THE GSI GROUNDWATER NEWSLETTER

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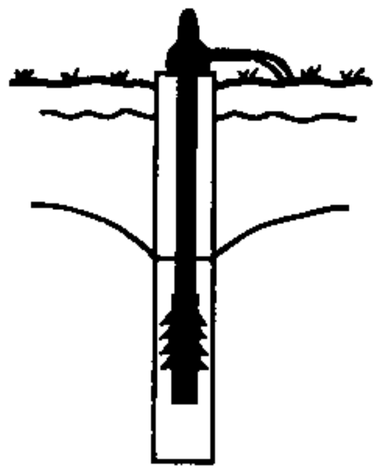

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IN THIS ISSUE

Peatland covers 16% of Ireland. In the past, peat and peatlands were often regarded in a negative way - "a soggy legacy of the past, a boggy problem for the future" as David Bellamy puts it. However in recent times this view has changed as peat has helped to provide employment, fuel, electricity, compost and tourists who come to Ireland to appreciate a landscape type that has been overexploited and often destroyed elsewhere.

This issue of the **Newsletter** concentrates mainly on the **uses of peat and peatland in preventing water pollution.** In our first item, Richard Thorn highlights the **adsorption capacity of peat** when describing laboratory experiments carried out at Sligo R.T.C. He follows this with a second study which illustrates an effective and practical **use of a peatland area to safely dispose of animal slurry** in a cost-effective manner. Most engineers, planners, E.H.O's and hydrogeologists must now be aware that a significant proportion of this country has geological and hydrogeological conditions which are not readily suitable **for septic tank effluent disposal.** At last there may be a remedy using a **specialised peat system** which is described by Pat Coffey on page 5. **Cutover bogs** have too often been used for unsightly dumping of refuse. However an article on page 6 suggests that they may be **suitable for properly engineered, low-cost, environmentally safe, waste disposal sites.** So far in Ireland we have had few problems from pipeline bursts or spillages. Shane Bennet, on page 8, describes a **toluene spill** in the US and illustrates the technology and expertise needed. A brief review of the groundwater pollution situation in Ireland is given on page 10.

On **groundwater development** we have an article from Tom Geraghty on **group schemes** (page 11) and a continuation of Kevin Barton's series on the use of **geophysics in groundwater exploration** (page 12).

The **Newsletter** is intended as a forum for discussion and communication. If you have views or information which would be of benefit to others or if you disagree with an article (provided it's not one of mine!) then write in to the **Newsletter.**

Donal Daly, Geological Survey of Ireland.

Peat - A Suitable Medium for Waste Disposal?

Peat possesses a number of characteristics which make it potentially a suitable medium for solid domestic waste disposal. In particular, the high cation exchange capacity (often two to three times more than the silicate clay minerals) should allow peat to attenuate leachate generated in waste disposal sites very effectively. In an attempt to provide some quantitative information on the attenuating properties of peat a set of laboratory scale leaching experiments were carried out in Sligo R.T.C.

The experiments consisted of leaching glass columns packed with peat, loam textured soil, a gravel-sand-silt-clay mix (G/S/S/C) devoid of organic matter and an acid washed sand with a landfill leachate. The potassium (K) and sodium (Na) concentrations of the leachate were determined prior to and following the leaching and the results expressed as the reduction in concentration (from the starting concentration) per unit weight of material. The ratio of adsorption of K was 36:11:9:1 per unit weight of peat, loam soil, G/S/S/C and acid washed sand. No Na was adsorbed onto the acid washed sand and the ratio of adsorption for the other three media was 8:1:1 per unit weight of peat, loam and G/S/S/C. The superior attenuation capability of peat is clear.

Lysimeter leaching experiments in Britain using the Lower Greensand, a rock with a high proportion of smectite - a silicate clay mineral - found that the quantity of rock required to adsorb one gram of metal ranged from 1.4kg for copper to 7.6kg for nickel. The results of the Sligo experiments on peat when expressed similarly are 3.1kg for K and 0.3kg for Na. Because of the differences in scale and experimental methods the two sets of results are not strictly comparable but nonetheless do suggest that the attenuating capability of peat is at least equal to that of the Lower Greensand - a lithology generally regarded as having good attenuating properties.

Further work needs to be carried out to quantify the attenuating properties of peat, particularly at pilot scale, and this could be tied to a field examination of waste disposal facilities currently operating on peat-land sites. A second set of experiments in Sligo simulated the movement and uptake of K and Na from a range of effluents, including landfill leachate, in a range of rock types and sediments, including peat, and the results of these experiments will appear in a later issue of the Newsletter.

Richard Thorn, Sligo R.T.C.

Slurry Disposal to a Peatland Ecosystem

The problem of slurry disposal is particularly acute in north-west Ireland where the growing season is short and where the soils frequently have a low permeability, thus allowing rapid runoff into water bodies. This article describes the results of an assessment of a system which has been using the natural attenuating properties of peat to overcome the problem.

The operation consists of a 150-170 cow dairyfarm situated on the shores of a lake in a drumlin region in northwest Ireland. (The accompanying sketch map shows the locations of the features referred to in the text.) The soils vary from well drained brown earths on the higher land to gleys on the lake shore. In the filtration area impermeable marl is overlain by 0.3-1.5m of peat. The slurry which accumulates during the four to six months that the cows are indoors is collected and stored in earthen tanks where the solids settle out. The settled liquor overflows into an effluent canal (which has an impermeable dam at its furthest end) in which anaerobic digestion occurs. The partially digested effluent is allowed to flow through and over the banks of the canal and into and onto the peat in the filtration area. A series of drains at the southern end of the filtration area collect the treated effluent and release it into the lake.

In early 1986 the local authority issued a notice under the Local Government (Water Pollution) Act 1977 requiring the farm to store all slurry in a slurry tank that was "soundly constructed" and to spread the waste on land. The local authority considered that there was a potential for pollution of the lake. However, the system, which has been in operation for over twenty years, was designed to overcome the danger of runoff into the lake that would arise from landspreading the slurries on the soils in the area which are not suitable for such spreading.

The study described here was carried out in Sligo R.T.C. during the summer months of 1987 following a request from the company running the farm and had as its objectives an assessment of the impact of the method of waste disposal being used and suggestions as to how the system might be improved. The study involved the collection of water and effluent samples for physical, chemical, microbiological, ecological and phytoplankton analysis from 37 points in the effluent canal and filtration area, the lake, lake bottom and lake shore.

The large volume of data collected show clearly that the method of waste disposal is having a minimal impact on the lake and that the slight eutrophication present in the lake has its source elsewhere. Particularly impressive was the attenuation afforded by the peat in the filtration area

to the slurry and this is illustrated clearly in the table below which summarises some of the water and effluent quality data for the canal and filtration area.

Sampling Site (see sketch map)

Parameter	A	B	F	G	H
Turbidity (FTU)	250	140	5	2	25
Colour (Hazen)	225	150	10	10	15
Nitrate (mg/l)	40.0	12.6	2.0	1.6	1.5
Ammonia (mg/l)	19.7	-	1.0	0.1	1.3
Phosphate (mg/l)	20.0	18.0	3.0	1.0	2.8
Potassium (mg/l)	200	195	3	5	35
Sodium (mg/l)	57	50	18	20	32
B.O.D. (mg/l)	24,000	24,000	12	7	21

Suggestions for improving the systems include filling in the ditches which drain the filtration area and building a bund at the south-western edge of the filtration area to protect it from possible inundation during winter months.

Such systems of waste disposal are in use in the U.S. where, according to R.H. Kadlec of the Wetland Ecosystem Research Group of the University of Michigan, they perform according to expectations.

Loretta Mathews, Richard Thorn and Eugene Brady, Sligo R.T.C.

Future Prospects for the Treatment of Septic Tank Effluent

Market: Many experts in the local authorities and health organisations throughout the country are becoming increasingly concerned about the potential dangers being posed by run-off from residential septic tanks. The dangers arise in regard to pollution of groundwater, streams, etc.

There are about 250,000-300,000 separate septic tanks for treating effluent in Ireland. In addition there is an unquantified number of sites throughout the country which take the effluent from groups of houses (say 20-50) into large single centralised system tanks and the highly polluted liquid run-off from these is discharged to drains or rivers.

Many of the septic tanks suffer from a number of problems including odour, the need for frequent emptying, leakage, etc. In addition and of more serious concern to the health and local authorities are the dangers arising when the run-off from septic tanks passes to groundwater in a polluted state and where percolation is poor or non-existent and the run-off is directed to nearby drains, streams, etc. The extent of the first problem has not been quantified to date although Donal Daly of the Geological Survey has highlighted that large areas of the country would be prone to such problems, especially in the area stretching from the west of the Shannon into east Galway and east Clare. There is also a band of medium- to high-risk areas stretching from Louth in the northeast to Limerick/North Cork in the Southwest. Medium- to high-risk areas for surface water contamination are concentrated along the entire western seaboard as well as the north central part of the country and a band which stretches from North Dublin through the Midlands to parts of Limerick and east Clare.

Currently it is estimated that at least 10,000 septic tank units on residential sites suffer from acute problems in relation to percolation. The number of larger local authority sites (groups of 20 or more houses linked to a single septic tank and not connected to mains sewerage) has not been quantified although local authority engineers and environmental health experts are unanimous in their view that there are many problem sites.

In the case of the 10,000 residential sites suffering from severe problems there is no cost-effective solution available on the market. A mechanical treatment system is available for the larger sites but scaled down versions for single septic tanks do not perform satisfactorily.

The New Treatment Concept: Based on work initiated in the U.S. ten years ago and first reported in the literature in 1982, Bord na Mona and Wavin have developed a cost-effective and technologically advanced modular

system using specialized peat for the treatment of effluent from single septic tanks.

The system is basically a cased-in unit consisting of the specialized peat, the distribution system and a specially developed cover to remove odour. It is intended to instal these at a number of individual detached sites in Clonmel within the next few months. Extensive monitoring of the results will be undertaken. Results from test applications are the same as those obtained in the U.S. Very high (over 90%) reductions in B.O.D. suspended solids, ammonia and bacteria have been achieved.

For larger scale problems a special pilot peat filter bed was designed, installed and commissioned in October 1987 to treat effluent from the Bord na Mona workshop at Blackwater works, Co. Westmeath. This workshop has a maximum manning level of thirty people.

Experience with this system shows that for large scale problems, which involve a centralized septic tank which takes effluent from groups of residences, more site-specific solutions are required. One such unit will be installed in Co. Kildare during 1988.

Eolas has provided some monitoring and technical input to the project.

The Future: It is proposed that once the Clonmel and Kildare sites are commissioned steps will be taken to undertake a full-scale launch of the product on the market during 1989. This will entail the creation of a joint venture company between Bord na Mona and Wavin.

H. Boyd*, P. Coffey, R. Kavanagh** and M. Weldon*.**

*** Wavin Ireland Limited; ** Bord na Mona.**

Cut-over Raised Bogs: A Suitable Resource for Waste Disposal?

As shown in the previous three articles, peat has exceptionally high adsorption and filtering capacities and consequently can purify and attenuate pollutants in industrial, sewage, septic tank and tip site effluents. In Ireland at present it is difficult for many local authorities to dispose of domestic refuse in properly located, investigated, designed and managed waste disposal sites due to financial constraints. Also there is still a tendency to fill in limestone quarries or gravel pits, both of which are usually unsuitable. Unlike Britain, we don't have suitable dilute and disperse type sites, which are relatively cheap to operate as leachate doesn't have to be collected and treated. However, could cut-over raised

bogs provide relatively cheap, yet environmentally safe sites for waste disposal? Have we a convenient, cost-effective, Irish solution to a worldwide problem?

The advantages and disadvantages of cut-over raised bogs are summarised below:

Advantages

1. Low land-use value.
2. Low population density in area.
3. Peat is relatively impermeable; groundwater not at risk.
4. Peat has high cation exchange capacity (CEC) which would assist in attenuating leachate.
5. Adjoining peatland could be used to treat the leachate.

Disadvantages

1. Bogs invariably are wet and difficult to operate on.
2. Has low load-bearing capacity.
3. No clay cover material on site.
4. Further research and trials are necessary to test their suitability and long term ability to treat leachate.
5. Peat is a fire hazard.

A principal advantage is that adjoining peatland could be used to treat the leachate, thus minimising costs but without significant detrimental environmental effects. The leachate could either be collected and sprayed on the peatland or it could be allowed to flow freely across a large purifying buffer zone between the tipped refuse and nearby streams. One of the main disadvantages is that the longterm ability of peat to attenuate leachate is not known, particularly where the pollutant loading rate is high. This problem could probably be overcome by covering and grassing over the refuse, thus reducing the generation of leachate and the loading rate. However, cover material is seldom present on peatland sites. So, it is not a simple solution.

I believe that we have in Ireland a resource which might enable financial savings to local authorities while at the same time providing an environmentally safer waste disposal system than the quarries and gravel pits used at present. I suggest that a desk study is needed to assess the literature and experience in other countries and that this could be followed by recommended designs and practices for the Irish situation. Some research in Ireland would be preferable but may not be necessary - the research from other countries and that already done in Ireland may well be sufficient.

These views may be contentious. If you either agree or disagree, write in to the Newsletter.

Donal Daly, Geological Survey of Ireland

Toluene Spill in Fremont, Ohio

Last February an underground pipeline rupture released 90,000 gallons of partially refined toluene to a north central Ohio creek feeding the Sandusky River. The spill forced the evacuation of 5,000 residents in Sandusky and Seneca counties, and the City of Freemont water treatment plant shut down its 6 mgd system for 40 hours.

An 18in. long rupture in an 8in. dia. corrosion (cathodic) protected steel pipe occurred close to a Sugar Creek tributary in Seneca County. The partially refined toluene, a petroleum derivative and suspected carcinogen, contained a small proportion of benzene and other aromatics. An estimated 20% of the spill infiltrated the land surface over the marshy area where the spill impacted. A partially precluding ice cover and permafrost restricted land surface absorption.

Sun Pipe Line is the transmission company for Sun Refining and Marketing Co., a subsidiary of Sun Co. Inc. Response and cleanup costs were not spared and complete coverage was immediately assumed by Sun Pipe Line.

The pipeline is 35 years old and is buried beneath 4 ft of soil in the rupture zone. A 3 to 4in. dia. plastic drain pipe had been placed at right angles on top of the pipeline at the rupture point. It is not known when the drain was emplaced, but it apparently interrupted the cathodic protection. The line flow rate was 1,000 gpm at the time the rupture occurred.

Suction pumps and absorbent booms were used at various points along the ice-choked creek and river in an effort to contain the spill. However, the product's high mobility limited the effectiveness of efforts to contain it and the contamination plume migrated downstream into lake Erie. A Geraghty & Miller, Inc. Emergency Response Team were contracted to monitor the plume along some 40 miles of impacted tributary, creek, river and lake.

As part of the monitoring program, Fremont's drinking water was sampled regularly at several locations. An unaccountable trace of benzene was detected during analysis. This anomalous incidence of benzene was unrelated to the spill and was traced to a poor quality carbon dioxide gas used in an aeration treatment process at the Water Treatment Plant.

Due to the solubility and highly volatile nature of toluene, less than 25% of the initial spill volume was recovered. Two days after the spill had occurred all unrecovered floating product had vaporized. The Geraghty & Miller monitoring program continued to study the soluble toluene and benzene concentrations along the river and in the Sandusky Bay area of Lake Erie. Discrete depth water samples were periodically collected at appropriate

locations in the river. Soil testing continued over the area where surface infiltration occurred. The affected soil in the rupture zone was excavated, placed on a liner and capped prior to removal and treatment.

Initially, the highest toluene concentrations detected were close to their maximum solubility levels of 490 ppm. Over a period of 156 hours the maximum concentrations decreased to 10 ppm. The drinking water treatment facility in Freemont installed granular-activated-carbon filters and an air stripper to treat drinking water when pumping began again two days after the spill. Initial pretreated toluence levels were reported at 1,190 ppb. In the bay area the dilution effect reduced the concentrations.

The spill apparently caused a massive fish kill in the river. Chad were the most affected fish species. However, according to a local source, a significant proportion of this species dies annually during the winter freezeup and their small carcasses litter the estuary every spring thaw. The increased fish kill this year may be partially due to abnormally cold seasonal temperatures.

The volatility and low specific gravity of toluene was responsible for its accelerated vaporization from the river. Adherence to sediments was noticeable in the tributary and the boom placement locations only. Cold air temperatures retarded the vaporization rate; however, winter conditions were responsible for the ice cover and permafrost at the impact area which reduced soil penetration and mobilization in the groundwater during the release period. A complete sediment sampling profile has just been completed by Geraghty & Miller, Inc. Observations during sampling suggest that analytical results will satisfy concerns over sediment contamination.

Monitoring was reduced to a biweekly frequency within two months of the spill. Total damage estimates await the sediment analytical results and an Ohio Environmental Protection Agency bioassay on the Sandusky River.

***Shane M. Bennet, Geraghty & Miller, Inc., Milwaukee, Wisconsin**

* Shane is a Dubliner, who graduated from UCD in 1983 with a degree in Geology and Physics. He then emigrated to the US and worked as a geophysicist with Zenith Exploration. Since 1985 he has worked as a hydrologist with Geraghty and Miller, Inc., one of the most successful hydrogeological consulting firms in the US. We wish Shane continued success.

Editor

Groundwater Pollution in Ireland: The Geological Survey View.

An Irish Times article on 11th May, based on a recent paper* of mine, referred to the views of the Geological Survey on groundwater pollution in Ireland. To clarify any misunderstanding which might be created by the article, the main conclusions of the paper are summarised below:

1. There are vast resources of groundwater in Ireland that are of good quality. However, an increasing number of wells and springs are polluted, mainly because they are located too close to pollution sources which are often inadequately constructed and managed. Also, there are some areas, particularly in the West of Ireland, where the pollution is more widespread. So for most of the country the vast reservoir of water in the ground is pure and safe to drink, but there are small polluted pockets beneath certain point pollution sources.

2. Geological and hydrogeological factors are critical to the determination of groundwater vulnerability, the assessment of potentially polluting developments and the alleviation of groundwater pollution problems. In particular, the Quaternary ("Glacial Drift") deposits are very important.

3. The main sources of groundwater pollution are considered to be farmyard wastes and septic tank effluent. Many of the major problems are probably caused by farming in view of the quantities of wastes generated and stored in farmyards. However septic tanks are an important source of minor problems, for instance pollution of low yielding private wells.

4. Fertilizers are not presently considered to be causing major problems although further research and monitoring is required.

5. Location of wells at "safe" and sensible distances from pollution sources, sanitary well construction and regular well disinfection will reduce the likelihood of pollution.

6. Positive contamination indicators include E.coli, nitrate, ammonia, potassium, chloride, iron, manganese, boron, fatty acids and trace organics.

7. Trace organics such as solvents, phenols and pesticides are important potential pollutants which require increased attention and monitoring.

8. A nationwide programme of regular chemical and bacteriological monitoring of groundwater in representative sources in our major aquifers is required.

All these points are developed further in the paper, so if you want a copy let me know.

* Groundwater Pollution in Ireland: A Review. Proceedings of Eleventh Environmental Health Conference, Kilkenny, 1988.

Donal Daly, Geological Survey of Ireland.

GROUNDWATER DEVELOPMENT

Groundwater for Group Schemes

Groundwater is the preferred choice if a group scheme has to provide its own source. The reasons are:

1. Drilled wells usually provide the quantities of water required;
2. There is usually no necessity for treatment;
3. Maintenance and operational costs are low.

The original group schemes were organised in response to the demand for domestic water supplies in rural areas but it became obvious at an early stage that there was also an urgent need for agricultural supplies. Prior to group scheme development there had been approximately 62,000 individual farm supplies - mostly deep wells adjacent to farmhouses and farmyards. The usual group scheme drilled well yielded from 1,000 to 2,000 G.P.H. Continuous pumping tests for 72 hours were carried out in order to establish if the source could supply the group's needs. The tests did not establish the full output of the sources or the extent of the aquifer. Nevertheless some very good sources were developed with yields of over 5,000 G.P.H. and some spring well sources had outputs in excess of 2 million gallons per day.

There are now approximately 120,000 dwellings and associated farms served by group schemes. About 60% are served from Local Authority mains. Approximately 2,000 schemes have groundwater supplies. The number of dwellings yet to be served with a piped water supply is about 50,000. There is an estimated need for 600 new deep wells to serve the schemes which will be dependent on developing their own sources (i.e. no public supply within an economic distance). Within the next ten years many of the older sources will require redevelopment. The reasons for this are:

1. many of these schemes have been extended beyond their original design capacity;
2. the wells or the aquifers were not fully developed;
3. no provision was made for the temporary breakdown of pumps (or source). No 'stand-by' systems were provided.

The further development of existing groundwater sources will be necessary in probably 1,000 schemes.

In recent years well drillers have brought their skills up-to-date. Modern scientific methods are being employed in locating and developing sources. Some of the very large schemes, covering perhaps 50 square miles, may find it beneficial to investigate the possibility of developing ground water sources in order to alleviate the cost of treating existing lake supplies.

Tom Geraghty, Department of Environment (Group Schemes).

3. Resistivity - The Pseudosection

Vincent McDonell carried out a number of resistivity surveys in the vicinity of a spring near Newcastle West, Co. Limerick to enable a better understanding of the geological controls in an area of thick glacial drift, possibly underlain by a contact between Reef and Calp limestone.

One resistivity method used was the co-linear dipole-dipole array which allows the production of a contoured resistivity depth section. This section (Fig. 1) shows the lateral and vertical variation of resistivity along the traverse line. The depth of investigation is approximately 20% of the length of the resistivity array. The data are presented in a standard format with each measured resistivity value being plotted at the intersection of two 45° lines drawn through the dipole centres (see Fig. 1). This geometric method of plotting the data does not allow direct correlation of the resistivity section with the geological section which gives rise to it. For this reason the resistivity section is known as a "pseudosection".

The initial interpretation of a pseudosection is done in a qualitative manner relating "zones" of high or low resistivity to the possible geological conditions which may give rise to them. Sharp contrasts in resistivity outlined by contours at or near 45° can be related to possible near-vertical geological structures such as contacts or faults. Computer programmes exist which can be used to precisely model geological structures which may give rise to the patterns seen in pseudosections.

The pseudosection in Fig. 1 shows resistivity slowly increasing with depth with lower values at the SE end of the line. The maximum depth of investigation would be about 20-25m and high bedrock resistivity values are not apparent. The conclusion drawn was that the section represented a glacial sequence overlying saturated bedrock. There was no evidence along the line of the pseudosection of a fault or geological contact existing within 20-25m of the surface.

Kevin Barton, Applied Geophysics Unit, U.C.G.

I.A.H. NEWS

The I.A.H. 8th Annual Groundwater Seminar, 12th and 13th April 1988: Were you there? Should you have been there?

The annual seminar organised by the International Association of Hydrogeologists (Irish Group) was held at the usual venue, the Killeshin Hotel, Portlaoise, in April, and I think all will agree that it was a successful, rewarding occasion. Some of the readers of this newsletter will have been present, but for those of you who were not, here are some thoughts on the meeting, which I hope will encourage you to attend next year!

The meeting serves a valuable purpose, disseminating hydrogeologic information to a wider audience, and providing an opportunity for a wide variety of individuals and organisations to come together and discuss groundwater-related topics. This year, the seminar had two themes: the future of groundwater development in Ireland and groundwater aspects of environmental impact assessments. The keynote address was given by Glyn Jones, an eminent hydrogeologist, who inaugurated the first post-graduate course in hydrogeology in Britain, and this was followed by papers from ten other speakers over the one and a half days, from varied backgrounds (hydrogeology researchers and consultants, engineers, drillers, planners, etc.). There is not space here to detail each of the speakers: suffice it to say that all lectures were of a high quality, and stimulated lively discussion. Thanks to the consideration of the speakers and good organisation by the committee, all sessions ran smoothly and to schedule.

For many of us, the importance of the meeting lies not only in the lectures and formal discussion, but also in the opportunity to exchange ideas in an informal manner over coffee and lunch. This year, the sixty delegates included hydrogeologists from Ireland and Britain (and two from China!) from the public service, universities and private consultancies, also well drillers, representatives from fourteen local authorities, and personnel from the Department of the Environment, An Foras Forbartha, Eolas, etc. I for one, hope that the annual seminars will continue to provide a useful forum for discussion and debate among this wide-ranging group for many years to come.

Catherine Coxon, Environmental Sciences Unit, T.C.D.

NEWS FROM ABROAD

Kansas

Water from private wells in fifty Kansas counties has been analysed for volatile organic compounds (VOC's), pesticides and inorganic compounds, in a study required by the 1986 Kansas Groundwater Quality Protection Strategy. About 28% of the tested wells contained nitrates above drinking water standards, 8% contained pesticides, and 2% showed VOC's. 128 public supply wells were also tested and 12 were found to contain one or more pesticides. Officials say the contamination of public wells must be prevented through well siting and well head protection.

(Source: The Groundwater Newsletter, Vol. 17, No. 6)

Editor

Job Prospects in United States!

A severe shortage of trained personnel faces the entire environmental field and especially the hazardous waste sector, according to Dr. Paul L. Busch, president-elect of the American Academy of Environmental Engineers. He estimates that the supply of graduates with special training in hazardous waste will meet less than 10% of the need in the next five years. After that, it gets worse.

(Source: The Groundwater Newsletter, Vol. 17, No. 5)

Editor

CONTRIBUTIONS FOR THE NEXT ISSUE OF THE NEWSLETTER

The **GSI Groundwater Newsletter** aims to improve communication among the many scientists and engineers involved with groundwater. It includes news, developments, reviews and opinions on all aspects of groundwater - exploration, development, management, water quality, pollution and energy. It is published at three-monthly intervals.

Your contribution to the dialogue would be welcome. These should reach the Geological Survey before **1st August 1988.** All items should be as short **(maximum 350 words),** interesting and newsworthy as possible