils. This is indicated by the ability of a sorbent to take up more than 50 % of the initial volume of oil when re-used. Drizit and Liquitrol are the most likely sorbents to be successfully re-used with both diesel and crude. Environment Canada have also tested re-use using a plate press and continued testing until either less than 50 % of the initial capacity is being recovered, or the sorbent disintegrates. From their results (1983, 1985, 1991) Oclansorb, Matasorb and Pig

Skimmer all have limited re-use of 1-5 times while Conwed and SPC have the potential to be used up to 10 times with weathered crude and Bunker C.

However, note that some pads actually takes in more weathered oil after the re-use than was lost via squeezing. This has also been noted by Environment Canada (1985) during tests with more viscous oils. The viscous nature of these oils probably limits the capillary action during the initial part of the test resulting in the oil forming a layer and preventing any additional oil from penetrating deeper into the sorbent. When squeezed, this initial layer is mechanically forced deeper into the sorbent leaving the surface clear for the next layer of oil.

Adsorption Speed

A comparison of the results with diesel from the Long Term Test (12 hours) with the results with diesel from the L Test (15 minutes) provides information on the adsorption speed of the sorbent. Table 4.7 contains these results along with the percentage of saturation at 15 minutes which is calculated as the amount of oil sorbed in the L Test as a percentage of that sorbed in the Long Term Test.

Table 4.7 Comparison of results with diesel from long term test and l test

Product	L Test g oil/g sorbent	Long Term Test g oil/g sorbent	Saturation %
Peat Sorb	4.5	6.8	66
Sphag Sorb	5.1	11.1	46
Zorb	2.2	3.5	63
Drizit Pad 0140	12.5	20.7	60
Liquitrol	10.2	12.2	84
Pig Pad REZ410	10.5	11.3	93
RP18	9.5	11.7	81
SPC Pad 21-1003	7.6	10.4	73

Sorbents which do not reach 90 % saturation within 15 minutes can be termed slow. All sorbents tested fall into this category except Pig Pad REZ410. Liquitrol and RP18, although within the slow category, do perform reasonably well with saturation values of > 80%. Note that the Drizit product only obtained a saturation percentage of 60 %. But this should not necessarily be considered as a weakness of the product as it still outperformed the other products on both the L Test and the Long Term Test. The low saturation value results from its continued ability to sorb the diesel even when it contains a quantity that would saturate other sorbents.

4.5 Field Evaluation

A range of specific sorbents were distributed to four Environment Protection Officers for testing and evaluation in the field. Comments were solicited on performance, handling and ease of use. Unfortunately only two responses were obtained; one referring to simulated tests rather than use in a real incident (Table 4.8) and another referring to the collection of diesel from a tarmac surface following a road traffic accident (Table 4.9).

Table 4.8 Agency evaluation of sorbents in simulated tests

	Sorbent			
	Liquitrol	**Drizit Pad 0140**	**Pig Pad REZ410**	**RP18**
Diesel on water	10/10	8/10	4/10	3/10
Waste oil on plastic	10/10	10/10	6/10	6/10
Diesel on finger	10/10	8/10	5/10	4/10
Capacity	6/10	6/10	10/10	9/10
Buoyancy	10/10	9/10	10/10	0/10
Durability	8/10	6/10	10/10	10/10
Retention on handling	10/10	9/10	8/10	2/10
General handling	10/10	7/10	5/10	6/10
Would you use again?	Yes	Yes	It's OK	No
General Rating	Best	Good	It's OK	Worst

Table 4.9 Agency evaluation of sorbents during a road traffic accident

	Sorbent				
	Liquitrol	**Drizit Pad 0140**	**Pig Pad REZ410**	**RP18**	**Sorbarix**
Diesel on Tarmac	Effective	Not so effective	Effective	Effective	Not effective
Rate of sorbance	Very quick	Not so quick	Very quick	Very quick	Not as good
General handling	Easy to use		Easy to use	Easy to use	Less flexible
Would you use again?	Yes	Not if others available	Yes	Yes	Possibly
General Rating	Good	Medium	Good	Good	Worst

Table 4.8 indicates that Liquitrol and Drizit Pad 0140 are considered to be the best two products of those tested in this evaluation. The RP18 product was considered the worst with a particular fault being its very poor buoyancy. (It sank during the evaluation procedure.) In general this evaluation by the Environment Agency staff supports the laboratory testing described earlier.

Table 4.9 indicates that Liquitrol, Pig Pad REZ410 and RP18 are considered to be the best three products of those tested in this evaluation. Sorbarix was considered to be the worst with a particular fault being its poor flexibility due to its thickness. The evaluation of the Drizit Pad 0140 indicated an intermediate position. As this was not in full agreement with the results of the laboratory tests for Drizit the Agency personnel involved with the evaluation was contacted. Discussions suggested that the Drizit product did not appear to sorb diesel as quickly as some of the other products. However, when advised that the Drizit product might be capable of taking in a similar quantity that would saturate other pads but without itself becoming saturated, the evaluator considered that this might explain a possible misinterpretation of apparent slower sorption.

4.6 Universal Sorbents

A limited examination of promotional literature for selected universal sorbents was undertaken. It was found that within the range of products that existed, both organic and synthetic, there was some considerable variation in the claims for the range of chemicals that could be treated and the sorbencies. Unfortunately, the manner of reporting on these issues is non-standard and so makes comparison difficult, especially as little information was available for different chemical types. Generally a single sorbency was quoted with no indication of what chemical was being considered or if sorbency varied with chemical type. Additionally, there is little information on the manner in which the data were obtained. Nevertheless, Tables 4.10 and 4.11 summarise available information for selected organic and synthetic universal sorbents respectively.

Table 4.10: Compatible liquids and sorbency capacities for organic universal sorbents

Product	Manufacturer/ Supplier	Raw Material	Compatible Liquids	Sorbency Compared to Clay Granules
Zorb 614	Darcy Products Limited	Harvested softwood	Oils, solvents, herbicides, pesticides, weak acids. Not extreme acids or oxidisers.	x 6 by weight
Peat Sorb	Zorbit Technologies (UK) Ltd	Modified peat product	Oils, solvents, organics. Not extreme acids and oxidisers	x 3-12 by weight
Sphag Sorb	Sphag Sorb Inc/ Yeo Valley Co Ltd	Modified Sphagnum Moss	Oils, solvents, pesticides, herbicides, organic chemicals.	x 10 by weight

It can be seen that the organic sorbents cannot deal with extreme acids and oxidisers. Consequently, they would not be appropriate for use in emergency situations where the nature of the spilled liquid is not known. Whereas sorbance capacities are presented as a comparison with clay it is interesting to note that the Sphag Sorb and Peat Sorb appear to have a greater absorption capacity compared to Zorb 614. This is comparable to the results obtained with absorption with oils.

Synthetic sorbents can generally deal with a wider range of chemicals than the organic sorbents. This includes some acids, bases, caustics and oxidisers. However, not all products can deal with the more extreme oxidisers and acids; many products generally indicate some chemicals that are not compatible while others use general phrases such as compatible with "most acids and alkalies".

Table 4.11 Compatible liquids and sorbency capacities for synthetic universal sorbents

Product	Manufacturer	Compatible Liquids	Sorbency
$SorbX_2$	Matarah Industries Inc	All liquids including acids and caustics	15 x weight
SPC Universal Plus	SPC Sorbent Products Co Inc	All liquids including acids, bases, inorganic and organic	16 x weight
Hazwik SOC	SOC Absorbents	Acids and caustics, solvents. Not hot or concentrated nitric and perchloric acid, fuming sulphuric acid at 60°C or liquid chlorine	7.5 x 120 cm sock = 2 litres*
Ergon Universal Hazardous Liquid Absorbent	Soc Absorbent	All liquids including 98% Sulphuric Acid	
Chemical Absorbents	Darcy Products Limited	All liquids except hot fuming acids and very strong oxidisers	
Liquitrol Universal Sorbent	Fosse Ltd	All liquids except strong oxidisers and hot acids	20 x weight 7.5 x 120 cm sock = 5 litres
Chemical Sorbents Miniboom P200	3M	Aggressive acids and alkalies	7.5 x 120 cm sock = 3.5 litres*
Haz Mat Absorbent Sock	New Pig	Acids and caustics	8.0 x 117 cm sock = 3 litres*

* The R+D Project Record P2/053/1 Project Record incorporates some estimates of sorbency by weight for these products. These estimates assume that the density of the relevant sorbent is the same as that of Liquitrol Universal Sorbent. Values vary from 8-14 x weight.

The relative sorbent capacities of the different products are all within the same order of magnitude. While there is some variation this should not be considered as significant as methods of testing, and variation between test chemicals are not known. Some sorbents are described as being able to take in 15-20 times there weight of liquids. This would equate to 15-20 g of liquid / g of sorbent. This compares with 8-20 g of oil / g of sorbent for synthetic oil only sorbents (Table 4.13).

The published literature indicates that organic universal sorbents can be expected to leach less than synthetic universal sorbents if disposed of to landfill.

4.7 Discussion

4.7.1 Sustainable Sources

Sorbents need to be manufactured and consequently their origin is from a natural resource of some kind. Additionally, once used, they are essentially disposable items. Recognising that there is a need for sorbents, the ideal situation would be where sorbents manufacture has minimal impact on natural resources and, as far as is possible, are manufactured from sustainable resources.

Some synthetic sorbents manufactured in the UK are made from non-waste polypropylene while others are made from waste polypropylene resulting from the manufacture of other products. This waste, which would otherwise go to landfill, is melted down and blown to make the sorbent pads and rolls. The polypropylene would have originated from the processing of fossil fuels. Whereas it has not been possible to determine which particular products arise from non-waste and waste, it is understood that several Fosse Liquitrol and Drizit products for oil are manufactured from waste.

Organic sorbents have their origin in current biological sources. Zorb is an African softwood product and is stated to be manufactured from naturally produced waste products. Spilkleen PLUS, produced by Fosse Liquitrol, is a cellulose sorbent produced from recycled paper waste.

Peat Sorb and Sphag Sorb are sphagnum peat moss products. They are described as being manufactured from harvested moss overlying peat bogs rather than from the peat of the bog itself. The moss originates from Canada and is harvested by members of the Canadian Sphagnum Peat Moss Association (CSPMA). This body adopts stringent guidelines and regulations to ensure that the ground can be re-used after the harvesting of the moss. The Canadian Sphagnum Peat Moss Association also asks its members to adopt a policy of peat land restoration and management.

Given the relative performance of synthetic and organic sorbents it would be better practice to use synthetic types for most applications. These may be made of otherwise waste materials and also do not involve harvesting of slow growing habitats (a situation which may be perceived as environmentally damaging) However, it is envisaged that particular applications might exist where organic sorbents are more appropriate. In this situation it is recommended that the Environment Agency ensure that any suppliers of peat moss products undertake the restoration and management scheme promoted by CSPMA.

4.7.2 Deployment/Recovery

Sorbents are supplied as either loose or contained (pads, rolls, socks etc.) forms. Each will be discussed separately. As a general rule the synthetic sorbents are contained while the organic sorbents are loose, although this does not always apply. For example, some organic sorbents can be obtained in contained form.

Loose

Deployment is achieved by manual spreading or using a blower or mechanical spreader. Many of the loose organic materials can be very dusty and contain very fine particles. On a windy day, controlled deployment may be difficult and dust masks may be necessary.

Recovery is undertaken from land using stiff brooms followed by shovelling, or from water by skimmer shovels, screened forks, pool skimmers or suction devices. The use of loose sorbents on open water is not recommended unless the spill is contained by booms. Even then, the recovery of loose sorbent is often difficult.

Contained

Deployment and recovery methods for all contained sorbents are generally manual. Pads, blankets and pillows are placed on the spill by hand and then retrieved using forks or similar equipment. Booms, sweeps and rugs are deployed across a water way or around a container and removed by hand. Deployment and recovery can be difficult on windy days or on waterways with appreciable flow. Very large sorbent booms however, might be deployed with mechanical assistance.

Table 4.12 indicates the potential applications for the different forms of sorbent.

Table 4.12 Applications of different forms of sorbent

Type	Form	Description	Use
I	Pads, Blankets	Products with length and width much greater than thickness	Small quantities of oil on rivers and roads
I	Rolls	As above, long lengths of sorbent which can be torn off to necessary lengths	Along riverbanks and to protect nearby unpolluted walkways
II	Loose	Dry particulate material	Oil in difficult access areas, oil spills on roads, forecourts etc.
IIIa	Pillows/Cushions and Socks	Materials contained by an outer fabric/netting which is permeable to oil	Deep interceptors and sumps if attached to rope, use socks around leaking drums, tanks
IIIb	Sorbent Booms	In the form of a long cylinder that is deployed as a boom	Intercepting oil on rivers, streams, ponds, drains, gullies and ditches
IIIc	Sorbent Sweeps	Long rolls of sorbent sewn to a nylon strap along one edge	Removing thin surface films from rivers, ponds etc.
IV	Ribbons, strips, open netting	Resemble pom-poms	Use on rivers, beaches for viscous oil recovery.

4.7.3 Re-Use

The property of re-use has both good and bad points. It does allow for sorbents to be wrung out at the scene of a spill and then be re-used, thus reducing the number of pads necessary for the collection of a specific volume of liquid. However, the concept does require that a wringer or press be available and that the temporary storage of collected liquids is possible. This temporary storage of the free liquid and also its subsequent transportation for disposal may pose environmental and health risks. Re-use of sorbents is appropriate for the recovery of liquids from solid surfaces, and can be used for the recovery of liquids from water surfaces. Synthetic sorbents are generally more amenable to re-use than organic sorbents.

It is recommended that sorbent re-use be confined to clean-up operations on solid surfaces.

4.7.4 Disposal Options

Any sorbent, once used, needs to be disposed of in an appropriate manner. The ideal disposal route would be one that minimises any environmental impact. As sorbents take on the characteristics of the contaminants that they sorb, and the associated hazards, they may therefore need to be treated as special waste, hazardous waste or toxic waste.

The sorbent manufacturers generally recommend disposal via landfill or incineration. Each will be discussed in turn.

Landfill

Disposal at an appropriately classified landfill is one possible disposal route for used sorbent. Once disposed of via this route, the processes occurring within the landfill might change the nature of the contained pollutant. Processes than might occur include evaporation, leaching, adsorption and biodegradation. The ideal situation would be where the pollutant is held within the sorbent until it is rendered harmless by, for example, biodegradation, and where the pollutant does not leach from the sorbent.

Suppliers of sorbent generally claim that their products can be left in the environment, as the sorbed oil will not be leached; instead it will retained within the sorbent where it will biodegrade. However, other available information suggests that contained liquids are less likely to leach out of organic sorbents than synthetic sorbents. The manufactures of Peat Sorb and Sphag Sorb both also claim that, although the moss within the product is also biodegradable, the oil will biodegrade first. Sphag Sorb is understood to fulfil the US Environmental Protection Agency's standards for disposal of solidified hazardous liquids in landfills.

As landfill costs are proportional to the weight of disposed material, the products that sorb the most liquid per gram of sorbent will represent the cheapest disposal option.

Incineration

The incineration of used sorbents at appropriate incinerators is an alternative disposal route. Any incinerator accepting this type of waste would need to be appropriately regulated and fitted with the appropriate gas scrubbing equipment.

An advantage of this disposal route is that all sorbent materials are themselves combustible and that the sorbed liquids themselves might have a calorific value. Ideally, the heat produced should be used for energy production. However, any significant water content would result in an energy penalty.

Organic solvents generally have an ash content of 2-10 % and an energy value of approximately 17 MJ/kg (exclusive of contained liquid) while synthetic sorbents generally have an ash content of 0.02-0.2 % and an energy value of approximately 46 MJ/kg (exclusive of contained liquid). The manufacturers of SPC, Peat Sorb and Sphag Sorb mention their respective ash residue and energy values for incineration purposes. SPC claims a 0.02 % ash residue and a high value, Peat Sorb an energy value of 9 MJ/kg (exclusive of contained liquids) and Sphag Sorb has a residue of <5 % with an energy value of 5.5-7 MJ/kg (exclusive of contained liquids).

Disposal by incineration should be the preferred route for disposal for both organic and synthetic sorbents although costs will probably be significantly higher than for landfill.

4.7.5 Safety Implications

Once used, sorbents take on the same properties and hazards as the original material that was spilled and therefore may be dangerous. When liquids are taken in by sorbents the surface area of the liquid can be increased. This can result in safety issues, especially if the liquid is volatile or has volatile components. Vapours arising from the liquid can be hazardous, e.g. toxic, explosive or flammable. Pads, sheets and ribbons can be expected to increase the surface area more than socks, pillows or booms.

Peat Sorb and Sphag Sorb are loose sorbents and can be added in sufficient quantity such that a dry layer occurs on the top. In this way both products are claimed to have been tested for vapour suppression capabilities. However, disturbance of the material during any subsequent recovery operation might still release some vapour.

If the nature of the spilled material is not known then maximum personal protection equipment should be worn. This should consist of self-contained breathing apparatus and full protective clothing. If the nature and properties of the spilled material are known then the relevant protective equipment should be chosen. This might include respirators, boots, goggles, face shields, hard hats, aprons, splash suits and fully encapsulated suits.

Safety glasses or goggles are recommended for use with the loose organic materials. As already mentioned, these products can contain a great deal of dust and adequate ventilation or a dust mask may be necessary.

4.7.6 Purchase Costs

Specific and meaningful details of costs could not be obtained although discussions with manufacturers and suppliers indicated that bulk ordering, either monthly or annually, would probably result in discounted rates. Bulk ordering could be achieved by the Environment Agency if supplies were ordered centrally and the products delivered directly to the various regional bases. This would enable bulk ordering to take place without the need for a single large stockpile and subsequent re-handling of stock. The deliveries may even be monthly which would eliminate the need for large amounts of storage space. This would also ease the stock flow for the suppliers as several supply and delivery episodes of smaller quantities would be favourable to a single episode of a larger quantity.

As an indication of relative performance and possible requirements the calculated weight of sorbent necessary to sorb a litre of diesel is shown in Table 13.

Table 4.13 **Calculated weights of sorbent required to sorb diesel**

Product	**Adsorption Rate**	
	Diesel g /g sorbent	**g sorbent/ litre oil**
Drizit 0140	20.7	48.3
3M Type 156	12.9	77.5
Liquitrol OPH 4843	12.2	82.0
Conwed Blanket	12.0	83.3
SPC 21-1003	11.9	84.0
Pig Pad REZ401	11.3	88.5
Sphag Sorb	11.1	90.1
RP18	10.4	96.2
Oclansorb	9.1	109.9
Pig Skimmer	8.1	123.5
Matasorb	8.0	125.0
Peat Sorb	6.8	147.1
Zorb	3.5	285.7

4.8 Conclusions

The Agency should consider identifying a restricted range of sorbent types based on performance, value for money and environmental implications. These can be purchased centrally to maximise cost benefits, but with periodic delivery arrangements to reduce storage requirements. Sorbents should be capable of dealing with a range of liquids, both chemicals and hydrocarbons.

As far as is possible, the Agency should also consider within their purchasing mechanism, the possibility of introducing some standardisation in the colour of sorbents used for particular duties. Ideally, sorbents for application to hydrocarbons should all be the same colour, while those for application to chemicals should all be another colour. It is further recommended that a combination of colour coding and labelling is used: all sorbents that are oil only should be white and bear the word "OIL" in black while all sorbents that are universal should be yellow and bear the word "UNIVERSAL" in black.

It is recommended that the most appropriate disposal route for used sorbents is incineration, although it is recognised that this may be more expensive than landfill.

4.8.1 Oil Only Sorbents

Most of the synthetic sorbents were similar in performance during the laboratory tests. However, of those tested, Drizit 0140 performed best in many aspects tested, sorbing most oil from both a solid surface and a liquid surface. Drizit 0140 also performed best across a range of viscosities of test liquids although was less effective with high viscosity HFO.

Sphag Sorb and Peat Sorb were the best of the organic sorbents tested with hydrocarbons. However, these materials are probably best suited for use on solid. Additionally, as their performance does not appear to be any better than the best synthetic sorbents, and as there are possible perceived negative environmental implications from the harvesting of the moss used in their manufacture, it is considered that the use of these products be restricted to special applications.

Frogmat has potential to protect vulnerable riverbanks although deployment and recovery might be difficult. It can be used to advantage to cover access points from vehicle and pedestrian damage and avoid the transfer of contamination on vehicle tyres and footwear.

The removal of oil sheen by sorbents would still appear to be problematical.

4.8.2 Universal Sorbents

Universal sorbents are capable of sorbing a wide range of chemicals but also take in oils and water. Synthetic sorbents are compatible with a wider range of chemicals than organic sorbents, although even many synthetics have potential restrictions with some chemicals. The absorption capacity of synthetic universal sorbents appears to be within the same range of the absorption capacity of synthetic oil only sorbents.

It is recommended that only synthetic universal sorbents be used as these are the most versatile in an emergency.

5 ENVIRONMENT PROTECTION OFFICER'S KIT

An Environment Protection Officer's kit list was drawn up following consultation with the Agency. The components of the kit were examined with a view to identifying on a generic basis the range and types of equipment that might be required.

In addition to reviewing the kit in general some specific aspects were examined in more detail. These were:

- sampling equipment
- photographic records
- dictation machines
- IT equipment.

Further consideration was given to how the components of the pollution officers kit should be stored in any response vehicle and how it might be transported from a vehicle to the specific location of concern.

5.1 Kit List

The range of equipment examined was concerned primarily with enabling the officer to attend an incident so that he can investigate, sample, record and make safe if necessary. The potential equipment that might be involved was tabulated according to the following categories:

- Personal Protection Equipment (Table 5.1)
- Investigation Equipment (Table 5.2)
- Sampling Equipment (Table 5.3)
- Recording/Reporting Equipment (Table 5.4)

- Security Equipment (Table 5.5)
- Other Equipment (Table 5.6).

Table 5.1 Environment Protection Officer's Kit, personal protection equipment

Item	Essential	Supplementary	Specialist
Hard hat	x		
Visor			x
Safety glasses	x		
Respirator			x
Fluorescent jacket with logo	x		
Water proof over-trousers	x		
Water proof jacket with logo	x		
Protective gloves	x		
Boots (mid-sole protected)	x		
Wellingtons	x		
Thigh or chest waders, or dry suit		x	
Life jacket	x		
Disinfectant/hand wipes	x		
Paper towels	x		
First Aid Kit	x		
Personal attack alarm	x		

Table 5.2 Environment Protection Officer's Kit, investigation equipment

Item	Essential	Supplementary	Specialist
Test kit	x		
pH meter and probe, or papers/sticks		x	
Dissolved Oxygen meter and probe		x	
Conductivity meter and probe		x	
Ammonia meter and probe		x	
Turbidity meter and probe		x	
Thermometer or other temperature recording equipment	x		
Dye tracing equipment	x		
Spare batteries for meters		x	

Table 5.3 Environment Protection Officer's Kit, sampling equipment

Item	Essential	Supplementary	Specialist
Sampling Procedures Manual	x		
Quality Manual			x
Sampling stationary	x		
Surface, near-surface sampling device[1]	x		
Depth sampling device[2]			x
Drain sampling device[3]		x	
Filters		x	
Filtration equipment		x	
Markers	x		
Funnel		x	
Preservative		x	
Sample bottles	x		
Sample bottle sealing tape	x		
Sample bottle carrier	x		
Sample bottle crate	x		
Sounding pole		x	
Cool box			x
Freezer packs			x
Polythene bags	x		
Refrigerator			x
Freezer			x
Thermometer	x		

1 - e.g. sampling container, chain, rope and/or extension rods
2 - e.g. sealed immersion device or pumping device
3 - e.g. down hole submersible pumping device

Table 5.4 Environment Protection Officer's Kit, recording/reporting equipment

Item	Essential	Supplementary	Specialist
Notebook and investigation stationary	x		
Pens/Pencils	x		
Camera	x		
Spare film	x		
Spare batteries	x		
Digital camera		x	
Pocket dictation equipment		x	
Mobile telephone	x		
IT Equipment[1]		x	

[1] e.g. Laptop computer, NOKIA 9000, Psion Organiser

Table 5.6 Environment Protection Officer's Kit, security equipment

Item	Essential	Supplementary	Specialist
Loud hailer			x
Incident tape	x		
Stakes		x	
Mallet/lump hammer		x	
Knife		x	
Vehicle hazard/flashing light	x		
Signs	x		
Cones		x	
Fencing			x
Rope	x		

Table 5.7 Environment Protection Officer's Kit, other equipment

Item	Essential	Supplementary	Specialist
Equipment check list/inventory			x
Equipment maintenance record			x
Equipment calibration record	x		
Health and safety manual		x	
Pager	x		
Maps and plans	x		
Emergency contacts list	x		
Identification card	x		
Uniform		x	
Torch (intrinsically safe)	x		
Spare batteries	x		
Tools			x
Tool box or bag			x
Man-hole key	x		
Crow bar	x		
Shovel		x	
Machete			x
Grip bags		x	
Stowage boxes with handles		x	
Baggage trolley/wheelbarrow			x
Polythene bags for soiled materials	x		
Absorbent towel/roll	x		
Car identifier	x		

5.2 Sampling Equipment

It is understood that the current sampling equipment used by the Agency consists of a series of sampling containers and a rope, extension rods or chain. This equipment is simple and versatile and can be used for most, if not all, anticipated sampling scenarios that may occur during an emergency incident or during normal sampling programmes. These are:

- sampling from bridges
- in-stream sampling
- sampling from the bank-side
- sampling from craft
- effluent discharge point sampling (e.g. outfalls, channels, drains or manholes).

A variety of alternative equipment exists that can also be used for sampling in many of these situations, although much of this has been developed for specific use in restricted situations such as the sampling of groundwater through monitoring wells. A range of such equipment has been reviewed to consider it for general use for emergency sampling. The following discussion was also circulated with the draft kit list for comment.

The range of equipment considered included:

- bailers
- inertia pumps
- bladder pumps
- peristaltic pumps
- submersible pumps
- eductors
- drum pumps.

On comparison to the existing sampling equipment used by Agency, none of this alternative equipment provides a versatile and simple approach to sampling which would satisfy all of the requirements of the agency. All equipment types would have one of more of the following potential disadvantages:

- increased size and weight - much of the equipment would represent an increase in size and weight when compared to existing Agency sampling equipment. This will have implications for storage, transport and handling
- over complex - most of the equipment is considerably more complex than that currently used and in general more complex than is needed for emergency sampling
- reduced versatility - much of the equipment is designed for specific purposes and, although might be used in the full range of scenarios required, it would not be as simple to use as the current equipment. As much of the equipment has been designed for use in monitoring wells its application to flowing water is difficult to evaluate
- increased potential for equipment failure - most of the equipment is mechanically based with moving parts or parts subject to wear and tear
- increased maintenance requirements - due to the mechanical nature of much of the equipment increased maintenance requirements would be anticipated
- increased set-up time - the time required to set-up much of this equipment will be longer than that required for the existing equipment
- increased cleaning requirements between samples - the complex nature of the equipment, along with the potential for extended sampling lines, would make cleaning between samples more difficult

- potential for sample deterioration due to residence time in any sampling line - the composition of any sampling line would need to be considered to minimise any potential changes in the concentrations of particular determinands
- equipment control to minimise contamination - control of equipment may be more difficult during operation than existing equipment. For example, prevention of contact of the sampling device with the sides of drains or gullies may be more difficult, and the possibility of disturbing any bottom sediments in rivers may be greater
- power supply requirements - much of the equipment will require some sort of power supply (generally electrical or compressed air, perhaps provided by a generator) which in turn adds to transport, storage and handling requirements, and maintenance and reliability issues.

The above discussion would suggest that the existing equipment may be the most versatile, trouble free and easy to use method of sampling in an emergency. The main sampling scenario where alternative equipment may be more appropriate is when sampling from manholes, drains or similar confined situations where the water body might be at a considerable depth. In these situations there may be some benefit in the use of equipment such as bailers, inertia pumps or down hole submersible pumps.

5.3 Photographic Records

At present conventional cameras utilising normal light sensitive film are used to create most photographic records. A potential alternative to this is the use of a digital camera. The following discussion was distributed with the draft kit list for consultation:

A digital camera records the photographic image electronically and requires that these be down-loaded using appropriate software for storage on, for example, compact disc (CD), floppy disc or computer hard disc. Additional appropriate software is needed in order to manipulate and reproduce the images. Digital cameras record a large number (e.g. in the vicinity of 90 to 190 depending on memory size) of colour images that may be reproduced in colour or black and white, and which can be cropped or overlain as desired. Images can be printed, played through a television screen or transferred to video tape. A particular advantage is that an instant view or the recorded image can be examined on the camera and an additional image recorded should the first not be satisfactory. Following processing the recorded images can be inserted directly into computer generated reports. The resolution of the reproduced image will broadly depend on the initial price of the camera. A disadvantage is that the subsequent stored images require a large amount of computer memory for storage. Costs can vary from about £350.

5.4 Dictation Machines

Pocket sized portable dictation machines offer a potential replacement for a notebook. They have the advantage of being able to record information more rapidly than may be possible with a note book and also are not necessarily influenced by inclement weather or arduous conditions. They can be operated by one hand whereas a note book will generally require two.

It would be necessary for additional tapes and spare batteries to be carried, and there is also the possibility of equipment loss or failure. Additionally, care would need to be taken in control of tapes to ensure that these are not lost or that existing records are not over-recorded.

This brief discussion was again distributed along with the draft kit list to solicit the views of Agency staff.

5.5 IT Equipment

Portable IT equipment also offers a potential replacement for a notebook, dictation machine and/or mobile phone. The following discussion was distributed for review and comment. Two types of equipment will be briefly discussed:

- laptop computer
- combined mobile telephone/fax and personal organiser.

A laptop computer would be capable of electronically storing much of the necessary information that might be required during an emergency response. This could include information on procedures, health and safety, contact lists, inventory lists, input sheet templates and quality requirements etc. The laptop would also be available for electronically recording information about the incident. However, a potential disadvantage of a laptop computer could be its size and weight. These items can be relatively large and heavy, depending on the model selected. Their use during arduous or inclement conditions may also be difficult. An additional potential problem may be theft of the computer as laptops are sometimes targeted by thieves.

An alternative to a laptop would be a portable communicator. These units offer communication and recording capabilities in a single versatile hand held machine. Capabilities can include mobile telephone/fax operations, personal organiser functions, internet terminal and www access and various standard personal computer capabilities such as calculator, calendar and note book functions. Some units can also be interfaced with personal computers. Potential disadvantages with this equipment would be similar to those characteristics to mobile telephones in general; limitations on standby duration and talk time, and possible problems of network connection. Again, as with a laptop, theft of this type of equipment is also a possibility. One system, the NOKIA 9000, weighing 397 g, has a 2 MB user memory, a standby time of 2 hours and a talk time of 30 minutes.

5.6 Equipment Storage in Vehicle

Storage of all equipment in a vehicle needs to be undertaken in such a manner that it is adequately secured yet readily accessible. Good organisation and housekeeping are essential, especially if storage space is restricted. An ideal situation will probably be a dedicated van where adequate stowage space and equipment are provided. However, in many situations it may be necessary to operate from the back of a smaller vehicle such a an estate car or similar. This section records a discussion of equipment storage that was circulated for consultation.

The ideal van would have storage compartments and cupboards, including a refrigerator/freezer unit, that can be adequately latched when the van is in motion. This will include a document cupboard, a chemical cupboard and a cupboard to hang protective clothing and store PPE. All storage units should be adequately labelled indicating the contents. Where any of the stored material needs to be carried from the vehicle to the incident site then this should be stored in a range of standardised storage containers fitted with carrying handles. Additionally, as far as possible the storage space should be arranged such that clean and dirty materials could be kept separate, and that any materials for disposal are isolated.

In less ideal situations a range of standardised storage containers may be an appropriate option, again adequately labelled indicating contents. Ideally these should be all of the same size and design, as far as is possible, and fitted with a carrying handle. The shape should be such that they can be safely stacked on top of each other while the size should be such that it is manageable when full. These should be packed so that equipment is segregated into function and such that equipment that may need to be transported away from the vehicle is separate from that which can remain with the vehicle. Where practicable equipment should be kept in their original containers, especially if delicate instruments are involved. When placed in the vehicle those containers holding items identified as essential should be placed such that they are the most easily accessed.

On occasion it may be necessary for quantities of equipment to be transported from the vehicle to the incident scene. In many incidents this can be done manually, and indeed, depending on terrain and access issues, this may be the only viable option. If this is the case then pre-packing into standardised and manageable containers would have benefits. Additional equipment could also be carried in a rucksack. On other occasions the use of some sort of wheeled device to convey equipment at least part-way may exist. In some past incidents wheelbarrows have been used but these are not necessarily the best design for this purpose. Again, if the majority of equipment to be transported is stored in standardised storage containers of similar size and shape then an alternative such as a sturdy baggage trolley with large wheels may be appropriate.

5.6.1 Storage of Personal Protective Equipment

PPE should be stored in a manner that is not likely to damage it or reduce its capability to provide the protection it is designed to provide. There may be advantages in segregating equipment into essential and supplementary categories and stowing these in separate containers. If cupboard or hanging space is not available then a standardised storage container or "grip" type canvas or waterproof bag would be suitable.

Following response to an incident it is desirable to have separate storage facilities for soiled and clean PPE. To this end it is beneficial to have large polythene bags available to accept dirty or contaminated clothing or wellingtons for example.

Any personal attack alarm should not be stored in a vehicle during a response but should be carried by the Officer.

5.6.2 Storage of Investigation Equipment

Investigation equipment should be stored in their original containers as far as is practicable. These containers in turn could be stored all together in a single standardised storage container fitted with a carrying handle. In this way all investigation equipment would be transportable as a single unit.

5.6.3 Storage of Sampling Equipment

Sample bottles should be stored in standard storage containers, crates, cool boxes or cooling units and adequately secured. These facilities should be adequate in order to segregate new bottles from filled bottles and to separate relatively uncontaminated samples from very contaminated samples.

Filled samples should contain the appropriate preservative if necessary, and be kept at the desired temperature. This can be achieved by the use of freezer packs or a refrigerator/freezer unit if available. Any freezer packs should be kept in the refrigerator/freezer unit until necessary. Filled sample containers should also be stored in the dark.

Preservatives and any other reagents should be stored in there original containers and kept in a secure cabinet or standardised storage container such that any released liquids are adequately contained in the event of a spillage or breakage.

Sampling equipment should be stored in a manner to keep it dry and clean. Again, standardised storage containers could be used if appropriate. Contact with any contaminated materials should be avoided while in storage and if the equipment is obviously contaminated it should not be used.

Filters and filtration equipment should be kept in a clean box and if any syringes are used a sharps disposal box should be included. These again can be included within a standardised storage container.

5.6.4 Storage of Recording/Reporting Equipment

Recording/reporting equipment should be securely stowed and in a manner to keep it clean and dry. A standardised storage container or a grip type canvas or waterproof bag could again be used. However, as it is possible that some items will be carried on the person during an incident, access to any such container would need to be rapid. Waterproof containers specifically for items such as mobile telephones and radios are also available.

5.6.5 Storage of Security Equipment

Any security equipment must be securely stowed and, if possible, located together in the same area of the vehicle. As access to this equipment would often be secondary following investigation it need not necessarily be stowed in the most readily accessible location. However, a loud hailer would need to be accessible.

5.6.6 Storage of Other Equipment

Some of the equipment identified as "other" may not in fact need to leave the vehicle; certain documents needed only as reference and any disposal bag or container for clean-up materials or consumables are examples. Such items would however require space within the vehicle.

Hand tools should be stowed in a standardised storage container, tool bag or box. Tool boxes and larger tools such as man-hole key, shovel and crow bar would need to be securely stowed, but remain accessible.

6 EQUIPMENT SUPPLIED TO FIRE SERVICES

The Environment Agency supplies selected equipment to the Fire Services as these organisations are often the first on the scene of an incident that might involve an oil or chemical spillage. In addition to equipment supplied by the Agency, some Fire Services also hold their own equipment that might be used in the event of a spillage.

The range of equipment that may be required by the Fires Services is briefly discussed under the following headings:

- containment
- recovery
- storage.

However, it is recognised that these three aspects are not necessarily independent and that the distinction between them is transitional. A major requirement of the equipment is that it must be intrinsically safe. Note that this discussion is not intended to be all encompassing and does not include health and safety equipment. Neither does it consider ancillary equipment that might be required such as manhole lifters, disposal bags for oiled or chemical waste, or items such as squeegees, brushes, shovels and spades.

6.1 Containment

Many spilled products are liquids at ambient temperatures and will therefore flow under the influence of gravity. In these situations a primary role of the responder is to contain the spilled liquid. The major issues of containment include liquid control:

- within a leaking vessel
- in non-confined (open) spaces
- at small entrances such as doorways and alleyways
- at drains and manholes
- on water surfaces.

Any Fire Service responding to a spillage will thus need to have appropriate equipment to fulfil these containment needs. Each is discussed in turn.

6.1.1 Containment within a Leaking Vessel

Methods for containing liquids within a leaking vessel include:

- reorientation of the leaking vessel so that the rupture is at its highest elevation - this may not always be practicable, especially with large vessels
- blockage of the leak with appropriate materials such as a leak sealant, patch or bandage
- placing the leaking vessel inside of another container such as an overdrum, drum sleeve or bund.

Leak sealants can be either epoxy or clay based. Dammit and Plug n' Dike are clay based products and are available both pre-mixed and dry; the latter requiring mixing with water prior to use. Although the Fire Service will often have ready access to water there may be situations when a premixed sealant will allow a more rapid response. Such sealants are suitable for small leaks in vessels and pipes of various sizes. The life of a repair with Dammit is stated as 24 hours which provides sufficient time for making the site of an incident safe.

Pig Repair Putty is a two part epoxy product that can be used as a leak sealant. Both parts of the product exist in the same tube and need to be kneaded together with the fingers prior to use. This can take a couple of minutes and might be detrimental in an emergency. The product also takes 20 minutes or so to set and dries hard within an hour.

Sealing bandages are also available but are more appropriate for small vessels or pipes only. They may also require the use of water to activate them and can be difficult to apply to an active leak. A curing time at specified temperatures may also be necessary. These materials would not be suitable for emergency use.

Overdrums and drum sleeves are useful for providing containment of leaking or damaged drums. However, a potential difficulty would be the handling of the damaged container to get it into the overdrum or sleeve. Overdrums and sleeves are also useful when damaged drums are being removed from the site of an incident or for the storage of any recovered liquids. It is recommended that any overdrum be lined if possible prior to use. This would minimise contamination and aid cleaning and so obviate the need to dispose of the actual overdrum.

The most useful item for containing liquid in vessels with small leaks would generally be a clay based leak sealant. If leaks are large they are extremely difficult to control and it is quite conceivable that all liquids above the leak would have already drained out. However, tanker leak seal kits are also available. In certain circumstances it might also be possible to use inflatable drain seals or pipe blockers to seal leaks in vessels.

6.1.2 Containment in Non-Confined Spaces

Possible methods of containing liquids in non-confined spaces include:

- sorbent socks/booms
- dykes of particulate sorbent or encapsulation material
- non-sorbent barriers such as flexible polyurethane or water filled plastic tubing (or even water filled fire hoses).

All methods involve the placement of the containing material around the site of the spillage. Sorbent socks or booms are versatile in that they can be laid to any geometry. However, on an extremely rough surface they may allow liquid to pass underneath, although some products claim to have very good ground hugging properties. They are rapid to deploy and have the added advantage in sorbing some on the spilled liquid and thus assisting with liquid recovery. They are also easy to recover.

Particulate sorbent and encapsulation material can also be laid to any geometry. It also has an advantage on very rough surfaces where it will readily conform to surface contours and so minimise the amount of liquid passing underneath. Particulate sorbents are less easy to recover in that they require sweeping, shovelling and bagging/drumming. However, they can have an important role in liquid recovery. A particular issue with sorbent materials is to ensure that they are compatible with the material being spilt. For example, different socks/booms are specifically available for oil and for chemicals.

Non-sorbent barriers are probably less versatile in both the geometry they can be laid in and also the contours to which they will conform. Thus leakage beneath them is possible on very rough surfaces. They also do not have a role in liquid recovery as they are non sorbent. Such barriers will also need to be cleaned should they be returned to storage.

The most useful items for containing liquid in non-confined areas would generally be sorbent materials. Both sorbent booms and particulate sorbent and encapsulation materials have a role. However, it is necessary to ensure that sorbents are available for both oil and chemicals.

6.1.3 Containment at Small Entrances

Methods for containing liquids at small entrances such as doorways or alleyways are similar to those described above for containment in non-confined areas. However, some of the proprietary non-sorbent products are also marketed specifically for this role. The same potential problems of potential leakage on very rough surfaces and no capability for liquid recovery again exist.

6.1.4 Containment at Drains and Manholes

Methods of containment at drains and manholes can take two approaches: either preventing the liquid from getting near the drain in the first place; or by preventing the liquid entering the drain once it gets there. The former approach uses those methods described for containing liquids in non-confined areas or at small entrances. The second approach uses a variety of methods including:

- customised drain covers
- non-customised drain seals fitting over the drain
- non-customised drain seals fitting within the drain.

Customised drain covers would generally exist only for site specific application; for example, at a location within a factory where a spillage is likely. They would not normally be of general application in an emergency elsewhere.

Non-customised drain seals that fit either over the drain cover or within the drain are more versatile. Their are various major types:

- sand bags
- water filled tetrahedral plastic bags
- sheets of flexible polyurethane material
- sheets (and tubs) of clay based material
- inflatable drain seals/pipe blockers.

Sand bags are an established method of blocking various openings. Once deployed they are generally stable. However, they may have some difficulty to conforming to very rough surfaces and so might permit some leakage of liquid beneath them. A disadvantage with sand bags is that they are heavy to transport in a filled condition, or require a source of sand or similar material should they be filled on site. The later approach will also lead to a delay in deployment while the bags are being filled. Sand bags will have some success in blocking road drains with both a vertical and horizontal opening but it will be difficult to prevent all leakage.

Tetrahedral shaped plastic bags are available in a variety of sizes. These are used by filling with water and placing over the drain or manhole. They thus require a source of water on-site for their deployment. As these drain seals can contain a depth of water of several centimetres within them they are generally stable even in the presence of a considerable amount of spilled liquid. However, they may have some difficulty to conforming to rough surfaces and so might permit some leakage of liquid beneath them. If the drain is slightly proud of the surrounding surface, and the perimeter metal surface is clean, then a better seal might be achieved. Water filled drain covers will have some limited success in blocking road drains with both a vertical and horizontal opening but it will be difficult to prevent all leakage. An advantage with this type of seal is that they are easily stored and transported.

Sheets of flexible dense polyurethane material can also be deployed. These are laid directly over the drain or manhole. The flexibility of the material allows it to conform to some extent to the underlying surface although with rough surfaces there may be some leakage. Again, if the drain is slightly proud of the surrounding surface, and the perimeter metal surface is clean, then a better seal might be achieved. In the event of a road side drain having both a vertical and horizontal opening then there will be additional difficulty in ensuring that an adequate seal is obtained against the vertical opening and at the angle between the two openings.

Sheets of clay based sealant such as Dammit X and Plug Rugs can be used to block drains and manholes. As many sheets as necessary can be deployed to fit a drain of any size. The various sheets can be moulded to the surface and joins reinforced with additional clay sealant from tubs. The sheets can also be used to seal road drain openings with both vertical and horizontal openings and any potential areas of leaks plugged with the additional clay sealant. Although this approach potentially provides a better seal on uneven surfaces as the clay can be moulded to shape the material is likely to take longer to deploy. In some situations it may be appropriate to use the clay sealant alone; for example for sealing between the joints of the cover-plates on manholes. Additionally, the clay could be used to seal around the edges of any other material (either drain seal or material such as plastic or metal sheeting) that is used to cover a drain.

Inflatable drain seals/pipe blockers fit inside the drain. As they need to be sized according to the dimensions of the drain/pipe it is necessary for several sizes to be available. However, cone shaped seals/blockers are available which are applicable to a wider range of orifice dimension. Drain seals/pipe blockers offer a potential to create a good seal, especially on clean surfaces but would be better suited for round drains rather than rectangular drains. As these devices are fitted within the drain/pipe, the roughness of the ground surface and the nature of the surface opening have no influence on their success. However, if the sides of the drain/pipe are particularly dirty then there may be some leakage. Inflatable drain seals/pipe blockers can also be used for other applications such as blocking large conduits containing ditch drainage under driveways or field entrances, and possibly for sealing leaking vessels.

The most useful items for containing liquid at drains are probably sheets (and tubs) of clay based leak sealant, inflatable drain seals/pipe blockers and possibly sand bags. As clay appears to perform the best on both clean and dirty, smooth and rough surfaces then where possible this should be the material of choice. However, in order to reduce the quantity needed, it could be used in conjunction with sheets of impermeable material such as metal, plastic or heavy duty polythene. In this way the impermeable sheet is placed over the drain and the clay used to seal around the edges.

6.1.5 Containment on Water Surfaces

Spilled liquids will float on the surface of a water body if their density is sufficiently less than water and if there is only restricted turbulence in the water. Such a liquid can be contained if conditions are favourable. The primary approach to containing floating liquids is the use of booms although bubble barriers can also be used. Three major types of boom can be deployed:

- sorbent boom
- inflation containment boom
- permanent buoyancy containment boom.

Sorbent booms are not specifically designed for containment on water surfaces but can be deployed for this purpose if there is negligible water flow. They do have the advantage in that they also undertake the role of liquid recovery. They are available specifically for hydrocarbons and for chemicals. For a containment function that can be rapidly deployed, being laid right across the width of a water course if necessary. They can also be used to contain other sorbent materials such as pillows or pads which are being used for recovery. Sorbent booms have a limited tensile strength which will restrict the range of flow rates with which they can be used and the length of boom which can be deployed. Sorbent booms have a very shallow draft once deployed, especially in the early stages of deployment when little material has been sorbed. This provides only limited containment capability when there is any water flow as any surface liquid may be entrained by the current and lost below the boom.

Inflation and permanent buoyancy booms provide a containment function only. However, they will generally be more robust than sorbent booms and can thus be deployed in greater lengths and with faster currents. These booms will also have a greater draft than sorbent booms and thus be more able to contain material in the presence of a current. However, they will still loose liquids by entrainment under the boom should the current exceeds 0.25 - 1.0 m/s (depending on the angle between the direction of flow and the boom). Permanent buoyancy booms are quick to deploy but are bulky to store, although some products are designed to fold and so ease storage and transport. Inflation booms need to be inflated before use but require less storage space.

Whereas sorbent booms can be used for containment on water surfaces where there is no flow they are not specifically designed for this purpose. However, containment boom, either inflatable or permanent buoyancy, is designed specifically fir this purpose and is to be preferred. Whereas as inflation boom has the advantage of easier storage, permanent buoyancy boom can be more rapidly deployed. Folding permanent buoyancy boom is available that is easier to store and transport than most permanent buoyancy boom.

6.2 Recovery

Recovery of a spilled product can be undertaken once containment has been achieved. The major situations from which a liquid needs to be recovered include:

- leaking vessels
- contained areas
- drains and manholes
- water surfaces.

Any Fire Service wishing to recover spilled liquids may thus need to have appropriate recovery equipment for these different situations. Each is discussed in turn.

6.2.1 Recovery from Leaking Vessels

The contents of leaking vessels can be recovered if necessary by manhandling to empty the liquid into an appropriate container. This may however, not always be practicable. An alternative would be to use an appropriate pumping mechanism although it would need to be intrinsically safe. Portable compressed air driven devices are available that entrain the drum contents by venturi suction. Drums would generally be appropriate to receive the recovered liquids and it is recommended that these be lined prior to use where possible. This would minimise contamination, aid cleaning and so obviate the need to dispose of drums.

Storage vessels can also be used to collect leaking liquids directly. One product, termed a Pop-Up Pool, is a sprung steel framed automatically expanding device. This has a low wall height (20 or 30 cm) and so can readily be positioned under leaking vessels such as a leaking fuel tank of a lorry.

6.2.2 Recovery from Contained Areas

The methods for recovery of liquids from contained areas are essentially by the use of sorbents or pumps.

Sorbents would be used in many instances for product recovery; either alone where the liquid layer is thin, or in conjunction with a pump if the liquid layer is thick. The range of sorbents that can be used for recovery include pads, mats, rolls, socks, pillows and particulate material. All are easy to deploy and recover. The particulate material would be useful in areas of complex geometry or difficult access but is more difficult to pick up in that it needs sweeping, shovelling and bagging/drumming. Sorbents for spill applications are specific for oil and for chemicals. However, consideration can also be given to the use of industrial grade sorbents that are cheaper; these might be used in situations where a spilled chemical is known to have only limited aggression while the more expensive chemical sorbents can be restricted to use with unknown or more aggressive chemicals. In this way it might be possible for more sorbent to be available for a given cost.

Pumps can be deployed in situations where there is sufficient depth of the liquid, or where the liquid can be directed to a sump area. Pump inlet hoses can also be fitted with appropriate shaped heads to improve suction when liquid depth is shallow. Any pump would again need to be intrinsically safe. Water driven pumps (either turbine or peristaltic) are available which can be driven by water from fire hoses.

Sorbent materials in a range of product types, including particulate material, are essential for liquid recovery. A pump is also advantageous in situations where the liquid layer is thick.

6.2.3 Recovery from Drains and Manholes

Liquid recovery from drains and manholes is probably beyond the role of the Fire Services. Consequently, this section is restricted to a listing of possible methods that might be used. These are:

- pumps
- gully suckers
- small skimmers
- sorbents.

6.2.4 Recovery from Water Surfaces

Liquid recovery from water surfaces is again probably beyond the role of the Fire Services. Consequently, this section will again be restricted to a listing of possible methods that might be used. These are:

- sorbents
- gully suckers
- skimmers.

6.3 Storage

Some storage capacity will be required for both recovered product or associated water, and any spent recovery products such as sorbents or encapsulation products. It may also be necessary for product:water separation equipment to be available so that the quantity of liquid needing to be stored is minimised.

The range of equipment available for these purposes is discussed more fully in later sections of this report. Collapsible rigid rectangular tanks such as Fastank and TroilTank are appropriate although the latter would be quicker to deploy. An alternative device called the Pop-Up Pool has a low wall height and would also function as a collection vessel.

6.4 Equipment Required by Fire Service

The range of equipment that any Fire Service should hold is shown in Table 6.1 and classified as either essential or desirable.

Table 6.1 Equipment required by fire services responding to a spillage

Item	Use	Essential/ desirable
Clay based leak sealant; ready mixed only or both dry and ready mixed	Containment • stopping leaks in vessels and pipes • use with other products to minimise leakage into drains and manholes	Essential
Overdrums/drum sleeves	Containment • leaking vessels Storage • recovered liquids	Desirable
Sorbent products (Oil only and universal)	Containment and recovery • non-confined spaces • doorways and alleyways • drains and manholes • water surfaces	Essential
Particulate sorbents and encapsulation products	Containment and recovery • non-confined spaces • doorways and alleyways • drains and manholes	Essential
Clay sheets and leak sealant[1]	Containment • drains and manholes	Essential
Inflatable drain seals/pipe blockers	Containment • drains and pipes • ditch conduits	Essential
Sand bags	Containment • drains and manholes	Desirable
Containment boom; permanent buoyancy or inflation	Containment • water surfaces	Essential
Small intrinsically safe pump	Recovery • leaking/damaged vessels	Desirable
Intrinsically safe pump	Recovery • contained areas	Desirable
Storage vessel[2]/container and/or liquid separation equipment	Storage • spent recovery materials • recovered liquids • liquid separation.	Essential

[1]Sheets of impermeable material such as metal, plastic or heavy duty polythene can also be used as drain covers with the edges being sealed with clay sealant. Water filled tetrahedral plastic bags can also be used although these may be prone to leakage on rough surfaces.
[2]Collapsible storage vessels of low height may also be used for collection of leaking liquids.

7 BOOMS

Booms are used for containing oil or other surface pollutants and can be used on inland waters, estuarine and coastal waters or at sea. The Agency's primary interest would be with inland waters, and estuarine and coastal areas. Various types of boom are available (inflation, permanent buoyancy and sorbent) which might be applicable in these locations, and the design of particular types can vary. This would have an impact on their potential for successful deployment and use in the field. Sorbent boom can also be used to recover oil or a pollutant.

In still water on a calm day almost any size of barrier is effective for corralling oil or other floating pollutant. Even a thick floating rope can be utilised to move significant quantities of pollutant to a point where it can be recovered e.g. by vacuum tanker. Slow moving water (or wind) can aid the thickening effect and careful positioning of the boom and recovery equipment can lead to a more efficient recovery. However, larger and longer booms are required as water velocity increases, in addition more attention needs to be paid to the moorings and the shape of boom layout. At velocities above 1 m/s entrainment of the oil can take place and booms will generally fail to capture oil. However, one company (Ohmsett) in America is currently testing a prototype new oil boom, developed by the University of New Hampshire, which is claimed to be effective in up to 2 m/s currents. At these higher velocities normal booms may still be effective as deflectors, but the oil can be expected to be carried underneath if any attempt is made to contain it. In these situations, other techniques can be utilised to temporarily reduce the flowrate such as damming (with or without the provision of underflow).

Assuming that the waterways are slow flowing enough for booming to be an effective countermeasure, then decisions of size, length and type of boom, need to be made. Other factors which need to be considered are connector and valve types.

The size and length of boom will be dependant on the current velocity and the width of the waterway. The type of boom is a balance between the required speed of deployment, the weight (if the boom needs to be manually transported to inaccessible areas), any volume constraints for storage and transportation and wave following and oil retention capabilities.

Inflation boom will be the lightest and take up least storage space but will need to be inflated using a lightweight blower before deployment. This will result in some time delay before the boom can be deployed. Permanent buoyancy boom can be used immediately but is heavier and takes up more storage space. Connectors need to be compatible if lengths of boom are to be joined together for larger waterways. Careful attention to valve quality and closure is required as grit in the seals etc. may cause leaks and result in the boom deflating in use.

This section examines the following three applications:

- sorbent booms
- containment booms for narrow waterways
- coastal and river containment booms.

7.1 Sorbent Booms

Sorbent boom is most useful in still water for recovering thin films. Generally there are no skirts fitted to sorbent booms although one or two models (e.g. a Drizit product) are available with them and may therefore be useful in slow moving water. If there is any appreciable flow then sorbent booms should be used in conjunction with containment booms and other sorbent forms.

The sorbency of these booms will in general be controlled by the sorbency of the sorbent material used in their manufacture. As such Section 4 gives some indication of the relative performance of different types. However, other factors can also influence their effectiveness. Generally the thinner booms are likely to be more efficient as they have a greater surface area to volume ratio. A disadvantage of sorbent booms is that the boom needs to be rotated so that the pollutant may contact all the contained sorbent. New styles of sorbent boom where the sorbent is loosely packed in side a loose netting of large mesh may also encourage more effective contact between the sorbent and the pollutant.

An evaluation of sorbent boom types that have potential for use in narrow waterways has resulted in the following recommendations:

- thin sorbent booms with or without skirts should be used
- booms without skirts can be used in still water
- booms with skirts should be used where there is any water movement
- sorbent boom should be used in combination with containment boom if there is any appreciable flow, such that the containment boom is downstream of the sorbent boom. Alternatively, the containment boom can be used in conjunction with other sorbent types
- consideration should be given to the use of double booms, more than one single boom or a single boom along with other sorbent types if the boom is to be left unattended.

Effectiveness of sorbent boom may depend to some extent on the sorbent used (see section on sorbents).

7.2 Containment Booms For Narrow Waterways

The types of boom for use in waterways up to ten metres wide will depend on the current velocity encountered. A very lightweight boom which can be footpump inflated takes up very little space in a vehicle and could perhaps be permanently kept in all relevant Agency vehicles for use in an emergency. Some types of boom are multi-use and others are designed as single use disposable items. Lightweight booms come in several different standard or custom lengths and have their own lightweight connection systems. These 'own brand' connectors (Figures 1 and 2) are probably quite suitable for this type of use as it is unlikely that they will need to be joined to heavier types of boom. However, it would be beneficial to decide on one type to maximise purchasing discounts and to ensure continuity so that lightweight boom can be connected together when necessary. Heavier boom (0.3m or greater) for deployment in faster flowing rivers probably needs to be carried in a dedicated response vehicle or held in strategic stockpiles.

For shorter lengths of boom used in narrower waterways with little or no wave following requirement, it would be feasible to use permanent buoyancy boom which is faster to deploy in an emergency. However, attention again needs to be given to the connector types, so that different types/sizes of boom may be joined together if required. Unicon and ASTM connectors (Figures 4.3 and 4.4) are both suitable and make reasonably rapid connections but are not compatible with each other. Other types of connection are usually slower and may involve the use of 'u' bolts and nuts (Figure 4.5), etc.

Tables 7.1 and 7.2 indicate the specification of some selected permanent buoyancy and inflatable booms respectively.

An evaluation of the various boom types that have potential for use in narrow waterways has resulted in the following recommendations for boom selection:

- for low velocity applications -
    - lightweight
    - high visibility
    - inflation or permanent buoyancy
    - own brand connectors
    - custom lengths
    - height; ~ 200-300 mm
    - freeboard; minimum of 30 % of height
    - draft; minimum of 50 % of height.

- for high velocity applications -
    - heavier
    - high visibility
    - fence boom with built in buoyancy but where weight, access or storage is a problem then inflation boom may be substituted
    - easily cleanable
    - standard ASTM or Unicon connectors
    - height; ~300 mm upwards
    - freeboard; minimum of 30 % of height
    - draft; minimum of 50 % of height.

It is further recommended that a range of boom lengths be purchased so that units can be connected to accommodate site specific length requirements.

7.3 Coastal and River Containment Booms

The compatibility of stockpiled Agency boom with that held by other organisations such as the MPCU, SEPA and OSRL was examined. It was found that the various stockpiles have equipment ranges that are largely non-compatible.

Three main aspects were identified that contributed to this non-compatibility:

- the different roles and areas of operation -the operational requirements to be served by different stockpiles resulted in widely different types and sizes of boom being needed
- purchasing for site specific applications - boom was often bought to fulfil the requirements of a particular location or role
- non-standard specification - even where booms of the same type were identified the problems of compatibility were not simply resolved. Numerous types of boom connector

exist, and any particular boom type could be fitted with a different connector type, even if obtained from the same supplier.

In view of these findings it was considered beneficial to develop a generic boom specification for the Agency. In this way, the Agency would progress towards internal compatibility over a number of years.

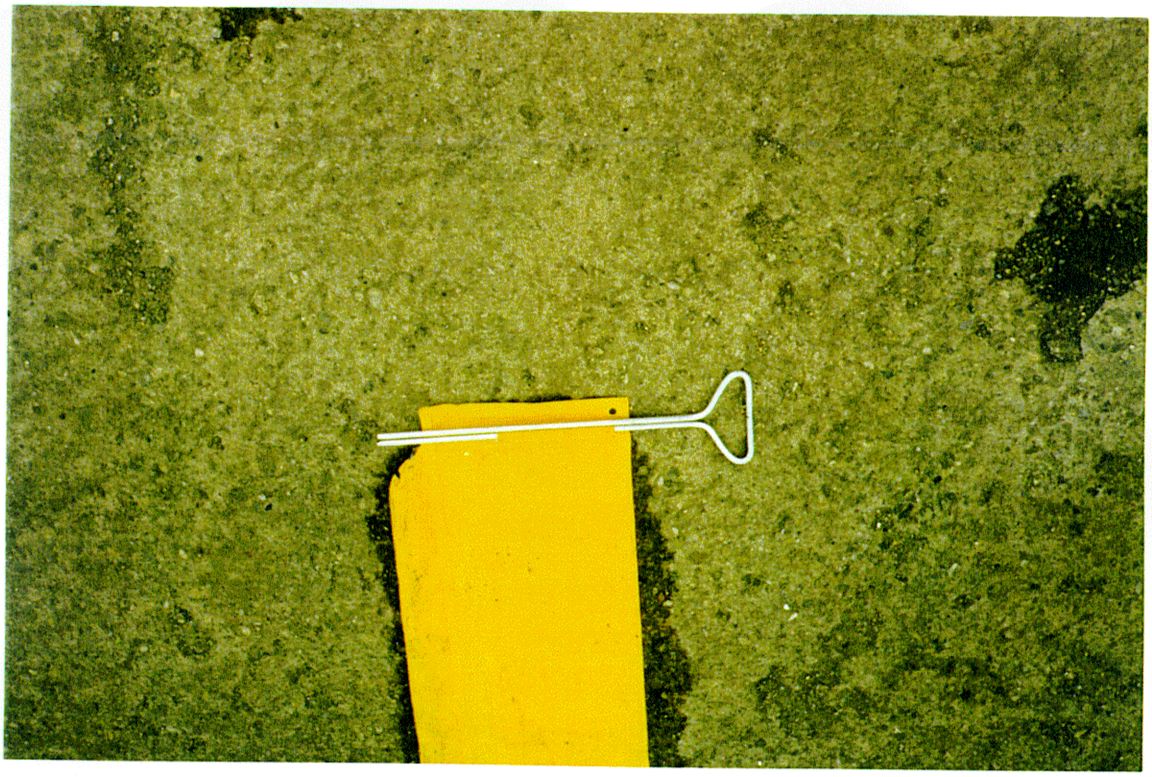

Figure 1: Darcy "Own Brand" Boom Connectors

Figure 2: Gilchrist "Own Brand" Boom Connectors

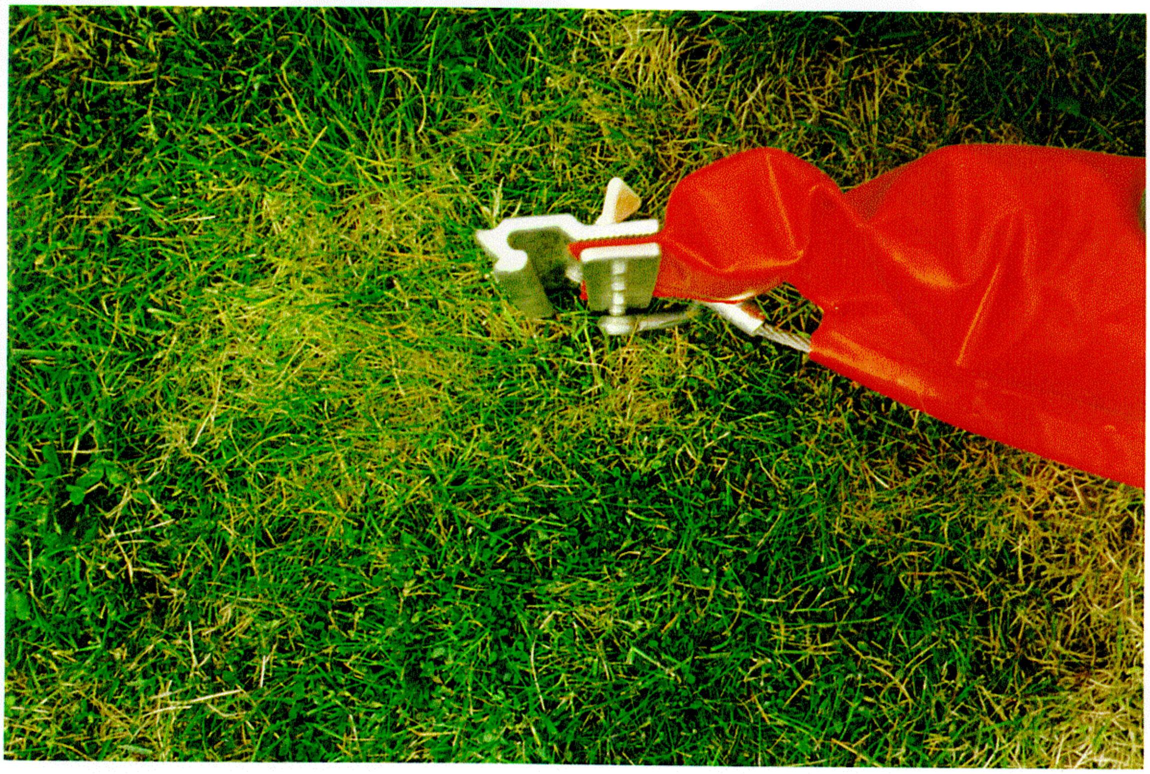

Figure 3: Unicon Boom Connector

Figure 4: ASTM Boom Connector

Figure 5: "U" Bolt and Nuts Boom Connector

Figure 6: Oil:Water Separator Supplied by Darcy Products Limited

Table 7.1 Specifications of selected permanent buoyancy booms

Boom Name	Height (m)	Freeboard (m)	Draught (m)	Weight/m (kg)	Strength of Boom Wall (tonnes)	Section Length (m)	Comments
Troilboom Curtain 450	0.45	0.20	0.30	3.1	4.40	15	U Bolt of ASTM quick connector
Troilboom Curtain 750	0.75	0.25	0.50	4.2	4.40	15	U Bolt of ASTM quick connector
Troilboom GP 250	0.25	0.08	0.17	1.7	2.0		U Bolt of ASTM quick connector
Troilboom GP 450	0.45	0.15	0.30	3.1	6		U Bolt of ASTM quick connector
Troilboom River 750	0.75	0.25	0.50	4.0	5.0	15	U Bolt
Silverboom 25P	0.25	0.10	0.15	1.0		2.5,5,10	
Silverboom 50P	0.50	0.20	0.30	3.5		5,10	
Hoyle 300	0.30	0.10	0.20	3.8		6,12,24	Minicon quick-fit connectors
Hoyle 600	0.60	0.15	0.45	7.3		10,20	Unicon quick-fit connectors
Edge Solid Boom	0.40						
OSCAR Boom	0.45						Navy connector/Quick connector
Global 50 Barrier Boom	0.25	0.10	0.15	1.0		2.5,5,10	
Global 200	0.50	0.20	0.30	3.5		10	Union connectors
Global 300	0.75	0.25	0.50			10	Union connectors

Table 7.2 Specifications of selected inflatable booms

Boom Name	Height (m)	Freeboard (m)	Draught (m)	Weight/m (kg)	Strength of Boom Wall (tonnes)	Section Length (m)	Comments
Ro-boom 610 River	0.61	0.21	0.30	4.0		13,25,50,100	12 Buoyancy chambers per 25m
Ro-boom 1000	1.60	0.36	0.43	5.5	(200N/mm)	15,25,50,100	Splash over prevention fin - 62 buoyancy chambers per 200m
Gilchrist Mini Flexi-Boom	0.25	0.13	0.10			5	Connector Bars & Karabiners. Can be made to measure. Disposable
Gilchrist Inflatable Boom	0.70					10,50,100	
Gilchrist Anti Pollution Boom	0.70	0.30	0.40	0.7		100	Disposable by incineration
Silverboom 45i	0.45	0.20	0.25	1.0		5,10	Weight is 2 kg/m with ballast chain
Silverboom 75i	0.75	0.35	0.40	2.0		10,20	
Edge River Boom	0.20						
Edge River Boom	0.40						
Global 100	0.45	0.20	0.25	2.0		10	Union connector - 5 air chambers/10m
OPEC River Boom	0.315	0.16	0.155			5	
Poly-boom		0.18	0.14			15,30,150	Used for containment on land or water. Can be cut to length and ends tied. Disposable

Coastal and river booms are generally larger types of boom (i.e. up to around 2 metres with a large freeboard). They would generally need to be inflation type to allow for easier handling and transportation although larger versions are still very heavy, need to be stored on a reel, require boat deployment and recovery and use of a winch. Inflatable booms have a better wave following capability and oil retention characteristics than other types of boom.

However, where a river is tidal, provision may need to be made to allow for rise and fall of the tide. In these circumstances a boom such as shore guardian, which is partially water filled and seals to the beach could be used. Another option is a proprietary tide following device called a tidal compensator which could be employed if booming from fixed structures e.g. across water intakes or from harbour walls solid jetties etc. though this would probably need to be permanently fitted to the structure as a previously planned booming point. Strength (and anchoring) needs to be considered with this type of boom as it may be left out in unfavourable weather or tidal conditions. Even although under these circumstances it may not be capable of pollution recovery or deflection, it may need to be left in position until such time as it can be conveniently reclaimed. If the boom is likely to be left unattended, then consideration should be given to using boom with a two stage valve system to minimise the possibility of deflation due to valve leakage. This normally means a diaphragm valve with a screw lid which is also capable of sealing.

When booms are deployed in larger rivers or coastal areas it is more likely that lengths of boom and different types of boom may need to be joined together. Potential requirements for connecting different boom types might be where long lengths of boom are to be used for deflection purposes, or when joining a beach sealing type of boom to a normal 'in water' type. It is therefore important to choose a connector that will allow this to be done easily and quickly during the deployment, and in unfavourable conditions. As with the booms used in smaller waterways the Unicon or ASTM connectors are both suitable.

The review of boom available for coastal and river use has resulted in the following recommendation for boom of normal use:

- high strength
- durable
- inflation boom
- easily cleanable
- standard ASTM or Unicon connectors
- multiple anchoring points
- height up to 2m
- freeboard; minimum of 30 % of height
- draft; minimum of 55 % of height
- minimum breaking load for rivers; 50 kN
- minimum breaking load for coastal areas; 100 kN.

It should be stressed that these recommendations might not necessarily apply to specific sites where site booming plans have been or will be undertaken. The specification for bespoke boom for such sites should be determined by a knowledge of local conditions of current flow, geometry and anchoring opportunities.

8 SKIMMERS

A literature review of skimmers was undertaken. This section first reviews the various types of skimmer available and then considers skimmer selection.

8.1 Types of Skimmer

The following skimmer types were identified from the literature:

- suction
- disc
- rope mop
- weir
- drum
- vortex
- belt
- brush
- submersion.

Skimmers will usually need to be used with some sort of thickening, deflection or encounter device such as booms. These are required in order to achieve one or both of the following: to minimise the amount of oil or chemical that might otherwise flow past the weir in a current; or to enable the pollutant to be brought to the device in a reasonable concentration and thickness. These measures help to increase the recovery rate of the pollutant and also improve the efficiency of the skimmer by avoiding excessive uptake of water. Excessive water uptake is undesirable because this:

- increases subsequent water/pollutant separation requirements
- can increase handling difficulties
- can result in increased transport and disposal costs.

Many of the types of skimmer are made in sizes small enough to be reasonably easily handled (by one or two people) and transported by car. Some come as vehicle mounted versions. Most have little or no on board oil storage of their own and therefore need to be used with pumps and temporary storage tanks or vacuum tankers.

The first four types of skimmer listed above would be the most useful for inland spills of oil, i.e. suction, weir, disc and rope mop. For spills of floating chemicals the range is mainly restricted to suction and weir skimmers. However, all types are briefly reviewed in the following sections.

8.1.1 Suction Skimmers

Suction skimmers are normally lightweight skimming heads that need to be attached to a vacuum tanker hose. Good vehicle access is needed as the use of long hoses can result in excessive pressure drop. Suction skimmers work well in calm water where there is a reasonably thick layer of pollutant, and over a wide range of viscosities. They are not very effective if the water is choppy and are susceptible to blockage by debris. They are low maintenance and inexpensive.

It is also possible to use the open end of the vacuum tanker or Vaculite hose without any skimmer but this may cause excessive water to be taken up. However in certain circumstances e.g. with viscous oils, use of the water as a high velocity carrier fluid in this way may be the only way to recover it.

8.1.2 Disc Skimmers

Disc skimmers are small units that can be easily deployed by one or two people; larger units can be fixed installations or may be deployed by crane. An external pump is required to recover oil from the skimmer trough. Disc rotation speed can normally be varied to optimise oil recovery rate and efficiency. Disc skimmers are effective in relatively rough water as long as the wave height is significantly less than the disc diameter. They tend to be most effective with medium viscosity oils but do work with low and high viscosity products, though they will eventually become clogged. They are also susceptible to blockage by debris. They are quite low maintenance items but tend to be expensive to purchase.

8.1.3 Rope Mop Skimmers

Rope mop skimmers are of several different types (including permanent in-situ and larger vessel mounted versions), each requiring various deployment strategies. The simplest type operates on the top of a 200 l drum which serves as the receptacle for the recovered pollutant. Care should be taken to ensure drums are only filled to maximum of two thirds of their capacity in order to avoid spillage and ease handling during transport. No external pumps are needed for this version, which works well in small waves and with any thickness of oil/pollutant including sheens. Rope mops achieve a good recovery for medium to high viscosity oils and they are not susceptible to blockage by debris. They are quite low maintenance items and reasonably priced. Dirty mop storage and cleaning requires care as does their deployment.

8.1.4 Weir Skimmers

Weir skimmers are also available as several different types. Smaller ones require an external pump while larger versions have an onboard pump. The weir height and pumping rate require adjustment in use to optimise the recovery efficiency and rate. They are good for light to medium viscosity products. Weir skimmers work best in thick layers of oil or pollutant but are not very suitable for use in choppy conditions. They are susceptible to blockage by debris. They are low maintenance items and relatively inexpensive and easy to deploy.

8.1.5 Drum Skimmers

Drum skimmers had at one time been largely replaced by disc skimmers although they are now being produced again. Drum skimmers are probably effective over a wider viscosity range than disc skimmers. They are also likely to be less susceptible to blockage by debris.

8.1.6 Vortex Skimmers

Vortex skimmers have reasonable recovery rates but poor efficiency. They work best in thick oil or pollutant layers but are not very suitable in choppy conditions (as vortex efficiency diminishes). Vortex skimmers are susceptible to blockage by debris. They are low maintenance items and relatively inexpensive.

8.1.7 Belt Skimmers

Belt skimmers are relatively bulky units with even the smallest generally requiring truck transportation. Most belt skimmers are vessel mounted. Consideration could be given to using belt skimmers (Egmopols) in the OSRL stockpile should appropriate circumstances arise.

8.1.8 Brush and Submersion Skimmers

Brush and submersion skimmers are normally vessel mounted, large and probably not appropriate for most inland applications.

8.2 Skimmer Selection

The major factor influencing the potential for use of a skimmer is the viscosity of the liquid being recovered. Table 8.1 summarises the potential for different skimmers according to viscosity groups.

Table 8.1 Skimmer selection for different viscosities

Viscosity		Skimmer
Low - medium	< 100 - 1000 cP	Suction Weir Vortex Belt (downward moving) Submersion
Medium	100 - 1000 cP	Disc Rope mop
Medium - high	100 - > 1000 cP	Drum Belt (upward moving)
All viscosities		Brush

Skimmers that are considered more versatile and of potential use to the Agency include the suction, weir and disc type along with rope mops. However, as usage by the Agency seems to be very low it is recommended that the Agency does not require any permanent pieces of equipment of this type.

9 AERATION, OXIDATION AND ABSORPTION TECHNOLOGIES

A review of the published documentation on aeration, oxidation and absorption technologies was completed and submitted to the Agency in November 1997. The executive summary of this report was included in the second progress report. Additional work has concentrated on operational and practical aspects of deploying aeration and hydrogen peroxide dosing equipment. Each is considered in turn.

9.1 Aeration

Five possible applications exist for the use of aeration equipment for the treatment of water:

- oxygenation - the primary purpose for treatment by aeration would generally be to increase rapidly the dissolved oxygen content of oxygen depleted waters or where there is a high chemical oxygen demand (COD) or biological oxygen demand (BOD)
- air stripping of volatile liquids - aeration can be used to strip volatile liquids such as solvents from water bodies
- air stripping of volatile gasses - aeration can be used to strip volatile gasses such as hydrogen sulphide from water bodies
- mixing - aeration equipment can be used to induce a degree of mixing in still or slowly moving water bodies should this be necessary
- chemical oxidation - the approach might also be used for the treatment of contaminated waters by chemical oxidation of any contaminants. However, it should be noted that chemical oxidation by air proceeds only very slowly.

Additional benefits from the use of aeration equipment is the maintenance of aerobic conditions for the biological oxidation of contaminants.

The method may be applied either after a pollution incident or because dissolved oxygen contents have becomes reduced. The approach is applicable to a wide range of moving and still waters including:

- ponds, lakes and reservoirs
- rivers, streams and canals
- ditches
- sewage, farm or industrial effluents.

However, the process is more effective for still or slow moving water. Fast flowing water is more difficult to aerate effectively unless large equipment or multiple units are used.

9.1.1 Effectiveness of Aeration

The effectiveness of any aeration process is dependent on a range of parameters. For example, if the primary aim of aeration is oxygenation, then the following parameters are important:

- oxygen transfer rating of equipment - this in turn is influenced by equipment design aspects such as air bubble size and mixing. Generally the smaller the bubble size and the greater the mixing the greater the oxygen transfer rate
- initial dissolved oxygen content of the water being treated - the rate of oxygen transfer is generally greater in those waters that have the greatest oxygen deficiency. Once the water being treated is saturated with oxygen then additional aeration will not increase the dissolved oxygen content

- water temperature - the oxygen transfer rate is greater at lower temperatures because of lower oxygen solubility as temperatures increase. For example, at sea level an oxygen solubility of 14.6 mg/l at 0°C falls to 9.2 mg/l at 20°C. This means that during periods of hot weather, not only can dissolved oxygen (DO) concentrations be expected to be lower, but it is also more difficult to increase these by aeration
- water depth - the amount of oxygen transferred into the water body increases with the depth of water above the aeration device
- mixing - in addition to any mixing induced by the equipment any natural mixing within the water body will increase the effectiveness of the aeration process as this will continually remove the treated water from the vicinity of the equipment and replenish it with untreated water
- atmospheric pressure and elevation - the effectiveness of aeration is also influenced slightly by atmospheric pressure and hence elevation. The solubility of oxygen is reduced with lower atmospheric pressure, and hence increasing elevation. However, the significance of any effects from atmospheric or elevational differences would not have any significant practical implications.

9.1.2 Methodology

Treatment of water by aeration requires suitable access to the water so that the necessary equipment can be brought to the site. Alternatively, some equipment might be appropriate for use from a boat.

If volatile liquids are present that might be amenable to air stripping it is important to consider the occurrence of these before any air stripping operation is undertaken. If, for example, the volatile liquid occurs as a free product on the surface of the water then the use of collection equipment such as sorbents or skimmers would probably be more appropriate.

In general the treatment of any particular water body can be improved by:

- the use of multiple aeration units
- the use of equipment with high oxygen transfer ratings
- increased treatment times
- increased mixing of the water body.

The number and type of equipment used for any particular application will depend on a variety of factors including:

- the size of the water body being treated
- whether the water body is static, slow flowing or fast flowing
- the degree and urgency of the treatment required.

With small water bodies, with limited flow, it may be appropriate to deploy small pumps and aerator units. Conversely, with larger water bodies, especially with flowing water, deployment of larger equipment (such as the River Rover) or multiple units, may be more appropriate. In situations where treatment is particularly urgent the use of hydrogen peroxide systems should also be considered.

The methodology for deployment of aeration equipment will vary according to the nature of the water body being treated. This will be discussed below for static and slow moving water, and fast flowing water.

Static and Slow Flowing Water

Aeration equipment will, in many cases, be used in static and slow moving water bodies. In these water bodies, if multiple units are available these should be distributed around the water body so that several areas are simultaneously treated. If only one unit is available then this should be deployed in a particular location and occasionally relocated. Where possible the equipment should be deployed in deeper water, unless operationally difficult, while ensuring that no bottom sediment is disturbed. In either situation, opportunity should be made to maximise opportunities for any mixing. For example:

- equipment could be deployed with a bias towards the upwind side of the water body
- equipment could be deployed near the location of any inflow to the water body. However, the potential benefits of this approach need to be considered; whereas any treatment here might encourage more rapid mixing, it is probable that any inflowing water already has a higher dissolved oxygen content than the water body being treated. (Conversely, if the inflowing water has a lower dissolved oxygen content then there are obvious benefits from treating as close to the inflow as possible)
- equipment should not be deployed near to the location of any outflow as any treated water may be removed rapidly from the water body being treated thereby providing no benefit to it. (Conversely, if the purpose of the treatment is to improve the treatment of the outflowing water, rather than the water body itself, then there are again obvious benefits in treating as close to the outfall as possible)
- the aeration equipment itself may induce some mixing. The level of mixing will depend on equipment type and number. Air diffusion units might induce some vertical mixing while venturi devices might also be used to encourage some horizontal mixing
- other methods of inducing artificial mixing (and often a degree of additional aeration) could employed. These include the use of pumps, pumps with sprayers, paddle wheels and water craft fitted with inboard and outboard motors.

Fast Flowing Water

Fast flowing waters are generally more difficult to treat effectively because the water that has been treated is continuously being removed from the area being treated. As a result larger or multiple aeration units may need to be used or treatment enhanced by the use of a hydrogen peroxide system.

When multiple aeration units are available these should be deployed across the channel width and, as far as possible, equally spaced. For example, if two units are available these should be placed at distances of one-third and two-thirds of the channel width. If only one unit is available then this should be placed towards the centre of the channel if possible, but can be biased towards any more slowly moving part of it such as an inner bank.

In any flowing rivers which are less rapid or turbulent, then the site of equipment deployment would be best suited to take advantage of any down stream mixing that might occur. For example, deployment just upstream of a constriction within the banks, or of a natural shoaling, would enhance mixing.

If it is deemed that treatment by aeration in one location only results in insufficient improvement of the DO concentration then it may be necessary to deploy additional equipment downstream at another location. This will provide a second opportunity to treat the plume of low DO. In the case of tidal water, the plume is likely to oscillate back and forth in the tidal reaches thus allowing it to be treated repeatedly at a single location as it passes back and forth.

9.1.3 Cessation of Treatment

Treatment of a water body by aeration should continue until any one of the following occurs:

- the conditions of the water are deemed adequate - it might be that particular target criteria for treatment have not been set prior to treatment. In this situation a pragmatic approach should be used to determine when to cease treatment. This might be when an odour problem has ceased or when dissolved oxygen contents are considered adequate
- the target conditions of the water are achieved - it might be that target criteria have been established for any treatment. These might be 80 % for dissolved oxygen content or a specific level for COD, BOD and TOC. When establishing any target criteria it should be remembered that the solubility of oxygen is lower in summer conditions than in winter conditions. For any contaminants, it might be reduction to the relevant Environmental Quality Standard
- resuspension of any solids - any disturbance of bottom sediment should be avoided; if this occurs then the treatment should be discontinued at the specific location and attempted elsewhere
- any hazardous situation arises.

9.1.4 Health and Safety

Aeration equipment is generally easily deployed and the procedure represents little or no additional environmental risk as no reagents are involved. (However, see paragraph below concerning air stripping operations.) Nevertheless, whatever equipment is used it is important that comprehensive operational and safety guidelines are available and followed.

Should any air stripping operations be undertaken then consideration should be given to health and safety, and environmental implications of any release of volatile compounds to the atmosphere. In some situations it may be necessary to undertake the process in an enclosed system. This is likely to result in practical constraints when operating in natural systems where large quantities of water are involved.

9.1.5 Equipment Availability and Utilisation within the Agency

The number and location of aerators held by the Environment Agency and included on the Strategic Pollution Equipment List is summarised in Table 9.1. However it is known that other equipment does exist that is not on the list, both in the Fisheries and Pollution Control functions e.g. Fisheries in Cheshire. The list alone indicates that some 45 aerators of various types are available, scattered through eight Regions and 19 Areas. However, it is known that the Strategic Pollution Equipment List is incomplete.

The utilisation of aeration equipment seems to vary considerably across the Agency. A major difference appears to exist particularly between the pollution control function and the fisheries function. With the pollution control function the utilisation is generally low and in some areas estimates suggest that this might be less than 10 % of available time. (In one case an estimation of <1 % was indicated.) Conversely, in Fisheries, utilisation appears to be considerably higher on occasion and may be approaching 100 %. In excess of ten incidents a day requiring the deployment of aeration equipment are by no means unusual and personnel indicated that additional aerating equipment was sometimes desirable. With fisheries, there were times when utilisation may be higher for particular reasons such as reduced water contents as a result of drought, or algal blooms or reduced DO contents as a result of prolonged hot weather.

In both the pollution control and fisheries functions, even when utilisation was low, it was stressed that ready access to equipment was necessary on those occasions when it was needed. Equipment sharing in times of need was found to occur. Particular ways in which this occurred were:

- Strategic Pollution Equipment list - this provided an awareness of what was available and where, and in some cases provided a contact telephone number
- equipment as a regional resource - some equipment was purchased as a regional resource but was held by a specific Area which would make it available to other Areas within their Region as necessary
- sharing of common resources between Fisheries and other functions of the same Area
- loans between Fisheries - equipment transfer between Fisheries in different Regions was found to occur if necessary.

Table 9.1 Location of Aeration Equipment across the Environment Agency

Region	Area	Aerator Type	Number
Anglia	Northern		0
Anglia	Central	Air Force Bubble Curtain River Rover Rose Water Vitox unit	1 3 3 1
Anglian	Eastern		0
Midlands	Lower Severn	River Rover	1
Midlands	Upper Severn	River Rover	1
Midlands	Lower Trent	River Rover	1
Midlands	Upper Trent	River Rover	1
North East	Dales	Maguire	1
North East	Northumbria	Aerator	1
North East	Ridings	River Rover Air Force	2 2
North West	North		0
North West	Central	Venturi Flowball AOLG2	3 3
North West	South		0
South West	Devon	Air Blowers	2
South West	North Wessex	River Rover (Mobile oxygen trailer)	1 (2)
South West	South Wessex		0
South West	Cornwall		0
Southern	Hampshire	Aerator	1
Southern	Kent	Echo Air Blower Flowball Aerator	2 2 1
Southern	Sussex	Aerator	3
Thames	West	Godiver with Vitox unit	1
Thames	South East	Aero 2	1
Thames	North East		0
Welsh	Northern	River Rover	2
Welsh	South East	River Rover	2
Welsh	South West	River Rover	2

While there are obvious benefits from equipment sharing during times of necessity there were also some reservations raised by the loaning party. These included:

- a need to ensure that the borrower would adhere to servicing and maintenance requirements of the equipment. For example, some equipment required oil changes after a given number of operational hours
- concerns over availability of equipment should the loaning party require it. The possibility of all appropriate equipment being out on loan and thus not available to the actual owner, was considered possible

- potential for damage of equipment. Concern was raised that the loaning party may have equipment returned in a damaged or un-serviceable condition. Concern was also raised about the need to cover capital, maintenance/servicing and storage costs on equipment that was then made available to others
- potential loss of equipment. In the past poor record keeping has resulted in loaned equipment not being returned.

A particular issue was raised by the fisheries function where, on occasion, during summer months there is a widespread demand for aeration equipment as many commercial fisheries were experiencing fish distress as a result of low dissolved oxygen content. Such fisheries might require aeration equipment for long periods and it was sometimes difficult to reconcile the loaning of Agency equipment to commercial organisations at a time when the Agency might require it themselves. A possible approach to meeting the demand of commercial fisheries might be to source appropriate equipment from hire companies. Such equipment need not necessarily be purpose built aeration equipment; pumps and spraying/jetting equipment might be suitably deployed to advantage instead. The Agency should consider the benefits of compiling a list of possible hire companies or other plant owners/suppliers who might provide such equipment. This list should be compiled on an Area basis and can then be accessed by commercial fisheries in times of need.

The Agency needs to ensure that the Strategic Pollution Equipment List continues to be up-dated routinely. This should also include equipment held by Fisheries.

9.2 Hydrogen Peroxide Injection

The Agency is currently funding an investigation into the use of hydrogen peroxide systems with a view of identifying appropriate guidelines and best practice for equipment application and deployment. The findings of this investigation should provide a more definitive statement of procedures for hydrogen peroxide use in the field. However, this section aims to give an indication of areas of application and methodology for the interim period.

Three possible applications exist for the use of hydrogen peroxide for the treatment of water:

- oxygenation - the primary purpose for the treatment of water with hydrogen peroxide would often be to increase rapidly the dissolved oxygen content of oxygen depleted waters or where there is a high chemical oxygen demand (COD) or biological oxygen demand (BOD)
- chemical oxidation - the approach might also be used for the treatment of contaminated waters by chemical oxidation of any contaminants
- odour control - hydrogen peroxide treatment can also be used for odour control. For example, the production of hydrogen sulphide by sulphate reducing bacteria can be eliminated.

Additional benefits from the use of hydrogen peroxide treatment can include a reduction in total organic carbon (TOC), maintenance of aerobic conditions for the biological oxidation of contaminants, removal of black sulphide deposits and reduction of microbial growth.

The method may be applied either after a pollution incident or because dissolved oxygen contents have becomes reduced. The approach is applicable to a wide range of moving and still waters including:

- ponds, lakes and reservoirs
- rivers, streams and canals
- ditches
- sewage, farm or industrial effluents.

Hydrogen peroxide treatment systems are considered to be more effective for increasing dissolved oxygen levels than aeration equipment using air or oxygen. As a result, a hydrogen peroxide system is likely to be more effective, and therefore preferred, in those situations where aeration equipment may have a limited effectiveness. These might include large water bodies, flowing water and situations where a more rapid increase in DO is required.

9.2.1 Methodology

Treatment of water with hydrogen peroxide requires suitable access to the water so that the necessary equipment can be brought to the site. Access difficulties might constrain the method used, and consequently the efficiency of the process. Alternatively, some equipment might be suitable for use from a boat.

In general the methodology for the treatment of static, slow and fast flowing water by aeration also applies to hydrogen peroxide treatment and so this will not be reiterated here. Instead, this section considers alternative ways of introducing hydrogen peroxide into water systems.

Three methods for introducing hydrogen peroxide into a water body exist:

- direct addition
- direct addition followed by artificial mixing
- addition by purpose built equipment.

In order to maximise the efficiency of oxygen transfer to the water it is necessary to ensure that minimum breakdown of the hydrogen peroxide occur prior to it entering the water body, and that adequate mixing occurs. The three methods above are listed in order of increasing efficiency to maximise the oxygen transfer to the water. However, there is also an associated increase in equipment requirements and costs. Each is discussed in turn.

Direct Addition

The direct addition of hydrogen peroxide has been achieved by either pouring or drip feeding directly onto the surface of the water body. This approach is generally the least efficient method and also has attendant safety issues for both operators and the environment. The rate at which the hydrogen peroxide can be added will depend on any natural mixing processes. If natural mixing is likely to occur (e.g. by flowing water in a stream) then rates of addition can be relatively fast. However, if natural rates of mixing are slow (e.g. in lakes or reservoirs) then rates of addition should be relatively slow. In these circumstances, the addition of the hydrogen peroxide would be best undertaken at a variety of locations around the water body, upwind if possible and not near the location of any outflows. The possibilities and potential benefits for addition at the site of any inflows should also be considered. Whereas treatment at inflows might encourage more rapid mixing of treated water, it is also probable that any inflowing water already has a higher dissolved oxygen content that the water body being treated.

Direct Addition Followed by Artificial Mixing

Artificial mixing can be undertaken to improve the oxygen transfer efficiency in water bodied where natural mixing is limited. This would also permit a greater rate of hydrogen peroxide addition and result in an increased treatment rate.

A variety of approaches can be used to encourage artificial mixing:

- pumps
- pumps with sprayers
- aeration systems
- paddle wheels
- water craft fitted with inboard or outboard motors.

A recent application of hydrogen peroxide to a canal within the Thames Region was achieved by dribbling the liquid from a boat into the propeller wash as the boat moved along the canal. Secondary mixing was achieved by a further boat which zigzagged across the canal behind the first boat. A further treatment of the canal was achieved some time later by dribbling the hydrogen peroxide into the canal at a lock gate and achieving mixing by opening the sluice gate of the lock.

Addition by Purpose Built Equipment

Purpose built equipment is available which can be used for aeration purposes or for the addition of hydrogen peroxide. Such equipment takes in water, forcing it through a venturi before ejecting it. The venturi suction can be used to draw hydrogen peroxide and add it directly to the water prior to it being ejected. This achieves efficient oxygen transfer and good mixing with the water body.

An added advantage with this type of equipment is that it can also be used for additional purposes such as aeration (without the use of hydrogen peroxide), gas stripping and mixing. If the primary purpose of any hydrogen peroxide treatment is oxygenation then, by comparison with aeration alone, the approach will enable a given volume of water to be treated in a shorter time, or allow more water to be treated within a given time. Consequently, should more than one site require oxygenation and the availability of oxygenation equipment is restricted, then the more rapid response achieved by the use a hydrogen peroxide would have obvious benefits.

Various types of venturi equipment suitable for this application have been identified:

- pumps and associated venturi devices
- Aquajet River Rover
- O_2 Spray Limited Oxyjet
- novel approach using prototype remote control boat.

The use of pumps in combination with venturi devices provides a versatile method for hydrogen peroxide treatment. This equipment is mobile and suitable for use in small water bodies. They can, for example, be used in small effluent channels which then acts as an additional mixing zone. They are particularly useful for shallow flowing streams that would otherwise be difficult to treat by aeration alone.

River Rovers and Oxyjet systems are custom built larger units and have the advantage that mixing of the hydrogen peroxide with the water would be more effective than with smaller venturi devices. The devices are supplied with trailers for transportation purposes. The Agency currently has about 16 River Rovers of which seven are suitable for use with hydrogen peroxide. Disadvantages with this type of equipment result mainly from its size and weight; requiring trailer mounting for transportation. It also means that ready access to the bank of the water body is necessary although units can be manhandled on trailers if necessary. The device is deployed into the water and so high or unstable banks would represent difficulties. There has also been some difficulties with deploying this type of equipment in waterways of limited size. The Oxyjet systems are more manageable and are provided with a smaller operational trailer to enable transport in more difficult conditions. If necessary the equipment can also be removed from the trailer and transported manually. The device is deployed on the bank, bridge or similar with only the end of an intake hose being placed in the water. In this way it is operationally easier to use and more versatile than the River Rover. However, the capability of the Oxyjet would be less than the River Rover although multiple units of the former would help overcome this.

A novel approach for the treatment of larger water bodies is to use dosing equipment on-board a radio controlled boat controlled from the bank. Such a prototype is being developed by O_2 Spray Ltd, the manufacturers of the Oxyjet system, and is expected to be trialed later in 1998. This approach will enable a water body to be treated across its entire surface and will encourage mixing.

All types of aeration and hydrogen peroxide treatment systems are reported to be prone to vandalism. Consequently they need to be attended continuously while in use unless deployed in secure areas.

9.2.2 Cessation of Treatment

Treatment of a water body by hydrogen peroxide should continue until any one of the following occurs:

- the conditions of the water are deemed adequate - it might be that particular target criteria for treatment have not been set prior to treatment. In this situation a pragmatic approach should be used to determine when to cease treatment. This might be when any odour problem has ceased or when dissolved oxygen contents are considered adequate
- the target conditions of the water are achieved - it might be that target criteria have been established for any treatment. These might be 80 % for dissolved oxygen content or a specific level for COD, BOD and TOC. For any contaminants, it might be reduction to the relevant Environmental Quality Standard
- resuspension of any solids - any disturbance of bottom sediment should be avoided; if this occurs then the treatment should be discontinued at the specific location and attempted elsewhere
- any hazardous situation arises.

When hydrogen peroxide dosing is undertaken for extended periods, measurements of residual levels of hydrogen peroxide in the water should be periodically made. This is particularly important in still or slow moving water.

9.2.3 Sourcing Hydrogen Peroxide

Commercially available hydrogen peroxide comes in a range of concentrations, typically from 3-70 %. The most common concentration for use in water treatment is 35 %, or occasionally 50 %. This concentration is relatively less hazardous than higher concentrations. For example, concentrations with > 65 % hydrogen peroxide can have extremely strong exothermic reactions in the presence of a suitable catalyst.

Typically, hydrogen peroxide is delivered in slightly acidic conditions (pH 5) in order to reduce the rate of decomposition during storage. Others stabilisers are also used, including such products as EDTA which would be undesirable in water treatment. It is, therefore, advisable to check the nature of any stabiliser before a commercial product is used in order to ensure the environmental acceptability.

9.2.4 Hydrogen Peroxide Required

The amount of hydrogen peroxide required to treat oxygen deficient water will depend upon a variety of factors. These include:

- initial dissolved oxygen content prior to treatment
- desired dissolved oxygen content after treatment
- method of hydrogen peroxide addition
- efficiency of oxygen transfer and mixing
- quantity of any additional oxygen taken up by aeration
- water temperature
- pH
- suspended organic content.

As an indication, one manufacture/supplier indicates that with a 30 kg drum of 35 % solution of hydrogen peroxide it is theoretically possible to treat 2.25 million litres of water such that the dissolved oxygen content increases from 60 % to 80 %. This equates to a body of water of approximately 40 m x 14 m x 4 m. In practice, however, it is unlikely that this theoretical maximum will be achieved.

9.2.5 Health and Safety

Hydrogen peroxide, like other oxidation reagents, is highly reactive and requires specific storage and handling procedures. Whatever method of use is adopted, it is important that comprehensive operational and safety guidelines are available and that these are followed. In the case of purpose built equipment such guidelines should be provided by the manufacturer. Concentrations of hydrogen peroxide used for water treatment would normally be 35 %; this concentration is less hazardous than higher concentrations. An appropriate hazard data sheet should be available.

Hydrogen peroxide can produce hydrogen gas (with attendant fire and explosion hazards) if it comes into contact with particular metals. Consequently, any materials used for the construction of storage vessels, valves, pumps or pipework that the hydrogen peroxide might come into contact with need to be selected with care. Because of the fire risk it would be necessary to have a fire extinguisher at hand.

During operation care should be taken to ensure that any drifting spray containing hydrogen peroxide does not come into contact with persons, animals or equipment. As far as is possible operations should be undertaken at locations where the wind is offshore.

Personal protection equipment should also be used by operators. This should include chemical coveralls, chemical gloves and appropriate footwear, face guard or safety goggles. Access to respiratory protection equipment may be required. Eyewash bottles, a supply of clean water and a First Aid Kit should also be available.

Some Agency staff who have used hydrogen peroxide injection procedures consider that the technique is too difficult to undertake in the hours of darkness. They consider that any benefits from improved aeration do not outweigh the risks involved. Consequently, they consider that operationally, hydrogen peroxide injection should be confined to daylight hours and that aeration only be undertaken during darkness. The provision of adequate lighting facilities such as arc lamps might help overcome this restriction.

9.2.6 Equipment Availability and Conversion

Table 9.2 indicates equipment identified on the Strategic Pollution Equipment List that is capable of water treatment using hydrogen peroxide. It is probable that additional smaller items of equipment such as pumps and venturies exist that can also be used.

Table 9.2 Location of hydrogen peroxide injection equipment across the Environment Agency.

Region	Equipment	Number
North East	Dosing System	3
Midlands	River Rover	4
Thames	Supplies of hydrogen peroxide	2
Welsh	River Rover	3

It can be seen that seven River Rover units currently exist that are capable of using hydrogen peroxide. It is also understood that one Area has an Oxyjet. However, the Agency does hold additional (in the vicinity of nine) River Rover units which are used for aeration alone. Discussion with the supplier of this equipment has indicated that these additional units should be capable of conversion to provide hydrogen peroxide treatment. Cost of such a conversion are estimated at £1900 subject to inspection. It is understood that one depot at Doncaster is currently considering such a conversion in the 1998-1999 financial year.

Utilisation of hydrogen peroxide treatment systems within the Agency appears to be similar to that for aerators. Discussion suggests that utilisation is generally low, but likely to be more frequent during periods of low river flows and high temperatures.

Should the ongoing investigation being funded by the Agency confirm the benefits of hydrogen peroxide treatment then the Agency should increase the amount of equipment they hold. This can be readily achieved by either of the following two approaches:

- conversion of existing River Rovers - this equipment would have potential for use in larger and deeper water bodies
- additional pumps and venturi devices - this equipment would have potential for use in both large/deep and small/shallow water bodies. The Oxyjet, for example, would appear to be versatile for these applications and it is recommended that this equipment be trialed and compared to the River Rover.

10 SPILL DETECTION AT NIGHT

The detection of oil and chemical spills at night was identified as problematical, especially when thin films are involved. The aim of this part of the work was to evaluate a range of low cost equipment that might have potential for this purpose. The initial investigations indicated that no portable and cheap equipment was available that was designed specifically for this application, although oil test paper did exist. However, a range of hand held equipment that might have potential has been identified and tested to evaluate its potential for this application. Additionally, a range of larger and more expensive equipment has been identified that might also have potential. Information on this equipment has been collected and evaluated.

10.1 Oil Test Paper

Macherey-Nagel Oil Test Paper is available commercially and is capable of detecting oil in water or in soil. In operation a drop of the water to be tested is applied to the test paper, or the paper is moved back and forth in a small sample of the water. The paper undergoes a colour change from light blue to dark blue or brown in the presence of hydrocarbons. The sensitivity of the test is described as depending on the solubility of the hydrocarbons present; see Table 10.1. When volatile hydrocarbons are being tested for, it is necessary to observe any colour change immediately. The oil test paper costs in the vicinity of £22.00 for a pack of 100.

Table 10.1 Sensitivity of oil test paper with different hydrocarbons

Product	Lower Limit of Detection mg/l	Clearly Detectable Limit mg/l
Petroleum ether	250	400
High octane gasoline	10	25
Heating oil	5	10
Lubricating oil	1	5

Qualitative laboratory tests were undertaken with the test papers using a range of different oil products. With most products single drops were added to beakers of water and the test paper moved around in the liquid. With the creosote, a test paper was pressed onto the surface of a creosoted wood surface that had been treated approximately 30 hours before and upon which some rain water had accumulated. With the car park runoff, a test paper was placed into a surface puddle following rainfall on a car park. The results of the tests are indicated in Table 10.2.

Table 10.2 Observed colour changes of oil test paper

Product	Final Colour Change	Comments
Unleaded petrol	Dark blue	
Kerosene	Dark blue	
Toluene	Dark blue	
Creosote	Brown	Brown staining
Forties Blend Crude	Brown	
Mix of unknown products and crudes	Brown	General discolouration
Car park runoff	Brown	Patchy brown staining

The results indicate that the Oil Test Paper would appear to have potential for use in detecting oil either on or in water at night. However, in practice it would be necessary to collect a water sample or to have access to the water body so that the test paper can be immersed.

10.2 Hand Held Equipment

The following range of hand held equipment was evaluated:

- Raytech Ultraviolet Equipment - a hand held, mains operated (230 volts, 50 HZ, 0.20 amps) unit with the capability of providing both long wave and short wave ultraviolet light
- MineralLight Lamp, Model UVSL-25 - a hand held, mains operated (240 volts, 50 HZ, 0.15 amps) unit with the capability of providing both long wave and short wave ultraviolet light
- Super Mini Ultra Violet Fluorescent Lantern with Torch - a hand held, battery operated (4 x AA size batteries) unit capable of providing only a fixed wavelength of ultraviolet light
- Moonlight Night Vision NV100 Compact - a hand held, battery operated (2 x AA size batteries) unit providing a combination of light amplification, magnification, and infra-red illumination capabilities.

Qualitative laboratory based investigations were undertaken with this equipment in both restricted light and in the absence of light (other than that provided by the equipment itself). The tests consisted of the comparison of any visual differences between a water surface with an oil or chemical with a water surface without the oil or chemical. Observations were generally undertaken against a dark background as this was considered to be more representative of field conditions than a light background. A range of petroleum products and chemicals was used and at two different thicknesses. The tests were also undertaken using both static and moving (swirling) water bodies. The results of the tests are indicated in Tables 10.3-10.4 for static water and Tables 10.5-10.6 for moving water.

Table 10.3 Visually observed differences resulting from the presence of oils/chemicals compared to a clear water surface - restricted light/static water

Equipment	Unleaded Petrol		Forties Blend Crude		Kerosene		Toluene	
	thin	thick	thin	thick	thin	thick	thin	thick
Raytech Equipment - short wave mode	None	Slightly cloudy	Yellow-brown	Yellow-brown	Cloudy-patchy	Whitish-cloudy	None	None
Raytech Equipment - long wave mode	None	Slightly cloudy	Yellow-brown	Yellow-brown	Cloudy-patchy	Whitish-cloudy	None	None
MineralLight Lamp - short wave mode	None	Slightly cloudy	Yellow-brown	Yellow-brown	Cloudy-patchy	Whitish-cloudy	None	None
MineralLight Lamp - long wave mode	None	Slightly cloudy	Yellow-brown	Yellow-brown	Cloudy-patchy	Whitish-cloudy	None	None
Super Mini UV Lantern - fixed mode	None	Very slightly cloudy	Yellow-brown	Yellow-brown	None	Whitish-cloudy	None	None
Moonlight Night Vision - light amplification mode	None	None	None	None*	None	None	None	None
Moonlight Night Vision - IR illumination mode	None	None	None	None	None	None	None	None

* looks brown if observed against a white background

Table 10.4 Visually observed differences resulting from the presence of oils/chemicals compared to a clear water surface - restricted light/moving water

Equipment	Unleaded Petrol		Forties Blend Crude		Kerosene		Toluene	
	thin	thick	thin	thick	thin	thick	thin	thick
Raytech Equipment - short wave mode	None	Slightly cloudy	Yellow-brown	Yellow-brown	Slightly cloudy	Cloudy white	None	None
Raytech Equipment - long wave mode	None	Slightly cloudy	Yellow-brown	Yellow-brown	Slightly cloudy	Cloudy white	None	None
MineralLight Lamp - short wave mode	None	Slightly cloudy	Yellow-brown	Yellow-brown	Slightly cloudy	Cloudy white	None	None
MineralLight Lamp - long wave mode	None	Slightly cloudy	Yellow-brown	Yellow-brown	Slightly cloudy	Cloudy white	None	None
Super Mini UV Lantern - fixed mode	None	Very slightly cloudy	Yellow-brown	Yellow-brown	None	Cloudy white	None	None
Moonlight Night Vision - light amplification mode	None	None	None	None*	None	None	None	None
Moonlight Night Vision - IR illumination mode	None	None	None	None	None	None	None	None

* looks brown if observed against a white background

Table 10.5 Visually observed differences resulting from the presence of oils/chemicals compared to a clear water surface - no light/static water

Equipment	Unleaded Petrol		Forties Blend Crude		Kerosene		Toluene	
	thin	thick	thin	thick	thin	thick	thin	thick
Raytech Equipment - short wave mode	None	Slightly cloudy	Yellow-brown	Yellow-brown	Cloudy-patchy	Whitish-cloudy	None	None
Raytech Equipment - long wave mode	None	Slightly cloudy	Yellow-brown	Yellow-brown	Cloudy-patchy	Whitish-cloudy	None	None
MineralLight Lamp - short wave mode	None	Slightly cloudy	Yellow-brown	Yellow-brown	Cloudy-patchy	Whitish-cloudy	None	None
MineralLight Lamp - long wave mode	None	Slightly cloudy	Yellow-brown	Yellow-brown	Cloudy-patchy	Whitish-cloudy	None	None
Super Mini UV Lantern - fixed mode	None	Very slightly cloudy	Yellow-brown	Yellow-brown	None	Whitish-cloudy	None	None
Moonlight Night Vision - light amplification mode	None	None	None	None	None	Whitish-cloudy	None	None
Moonlight Night Vision - IR illumination mode	None	None	None	None	None	None	None	None

Table 10.6 Visually observed differences resulting from the presence of oils/chemicals compared to a clear water surface - no light/moving water

Equipment	Unleaded Petrol		Forties Blend Crude		Kerosene		Toluene	
	thin	thick	thin	thick	thin	thick	thin	thick
Raytech Equipment - short wave mode	None	Slightly cloudy	Yellow-brown	Yellow-brown	Slightl y cloudy	Cloudy white	None	None
Raytech Equipment - long wave mode	None	Slightly cloudy	Yellow-brown	Yellow-brown	Slightl y cloudy	Cloudy white	None	None
MineralLight Lamp - short wave mode	None	Slightly cloudy	Yellow-brown	Yellow-brown	Slightl y cloudy	Cloudy white	None	None
MineralLight Lamp - long wave mode	None	Slightly cloudy	Yellow-brown	Yellow-brown	Slightl y cloudy	Cloudy white	None	None
Super Mini UV Lantern - fixed mode	None	Very slightly cloudy	Yellow-brown	Yellow-brown	None	Cloudy white	None	None
Moonlight Night Vision - light amplification mode	None	None	None	None	None	None	None	None
Moonlight Night Vision - IR illumination mode	None	None	None	None	None	None	None	None

In the test conditions of the laboratory the Raytech Equipment and the MineralLight lamp performed best and resulted in an observable difference for Forties Blend Crude and kerosene as both thin and thick layers, and unleaded petrol as a thick layer. There appeared to be no difference in observations between short wave and long wave modes for either lamps.

The Super Mini UV Lantern was able to detect both thin and thick Forties Blend Crude and thick kerosene and petrol. However, in general performance was not as good as the other two uv lamps (Raytech and MineralLight), presumably as reduced power resulted in a less powerful light.

A practical disadvantage with all three types of ultraviolet lamps is the need for them to be held fairly close (within 30-50 cm) to the water surface for them to be most effective. The lamps produce only a diffuse light rather than a focused light or beam as they do not incorporate a reflector. Additionally, it has not been possible to evaluate their effectiveness in the field in a flowing system where it is anticipated that any observable differences may be more difficult to detect, especially with those products that reduce only a restricted observable difference compared with water.

The Moonlight Night Vision equipment proved to be ineffective in both light amplification and IR illumination mode.

10.3 Less Mobile Equipment

A range of larger and more expensive equipment was evaluated for potential application for the detection of oil and chemical spills on inland water at night. This evaluation was undertaken by examination of available literature and by discussion with manufacturers and distributors. The range of equipment evaluated was:

- DKK Oil-on-Water Alarm
- Crest Flowline CB2000 Oil on Water Detector
- pHOX Series 500 Oil-on-Water Monitor
- Ionics SlickWatch IR Oil Slick Detector
- Nereides Oil Spy
- Ayles Fernie Oil Spotter
- AEA Technology Microwave Pollution Monitor
- interface meters.

The DKK Oil-on-Water Alarm is designed for permanent installation as an oil on water monitor. The system uses a laser beam directed at the water surface and measures the amount of reflected visible light to indicate the presence of oil. The equipment weights approximately 55 kg and has AC power requirements. The instrument is installed between 0.3 and 3 m above the water surface on, for example, a waterway wall, bridge or in a manhole. The weight, size and power requirements of this equipment would make it unsuitable for portable field use.

The Crest Flowline CB2000 Oil on Water Detector is a permanently installed infra-red monitoring system designed for use in separators, lagoons and waterways. A floating detector head is moored in the water body and is connected by cable to a separate indicator/alarm system. The system is mains powered but with a battery back-up. This equipment would be inappropriate for portable field use.

The pHOX Series 500 Oil-on-Water Monitor is similar in design and operation to the Crest Flowline CB2000 Detector and is again designed for permanent installation. A floating sensor head is moored in the water course and is connected to a separate control unit which is mounted on land. The floating sensor head houses an infra-red light source and receptor for reflected light. The amount of reflected light will be proportional to the amount of oil present.

The equipment is mains powered with a battery back-up. The equipment is described as being able to detect oil films as thin as 0.1 µm. The weight, size and power requirements of this equipment would again make it unsuitable for portable field use.

The Ionics SlickWatch IR Oil Slick Detector consists of an IR transmitter and receiver mounted permanently side by side above the water surface. It is designed for the permanent monitoring of waterways that are in areas prone to oil spillage. The transmitted beam is reflected from the water surface back to the receiver; the reflection characteristics changing in the presence of oil. The equipment is described as being able to detect oil films as thin as 0.1 µm. The combined weight of the transmitter and receiver is some 33 kg and it requires an alternating current power source. The weight, size and power requirements of this equipment would again make it unsuitable for portable field use. It is also very costly, in the region of £8500

The Nereides Oil Spy is a detector system specially designed for floating hydrocarbons and chloride solvents. The system incorporates a sacrificial polymer membrane which dissolves in the presence of the pollutant and so triggers an alarm. The system is designed for permanent installation with the alarm system being connected by electric cable, radio or telephone link. However, as the basic probe housing the polymer membrane is easily portable, and reacts to the pollutant rapidly, there is possible scope to use this equipment as a portable detector. In this case the presence of the pollutant would be determined by dissolution of the membrane rather than the alarm itself. The equipment is described as being able to detect oil thickness as thin as 0.1 mm, with a reaction time that varies with the type of pollutant: super grade petrol, 4 seconds; trichloroethylene, 10 seconds; kerosene, 26 seconds; gasoil, 2 minutes; and crude oil, 2 minutes.

The Ayles Fernie Oil Spotter is an oil on water detection system based on the use of an ultra-violet fluorescence emitter. The equipment was designed as a prototype for detecting spilt oil on the sea at night, and to be operated from a small patrol or pilot launch. Although originally designed to be powered from a launch's power system a version could probably be developed for operation from a vehicle. However, a portable version was found to be impractical as the weight of the required batteries would be excessive. The equipment remained only as a prototype and has not yet been deployed commercially.

The prototype AEA Technology Microwave Pollution Monitor has been developed for detecting surface oil layers developing in oil interceptors. This system was designed for use with calm surface water and is believed to perform best with oil layers of about 1 mm thick or more. However, the prototype system would not be satisfactory in flowing water and has an added disadvantage of being expensive, probably costing in excess of £2000. Attempts to develop and market the equipment have been largely unsuccessful.

Interface meters are designed to locate and measure the thickness of floating or sinking product layers within boreholes or storage tanks. As such they are designed for use in effectively non-flowing water. The equipment incorporates two sensors; an infra-red beam and a conductivity circuit. The former detects non-conducting liquids while the latter detects water. Models are described as being able to detect floating layers down to 1.0 to 1.5 mm in thickness, although it is considered unlikely that they can be operated successfully in flowing water where surface fluctuations are likely to occur. The operational procedure required for this type of equipment would also be difficult to undertake in the dark, especially in exposed situations or inclement weather, as the meter requires lowering into the liquid using a guidance tape, and accurate measurements subsequently being taken from the tape. The equipment is relatively lightweight consisting mainly of the tape reel and meter/probe unit. It is battery operated.

10.4 Conclusions

Following an evaluation of low cost methods and equipment for the detection of oil and chemical spills at night the following conclusions have been drawn:

- there is no portable and cheap equipment that has been specifically designed for this purpose
- oil test papers are available commercially that can detect hydrocarbons. However, these require that a sample of the water be collected or that access to the water body is possible
- ultraviolet lamps have a potential to assist in the observation of some hydrocarbons, especially if present in thicker layers. However, the most effective equipment appears to be mains operated rather than battery operated and needs to be held close to the water surface. This will result in operational restrictions
- a range of less mobile, and more expensive, equipment has been examined and, in general, none of this is appropriate for use as portable equipment. All have some problems associated with high cost, weight and power requirements or are specifically designed for permanent installation or for use in specific circumstances. However, the Nereides Oil Spy incorporates a probe that might have some potential for use as potable equipment.

11 ENCAPSULATION

Two proprietary encapsulation products, Unibiber and Unisafe, have been evaluated. This evaluation consisted of the following:

- laboratory testing
- review of previous testing
- review of operational experience by Fire Services.

11.1 Laboratory Testing

Tests were undertaken in a fume cupboard at ambient conditions. 25 ml of the test liquid were placed into a beaker and sufficient of each product added until all liquid was taken up. (This approach was considered to be representative of how the products might be used in an incident.) The weight of the beaker and fluid was taken before and after addition of the product so that the weight added can be determined. The weight was again recorded after 30 minutes to evaluate any weight loss as a result of evaporation during this time.

Observations undertaken during the tests also included:

- nature of the beaker contents (qualitative) - whether a liquid, slurry, paste, solid
- any changes in temperature (quantitative)
- any adverse reactions (qualitative)
- whether any fumes were produced (qualitative).

The tests liquids used were:

- Sulphuric acid 98 %
- Hydrochloric acid 37 %
- Nitric acid 72 %
- Oil:water mixture 1:3 ratio (viscosity of crude oil 70 mPa s at 10°C)
- Sodium hydroxide 1 molar solution
- Acetone
- Ethanol.

The results are indicated in Table 11.1 for Unibiber and Table 11.2 for Unisafe. It can be seen that both products were successful in immobilising all liquids during the test. This process was associated with varying degrees of temperature change. With Unibiber a significant temperature increase occurred with Sulphuric acid while with Unisafe significant temperature increases occurred with Sulphuric acid and Nitric acid. The detection of any release of fumes by visual or olfactory means occurred only with ethanol; being detected with both Unibiber and Unisafe. However, measurements of evaporative loss, resulting from the loss of liquid to the atmosphere, indicate that both products allowed vapour loss with several liquids. In general this appears to be slightly greater with Unibiber than with Unisafe. Both Unibiber and Unisafe lost significant quantities of ethanol and acetone, while Unibiber lost more Hydrochloric acid than Unisafe.

Table 11.1 Results of laboratory tests with Unibiber

Test Liquid	Quantity required to achieve treatment[1], kg/l	Temperature change, °C	Fumes	Evaporative loss at 30 minutes, g	Nature of final product	Cost/litre treated[2], £
NaOH	2.31	-2	No	0.81	Solid	19.32
H_2SO_4	1.756	19	No	-0.74	Solid	14.68
HCl	1.672	3	No	0.98	Solid	13.98
HNO_3	1.5428	4	No	0.3	Solid	12.90
Ethanol	2.7792	1	Yes	4.47	Solid	23.24
Acetone	2.0784	-3	No	13.58	Solid	17.38
Oil:water	1.252	2	No	0.1	Solid	10.47

[1] note that Unibiber is considerably more dense than Unisafe
[2] assuming a cost of £95 per 11.36 kg

Table 11.2 Results of laboratory tests with Unisafe

Test Liquid	Quantity required to achieve treatment[1], kg/l	Temperature change, °C	Fumes	Evaporative loss at 30 minutes, g	Nature of final product	Cost/litre treated[2], £
NaOH	0.4268	8	No	0.61	Solid	6.74
H_2SO_4	0.432	16	No	-0.94	Solid	6.83
HCl	0.556	5	No	-0.3	Solid	8.78
HNO_3	0.5876	16	No	0.33	Solid	9.28
Ethanol	0.6224	1	Yes	4.38	Paste	9.83
Acetone	0.608	-7	No	10.27	Solid	9.60
Oil:water	0.216	2	No	0.0	Solid	3.41

[1] note that Unisafe is considerably less dense than Unibiber
[2] assuming a cost of £75 per 5.0 kg

Estimates of the cost of treatment are also indicated in Tables 11.1 and 11.2. This are based on purchase prices obtained in October 1997. Given this price structure, treatment by Unisafe would appear to be considerably cheaper than treatment by Unibiber.

An additional observation during testing with the oil:water mixture was that the Unisafe appeared to be selective initially in preferentially taking in the oil rather than the water. Only when most oil was taken in was the water then taken up. This might have operational advantages in those situations were only a limited quantity of product was available for an oil:water spill. The Unisafe would possibly only take up oil whereas the Unibiber would take up both oil and water.

11.2 Previous Testing

Previous comparative testing of these two products has been undertaken by the National Laboratory Service of the Agency and by Matthew Sommerville. Available information on this testing was also reviewed. The results form the two testing programmes appear to be contradictory in some aspects and it is considered that this arises from a difference in the testing protocol undertaken. The National Laboratory Service added sufficient product to take in the liquid while Sommerville added only a fixed quantity.

Significant conclusions of Sommerville's work are that:

- Unibiber is able to sorb liquids better than Unisafe
- neither Unibiber or Unisafe sorb ethanol
- neither Unibiber or Unisafe sorb acetone
- significant temperature increases occurred with concentrated Nitric and Sulphuric acids with both Unisafe and Unibiber although this was greater with Unisafe.

Significant conclusions of the National Laboratory Service work are:

- Hydrochloric acid vapours were better contained by Unisafe than by Unibiber
- Unisafe outperforms Unibiber with oil:water mixtures

- Unisafe does sorb ethanol
- Unisafe does sorb acetone.

In general, it is considered that the findings of the National Laboratory Service are more pertinent than those of Matthew Sommerville in that the test methodology is more akin to the procedure that is likely to be adopted in the field. The findings of the National Laboratory Service are also similar to those of the experimental work undertaken within this project.

11.3 Operational Experience

Discussions were held with the Fire Services to solicit views on the relative performance and advantages of the two products. In some instances views were contradictory although Table 11.3 summarises the various views expressed. One Fire Service reported using Unisafe for a fire fighting application in addition to spill control. The product was used successfully to extinguish a phosphorous fire by pouring it over the burning material.

Table 11.3 Summary of views on operational experience with Unisafe and Unibiber

Aspect	Unisafe	Unibiber
General performance	Good product and considered better by some. Some operators were aware of limitations with strong oxidisers but did not feel that this was a significant problem	Good product and considered better by some
Ease of application	Difficult to get even distribution by pouring from tub but no problem if distributed by scoop	Easy as supplied in container with pouring device and handle
Application in wind	Tends to be blown away as light	Less likely to be blown away as more dense
Liquid retention in water	Tends to loose encapsulated liquid if re-spilled into water	Tends to hold encapsulated liquids better
Pre-treatment of area of spill	Pre-treatment may be required with water spray to improve product efficiency	No pre-treatment required
Ease of pick-up	No problems expressed	With some materials tends to form a slurry which is difficult to pick up
pH indicator	pH indicator present and considered useful by some but not useful by others	no pH indicator

11.4 Discussion and Conclusions

Desirable features of an encapsulation product are considered to be:

- encapsulation of liquids - effective control of a wide range of liquid chemical types
- vapour suppression - minimisation of vapour release following encapsulation

- liquid retention - no significant re-release of any liquid in, for example, re-spillage into water
- ease of application - easy to dispense in the desired quantity, in the desired place and without any losses due to wind blow. Minimum requirements for any pre-treatment (for example by water spraying)
- ease of recovery - easy to pick-up after liquids have been encapsulated, leaving surface in non-hazardous state
- safety - safe application with no unforeseen adverse reactions
- cost - treatment costs should be acceptable.

Both Unibiber and Unisafe are successful in encapsulating a range of chemicals. Vapour suppression appears to be better with Unisafe although liquid retention might be better with Unibiber. Application is reported to be easier with Unibiber although this would not appear to be a significant issue with Unisafe. The potential for some heating to occur exists with both products and it is important that operators are aware of this potential. With some specific chemicals this heating may be extreme. Such chemicals are likely to include Chromic and Perchloric acids. The presence of a pH indicator is considered an advantage by some operators and is only present in Unisafe. With the existing price structure for these two products it would appear that the cost of treatment is significantly less with Unisafe. It is thus recommended that, while this cost differential exists, Unisafe be used rather than Unibiber. However, users need to be informed that there are potential hazards when this product is used with strong oxidisers.

Discussions with the manufactures of Unibiber indicate that its formulation is going to be changed within the next six months or so too improve its performance. A constituent, termed Polarbiber, will be included which is aimed at improving absorption of such chemicals as ethanol and acetone. It is recommended that additional comparative testing be undertaken once this new product is available, and/or at a time when the cost differential between Unibiber and Unisafe has reduced.

12 DRAIN SEALS

The proposed work programme for Stage 2 was to include the testing of a variety of drain seal types using a fabricated test facility to simulate roadside drains and manholes. However, this proposal had to be modified because of difficulties in obtaining samples of drain seals from suppliers. Only a restricted range of drain seals was obtained and in limited quantities. Consequently, only limited testing was undertaken and on a smaller facility.

12.1 Laboratory Tests

The test facility consisted of a stainless steel vessel incorporating a 5 cm diameter hole and plastic drainage tube. The vessel was wetted prior to the test being undertaken. The seal to be tested was placed over the hole according to suppliers instructions and a minimum of 2 litres of water poured into the vessel. This provided a water depth of approximately 1.5 -2 cm. Any liquid draining from the drainage tube was collected and the volume determined after 5, 30 and 60 minutes. Additional water was added to the vessel if large quantities leaked out.

The drain seal types tested were:

- sand bag - a woven nylon bag containing wet sand
- water filled tetrahedral plastic bag - this was not a proprietary product as one was not available. Instead the product was simulated using polythene
- sheet of flexible polyurethane material - this was the proprietary product DRAINBLOCKER
- clay based material - this was the proprietary product Dammit. This was the ready mix product designed for blocking leaks from tanks and pipes but which can also be used in conjunction with sheets of similar material to block drains. Prior to use, the ready mix Dammit was moulded into a sheet which was then place over the hole
- inflatable seal - this was not a proprietary product as one was not available. Instead the product was simulated using an inflatable elastic bladder.

Tests were undertaken with both the clean stainless steel surface, and also with a sprinkling of fine sand over the previously wetted stainless steel surface (to simulate a non-clean surface). With the inflatable seal, sand was sprinkled within the previously wetted plastic drainage tube as this was where the device would be fitted.

The results obtained from the drain seal tests are indicated in Table 12.1. An initial test using the tetrahedral plastic bag on clean stainless steel resulted in immediate leakage as it was not well seated to the contours of the test vessel. Slight repositioning and an increase in the water contained within it overcame this problem. An initial test with DRAINBLOCKER on clean stainless steel also resulted in an immediate leakage. This was again overcome by a slight repositioning of the sheet. Both of these initial tests were discounted but they do indicate the limitations of these products in conforming to contour changes. Note that in practical operations in the event of a spill it is unlikely that any leakage would be detected and so it would not be known that the seals needed repositioning.

Table 12.1 Accumulative leakage with various drain seals

Drain Seal	Accumulative leakage[1], ml						
	Stainless Steel[2]			Stainless Steel[2] with Sand			
	5 mins	30 mins	60 mins	5 mins	15 mins	30 mins	60 mins
Sand bag	85	590	1280	910	2330	4100	6700
Tetrahedral plastic bag	0	0	0	5250	15250	-	-
Polyurethane sheet	0	0	0	17000	-	-	-
Clay material	0	0	0	0	0	0	0
Inflatable seal	0	0	0	5	>5	35	65

[1]Note that very small quantities of water accumulating in the collection vessel were discounted as being residual quantities from the previously wetted system.
[2]Note that the inflatable seal was installed against plastic.

With clean surfaces all drain seals, with the exception of the sand bag, performed excellently with no leakage being detected within an hour observation period. With the sand bag there was some slight leakage although this was not as much as the leakage rate associated with the badly positioned tetrahedral plastic bag and polyurethane sheet indicated earlier.

With the surfaces that had been sprinkled with sand the tetrahedral plastic bag and the polyurethane sheet performed poorly. The tests were terminated after 15 and 5 minutes respectively when >15000 ml had leaked out. The sand bag performed reasonably well but did allow significant leakage; >6000 ml in an hour. The inflatable seal performed very well, allowing only very minor leakage. The clay material performed excellently with no detectable leakage.

12.2 Discussion

Flexible drain mats made of materials other than polyurethane are also available. This includes a product made of neoprene. Although this product was not directly tested it is anticipated from available literature that is performance would be similar to the polyurethane mat. It is also realised that the performance of these types of product might be significantly improved if additional weighting was used on the mat to encourage it to conform to contour variations. However, the requirement to apply this weighting could compromise the speed of response in an emergency situation.

12.3 Conclusions

On clean surfaces all drain seals tested can be expected to perform well although the sand bag will probably allow some leakage. With non-clean surfaces, or surfaces with some roughness, the clay material and the inflatable seal can be expected to perform well. The sand bag is likely to allow significant leakage. The tetrahedral plastic bag and the polyurethane sheet are likely to result in excessive leakage.

13 TEMPORARY STORAGE

A range of temporary storage tanks has been reviewed for use by the Agency. Tanks have been considered within categories based on possible transport and access limitations according to the following:

- transport by large vehicles
- transport by smaller vehicle or manually
- transport by boat.

13.1 Transport by Large Vehicles

13.1.1 Skips

Skips require plastic liners to ensure water tightness and to aid cleaning. They are readily available in a range of sizes. Skips should not be overfilled due to the risk of spillage during loading and transport, especially over rough ground. Although they have potential use they are not appropriate for immediate emergency use as time will be required for their acquisition.

13.1.2 Vacuum Tankers

Vacuum tankers have the advantage of being able to skim and recover the pollutant themselves. Their tanks are also spill proof. Vaculites are a smaller and more specialist (non self propelled) variation of the vacuum tanker and could be towed behind a 4-wheel-drive vehicle to more remote or inaccessible areas, or even mounted and operated from a small landing craft. This type of equipment has potential for both storage and recovery. Vacuum tanks will also often be used to empty other types of storage vessel.

13.2 Transport by Smaller Vehicle or Manually

13.2.1 Collapsible Storage Units

Collapsible storage units such as plastic swimming pools or other commercially available tanks or bladders (e.g. Fastanks, Instee Storage Tank, Floatank, Pop-Up Pools, Texatank, Texablad, TroilTank) are easily transported by smaller vehicles and can even be carried short distances on foot. These collapsible storage tanks are easily erected on site and form excellent separation/temporary storage tanks. These tanks generally require reasonably level ground to be stable, with some forms being inherently more unstable than others. Rectangular tanks with rigid frames and relatively low sides would be more stable than less rigid, circular tanks with high sides. Tanks and other open topped versions can also be used for collecting liquids from leaking vessels, fish storage, soiled equipment storage or for equipment and personnel wash-down. Some means of emptying them must be available if access is limited. If a separation process is to be undertaken then tanks rather than bladders would be more suitable as these would generally have a greater depth of liquid.

One particular product, the Pop-Up Pool, is an automatically expanding light weight vessel with a relatively low (20 or 30 cm) wall height. This low height makes the vessel appropriate for use in spaces of limited clearance where it can be used to catch leaking liquids; for example to collect leaking fuel directly from the fuel tanks of vehicles.

13.2.2 Drums and Overdrums

Drums are generally manageable even when filled, although have only a restricted capacity. They can be used for the storage of both recovered liquids and soiled equipment such as sorbent. If used for liquids storage they should only be filled to about two thirds of their capacity to ensure that its possible to handle them and avoid spillage. A disadvantage with drums is that they require considerable space for storage when not in use compared to collapsible tanks.

Drums and overdrums should be lined with plastic where possible prior to use. This will minimise contamination of the vessel, thereby reducing cleaning requirements and perhaps obviating the need to dispose of the drum as well as its contents.

13.2.3 Plastic Bags and Tubing

Plastic bags and tubing can be used for liquids storage but are probably more useful for solid waste such as used sorbent etc. Plastic should also be used to line drums and overdrums where possible. Plastic tubing can be pulled off and either sealed with a heat sealer or simply tied in a knot. An advantage with tubing is that almost any length can be used as required. Tubing also has an additional advantage in that it can be filled with water and used as a makeshift containing dam during a spillage incident on land.

13.3 Transport by Boat

13.3.1 Flexible Towable Tanks

Flexible towable tanks, termed dracones (e.g. Texablad Marine Bladder, Unitor Oil Bag, Sea Sentry TSB), are available for storage of liquids collected by water craft. The tanks are deployed into the water and require only a shallow draught.

13.3.2 Barges and Deck Tanks

Barges or boats with deck tanks or any of the shore based tanks mentioned earlier could also be utilised.

13.4 Oil:Water Separation

Many of the above tanks may be used as oil water separators merely by leaving the oil and water to settle for long enough; clean water can then be run off from the base of the tanks and returned to the waterway. This reduces both transport and disposal costs. Where the liquid recovery rate is high however, it may not be possible to leave the tanks for the required residence time for a good separation to take place. Consideration could then be given to using an oil water separator to enhance the process, thus increasing the liquid throughput or decreasing the number of storage tanks required for the process to take place.

Another option would be to use an oil concentration monitor on the 'clean' water discharge which is being returned to the waterway. This may reduce storage times as it would be known when it was possible to return water and when this should be stopped. If necessary, discharge water could be returned through a sorbent material for final polishing and also returned upstream of the recovery device so that any remaining contamination in the discharge may be re-recovered.

Two oil:water separators were demonstrated to Agency personnel as part of this project. These are supplied by Darcy (Figure 6) and Richard Mozley Limited. The manufacturers claimed that both devices provide good separation efficiencies and low ppm levels in the discharge. Another device, developed by Costner Industries Nevada Corporation, is also reported to have a high efficiency. A further device, marketed by Geotechnical Instruments, is reported as being able to handle 250 l/min with the recovered oil being automatically passed to a storage sump. Without undertaking specific testing of these separators and comparing results against the possible separation efficiencies attainable with other storage tanks, it is not possible to make specific recommendations. However, it is considered that potential advantages are likely to exist with the use of proprietary oil:water separators.

13.5 Choice of Container for Temporary Storage

The most appropriate temporary storage container for immediate emergency use is considered to be rigid rectangular collapsible storage units such as Fastank and TroilTank. The TroilTank is the most rapid to deploy. Additionally, a low walled flexible tank such as the Pop-Up Pool is recommended as this has potential for the collection of leaking liquids in restricted spaces.

On the longer term during an incident, then other storage equipment can be utilised. Vacuum tankers or Vaculites, would be particularly useful as they also have a role for emptying other temporary storage units and enabling the transport and removal of liquids.

14 CONCLUSIONS AND RECOMMENDATIONS

14.1 General Discussion

The range of equipment available for water pollution control is great and varied. Whereas the exact requirements for the various regions of the Agency, and therefore the criteria for selection, might differ there will obviously be a considerable degree of overlap in their general requirements. Additionally, due to budgetary constraints there will be a limited range and quantity of material that each region could stockpile. Consequently, in the event of there being a major incident there is a probability that equipment will be utilised between Regions, or even between the Agency and other bodies such as SEPA, MPCU or the Environment and Heritage Service (Northern Ireland). Should this happen there are obvious advantages if equipment is standard across the Regions. These advantages include:

- familiarity of personnel with the equipment, its uses, capability, deployment and operation
- less likelihood of specific equipment being used erroneously
- compatibility of equipment from different sources
- opportunities for financial savings if items were to be purchased in bulk.

However, even if the equipment is standard that is not to say that all regional depots should stockpile identical equipment ranges and quantities. Indeed, there are good reasons why the requirements of each regional depot might differ. For example, depots with coastal stretches and estuaries might need relatively large boom for use in these areas while depots without coastal stretches and estuaries will not. What is important is that when a depot does have large boom it is compatible, as far as is possible, with large boom from other depots.

Similarly, standardisation and compatibility between Agency equipment and that held by other stockpiles such as the MPCU, SEPA and the Environment and Heritage Service (Northern Ireland) would have similar benefits.

Other possibilities for a national approach are:

- standardisation of identification documents/indicators for pollution response officer and response vehicles
- continued further development of the Strategic Pollution Equipment List to include all equipment including that held by Fisheries. This could also include equipment held by other relevant organisations
- a national purchasing policy managed centrally.

14.1.1 Equipment Review and Purchasing

There would be benefits if the review and purchase of spill response equipment for the Agency was managed nationally by a single group or department. This group would act as a single focal point and would:

- need to understand the requirements of the Agency
- be an informed contact for equipment suppliers and manufacturers
- evaluate products
- arrange trials and demonstrations if required by Agency regions
- co-ordinate any regional feedback
- make recommendations
- negotiate with suppliers on purchases
- ensure necessary standardisation and compatibility
- maintain the Strategic Pollution Equipment List.

14.2 Sorbents

The Agency should consider identifying a restricted range of sorbent types based on performance, value for money and environmental implications. Whereas organic sorbents are generally reported to be derived from sustainable resources there may be a perceived environmental implication in their use. In contrast, some synthetic sorbents are manufactured from otherwise waste materials that would be disposed of to landfill. Once selected, sorbents can then be purchased centrally in bulk to maximise cost benefits, but with periodic delivery to minimise storage requirements. Sorbents should be capable of dealing a range of liquids, both chemicals and hydrocarbons.

As far as is possible, the Agency should also consider within their purchasing mechanism, the possibility of introducing some standardisation in the colour of sorbents used for particular duties. Ideally, sorbents for application to hydrocarbons should all be the same colour, while those for application to chemicals should all be another colour. It is further recommended that a combination of colour coding and labelling is used: all sorbents that are oil only should be white and bear the word "OIL" in black while all sorbents that are universal, and capable of handling the more aggressive chemicals, should be yellow and bear the word "UNIVERSAL" in black.

Most synthetic oil only sorbents were found to be similar in performance during laboratory tests although, of those tested, Drizit 0140 performed best in many aspects. Liquitrol OPH 4843 also performed well and was rated highly by Agency staff during their evaluation.

Sphag Sorb and Peat Sorb were the best organic sorbents tested with oil. However, these materials are probably best suited for use on solid surfaces. Additionally, as their performance does not appear to be better than the best synthetic sorbents, and as there are possible perceived negative environmental implications from the harvesting of the moss used in their manufacture, it is recommended that use be restricted to special applications where oil needs to be recovered from hard surfaces.

Frogmat has potential to protect vulnerable riverbanks although deployment and recovery might be difficult. The removal of oil sheen by sorbents would still appear to be problematical.

Most synthetic universal sorbents are appropriate for many chemicals but most are incompatible with at least some of the more stronger acids, caustics and oxidisers. Organic universal sorbents should be avoided for use on many chemicals. It is therefore recommended that synthetic sorbents only be used for chemicals.

It is recommended that sorbent re-use be confined to the clean-up of solid surfaces.

It is recommended that sorbent disposal by incineration should be the preferred route for both organic and synthetic sorbents although costs will probably be significantly higher than for landfill.

14.3 Environment Protection Officer's Kit

A list of kit which should be accessible to an Environment Protection Officer has been developed. The adoption of this list will provide some uniformity across the Regions and thus facilitate any transfer of staff. Again, if similar equipment is adopted nationally then purchasing can also be undertaken nationally and cost benefits obtained from a larger purchasing power.

14.4 Equipment Required by Fire Services

A list of equipment required by Fire Services responding to a spillage has also been developed. The following recommendations for best practice are also made:

- due consideration should be given to the leave alone option
- clay leak sealants should be preferred compared to epoxy based leak sealants
- sheets (or tubs) of clay based material, and inflatable drain seals/pipe blockers should be preferred to water filled plastic bags or polyurethane sheeting for blocking drains. Where appropriate the clay sealant should be used in conjunction with metal sheeting to reduce quantities used
- sorbent booms or other sorbent types should be used in conjunction with containment booms for containment and recovery of liquids on water surfaces
- wherever possible drums and overdrums or similar vessels should be lined with plastic prior to use, thus enabling potential re-use.

14.5 Booms

Recommendations for booms deployed under different situations have been identified. Should these recommendations be pursued then the Agency will gradually move towards some standardisation for boom.

14.5.1 Sorbent Boom

An evaluation of sorbent boom for use in narrow waterways has resulted in the following recommendations:

- thin sorbent booms with or without skirts should be used
- booms without skirts can be used in still water
- booms with skirts should be used where there is any water movement

- sorbent boom should be used in combination with containment boom if there is any appreciable flow, such that the containment boom is downstream of the sorbent boom. Alternatively, the containment boom can be used in conjunction with other sorbent types
- consideration should be given to the use of double booms, more than one single boom or a single boom along with other sorbent types if the boom is to be left unattended.

14.5.2 Containment Boom for Narrow Waterways

An evaluation of containment boom for use in narrow waterways has resulted in the following recommendations for boom selection:

- for low velocity applications -
    - lightweight
    - high visibility
    - inflatable or permanent buoyancy
    - own brand connectors
    - custom lengths
    - height; ~ 200-300 mm
    - freeboard; minimum of 30 % of height
    - draft; minimum of 50 % of height.

- for high velocity applications -
    - heavier
    - high visibility
    - fence boom with built in buoyancy but where weight, access or storage is a problem then inflation boom may be substituted
    - easily cleanable
    - standard ASTM or Unicon connectors
    - height; ~300 mm upwards
    - freeboard; minimum of 30 % of height
    - draft; minimum of 50 % of height.

It is further recommended that a range of boom lengths be purchased so that units can be connected to accommodate site specific length requirements.

14.5.3 Coastal and River Boom

The review of containment boom for coastal and river use has resulted in the following recommendations:

- high strength
- durable
- inflation boom
- easily cleanable
- standard ASTM or Unicon connectors
- multiple anchoring points
- height up to 2m
- freeboard; minimum of 30 % of height

- draft; minimum of 55 % of height
- minimum breaking load for rivers; 50 kN
- minimum breaking load for coastal areas; 100 kN.

It should be stressed that these recommendations might not necessarily apply to specific sites where site booming plans have been or will be undertaken.

The Agency should also evaluate the cost benefits of purchasing connector adapters to enable existing booms with different connectors to be joined.

14.6 Skimmers

The potential for application of the main skimmer types has been identified. Skimmers that are considered more versatile and of potential use to the Agency include the suction, weir and disc type along with rope mops. However, as usage by the Agency seems to be very low it is recommended that the Agency does not require any permanent pieces of equipment of this type.

14.7 Aeration Technologies

Aeration technologies are important to the Agency operations. It is considered that the use of hydrogen peroxide to achieve rapid oxygenation has considerable potential and achieves a more rapid improvement of oxygen levels than aeration alone. Should the ongoing investigation being funded by the Agency confirm the benefits of hydrogen peroxide treatment then the Agency should increase the amount of equipment they hold. This can be readily achieved by either of the following two approaches:

- conversion of existing River Rovers - this equipment would have potential for use in larger and deeper water bodies
- additional pumps and venturi devices - this equipment would have potential for use in both large/deep and small/shallow water bodies. The Oxyjet, for example, would appear to be versatile for these applications and it is recommended that this equipment be trialed and compared to the River Rover.

14.8 Spill Detection at Night

Following an evaluation of low cost methods and equipment for the detection of oil and chemical spills at night the following conclusions were drawn:

- there is no portable and cheap equipment specifically for this purpose although oil test papers are available
- ultraviolet lamps have potential to assist in the observation of some hydrocarbons, especially if present in thick layers. However, the most effective is mains operated and needs to be held close to the water surface.

14.9 Encapsulation

Two encapsulation products, Unisafe and Unibiber, are both suitable for encapsulating a range of chemicals. Vapour suppression appears to be better with Unisafe although liquid retention might be better with Unibiber. The ease of application is reported to be easier with Unibiber although this would not appear to be a significant issue with Unisafe. The potential for some heating to occur exists with both products and it is important that operators are aware of this potential. With some specific chemicals this heating may be extreme. The presence of a pH indicator is considered an advantage by some operators and is only present in Unisafe. With the existing price structure for these two products it would appear that the cost of treatment is significantly less with Unisafe. It is thus recommended that, while this cost differential exists, Unisafe be used rather than Unibiber. However, users need to be informed that there are potential hazards when this product is used with strong oxidisers. When either product is used on unknown chemicals only a small amount should be applied initially.

14.10 Drain Seals

Laboratory based investigations suggest that, on clean surfaces, all types of drain seals tested can be expected to perform well although sand bags will probably allow some leakage. With non-clean surfaces, or surfaces with some roughness, clay material and inflatable seals can be expected to perform well. The sand bag is likely to allow significant leakage. The tetrahedral water-filled plastic bag and the polyurethane sheet are likely to result in excessive leakage.

14.11 Temporary Storage and Oil-Water Separation

The most appropriate temporary storage containers for immediate emergency use are rigid rectangular collapsible storage units such as Fastank and TroilTank. The TroilTank is the most rapid to deploy. Additionally, a low walled flexible tank such as the Pop-Up Pool is recommended as this has potential for the collection of leaking liquids in restricted spaces.

Oil-water separation procedures would have potential in reducing the quantity of liquids that need to be transported and disposed of. Separation would occur within storage tanks with bottom drawn liquid being discharged to the environment. This should be discharged through a sorbent filter if necessary or with the use of an oil-in-water monitor to ensure water quality. Any discharged liquid should be returned upstream of the collection point. The use of skimmer heads while collecting fluids into vacuum tankers would also assist in reducing volumes to be disposed of.

Proprietary oil-water separators are expected to provide a better performance than separation in ordinary storage units.