THE GSI GROUNDWATER NEWSLETTER

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Published by the Geological Survey of Ireland.
Beggars Bush, Haddington Rd.,
Dublin 4. ☎ (01) 609511

Foilsithe ag an Suirbhéireachta Gheolaíochta Éireann.
Tor an Bhacaigh, Bóthar Hadington,
Baile Átha Cliath 4. ☎ (01) 609511

Edited by: Donal Daly.

No. 14. December, 1989

IN THIS ISSUE

There has been a tendency in recent years for many groundwater scientists and the media to concentrate on pollutants such as nitrates, metals and trace organics. While these undoubtedly deserve attention, there has perhaps been too little notice paid to what are, in my opinion, the most dangerous groundwater pollutants - **faecal bacteria** and **viruses.** In my own case it is only in recent years that I appreciated the degree of bacterial pollution of groundwater sources in Ireland. A recent symposium **"Bacterial Contamination of Groundwater"**, held at Sligo RTC, has helped to draw attention to this problem. Summaries of the papers are given on pages 9-13.

Articles on **peat** are a regular feature of the **Newsletter.** But then why not - peatlands cover 16% of Ireland. On page 4 Fionnuala Collins describes a **hydrochemical study** of two **fens** in the east of England.

On page 2 Shane O'Neill describes the benefits of using **Pionjar drilling** and **geophysics** in locating boreholes on river flood plains; Catherine Coxon summarises a lecture on **trace organics** (particularly pesticides and solvents) by Lewis Clark on page 6; and on page 8 Kevin Cullen presents a thought provoking view of the **Local Government (Water Pollution) Act, 1977** as it relates to **farm wastes.**

Donal Daly, Geological Survey of Ireland.

GROUNDWATER DEVELOPMENT

A Combined Approach to Siting Exploration Boreholes on River Flood Plains

Introduction

A groundwater supply of 35l/s was required to augment a river supply for a fish farm during periods of low flow. The advantages of constant temperature and chemistry were other reasons for opting for a groundwater supply.

Exploration Borehole Location

The fish farm is located between two rivers, one of which is being used to supply the farm. The second river is below the fish farm and has a flood plain on both sides. Flood plain gravels were considered to have the greatest potential of meeting the discharge requirements of the project. It was hoped that they would be reasonably thick so that river water could then be induced through a good thickness of gravel towards the borehole resulting in a high yield of filtered river water. It was decided to locate the exploration holes on this flood plain. The option of locating boreholes on the flood plain of the river already supplying the farm was not considered as they would lower the flow of the river by inducing water from it.

Resistivity Survey

The flood plain surrounding the lower river is about 11 ha in extent. A resistivity survey using an offset Wenner array and the Barker system was carried out. A series of resistivity soundings were done first. It identified a four and five layer model under the flood plain. It was decided to target the lower of the three layers with the resistivity profiling.

The profiles were carried out at three different electrode spacings. The 8 metres electrode spacing profiled variations in the thicknesses of the near surface layers. The 16 metres electrode spacing profiled variations in the overall thickness of the alluvial sequence. The 32 metres electrode spacing profiled variations in the permeability of the underlying limestone bedrock. This was done in case the gravels proved to be too thin and the limestone had to be exploited.

The results of the resistivity survey identified five possible sites. They were ranked in order of potential to meet the needs of the project. Drilling would be the only way to find out which of the five sites were the most suitable. The cost of drilling five boreholes that were between 10 to 15 metres in depth would be in the order of £7,000. It was decided to use a Pionjar hand held overburden sampler to determine the alluvial sequence at each of the five sites.

Pionjar Percussion Drill

The Pionjar is a percussion tool powered by a petrol engine, it weighs

50 lbs and is very mobile. It uses one metre long mild steel rods, one inch in diameter. A one inch diameter sampler or a 1.5 inch sampler is attached to the end of the rods. It can reach depths of up to 30 metres. It cannot penetrate solid bedrock. Large boulders in a boulder clay or very coarse gravel can cause problems.

Each of the five sites was drilled using the Pionjar. Each hole went down to bedrock. This was at a depth of between 6.5 to 8.0 metres. A sample was taken every metre. This involved withdrawing the rods each time and retrieving the sample retained in the sampler. The depth to the water table was also recorded. The Pionjar drilling programme took one day to complete. The results allowed the resistivity survey to be accurately calibrated.

The end result of the combined approach of using a resistivity survey and the Pionjar was that none of the five sites were adequate to meet the requirements of the project. It was therefore decided to exploit the limestone bedrock. The location of the exploration borehole in the limestone was decided by the resistivity results only.

However the thickness of each layer, the depth to each layer, the depth to bedrock, the grain size and the type of sediment in each layer was known. If the results had been positive it would have been possible to know in advance how much screen and casing would have been needed, the slot size, the likely diameter and the complete depth of the exploration hole. This would have allowed a very accurate borehole design to be drawn up, with very accurate costings for the client.

The cost of the Pionjar is between £250 to £400 per day. It is certainly good value for money.

Summary

The **advantages** of the combined use of a resistivity survey and the Pionjar are:

i) It allows the resistivity sounding curves to be calibrated;
ii) The potential of each target site can be quickly assessed;
iii) The drilling is quick (about 7 metres per hour);
iv) The Pionjar is very mobile;
v) It allows an accurately designed and costed exploration borehole to be drawn up.

The **disadvantages** of the combined approach are:

i) Sampling is only every one metre;
ii) The volume of the sample is very small and the grain size of the sample will always be less than 0.75 inches, the I.D. of the sampler;
iii) If the results are positive an exploration borehole still has to be drilled in order to determine the aquifer properties;
iv) Boulders and very coarse gravels are difficult to drill and it may be necessary to try several times to get past a large obstruction.

Shane O'Neill, Environmental Resources Analysis Ltd.

PEATLAND RESEARCH

A Hydrochemical Study of two Norfolk Wetlands: Badley Moor and Catfield Fen.

Introduction: Wetlands are fed by combinations of groundwater, hillslope surface water and/or direct precipitation. This study examines the hydrochemical aspects of two Norfolk wetland sites with the objective of using the hydrochemical data as an aid to delimit the source(s) of water which supply and maintain each site. This involves determination of whether the data can assist in the recognition of the types of hydraulic and chemical processes which operate, allow the classification of water types and determine their evolution.

At each site a comprehensive hydrochemical survey was undertaken involving measurement of conductivity, alkalinity, pH and temperature. Water levels were monitored. Sampling was undertaken and the samples analysed for the major ion suite: calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), chloride (Cl^{-}), sulphate (SO_4^{2-}) and total oxidized nitrogen (T.O.N.) and the minor ions and trace metals: boron (B), silica (SiO_2), strontium (SR^{2+}), iron (Fe^{2+}) and manganese (Mn^{2+}). Piezometric, geophysical and pre-existing geological and hydrogeological information were utilized throughout the study. The interpretation of the chemical data was aided by use of data handling and chemical modelling computer programmes.

Site A Badley Moor: Badley Moor is situated in the upper reaches of the valley of the River Tud. The area is predominantly covered by chalky boulder clay with glacial and riverine sands exposed in the valleys. The Drift cover is underlain by the Upper Chalk. A layer of Putty Chalk (a glacially disturbed Chalk surface) may be present.

Calcareous springs emerge from the valley side and are marked by well developed tufa formations created by the deposition of calcium carbonate resulting in a large hummock at the centre of the moor.

A buried channel in the Upper Chalk caused by glacial overdeepening of a pre-existing valley is believed to underlie the moor.

Samples were taken from surface ponds, surface water courses and piezometers at various depths within the tufa mound.

The moor waters were found to be hard, calcium-bicarbonate rich and similar in composition to both local Chalk and Drift groundwaters. Measurements of piezometric head at the moor reveal that flowing artesian conditions exist. However both the local Chalk and Drift groundwater were also under artesian pressure. The distribution of T.O.N., its source being inorganic fertilizer, indicates that surface runoff is lost to a series of drains and streams in the area. Therefore, the chief water source feeding the moor is groundwater from either of the following systems:

a) the sand and gravel aquifer within the Drift cover isolated from the underlying Chalk by the layer of Putty Chalk.

b) the Chalk aquifer connected to the sand and gravel lenses within the boulder clay in the absence of the Putty Chalk layer.

Geophysical soundings undertaken by Barbara Metcalfe (University of Birmingham) confirmed the presence of a buried channel beneath the moor but failed to detect the Putty Chalk layer. Assuming that this layer is absent then the moor is likely to be fed by the dual Chalk - sand and gravel aquifer system. Solutional activity in the past will have preferentially developed the secondary permeability to a greater extent in this valley.

Chemical modelling undertaken on the moor groundwaters indicate that the dominant process which occurs is exsolution of carbon dioxide (CO_2) by groundwaters which equilibrated with calcium carbonate at a greater partial pressure of CO_2. This results in a suite of saturated and oversaturated waters in which calcium is being deposited in the form of tufa.

Site B Catfield Fen: Catfield Fen lies in an area of Cray*. The site is bordered by the River Aut in the west and by 'Uplands' elsewhere. The fen is dissected by a network of dykes which result in a series of fen compartments. The fen proper has no direct connection with the river as it is isolated by a solid peat wall.

An initial survey of electrical conductivity revealed fundamental variations which were used as a basis for more detailed measurements and sample collection. Study of the fen groundwater chemistry enabled the recognition of four basic chemical types:

Type 1 Groundwater: This water is restricted to the peat surface of most fen compartments and is characterized by a low concentration of dissolved constituents and low pH which increase rapidly at the fen margins. The water is chemically similar to precipitation and has had no interaction with groundwater. The lack of mineral base supply to neutralize acids produced by peat decay renders the water acidic. The increase in dissolved solids and pH toward the fen margins may reflect the increasing influence of dyke groundwater.

Type 2 Groundwater: This water is characterized by an elevated level of dissolved constituents relative to type 1 and an accompanying rise in pH. It occupies the north east fen and the northern and eastern segments of the marginal catchwater dyke. It is richer in mineral constituents than local Crag groundwater sampled from a well at the fenside. This indicates that surface water from the adjoining mineral rich highly fertilized upland soils provides a dominant source water to the fen.

Type 3 Groundwater: Type 3 groundwater is characterized by an intermediate concentration of dissolved solids relative to types 1 and 2. It occupies the remainder of the ring dyke and the majority of dykes which dissect the fen. It represents a mixing of type 2 groundwater with type 1 along the groundwater flow path, resulting in its relative dilution.

Type 4 Groundwater: Type 4 groundwater is characterized by elevated concentrations of Mg^{2+}, Na^{+}, K^{+} and HCO_3^{-} and significantly lowered SO_4^{2-} levels relative to groundwater types 1, 2 and 3. It occurs in a dyke to the 'north of the fen'. This water is believed to be polluted by seepage from a septic tank. The process of sulphate reduction is believed to be important in this area resulting in low SO_4 concentrations accompanied by very high levels of HCO_3^{-}.

In conclusion a study of the fen hydrochemistry indicates that the dominant water sources to the fen are those of surface runoff from the surrounding uplands and direct precipitation.

* Early Pleistocene sands and gravels with interbedded clays.

Fionnuala Collins**

** Fionnuala Collins graduated from T.C.D. in 1987 with a degree in Geology. She has just completed an M.Sc. in Hydrogeology at the University of Birmingham.

Editor

GROUNDWATER QUALITY AND POLLUTION

Trace Organics in Groundwater - a Major Issue in the 1990's

Pesticides and organic solvents are two major groups of synthetic organic chemicals (often referred to as trace organics because of their significance at trace levels of the order of parts per billion and less). Many are known or suspected carcinogens, and a tiny quantity can contaminate and render unusable a large volume of aquifer. These substances provided the subject of the IAH Autumn Lecture, which was given by Dr. Lewis Clark of the Water Research Centre (WRc), UK, on 12th October. The meeting provided much food for thought for everyone concerned with water quality here in Ireland; a few of the issues raised in the talk and the subsequent discussion are highlighted here.

A study of pesticide levels in groundwater encounters a number of difficulties. Great care is needed when sampling, as the dangers of cross-contamination are very great when dealing with such minute quantities. Sample preparation involves a 10,000-fold concentration of the sample in a number of steps, and analysis requires very sophisticated and expensive equipment. Even the most sensitive equipment cannot reach detection limits as low as the E.C. limit of 0.1 µg/l in the case of some pesticides. (Incidentally, the point was raised that this E.C. limit is illogical and unscientific as it applies equally to relatively non-toxic and to deadly toxic pesticides - however it appears unlikely to be altered).

The WRc have carried out a detailed study of pesticides in the Granta catchment in eastern England. This study demonstrated very large seasonal variations of levels in river water - in the case of one pesticide, varying from undetectable in summer to 10-60 times the E.C. limit during winter floods. This means that in surface waters a once-off sampling is meaningless; this is also likely to apply to our fissured limestone aquifers, so it is important that any study undertaken should have a time dimension. The study also found that wells tapping shallow groundwater had higher pesticide levels than major public supply wells (which were presumably diluted by clean, deeper groundwater) - suggesting that any studies undertaken should include not only major supply wells but also low-yielding, shallow wells, as these may be more vulnerable. Another lesson which we might learn from the WRc experience is the need for an interdisciplinary team approach in such studies, involving agricultural and soil scientists, hydrogeologists, hydrologists, meteorologists etc.

One very interesting point which emerged from the catchment study was that the two most commonly occurring pesticides in groundwater samples (atrazine and simazine) are not commonly used in agriculture in the area, but are used to keep down weeds on bare ground such as railway tracks and gravel paths. It appears that non-agricultural pesticide sources may be at least as great a problem as agricultural sources. Also, in the case of agricultural use, the problem may not arise so much with actual land spraying as with concentrated inputs to groundwater due to the washing of equipment and disposal of containers in field drains and soakaways. The risk posed by incorrect disposal of sheep-dip was also raised: this is another issue which needs investigation in Ireland.

The risk to groundwater resources posed by organic solvents is another important aspect of the trace organics issue. A study of solvents under the city of Birmingham found that high levels in groundwater showed a high correlation with metal industries. However, lest we be complacent here in less heavily industrialised Ireland, it is worth emphasising that garages carrying out car repairs, using various degreasing agents, are a significant hazard in this context. Another small business which can cause problems is dry cleaning, which uses organic solvents; in one UK town, the worst groundwater quality arose where the effluent from a dry cleaners was entering the aquifer via a soakhole.

Here in Ireland, we have no studies in progress along the lines of those being undertaken by the WRc. The meeting served to highlight the need for a baseline study of trace organics in our aquifers. The sophisticated sampling and analytical techniques required mean that this is a project which must be tackled at a national level.

Catherine Coxon (Secretary, IAH Irish Group)

Transport of Dangerous Substances by Road

Have you noticed tankers, lorries and vans displaying orange plates with or without numbers? Do you know what these mean? The Dangerous Substances Act, 1986, came into operation on January 1st 1987. The aim of this Act was to implement a warning system that would tell the public and emergency services about the nature and hazard potential of a particular package or load. The Act covers virgin substances and wastes and implements here the international A.D.R. agreement which is a European Agreement concerning the international carriage of dangerous goods by road. Any substance that is harmful to humans or the environment, not just substances described as toxic and dangerous by the E.C. directive, is covered by the A.D.R.

A lorry displaying a blank orange plate means a mixed load of dangerous substances, i.e. packages of pesticides, chemicals etc. A lorry or tanker displaying an orange plate with two sets of numbers indicates a single load; the upper set gives an indication of the hazard associated with the load or tanker, e.g. 60 means toxic while 66 means very toxic and 666 extremely toxic. The lower sets of numbers are a compound identification system; e.g. Acetone = 1090; Ethylene Glycol = 2810. In addition to the orange display plates, each vehicle is required to carry a transport document giving substance information outlining measures in case of accidents.

So, watch out for the orange plates; you have been warned!

Kevin Cullen, Consulting Hydrogeologist

Farm Effluent and the Water Pollution Act, 1977 - Some Thoughts

The Local Government (Water Pollution) Act 1977, covers the discharge of trade effluent or sewage to any waters under and in accordance with a licence issued under the Act. "Trade" is defined to include agriculture, aquaculture, horticulture and any scientific research or experiment. "Waters" include any (or part of any) river, stream, lake,canal, reservoir, pond, aquifer, water course or other inland waters, whether natural or artifical. The act defines an "aquifer" as any stratum, or combination of strata that stores or transmits sufficient water to serve as a source of water supply.

The 1977 W.P.A. is a far reaching piece of legislation which would appear to provide a licencing system for all effluent discharging to either surface waters or groundwater. While it can be readily applied to discharges to surface waters its application to the disposal of effluent to land is much more difficult to interpret. Clearly, the spreading of farm effluent on to the land has two functions, (a) to enhance the chemical and physical make up of the soil layer and (b) to dispose of the liquid fraction of the effluent. The liquid component must infiltrate through the unsaturated zone before eventually passing into the groundwater regime either in overburden deposits or bedrock. As most if not all overburden or bedrock strata can be classed as aquifers as defined in the Act the disposal of farm effluent to land would appear to be covered by the licencing system provided by the Act. In this case, spray irrigation systems would require a licence and theoretically the farmer discharging a tanker of effluent to his/her land might also require a licence under the W.P. Act as "a person shall not cause or permit any polluting matter to enter waters".

Clearly, there is a problem as the 1978 Regulations, under which the Act is operated, only allows effluent exemptions for domestic sewage discharges of less than $5m^3$/day or trade effluent discharges by Local Authorities. All agricultural effluent discharges would appear to be covered by the 1977 Act whether they are discharged to surface water or to aquifers by land disposal. This apparent situation can be viewed with dismay or delight depending from which side of the "green" fence you are viewing the situation. An environmentalist would see the possibility of controlling all discharges to the hydrological cycle while the responsible authority would see the generation of an enormous paper work exercise that might be impossible to implement.

However, it may well be the time to implement the W.P. Act regarding agricultural effluents and so prevent the uncontrolled discharges of agricultural effluent to the nation's groundwater resources. An Act drawn up in less enlightened times appears to provide a timely means by which the present quality of the nation's groundwater can be retained for future generations.

Kevin Cullen, Consulting Hydrogeologist

BACTERIAL CONTAMINATION OF GROUNDWATER

The following six articles are summaries of papers presented at the Sligo RTC/IAH (Irish Group) seminar "Bacterial Contamination of Groundwater" held in Sligo on 22nd September 1989. These are published with the permission of Sligo RTC. Copies of the proceedings cost £10 and can be obtained from Richard Thorn, Sligo RTC, Tel. No. (071) 43261.

Editor

Bacterial Contamination of Groundwater - Hydrogeological Considerations

To date in Ireland, the microbiological involvement in groundwater quality assessment has rarely exceeded the occasional analysis of water samples for faecal coliforms. There has been little attempt to understand the significance, in hydrogeological terms, of bacterial contamination of groundwater, e.g. at what time of year does contamination appear most frequently and under what meteorological and geological conditions does contamination take place.

The paper describes a study which has as its main aim an examination of temporal variations in water quality in some Irish limestone aquifers. Part of the study involved an examination of short term changes (sampling every two days for a fortnight) in the microbial quality of some springs draining limestone aquifers. Three karst aquifers in the Sligo area were selected for investigation. The aquifers have flow rates ranging from 100m/hr at medium to high flows to 4m/hr at low flows. One of the aquifers was overlain by glacial sands and gravels of varying thickness (0 to 15m).

The results of the investigation showed that first, where there are few sources of pollution, faecal coliform counts in karst aquifers may be high (in this study 800cfu's/100ml). This is particularly the case where there is a patchy or non-existent overburden providing protection from pollutants. Second, the faecal coliform counts in karst aquifers may vary dramatically (in one instance from 50 to 800 cfu's/100mls in two days). The fluctuations result from a combination of bacterial fixation in the soil and subsequent flushing during rainfall events.

The paper concludes by noting that management of karst aquifers is problematic and that it is vital that the hydrogeology of the aquifers is understood if management measures are to succeed.

Richard Thorn, Sligo RTC. and Catherine Coxon, TCD

The Role of Microorganisms in Soil and their Impact on Groundwater Quality

The soil contains the microbial populations that carry out the transformations of naturally occuring plant and animal remains and of other organic amendments of human origin. The activities of these microorganisms are fundamental and irreplacable. Many different groups of microorganisms (bacteria, fungi and actinomycetes) are involved in these processes. These processes include the release of bound carbon, nitrogen, sulphur and phosphorus from organic substrates and they also influence the solubility and availability of inorganic ions. The soil can be viewed as a biological filter with the function of renovating added waste materials.

The types, abundance and activities of microorganisms carrying out the above mentioned transformations are determined largely by soil type and environmental factors such as moisture content, temperature and pH. The end products of the transformations, such as nitrate, may migrate to groundwater. Therefore, the activities of soil microbial populations play an important role in the contamination of groundwater supplies by chemical as well as biological pollutants.

Soil acts as a sink for the disposal of a variety of waste materials from domestic, municipal, agricultural and industrial sources. All of these materials act as sources of chemical and biological pollutants which may contaminate groundwater.

Land disposal of wastes has generated a number of environmental concerns. From an ecological point of view, the soil microbiologist is concerned with protecting the microbial diversity required to carry out nutient recycling and is therefore concerned about the impact wastes have on the activities of the soil microflora. Many of the microbial communities in soil are sensitive to disruption e.g. the nitrogen-cycle population of bacteria, is particularly susceptible to toxic organic chemicals such as pesticides. Such disruption alters the soil's capacity to carry out it's normal biological functioning.

From a waste management point of view, the soil microbiologist is concerned with selecting for and enhancing the activities of those microorganisms that transform and detoxify hazardous substances that may be introduced to the soil. However, care must be taken as many of the by-products of microbial transformations find their way into groundwater and may be even more toxic than their precursors, for example the pesticide DDT is converted to DDD by the soil microbial population.

From a public health point of view the microbiologist is concerned with the introduction of pathogenic microorganisms and viruses into the soil. Their viability and elimination from the soil, their transfer to the human food chain, their movement through the soil and subsequent contamination of groundwater are all matters of public health concern.

Therefore from the microbiologist's point of view the soil can be looked upon as a complex living tissue that responds to the introduction of chemicals and pathogens.

How the microorganisms respond to waste amendments and how they ultimately influence groundwater quality are the concerns of this paper and the proceedings of the seminar.

Michael Broaders, Sligo RTC.

Mobilisation of Manganese from Soil

Manganese can vary in valence state from -2 to +7 although in nature only divalent (II), tetravalent (IV) and to a lesser extent trivalent (III) forms are found. The Mn (III, IV) oxide minerals are thermodynamically stable in oxygenated solutions, but are reduced to Mn^{2+} under anoxic conditions in the presence of reducing agents. Reduction increases the solubility of Mn oxide/hydroxide minerals by several orders of magnitude, leading to dissolution and geochemical mobilisation.

Under aerobic conditions aerobic microbes are capable of oxidising complex organic compounds to carbon dioxide (CO_2). However, under anaerobic conditions the situation is more complex. Fermentative organisms transform complex organic compounds into short-chain fatty acids, aldehydes, alcohols and other metabolites. Complete mineralisation into CO_2 is not possible without the use of external electron acceptors such as nitrate, manganese oxides or iron oxides.

An experiment was set up in Sligo R.T.C. to investigate the relationship between the external electron acceptors, nitrate and manganese oxide. This was carried out using rubber-capped flasks containing a nutrient broth and innocculated with various soils. It was found that as the nitrate levels decreased the concentration of reduced/mobilised manganese increased. It was also demonstrated that the flask which was innocculated with an acidic soil demonstrated the greatest increase in mobilised manganese.

The mobilisation of manganese from soil into groundwater was shown to be controlled by chemical and microbiological processes and may be associated with the decrease of other inorganics such as nitrate. These findings were used to back up previous work on the leaching of manganese from soils treated with different effluents. This inital experiment demonstrated the potential for silage effluent and farmyward washings to mobilise manganese.

Tom Dempsey, Sligo R.T.C.

The Use of the Bacterial Species Bacillius globigii and Escherischia coli as Tracers of Septic Tank Effluent to Groundwater

The contamination of groundwater supplies by microbial rich wastes with attendant health hazards is well documented in the literature. Septic tank effluent has been identified as one of the major pollutants of groundwater supplies. In 1984, it was the most frequently reported cause of groundwater contamination in the United States and was responsible for 58% of the illnesses caused by the use of contaminated untreated wellwater.

The ability to trace the movement of septic tank waste to groundwater is essential in recognising the potential transmission of disease-causing organisms. It has been established that chemical tracers do not always reflect the movement of microorganisms in soils or groundwater systems. Techniques are therefore needed to predict the movement of suspected pollution sources with highly distinctive tracer organisms which can be easily identified in the groundwater system. It is important to use such tracer techniques to monitor microbial migration with percolating wastewater when assessing the potential of new sites for septic tank drainfields.

A series of tracing experiments were carried out in the Sligo area as part of a postgraduate research study on the migration of septic tank effluent through soils to groundwater. Two bacterial species, Escherichia coli (streptomycin resistant at 150μg/ml) and the endospores of Bacillus globigii were used in three different septic tank systems, at sites with different soil types and hydrogeological characteristics. Monitoring boreholes were installed by the Geological Survey of Ireland at each of the sites. Liquid cultures of the two organisms were prepared in the laboratory and were added to the three septic tanks.

The results show that the bacteria migrated through the unsaturated zone and appeared in the groundwater downgradient of the septic tank systems. Both organisms were isolated from the monitoring boreholes at sites 1 and 2. The soils at these sites gave poor (site 1) and medium (site 2) groundwater protection. Only Bacillus globigii was detected at site 3, where the overburden afforded good groundwater protection. The boreholes at all three sites has previously been shown to be contaminated by septic tank effluent. Thus the results of the study indicate that the Bacillus globigii endospores were a more accurate monitor of the migration of the effluent microorganisms to groundwater. The success of the Bacillus spores over the E.coli bacteria is attributed to their smaller size and superior survival characteristics in the overburden materials. It is concluded that the Bacillus globigii endospores have considerable potential as tracer in assessing the suitability of new sites for septic tank effluent disposal systems.

Hubert Henry, Sligo R.T.C.

An Assessment of the survival of Escherichia coli in three different soils

One of the most critical aspects in the use of septic tank systems for the disposal of domestic effluent is the bacterial contamination of well water supplies. The number of contaminated wells appears to be extremely high. Bitton and Gerba (1984) quote percentages of between 22 and 77% for the United States, while a more recent study by Thorn et al (1986) in the north west of Ireland showed that out of 42 wells and springs 34 were polluted with faecal coliform bacteria. The potential health effects of such contamination are considerable. Outbreaks of typhoid fever, cholera and gastrointestinal sickness, which can be directly linked to groundwater contamination from septic tanks, are well documented in the United States.

Bacteria and most other microorganisms present in excreta pass easily through the tank to the soil treatment system. The microorganisms are incapable of self propulsion, and their movement through the overburden is dependent on the flow of the liquid in which they are suspended.

The survival of the bacteria once they are released into the soil is a major factor in determining the degree of contamination which may occur. A recent study at Sligo Regional Technical College investigated the survival of Escherichia coli (a commonly used indicator of faecal pollution) in three soils, using large diameter leaching containers. The leaching containers were filled with soil to a fixed depth. An innoculation tube, similar in construction to the perforated pipes in a septic tank soil adsorption system, was then placed in the soils. The bacterial culture was passed into the soil through this tube. The three soils used in the study were clay/loam, organic peat and sand/silt. Survival of the organisms in soils was shown to be very significant. Viable bacteria (counts of 2.6×10^3 c.f.u.'s/g soil) were detected after 44 days of sampling. The die off of the bacteria in all three soil types was demonstrated to follow an exponential decay pattern. Calculated T_{99} values (the time taken for 99% of the bacteria to die) for different soil types were 28, 36 and 31 days for clay/loam, sand/silt and organic peat soils respectively.

The implications of these results are significant, given that the regulations concerning wellhead protection are frequently based on a 30 day survival time of enteric bacteria in soil. In view of this, these regulations should be reviewed. The results also suggest that the effect of soil type on the survival of bacteria may not be as significant as has previously been reported in the literature. The much acclaimed antimicrobial properties of peaty soil was not demonstrated in the study.

Bitton, G. and Gerba, P. 1984. Groundwater Pollution Microbiology. John Wiley and Sons, New York.

Thorn, R.H., Doyle, M. and Henry, H. 1986. A preliminary investigation of the groundwater resources of south County Sligo. Sligo RTC Technical Report 86/1.

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One of the most critical aspects in the use of septic tank systems for the disposal of domestic effluent is the bacterial contamination of well water supplies. The number of contaminated wells appears to be extremely high. Bitton and Gerba (1984) quote percentages of between 22 and 77% for the United States, while a more recent study by Thorn et al (1986) in the north west of Ireland showed that out of 42 wells and springs 34 were polluted with faecal coliform bacteria. The potential health effects of such contamination are considerable. Outbreaks of typhoid fever, cholera and gastrointestinal sickness, which can be directly linked to groundwater contamination from septic tanks, are well documented in the United States.

Bacteria and most other microorganisms present in excreta pass easily through the tank to the soil treatment system. The microorganisms are incapable of self propulsion, and their movement through the overburden is dependent on the flow of the liquid in which they are suspended.

The survival of the bacteria once they are released into the soil is a major factor in determining the degree of contamination which may occur. A recent study at Sligo Regional Technical College investigated the survival of Escherichia coli (a commonly used indicator of faecal pollution) in three soils, using large diameter leaching containers. The leaching containers were filled with soil to a fixed depth. An innoculation tube, similar in construction to the perforated pipes in a septic tank soil adsorption system, was then placed in the soils. The bacterial culture was passed into the soil through this tube. The three soils used in the study were clay/loam, organic peat and sand/silt. Survival of the organisms in soils was shown to be very significant. Viable bacteria (counts of 2.6×10^3 c.f.u.'s/g soil) were detected after 44 days of sampling. The die off of the bacteria in all three soil types was demonstrated to follow an exponential decay pattern. Calculated T_{99} values (the time taken for 99% of the bacteria to die) for different soil types were 28, 36 and 31 days for clay/loam, sand/silt and organic peat soils respectively.

The implications of these results are significant, given that the regulations concerning wellhead protection are frequently based on a 30 day survival time of enteric bacteria in soil. In view of this, these regulations should be reviewed. The results also suggest that the effect of soil type on the survival of bacteria may not be as significant as has previously been reported in the literature. The much acclaimed antimicrobial properties of peaty soil was not demonstrated in the study.

Bitton, G. and Gerba, P. 1984. Groundwater Pollution Microbiology. John Wiley and Sons, New York.

Thorn, R.H., Doyle, M. and Henry, H. 1986. A preliminary investigation of the groundwater resources of south County Sligo. Sligo RTC Technical Report 86/1.

Hubert Henry, Sligo R.T.C.

Groundwater Quality in Knocknarea Peninsula Co. Sligo

The Knocknarea Peninsula occupies an area of approximately 20 km^2. It is bounded on three sides by the sea and on the other side by the Lough Gill Catchment area.

A study was carried out over an eight month period to determine what relationships, if any, existed between groundwater quality and the following: overburden type and depth; geology; soil type and depth; climate and weather; and surface activities - farming and septic tanks.

Over the duration of the study 108 water samples were taken from 18 wells and boreholes. Samples were analysed for a range of parameters including total and faecal coliforms.

Of the eighteen wells and boreholes examined only two were found to be consistently free from contamination by faecal coliforms. There were also only extremely low levels of total coliforms present at these two sites. Both clean wells were found to occur in an area of thick overburden and with the water table at a depth of more than 20m. Farm activity was absent in this area except for open grazing.

Other wells located in areas of similar overburden and soil characteristics, but which were associated with agricultural developments (housing units with poor effluent management facilities and silage making) were found to be contaminated to varying degrees. Three such wells had average numbers of E. coli of 80, 174 and 342 C.F.U.'s per 100 mls. These wells were consistently polluted throughout the duration of the study. The only apparent reason for this contamination was poor control of farmyard effluent.

Septic tank systems were not found to be a significant source of contamination of groundwaters. This is borne out by the fact that the area which had the cleanest wells also had a septic tank density equal to, or greater than, the mean septic tank density of the entire peninsula.

Frank Clinton, Sligo County Council.

CONTRIBUTIONS FOR THE NEXT ISSUE OF THE NEWSLETTER

The **GSI Groundeater 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 20th February 1990. All items should be as short **(maximum 350 words)**, interesting and newsworthy as possible.