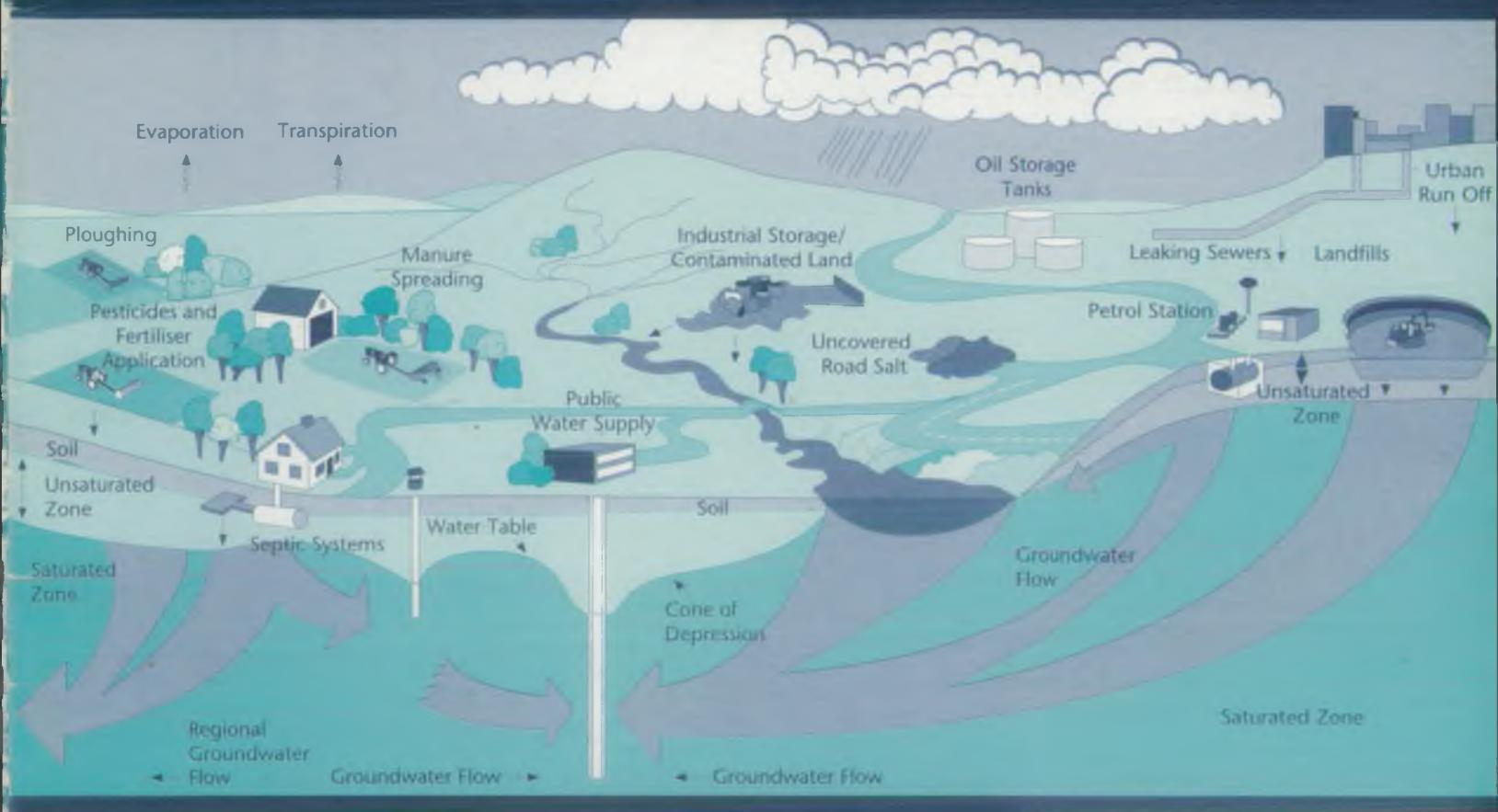


groundwater pollution

evaluation of the extent and character of groundwater pollution from point sources in England and Wales



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abstract

This document presents an overview of the extent and character of groundwater pollution from point sources in England and Wales carried out for the Environment Agency. The data was derived mainly from National Rivers Authority (NRA) field officers, with additional contributions from the water industry. The limitations of the provenance of the data need to be taken into account when analysing the results but the study is the most comprehensive to have been undertaken in the UK. Five case studies are presented to illustrate the severity classification codes used. Although landfills are the largest category of point source contamination, the severity of their impact is not considered to be as great as other land-uses. Solvent contamination, for example, appears to be more closely associated with the higher severity point sources. The study sought to answer the following broad questions:-

- ◆ To what extent is groundwater pollution identifiable to particular geographic locations?
- ◆ How many abstractions are affected?
- ◆ What is the proportion of point sources known to have caused contamination?
- ◆ How does the classification of point sources (confirmed or suspected) differ between regions?
- ◆ What are the main industries and activities causing groundwater pollution?
- ◆ What are the main groundwater contaminants?
- ◆ Which aquifers have been most affected?
- ◆ To what extent has groundwater remediation been undertaken?
- ◆ For the total number of point sources identified what is the severity of groundwater pollution from point sources in England and Wales?
- ◆ For those point sources for which dates of incidents/identification have been provided are there any recognisable trends in the generation of information?

background

The Environment Agency has statutory duties to monitor the extent of pollution of controlled waters. As part of a national review of water quality monitoring (BGS, 1994) the Agency is to establish a national groundwater quality monitoring network. It is proposed that this network be established on a hierarchical basis with a strategic national surveillance network supplemented by locally specified monitoring to meet local needs. The network will build on the varying existing Regional networks.

The known or suspected presence and nature of areas of local contamination are important factors in defining the overall quality of groundwater and the extent of useable resources. Local monitoring systems need to reflect this information which otherwise could be missed if they are based uniquely upon active points of abstraction.

In 1988 the Department of the Environment (DoE) contracted Sir William Halcrow & Partners Ltd to carry out an assessment of groundwater quality in England and Wales. Since that report (DoE, 1988) was a broad overview, Entec UK Ltd was commissioned by a predecessor body to the Environment Agency, the National Rivers Authority, to undertake a detailed and more comprehensive study using information available to it, largely from internal sources. The definition of a point source was designed to exclude true diffuse contamination such as from the use of fertilisers and pesticides in agriculture, but to include nitrate from leaking sewers, intensive spreading of sewage sludge, dense concentrations of septic tanks etc.

The information for the study was derived mainly from discussions with field officers in the NRA and data held at regional centres. Additionally, the following sources of data were considered and, where appropriate, pursued:

- ◆ Water companies were asked to volunteer information on abstractions contaminated by point sources. A little over half responded, and the data was of high quality.
- ◆ A representative selection of Waste Regulation Authorities (WRAs) were contacted to verify and augment NRA data.

Their location was scoped to include areas where existing NRA data were limited, and information was requested to avoid providing a bias towards the identification of waste disposal sites.

- ◆ An extensive search of published technical literature was undertaken.
- ◆ Environmental consultancies were considered but not pursued due to client confidentiality constraints. Entec, however, conducted a search of in-house projects detailing relevant point sources and where possible updated information received from the NRA.
- ◆ The possibility of obtaining information from industry was also considered, though informal and confidential enquiries to industrial organisations did not generate any additional project data. Concerns over confidentiality and/or regulatory action in the uncertain legislative circumstances of 1995 have largely prevented this. It is considered that the inclusion of data from this source could have probably increased the number of sites considerably.

Throughout the study, data have been collected in as an objective a manner as possible. The results of the study give a good indication of the nature and number of point sources of groundwater pollution in England and Wales, however, the data needs to be viewed in light of following limitations:

- ◆ The Environment Agency has inherited no systematic methods of recording groundwater contamination events that were not captured by routine monitoring and, therefore, the database has been compiled mostly from anecdotal information. It is, therefore, subject to bias because of the vagaries of changes in local staff and their historic knowledge of events in their area.
- ◆ Regional variations in general awareness of groundwater quality issues may have influenced the apparent regional differences. It should also be recognised that between regions the emphasis on pollution control records and direction of staff resources will influence the details available and so introduce a bias on the data.

background

- ◆ The results of previous local studies undertaken by various NRA Regions (eg: studies of solvent use and impacts to groundwater in Coventry, Lerner-1993) have in some cases clustered point sources, giving the inaccurate impression that the areas in question are much more polluted than others.
- ◆ There is a bias towards waste disposal point sources which reflects the fact that groundwater issues relating to these sites are key in the mind of most Agency staff due to the historical focus of statutory authorities and public interest in such sites.
- ◆ Gaps in the data have also resulted from not being able to obtain information from industry, as well as from only a little over 50% of the water companies. In addition, a number of sites may never have been recognised or have gone undetected.
- ◆ The original project brief to identify point sources of pollution affecting only major aquifers was relaxed somewhat in the course of the study. In the final analysis, 57% of the sites were underlain by major aquifers, 39% by minor aquifers, and 4% by non-aquifers. However, the inherent bias introduced by focusing on data collection where groundwater is most vulnerable and is an actual, or potential, resource means that no further inference should be placed on these figures.
- ◆ The majority of data collected is for point sources identified since 1990 and reflects the growing awareness of issues related to contaminated land. The scale of the impact on groundwater is hard to quantify and the definition of an impact is somewhat arbitrary and subjective. The apparent lack of severity may reflect the absence of any detailed assessment.
- ◆ The data presented was collated in 1995 and although the potential rate of increase in the number of point sources is unknown, it is likely that the number will have grown since then.

the study

For the purposes of data classification, the various land-uses causing pollution and the contaminants identified as a result were grouped into several categories.

The land-use categories used are as follows:

- ◆ **Chemicals**
(pharmaceuticals, wood treatment plants, paint works)
- ◆ **Petrochemicals**
(oil refineries, fuel storage depots)
- ◆ **Metals**
(iron & steel works, smelters, electroplating/anodising/galvanising works)
- ◆ **Energy**
(gasworks, power stations)
- ◆ **Transport**
(garages, maintenance shops, railway depots/sidings)
- ◆ **Waste Disposal**
(landfill sites)
- ◆ **Water Supply & Sewage Treatment**
(septic tanks, sewage treatment plants)
- ◆ **Agriculture**
(leaking silage clamps, pesticide preparation)
- ◆ **Residential**
(fuel oil spills, leaking fuel oil tanks)
- ◆ **Retail**
(retail parks, fuel oil spills)
- ◆ **Military**
(MoD sites eg military airbases)
- ◆ **Petrol Service Stations**
(spillages, leaking underground storage tanks)
- ◆ **Light Industrial**
(light industrial warehouses, premises)
- ◆ **Pits and Quarries**
(sand & gravel extraction, quarrying)
- ◆ **Mines and Spoil Heaps**
(abandoned mines and associated spoil heaps)
- ◆ **Miscellaneous**
(docks, wharfs, quays, sites not falling into any other category)

the study

Contaminants are grouped as follows:-

Metals	Inorganic (other)
Solvents	Sewage
Hydrocarbons	Landfill Leachate
Pesticides	Silage
Phenols	Radioactivity
Organic (other)	Miscellaneous Industrial

A subjective assessment of the point source severity was applied in an attempt to prioritise sites on a scale of national importance and thus provide an indication of the magnitude of groundwater pollution in England and Wales. The point sources have been allocated severity codes on a numerical system of 1 to 5 where code 1 represents a site where there is likely to have been gross contamination of a Major Aquifer, and code 5 represents slight contamination of a Minor or Non-Aquifer. The five case studies presented below illustrate these severity classification codes.

the national situation

The national situation of groundwater pollution has been assessed by performing a series of database queries on all the data collated. The answers to ten broad questions are presented below.

To what extent is groundwater pollution identifiable to particular geographic locations?

A total of 1205 point sources of pollution have been identified. These fall into 3 categories of certainty:

- a) abstractions known to be contaminated;
- b) Known groundwater contamination, but no confirmed impacts to abstractions and;
- c) suspected groundwater contamination, but no evidence.

A large number of pollution sources are located on the outcrop of the Chalk aquifer in the Anglian and Thames Regions specifically. Dense concentrations of point source pollution also occur on the Triassic sandstones in the Midlands and North West. This is particularly the case in respect of east Lancashire. The outcrop of Jurassic Limestone has a relatively low incidence. There are significant concentrations of sites around some of the major conurbations and industrial

areas which overlie Major Aquifers. This reflects a bias related to the intensity and history of industry in these locations and the level of development. Other areas of historic industrial activity do not show so clearly since the study was largely confined in scope to Major and Minor Aquifers. For example there was limited information collected for the London area, although much is held by the Thames Region relating to sites on non-aquifers. Also the area around Tyneside and Teeside did not give rise to the same amounts of information as further south because of the inherent protection afforded to groundwater resources by the thicker layers of Drift.

How many abstractions are affected?

A total of 251 abstractions have been identified as being affected by 210 point sources. This includes information provided by water companies of which only about half have responded. Sometimes more than one abstraction has been affected by any one point source of pollution. Of these 251 abstractions, 114 are public and 137 are private (domestic potable, industrial, agricultural, disused, miscellaneous/other).

The majority of the affected abstractions are located on the Chalk aquifer. However, there is also a significant number on the Triassic sandstones. For example in Coventry and Birmingham. The widespread contamination of the Coventry aquifer has previously been investigated by Birmingham University, and several Public Water Supply abstractions are known to be affected, mainly by the ubiquitous use of chlorinated solvents.

In addition to the abstractions which are known to be contaminated, a further 368 public and private abstractions are considered to be at risk from existing point sources of groundwater pollution.

What is the proportion of point sources known or suspected to have caused groundwater contamination?

Of the 1205 point sources identified a total of 777 (64%) are known to have caused some groundwater pollution. Of these, 210 (17% of total point sources) are impact on an abstraction.

A total of 428 point sources are suspected of causing contamination of groundwater, and appear to be clustered in various areas. The large number of sites in

the Lower Trent catchment and in South Wales are associated with the legacy of mining and associated activities in these areas, whereas the sites concentrated around Sheffield, Leeds and Merseyside relate to the impact of intense industrial activity.

How does the classification of point sources (ie confirmed or suspected) differ between Regions?

The distribution of all point sources identified in England and Wales is illustrated in *Figure 1*. The Environment Agency's North West, Midlands, Thames and Anglian Regions have the largest numbers of confirmed groundwater contamination occurrences. To some extent this reflects the Regional differences in the collection of data and the relative importance placed upon groundwater issues. There is a broad correlation between groundwater usage and the intensity of industrial activity but further interpretation would not be sensible without more comprehensive data.

What are the main industries and activities causing groundwater problems?

Figure 2 indicates that the main land-use contributing to groundwater pollution is waste disposal. It should be noted, however, that half of the occurrences of point sources within this category relate to suspected contamination only. In addition, the activity of landfilling is highly regulated and monitored when compared to other land-uses and activities. Consequently, there is generally a greater awareness of impacts to groundwater from landfill sites and thus a greater availability of relevant data. On a regional scale, although waste disposal still appears to be the dominant land-use category, other trends are also apparent. The three other most frequently identified land-use categories in each region are listed below:

Anglian:	Chemicals, Metals, Military
North East:	Metals, Chemicals, Energy
North West:	Chemicals, Metals, Petrol Service Stations
Midlands:	Metals, Chemicals, Energy
Southern:	Water Supply/Sewage Treatment, Energy, Chemicals
South West:	Agricultural, Metals, Chemicals
Thames:	Water Supply/Sewage Treatment, Metals, Chemicals
Welsh:	Chemicals, Metals, Energy

Within the Southern Region more than any other, the bias towards the identification of landfill sites was very noticeable. Also, contamination from the industrial use of solvents is perceived to be one of the biggest risks to groundwater in the Region, but the lack of an adequate monitoring network results in there being no real evidence to support this.

It should be noted that there are not many sites within the military land-use category. This is attributed to the fact that information for this area is not readily available. By comparison with other countries it is suspected that there are many instances of groundwater pollution associated with military activities. There are numerous references in the literature concerning contaminated military lands in the US and Europe and the similarities of the incidents with those in the UK which have been published.

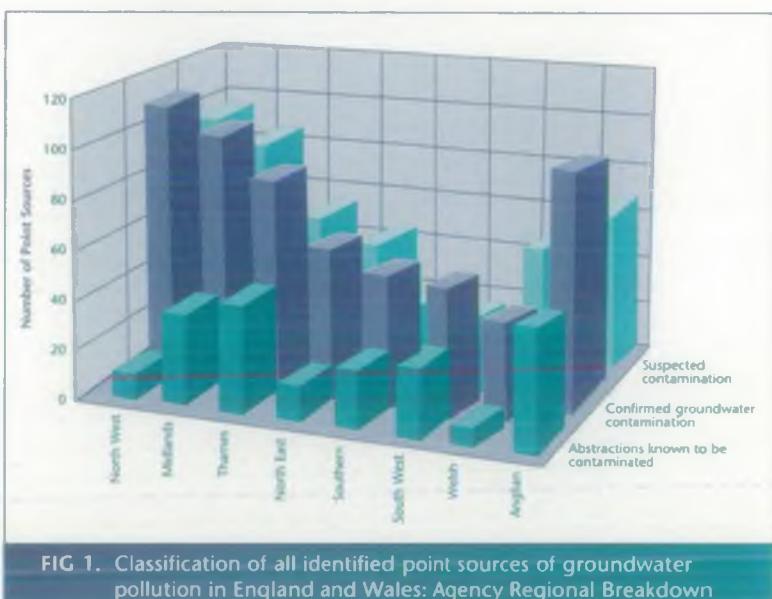


FIG 1. Classification of all identified point sources of groundwater pollution in England and Wales: Agency Regional Breakdown

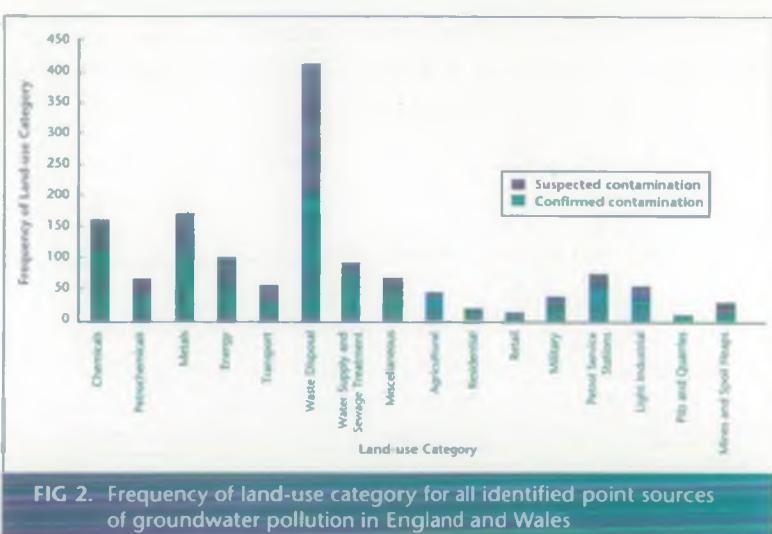


FIG 2. Frequency of land-use category for all identified point sources of groundwater pollution in England and Wales

Estimates in the Netherlands, for example, indicate that there are about 2500 potentially polluted military sites (more than 1 site per base possibly) in a country which is less than a third the size of England and Wales (Cox, 1995).

What are the main groundwater contaminants?

Figure 3 illustrates the most frequently identified groundwater contaminants as metals and landfill leachate. If, however, data relating to confirmed contamination only are considered, then metals, solvents and hydrocarbons are the most frequently identified contaminant groups. The high occurrence of leachate contamination reflects the number of point sources within the waste disposal category, whereas the occurrence of solvents and hydrocarbons is associated with industrial activity on a national scale. The high frequency of metal contamination is considered to be associated with a variety of land-uses including general industry, as metals are fairly ubiquitous contaminants and may therefore be present on almost any site.

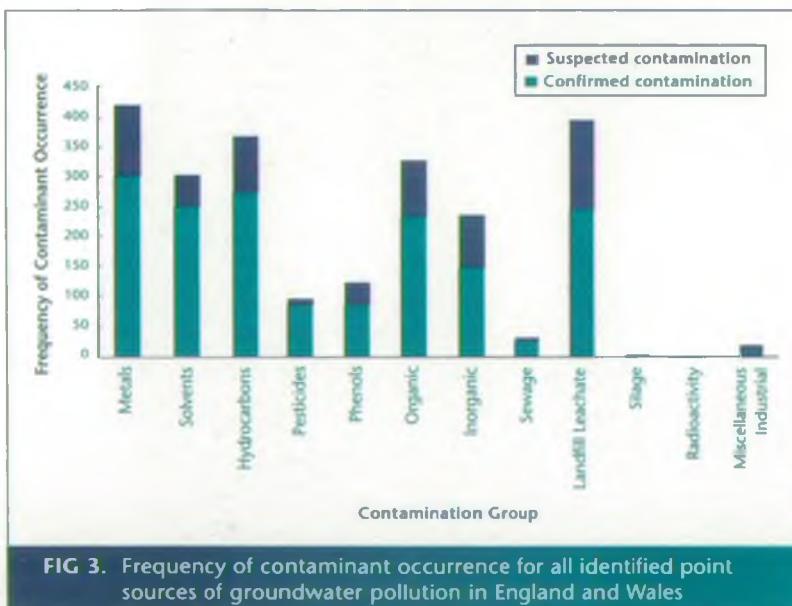


FIG 3. Frequency of contaminant occurrence for all identified point sources of groundwater pollution in England and Wales

Figure 4 details the association between the various contaminant groups and the severity classification. It can be seen that although metals were one of the most frequently identified contaminant groups, the contamination was associated largely with medium and medium-low significance point sources. This also applies to the hydrocarbons and landfill leachate contamination. Solvent contamination, however, appears to be more closely linked to the higher severity point sources with the majority of occurrences falling

within the high, medium-high, and medium significance groups.

The three most frequently identified contaminants within each contaminant group (where appropriate) are detailed below:

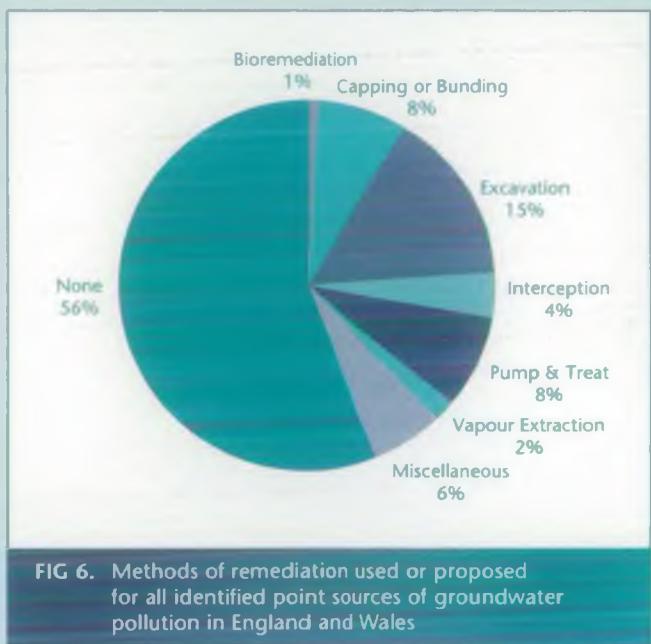
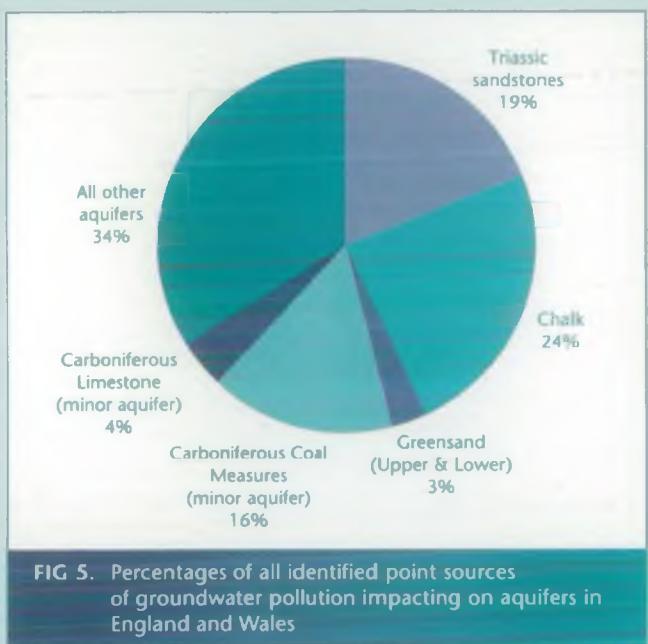
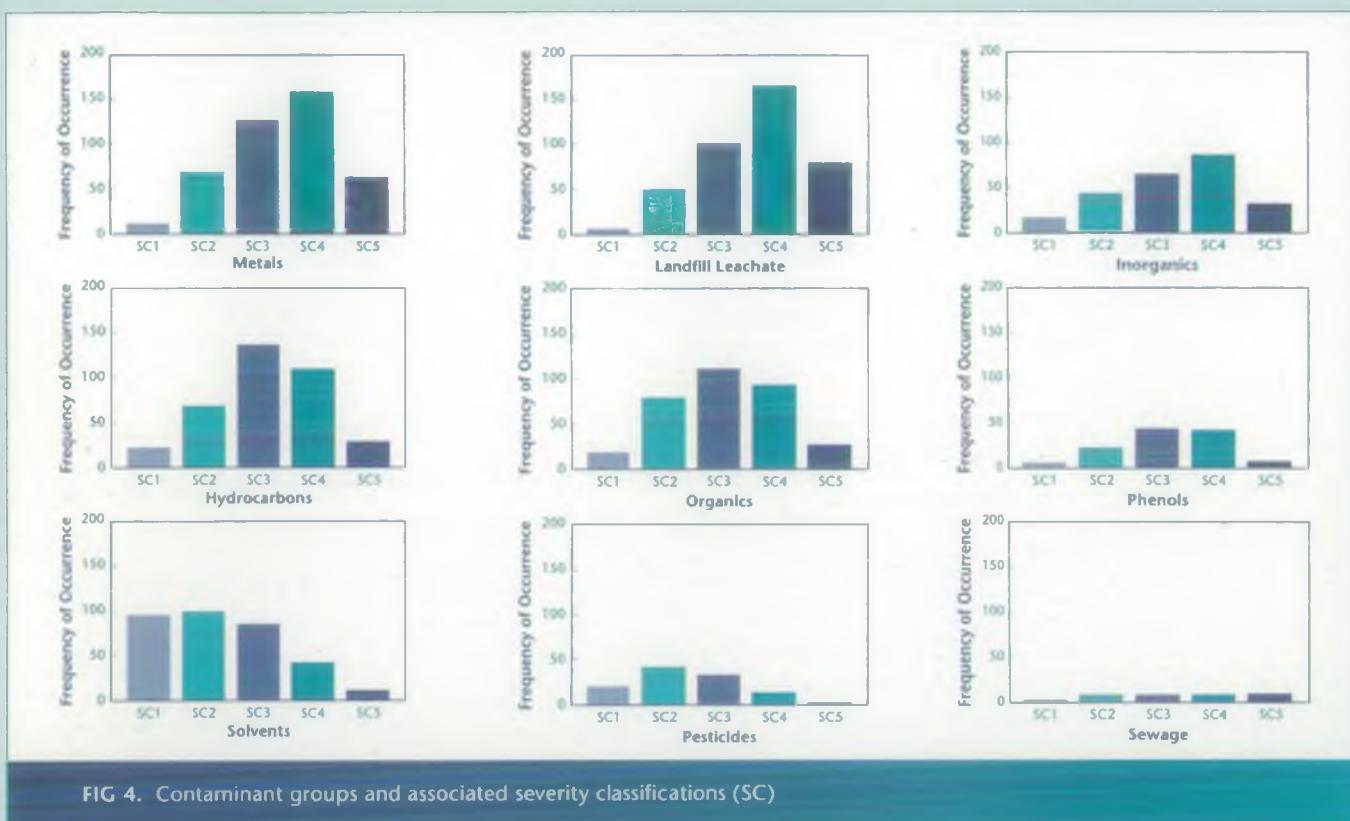
- ◆ Metals: Arsenic, Copper, Chromium
- ◆ Solvents: TCE, TeCE, TCA
- ◆ Hydrocarbons: Diesel, Petrol, Fuel Oil
- ◆ Pesticides: Atrazine, Simazine, Dieldrin
- ◆ Organic (other): PAHs, PCBs, BTEX
- ◆ Inorganic (other): Cyanide, Ammonia, Sulphate
- ◆ Landfill Leachate: Ammonia, Chloride, COD

Which aquifers have been most affected?

Figure 5 shows that 24% of all point sources identified nationally are impacting on the Chalk, with a further 19% of sites located on Triassic sandstones. In addition, 16% of sites are affecting the Carboniferous Coal Measures. Other Major Aquifers, Minor Aquifers, and Non-aquifers are impacted collectively by a total of 41% of all point sources of groundwater pollution identified. However, the study specifically addressed Major Aquifers, and some areas without Major or Minor Aquifers were not covered. Some caution is therefore needed when considering the statistics.

To what extent has groundwater remediation been undertaken?

Figure 6 indicates the methods of remediation which have been used or are proposed for the point sources identified during the study. There is often a combination of more than one type of remediation at each site. In general, the work undertaken relates to remediation of the site itself, thereby removing or containing the source of the contamination, rather than remediation of the contaminated groundwater beneath the site. The most commonly employed methods were excavation, capping/bunding and groundwater pump and treat. For the majority of point sources, however, it is apparent that no active remediation has been undertaken and contamination has been left to attenuate naturally, but not in any considered or planned way.



For the total number of point sources identified, what is the severity of groundwater pollution from point sources in England and Wales?

The severity classification has been applied to all of the 1205 point sources identified and the distribution is as follows:

Severity Code	Number of Point Sources
1 High Significance	8%
2 Medium-High Significance	17%
3 Medium Significance	28%
4 Medium-Low Significance	32%
5 Low Significance	15%

From these totals it would appear that approximately 8% of the total identified sites fall into severity code 1. This equates to an average 12 priority sites per region that are of national significance in terms of groundwater pollution. However, it should be noted that this assessment is subjective and should not be regarded as definitive. Approximately 47% of the point sources have been grouped into severity classes 4 and 5.

For those point sources for which dates of incidents/identification have been provided, are there any recognisable trends in the generation of information?

Of the point sources for which dates of incidents/identification were provided, 57% of the sites were not identified until after 1990 and less than 3% of the sites were identified prior to 1970.

This may be a reflection of the fact that increasing awareness of pollution issues has been driven by a greater awareness of the issues promoted since the establishment of the National Rivers Authority in 1989 which had a wider brief to monitor and protect the groundwater environment than its predecessors.

There has also been a greater awareness of the legal situation, both pollution control and civil liability legislation, as well as pending legislation on contaminated land.

case studies

The following 5 case studies of actual point source pollution of groundwater are used to illustrate the severity classification codes 1 to 5.

Point Source Severity 1

Point Source:

Dry Cleaning Facility.

Land-use/Activity:

This site has been occupied by dry cleaning establishments for over 100 years. There is an on-site process water abstraction borehole, and a brewery potable supply borehole is located across the road.

Nature of Contamination:

Solvents – TeCE and TCE.

Extent of Contamination:

The Environment Agency are monitoring solvents in the groundwater from the site borehole and from the brewery borehole. Levels recorded include: 50µg/l of TeCE in the dry cleaning abstraction, and <5 µg/l of TCE and TeCE in the brewery borehole. The levels of TeCE in the brewery abstraction are below drinking water standards, however, the reverse osmosis treatment is continued because of the sensitive nature of the abstraction.

Date of Pollution:

The contamination was first noted during 1993 as part of an NRA study of solvent usage in the area.

Hydrogeology:

The exposed Triassic Sherwood Sandstone Major Aquifer is affected. The site is also located within Zone 1 of a Source Protection Zone.

Remediation:

None implemented nor proposed to date.

Point Source Severity 2

Point Source:

Engineering Works.

Land-use/Activity:

The site was used for tank cleaning and refurbishment. Wastes were disposed illegally down an old mine shaft.

Nature of Contamination:

Hydrocarbons, PCBs, solvents.

Extent of Contamination:

The contaminant plume covers an area of approximately 2 hectares, and has spread to 60-70m below ground level. The groundwater is known to be contaminated but there are no confirmed impacts to abstractions.

Date of Pollution:

Contamination of groundwater occurred from the 1950s onwards, but was first brought to the attention of the NRA in 1992.

Hydrogeology:

The Carboniferous Limestone Major Aquifer is affected.

Remediation:

Extensive investigations have been carried out, and it is now proposed to remove the contamination from the mine shaft during the next 12 months (1996).

Point Source Severity 3

Point Source:

Petrol Filling Station (vacant).

Land-use/Activity:

Garage and petrol filling station.

Nature of Contamination:

Petroleum hydrocarbons.

Extent of Contamination:

Slight but widespread. Groundwater is known to be contaminated but there are no confirmed impacts to abstractions. The pollution was generally most extensive in the superficial made ground and drift deposits rather than in the underlying sandstone.

Date of Pollution:

Unknown.

Hydrogeology:

Boulder Clay (Non-aquifer) overlying Triassic Sherwood Sandstone (Major Aquifer). The site is also located within Zone 2 of a Source Protection Zone.

Remediation:

The leaking tanks and pipelines causing the problem were removed.

case
studies

Point Source Severity 4

Point Source:

Gasworks.

Land-use/Activity:

Gasworks and coal carbonization.

Nature of Contamination:

PAHs, mineral oils, cyanide.

Extent of Contamination:

Gross widespread contamination. Groundwater is known to be contaminated but there are no confirmed impacts to abstractions.

Date of Pollution:

Unknown, although a site investigation was carried out by consultants in December 1994.

Hydrogeology:

Alluvium overlying Lias Clay. Surface waters are indirectly affected by point source.

Remediation:

The site is currently the subject of redevelopment as offices/commercial, but the Environment Agency will object unless proper remedial measures are undertaken. An application by the developers for an EC grant to fund the remediation was refused. As a result, the final proposals for remediation have yet to be agreed.

Point Source Severity 5

Point Source:

Landfill Site.

Land-use/Activity:

Completed landfill site for domestic and industrial wastes.

Nature of Contamination:

Landfill leachate – ammonia.

Extent of Contamination:

Groundwater is known to be contaminated but there are no confirmed impacts to abstractions. Extent unknown.

Date of Pollution:

Unknown.

Hydrogeology:

Non-aquifer Lias Clay. Surface waters are indirectly affected by point source.

Remediation:

None.

case studies

conclusions

Although this study is the most comprehensive to have been undertaken in the UK and therefore provides us with a better indication of the present character and extent of groundwater pollution from point sources in England and Wales than has hitherto been available, the dynamic character and limited scope of the data will necessitate further information gathering in order to be even part-way comprehensive. However, cautious use of the data enables us to make tentative conclusions and recommendations for future work.

Categories of land-use activities which present the greatest threat to groundwater quality have been identified. Landfill sites are numerically the most significant category, but in terms of their actual and perceived impacts on groundwater are considered to be somewhat less of a problem than other sources and types of pollutants. The data collected is biased towards those land-use categories which are highly regulated and therefore likely to be better monitored. It is therefore not surprising that waste disposal activities are so prominent in the study.

Metallic compounds are seen as the most frequently occurring contaminant group but pollution by organic compounds (hydrocarbons, solvents and landfill leachate) outweighs problems with inorganic pollution. The number of groundwater pollution incidents relating to pesticide contamination is relatively low in comparison. However, the severity of pesticide contamination occurrences is seen as being greater than for other categories, with the exception of solvents where the majority of occurrences are in the highest severity classes. In contrast the majority of inorganic and landfill leachate contamination occurrences are in the lowest severity classes.

Active remediation of groundwater pollution is clearly at a low level in England and Wales. Of the point sources of pollution identified only 44% were having some form of remedial action applied and of these only 25% (11% of the total) seemed to be having positive remedial schemes involving techniques other than surface capping or excavation of overlying soils. Pump and treat operations were being carried out in only 8% of the occurrences identified. Intrinsic bioremediation has been adopted as a strategy in many cases by default. Little to no monitoring takes place on its effectiveness.

The study forms a basis on which the Environment Agency can build in order to:

- a) provide a focus for future groundwater pollution monitoring networks on areas of poorer groundwater quality and to ensure that data is collected by Regions on a more uniform basis;
- b) provide a better focus for the targeting of Environment Agency pollution prevention resources;
- c) identify those activities presenting the greatest risks of pollution to groundwater but which are currently not well regulated in order to develop appropriate controls, including new legislation if applicable (eg the storage and use of solvents);
- d) initiate investigations where the sources of contamination are unknown, especially when Public Water Supplies are involved;
- e) identify areas where remediation may be needed, especially sites with the highest severity codes and;
- f) evaluate the efficiency of groundwater clean-up which has taken place and review other appropriate methodologies.

This study is far from comprehensive and further work is required to confirm some of the tentative conclusions. Among the work identified is:

- a) co-ordination between the new partners of the Environment Agency, especially with waste regulators over information in their particular databases;
- b) examination of the potential for obtaining data from such sources as Environmental Health departments, Local Authority information resulting from the application of S.57 of Part II of the Environment Act 1995, and details of contaminated private and domestic water supply boreholes held by Local Authorities;
- c) establishment of a closer working relationship with industry, including the MoD, in order that the information gained can be added to and some of the inherent bias introduced by the data collection techniques eliminated.

conclusions

references

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abbreviations

BTEX:	Benzene, Toluene, Ethylbenzene, Xylene
COD:	Chemical Oxygen Demand
PAH:	Polycyclic Aromatic Hydrocarbons
PCB:	Polychlorinated Biphenyl
TCA:	Trichloroethane
TCE:	Trichloroethylene
TeCE:	Tetrachloroethylene

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The Environment Agency delivers a service to its customers, with the emphasis on authority and accountability at the most local level possible. It aims to be cost-effective and efficient and to offer the best service and value for money.

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