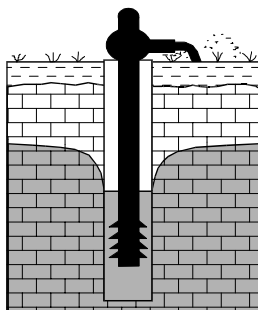


THE GSI GROUNDWATER NEWSLETTER

- Exploration
- Management
- Pollution
- News from abroad
- Development
- Quality
- Reviews
- Opinion Forum



NUACHTÁN SCREAMHUISCE SGÉ

- Taiscéalaíocht
- Bainistíocht
- Truailliú
- Nuacht idimáisúnta
- Forbairt
- Cáilíocht
- Athbhreithniú
- Tuairimí

Published by the Geological Survey of Ireland,
Beggars Bush, Haddington Rd.,
Dublin 4.
Tel: (01) 6707444 Fax: (01) 6681782

Edited by: Donal Daly

Foilsiú ag an Suirbhéireacht Gheolaíochta Éireann,
Tór an Bhacaigh, Bóthar Haddington,
Baile Átha Cliath 4.
Tel: (01) 6707444 Fax: (01) 6681782

No. 37 July 2000

In This Issue

Bugs in Boreholes

Monitored Natural Attenuation

Impacts of Urban Groundwater on Surface Water in Birmingham

Nutrient Removal from Wastewaters

The Quality of Groundwater in Ireland

Ireland's Environment: A Millenium Report

IAH (Irish Group) News

Sherkin Island Conference Proceedings

Farewell to John Dunne

What is the quality of groundwater in Ireland? While the GSI has attempted to answer this question in the past, we could not do it adequately due to lack of data. However, thanks to **the EPA's National Groundwater Quality Monitoring Programme**, at last we are starting to get a good national overview. This programme commenced in 1995 and monitoring is carried out twice a year. Chapter 5 of the EPA publication 'Water Quality in Ireland 1995-1997', which is entitled '**The Water Quality of Groundwaters**', is reproduced in full in this Newsletter (see page 11). The chapter includes a summary of the following parameters: **ammonia, nitrite, nitrate, chloride, phosphate, iron and manganese and bacteria**; and provides essential information for every hydrogeologist working in Ireland. Your attention is also drawn to two further EPA publications: the superbly produced '**Ireland's Environment: A Millenium Report**' (page 10); and a Wastewater Treatment Manual many have been waiting for – '**Treatment Systems for Single Houses**' (page 8).

In the past we have dealt with **iron problems** in wells in the Newsletter. However, we have lacked information on the impact of bacteria. This is rectified in an article by 2 experts in the area (Peter Howsam & Sam Tyrrel), who cover the topics of **biofouling** and **biocorrosion** (see page 4).

Children have few, if any, opportunities to be introduced to 'groundwater'. This may now change if Melissa Swartz's proposal (see page 2) is supported. On page 5, Colette Cronin and Bruce Unger advocate **monitored natural attenuation** as a good option for remediation in certain circumstances. Donal Hogan, Michael Rivett and Paul Ellis describe **the impacts of urban groundwater upon surface water quality in Birmingham** on page 7. Nick Gray and Orla O'Donnell present (page 9) an interesting means of reducing contamination by **removing nutrients from wastewater** through the use of **urine separation toilets**.

Our final article in this Newsletter is a farewell to **John Dunne**. While it may be seen as a sad way to end the Newsletter, on the other hand many of us had the luck, privilege, satisfaction and pleasure of knowing him.

Editor

Volunteers Needed to Explore Groundwater during Dúchas's Heritage Week

Along with the Celtic Tiger economy here in Ireland, people's awareness of environmental issues is also on the rise. More and more, environmental aspects are being introduced into the classroom, and the number of third-level students interested in environmental studies is steadily increasing. However, one aspect that is often over-looked - especially at the primary and secondary levels - is groundwater.

In a small attempt to remedy this, the IAH (Irish Group) and GSI are sponsoring a day of fun filled "interactivities" geared at explaining groundwater to the general public during Heritage Week (3-9 September 2000). The event itself will be held on Saturday, 9 September 2000 from 11am – 4pm at the GSI.

Through the use of "hands-in" activities, some of which are outlined below, we hope to provide a fun filled day of learning for the young and young-at-heart alike. To make this happen however, we need your help - especially with organisation and presentation of activities. With this small effort, hopefully we can increase the general knowledge of Ireland's groundwater resources. Who knows? Maybe we will even inspire a few budding hydrogeologists!

Potential Activities

With a little imagination, the possible activities are endless. The following list is in no way complete, and represents only a few potential ideas. Volunteer presenters are needed for almost all activities.

Activity	Description
Water Tasting	In a blind taste test, can you tell the difference between tap water and different Irish bottled waters? The volunteer will explain why they taste differently.
Water Races	Explores the concept of permeability using different earth materials. Specifically, participants measure how long it takes water to flow through funnels filled with gravel, sand and clay, etc.
Is Dilution the Solution?	Helps conceptualise what dilution means and how it works by adding drops of food colouring or vinegar to varying amounts of water.
Water Distillation	Using a bucket and a heat lamp, a simplified distillation unit can be created.
Water Usage	Either a display or an activity outlining general water usage and water saving tips.
Water Level Monitoring	A display of an automatic water level recording instrument.
Water Quality Testing	Participants make temperature, pH and conductivity measurements on various water samples.
Groundwater Maze	A simple take-home activity: Help the drop of water find its way through the subsoil and (karstic) aquifer.
Fizzing Rocks (karst)	A display using photographs and samples of different limestones, with the chance to do an "acid" (vinegar) test.
Pump a Well	Pump water from a borehole using a Waterra pump.
Groundwater Protection	Display of groundwater protection schemes, what they are and what they do.
A competition?	Prize for the correct completion of a groundwater crossword or a colouring contest?

Getting Involved

If you're interested in providing your time, energy and/or ideas to this one-day event, please contact me at 01-604-1408; swartzm@tec.irlgov.ie, for further information. In the future, we hope to see a

stand-alone, multi-day "Children's Groundwater Festival" aimed at schools and families to fill this role, possibly in the spring 2001. In the meantime, we hope to see many of you on the day enjoying the activities!

Melissa Swartz, Geological Survey of Ireland

Bugs in Boreholes

Awareness of the problems of bugs in wells and aquifers has increased greatly over the last decade in the UK (Howsam & Tyrrel 1997). Of the most common are the iron-related (commonly *Gallionella*) and sulphate reducing (commonly *Desulfovibrio*) bacteria.

Biofouling

The appearance of iron biofouling deposits is highly variable and it is this that has helped to perpetuate the belief that such deposits are chemical rather than biochemical or microbial in origin. Such deposits found coating and clogging well screens, pumps, rising mains and distribution systems range in nature from hard brittle, powdery, sludgy, to soft and slimy; and in colour from white, buff, orange, red-brown, olive brown to black.

The consequences of iron biofouling impinge on hydraulic performance and on groundwater quality. In the latter case dislodgement of iron biofouling deposits from within the system, commonly occurs at pump start-up. This will cause the production of iron rich waters. This creates aesthetic problems for the consumer with obvious discoloration often accompanied by taste and odour problems. High bacterial counts may also be associated with such incidents that may falsely indicate public health/pollution problems.

On the hydraulic front iron biofouling can cause clogging in most parts of a groundwater abstraction system including the distribution system. Surprisingly field evidence suggests that fouling can be more of a problem where velocities are highest (Tyrrel & Howsam 1994). Current understanding of biofilm behaviour and chemical processes supports this situation. In the latter case chemical nucleation and hence precipitation (of iron) is enhanced by turbulence, which is associated with high velocities. In the former case biofilm development is enhanced by high velocities and turbulence as this maximises nutrient supply and uptake conditions for the sessile bacteria, particularly for groundwaters which typically have low nutrient concentrations. Dense and resilient iron deposits have been found in the highest velocity sections of borehole pumps. In laboratory studies biofilms have been able to withstand velocities up to 16 m/s.

Avoidance of iron biofouling problems can be achieved by minimising the factors that enhance the process. This can largely be achieved by

attention to borehole design and construction and operating schedules, which minimise high velocities and oxygenation of the groundwater in the borehole system and the immediate aquifer environment.

Biocorrosion

Biocorrosion is the inducement or enhancement of electrochemical process of corrosion by the activity of sessile bacteria in forming biofilms (Tiller 1990, (Howsam et al 1995). In many cases the activity results in conditions in localised microenvironments which are different from the macro-environment of the borehole and aquifer. Iron-related bacteria and other consortium bacteria typically found in borehole/aquifer environments are involved.

Common processes include the setting up of concentration cells on the surface of the metal where a biofilm develops. Basically in an environment where oxygen is present, microbial activity within the biofilm will reduce oxygen forming a differential aeration cell. The centre of the biofilm becomes anodic compared to the edge of the biofilm where oxygen is present, which becomes cathodic. This process results in localised pitting.

The metabolic activity within an iron biofilm leads to a depletion of oxygen from the lower biofilm layers, where redox conditions can be created suitable for the growth of anaerobic sulphate reducing bacteria, which are able to enhance/induce corrosion processes – often seen and described as ‘rust’ tubercles.

The sulphate reducing bacteria are key players in biocorrosion. The removal of cathodic hydrogen by sulphate reducing bacteria promotes continuation of the corrosion process by depolarising the cathodic area of the metal surface. The depassivation of the metal surface produced by the microbial reduction of insoluble ferric deposits to soluble ferrous compounds can also occur.

Furthermore the formation of corrosive metabolic by-products from the bacterial activity within a biofouling deposit can enhance corrosion rate. Examples include the production of sulphuric acid by sulphur-oxidising bacteria, and the production of organic acids, hydrochloric acid, hydrogen sulphide, ferrous sulphide, ferric chloride and

elemental sulphur, by anaerobic sulphate reducing bacteria (Hamilton 1985).

The consequences of biocorrosion in a groundwater abstraction system are varied. Severe corrosion if allowed to continue will affect the integrity of the system components, i.e. loss of mechanical strength, leading to screen/casing failure and collapse or screen/casing parting at weakened joints; rupture of pump line-shift or riser; and disintegration of pump components (Kelly & Kemp 1974). All of these result in the need for costly and inconvenient measures to recover supply.

On the hydraulic side, corrosion-incrustation increases surface roughness and reduces conduit dimensions and will therefore increase head losses. Severe biocorrosion resulting in perforation of the pipe wall will result in leakage of water from the system.

Biocorrosion can influence the quality of the water in the system affected (Lee et al 1979):

- ◆ increase in iron content and red 'rust' water
- ◆ metabolic by-products can produce compounds with unpleasant tastes/odours (the bad-egg smell of hydrogen sulphide is common) and typically impart an oily sheen to water surface.
- ◆ release of trace metals from corroded materials into the groundwater.

Furthermore perforations resulting from biocorrosion may permit ingress of poor quality or polluted groundwaters entering the well which should have been designed and constructed to prevent such occurrences.

As with biofouling, biocorrosion problems in boreholes relate more to engineered system in use being inappropriate rather than to the characteristics of the hydrogeological environment. Good understanding of biocorrosion processes, of

the engineered system and of the environment, coupled with appropriate design and construction, operation and maintenance practices, should enable such problems to be minimised or avoided (Howsam et al. 1995).

Hamilton, W.A. (1995). Sulphate reducing bacterial and anaerobic corrosion. *Ann. Rev. Microbiol.*, Vol. 39, pp.195-217

Howsam, P. (1988). Biofouling in wells and aquifers. *J.Inst. Water & Env. Management* 2, 209-215.

Howsam, P., Misstear, B.D & Jones, C.R.C. (1995). *Monitoring, Maintenance & Rehabilitation of Water Supply Boreholes*. (CIRIA publication R. 137, London

Howsam, P, Tiller, K & Tyrrel, S.F. (1995). Biocorrosion in groundwater abstraction systems. In : *Microbial Corrosion* (Eds. AK Tiller and CAC Sequeira), European Federation of Corrosion publication 15, 354-366.

Kelly, G.J. and Kemp, R.G. (1974). The corrosion of groundwater pumping equipment. *Australian Water Resources Council Technical Paper 12*, Canberra.

Lee, S.H. O'Connor, J.T. and Banerji, S.K. (1979). Biologically mediated corrosion and water quality deterioration. In : *Proceedings of Conference on Water Quality Technology* (Philadelphia) American Water Works Association, Denver.

Tiller, A.K. (1990). Biocorrosion in civil engineering. pp.24-38 In : *Microbiology in Civil Engineering*, edited by P. Howsam E & F.N. Spon. London.

Tyrrel, S.F. & Howsam, P. (1994). Field observations of iron biofouling in water supply boreholes. *Biofouling* 8, pp.65-69

Tyrrell, S.F. and Howsam, P. (1997). Aspects of the occurrence and behaviour of iron bacteria in boreholes and aquifers. *Quarterly Journal of Engineering Geology* 30, 161-169

Peter Howsam & Sam Tyrrel, Institute of Water & Environment, University of Cranfield, UK

Monitored Natural Attenuation of Groundwater Contaminants

Introduction

Monitored Natural Attenuation (MNA) refers to the reliance on natural processes to achieve

contaminant remediation. MNA processes include a variety of chemical, physical or biological processes that under favourable conditions act without human intervention to

reduce mass, toxicity, mobility, volume or concentration of contaminants in soil and groundwater. In-situ processes include biodegradation, dilution, sorption, volatilisation, and radioactive decay. Monitoring to prove that natural attenuation is actually occurring is integral to the application of this process to contaminated sites.

MNA may be sufficiently effective to achieve remediation objectives at a site without the use of active remedial measures. Typically, however, MNA is used in conjunction with active remediation.

Contaminants of concern include:

- ◆ Petroleum-Related Contaminants
- ◆ Inorganic Contaminants
- ◆ Chlorinated Solvents

Petroleum Related Contaminants

MNA processes, particularly biodegradation, have been documented extensively at petroleum fuel spill sites. BTEX (benzene, toluene, ethylbenzene, xylene) associated with petroleum, may degrade naturally through microbial activity to ultimately produce non-toxic end products (CO₂ and water). MNA of these contaminants is most effective under aerobic conditions.

Inorganic Contaminants

MNA processes may effectively reduce dissolved concentrations of inorganic contaminants in groundwater/soil. Sorption and redox reactions are the dominant mechanisms responsible for the reduction of mobility and toxicity of inorganic contaminants. Sorption reactions include precipitation, absorption into the matrix of soil minerals, or partitioning into organic matter.

Redox reactions can transform the valence states of some inorganic contaminants into less soluble and thus less mobile forms (hexavalent uranium to tetravalent uranium) and/or to less toxic forms (e.g. hexavalent chromium to trivalent chromium).

Chlorinated Solvents

Chlorinated solvents typically occur as dense non-aqueous phase liquids (DNAPLs) in their pure states such that they tend to sink through the groundwater column toward the bottom of the aquifer. Because of the varied nature and

distribution of chlorinated compounds, they are typically difficult to locate, delineate and remediate even with active measures. Cleanup of solvent spills is also complicated by the fact that a typical spill contains multiple contaminants, including some that tend not to degrade readily in the subsurface. Some of the mechanisms potentially responsible for degrading these solvents are as follows:

Biodegradation

Biodegradation is a biological process by which contaminants are broken down. Factors influencing biodegradation include:

- ◆ **pH:** Ideal pH 6.5–7.5, however, biodegradation occurs between 5 and 9.
- ◆ **Matrix:** Ideally gravels, sands, silty sands.
- ◆ **Oxygen:** Required for biodegradation of many contaminants, although some degrade better in the absence of oxygen.

The principle methods of biodegradation of chlorinated solvents are outlined as follows:

Direct Biodegradation

a) Direct Aerobic Biodegradation

Chlorinated solvents are degraded in aerobic conditions by microbes which gain energy and carbon from the process. This method is limited to the less chlorinated solvents such as dichloromethane (DCM), dichloroethene (DCE), 1,2-dichloroethene (1,2-DCE), vinyl chloride (VC).

Under these conditions, VC has been observed to degrade at a field half-life rate of 3 to 300 days. The observed half-life of 1,2-DCE is slightly longer at approximately 400 days.

b) Direct Anaerobic Biodegradation

VC and 1,2-DCE can also be degraded under anaerobic conditions. VC has been observed to degrade by direct anaerobic degradation at a half-life rate of 50–250 days.

Aerobic Co-Metabolic Biodegradation

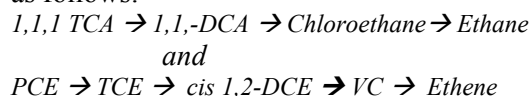
Chlorinated solvents are fortuitously degraded by co-metabolic bacteria, which use *other* contaminants (such as toluene, phenol, and ammonia) as substrates. This process has been

observed to be effective in degrading trichloroethene, 1,1-dichloroethene, 1,2-dichloroethene and vinyl chloride.

Reductive Dechlorination

a) Dehalorespiration

This process occurs in anaerobic and highly reducing conditions. The microbes use the chlorinated solvents as respiratory substrates. This involves the replacement of chlorine atoms by hydrogen atoms during highly reducing conditions. Examples of reductive dechlorination are as follows:



DCE produced biologically by the reductive dechlorination of TCE is almost 100 % cis-1,2,-DCE, whereas manufactured DCE is mostly 1,1-DCE and only contains 10-20% cis-1,2,-DCE. Therefore it is easy to identify biologically degraded DCE.

Monitored Natural Attenuation – Lines of Evidence

In order to assess whether MNA should be applied at a site, it is important to establish 'lines of evidence'. These include:

- ◆ Observed reduction in contaminant concentrations along the groundwater flow path.
- ◆ Documented loss of contaminant mass on the field scale using rigorous estimation of flow and transport parameters, and chemical analysis data to support degradation mechanisms.
- ◆ It is important that a good hydrogeological conceptual model has been developed for the

site, so that any alternative contaminant loss mechanisms can be accounted for.

This may require a relatively extensive site investigation, monitoring network and analytical programme, which may be costly. As such, it should first be established whether there is a quick and inexpensive solution (such as shallow excavation) before MNA is applied. However, the cost of MNA could be orders of magnitude lower than other alternatives (such as pump-and-treat).

When is MNA an Appropriate Corrective Action?

- ◆ Once contaminant sources (i.e., leaks) have been eliminated and free product removed or controlled.
- ◆ Contaminant plume is stable or shrinking.
- ◆ There are no obvious, cost-effective alternative corrective action plans.

MNA would **not** be an appropriate corrective action where there is a current or imminent threat to a sensitive receptor. A more aggressive and rapid response would be required in this instance.

References

Use of Monitoring Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites. Directive 9200.4-17P, produced by Office of Solid Waste and Emergency Response (OSWER), US EPA (1999).

Natural Attenuation; Remediation of Contaminated Land and Groundwater. A course presented by the Groundwater Protection and Restoration group, at the University of Sheffield, January 2000.

Colette Cronin and Bruce Unger, Dames & Moore, Cork.

Impacts of Urban Groundwater upon Surface Water Quality in Birmingham

The main aim of this project is to investigate the link between groundwater and surface water quality within an urban catchment. The River Tame – Birmingham aquifer system was selected as the field study area. The description below is based on results of an MSc project conducted under the University of Birmingham MSc

Hydrogeology course (Hogan, 1999). The project was intended to serve as a preliminary study to a more detailed 3-year long PhD research study of that urban catchment now underway by the University of Birmingham (Ellis, Rivett and Mackay) and the Environment Agency (Ward and Harris). As direct outfall (pipe) discharges or

sewer overflow of poor quality water to urban surface waters is increasingly reduced through industry closure or tighter environmental regulatory controls, the quality of groundwater contributing to urban surface waters becomes increasingly important in controlling the ultimate river quality. This issue is a key driver for the Birmingham-Tame study.

The Tame flows through areas that likely contain significant legacies of land contamination and poor quality groundwater due to high previous industrial landuse. Birmingham and the surrounding West Midlands from which the Tame rises have been a key Midlands industrial centre since the 19th century due to their close proximity to coalfields. The majority of Birmingham industries were involved in metals production and manufacture. The use of chlorinated solvents such as Trichloroethene (TCE) and 1,1,1-Trichloroethane (TCA) to degrease metals has been prevalent and shown to have caused significant contamination of groundwaters beneath Birmingham at least. Solvent occurrence is not only attributed to their widespread use and casual handling practices in the past, but also to their DNAPL (dense non aqueous phase liquid) nature that permits deep solvent penetration below the groundwater table and also their recalcitrant nature relative to other organic contaminants such as hydrocarbon fuels that are much more easily biodegraded.

The Tame rises in the urban Carboniferous Coal Measures sequence, flows across the unconfined Triassic sandstone aquifer and onto the Mercia mudstone group to the east side of the Birmingham Fault that confines the eastward dipping Triassic sandstones. The sandstones have been used as a significant groundwater supply, particularly by industry located over the unconfined aquifer in the Tame Valley and Smethwick areas. Abstraction, however, has steadily declined since the 1940's peak resulting in rising water table and increased baseflows to the Tame. Rising groundwaters may cause increased leaching of contamination previously held in the unsaturated zone.

The MSc project involved collection of surface water samples from an 18 km stretch of the River Tame centered upon Birmingham from June to August 1999 - a summer low river flow period. Samples were analysed for chlorinated solvents, inorganic major ions and some trace metals. Landuse and outfall locations were studied to provide background data. Preliminary assessment of baseflow was made through study of

groundwater and surface water hydrograph data. Drift, alluvium and fill material were studied to determine preferential flow paths for shallow groundwater. The study also used previous groundwater quality data and modelling studies on Birmingham by others

The project indicated TCE was the main chlorinated solvent observed in the River Tame. TCE values were low on the Carboniferous strata, with increased values seen across the unconfined Triassic sandstone section followed by perhaps a decline in values across the Mercia mudstone section; more samples would be required to confirm the latter. Peak river TCE concentrations were relatively low at a little below 0.01 mg/l (prescribed concentration value for drinking water in England and Wales is 0.03 mg/l). River dilution and ready volatilisation of TCE from surface water would however, suggest concentrations in any TCE contaminated groundwater baseflow will be greater. TCE was the main solvent found in previous surveys of unconfined aquifer boreholes and increased levels of TCE in the Tame section overlying the unconfined aquifer are mainly attributed to the baseflow of contaminated groundwater. There are now very few pipe discharge outfalls to the Tame along the studied section – more research needs to be done on the potential impact of these discharges, however, the preliminary conclusion is that they do not significantly influence River Tame chlorinated solvent profiles obtained. Repeat surface water sampling to confirm the above solvent trends, sampling of groundwaters below the river-bed and also assessment of chlorinated solvent biodegradation to cis-dichloroethene, vinyl chloride and ethene which is probable in anoxic river bed sediments is the subject of the on-going research programme.

Some of the major ion concentrations tended to decline across the unconfined aquifer region and is likely ascribed to mixing and dilution of surface water with cleaner effluent groundwater flows. The inorganic data is, however, complex and needs further analysis and sampling work. A sample snapshot of the river that captures inorganic samples from the entire river stretch rapidly would be of great value. Preliminary hydrograph analysis showed effluent flows occur from groundwater to surface water along most of the unconfined sandstone section. Again better quantification of flow volumes is being currently sought through direct baseflow seepage measurements and

analysis of further groundwater hydrograph data that have recently become available.

Such field-based research studies on urban groundwater and surface-water quality interaction at the catchment/aquifer scales, rather than smaller

specific site-study scales are likely to become key as the future European Water Framework Directive will require a more integrated approach to predict the impact of urban land and groundwater quality upon the surface water quality of catchments.

Donal Hogan (Dames & Moore - Cork, Ireland), Michael Rivett & Paul Ellis (School of Earth Sciences, University of Birmingham, UK)

EPA Wastewater Treatment Manual ‘Treatment Systems for Single Houses’

To protect public health, Mr. Dan Wallace, Minister of State at the Department of the Environment and Local Government recently launched a manual on behalf of the Environmental Protection Agency. The manual requires improvement in the design and siting of wastewater treatment systems. Such systems include septic tanks and commercially designed treatment systems. The guidance manual will later this year replace SR6:1991, which was published by the National Standards Authority of Ireland.

The manual outlines the steps which should be taken to characterise a site before designing an on-site system. Characterisation of a site is divided into a desk study followed by an on-site assessment. The on-site assessment is subdivided into a visual assessment, a trial hole and a percolation test. The significance of the information collected during the desk study and the on-

site assessment is outlined. A methodology for choosing an on-site treatment system and the optimum discharge route is described in addition to information on the design, construction and maintenance of a septic tank, soil percolation area, intermittent filters, constructed wetlands and polishing filters. The manual includes information on mechanical aeration systems, which again are followed by a polishing filter. Finally, to assist in the selection of an on-site treatment system and to standardise the assessment process, a site characterisation protocol has been prepared. This should accompany all planning applications for on-site treatment systems for a single dwelling house.

Copies of the EPA manual ‘*Treatment Systems for Single Houses*’ are available from the EPA Publication’s office St. Martins House, Waterloo Road, Dublin 2 (01 6674474).

Irish National Hydrology Seminar on ‘River Basin Management’ 21 November, 2000; Tullamore, Co. Offaly

The Irish National Committees of the IHP and ICID, in association with IEI, ACEI, IAH (Irish Group), CIWEM and BHS are holding a one-day hydrology seminar on 21st November, 2000. This seminar will comprise the presentation of papers and discussion on a variety of topics, including the EU Water Framework Directive, which will have a significant impact on the way in which many aspects of Europe’s river basins are managed in the future. Other topics include flood risk

mapping, urban river management, low flows and water supply, groundwater recharge, wetland habitats and a number of selected case studies and project reviews.

For details contact:

Mark Adamson, Office of Public Works, 17-19 Lower Hatch Street, Dublin 2, Ireland (tel: 01 647 6734, fax: 01 676 1714, email: mark.adamson@opw.ie)

Nutrient Removal from Wastewaters at Source

The problem of nutrients in wastewater is proving to be a major challenge for environmental engineers. Although the concept of nutrient removal is slowly emerging into actual practical designs for larger waste water treatment plants, nutrient removal remains difficult and costly, especially for small treatment systems. While nitrogen is lost through denitrification to atmospheric nitrogen, phosphorus is removed in the sludge where it can be quickly released once landfilled or spread on land. The concept of sustainable sanitation has encouraged engineers to examine separation and recycling technologies as opposed to end of pipe solutions. With the

increasing concern over the sensitivity of groundwater to contamination by sewage derived nutrients, one particular innovation could become widely adopted in aquifer sensitive areas around Europe. This is urine separation.

Human urine is the largest contributor of nutrients to domestic wastewater. Excluding phosphate derived from detergent usage, some 60% of the phosphorus, 80% of the nitrogen and 65% of the potassium in domestic wastewater comes from urine (Table 1). So the separate collection of urine can significantly reduce the amounts of nutrients going to percolation areas and soakaways.

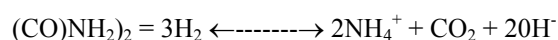
Table 1 Characteristics and daily loads of fresh urine in Germany ⁽¹⁾

	Units	Mean	Standard deviation
Volume	L/ca/d	1.6	0.58
pH		6.1	0.4
Conductivity	mS/cm	17.5	5.56
NH ₄ -N	mg/ca/d	571	193
Urea	g/ca/d	16.8	3.7
Total-N	g/ca/d	10.8	2.1
Total-P	g/ca/d	0.93	0.22
K	g/ca/d	2.6	0.58
COD	g/ca/d	13.0	4.97
BOD ₅	g/ca/d	6.1	2.19
N:P		12.0	2.77
P:K		0.38	0.13
N:K		4.39	1.40

Urine separation toilets are now widely available. The toilet is slightly longer to incorporate two separate bowls. A front bowl collects the urine while the rear one is used for faecal material. There are two separate outlet pipes, one takes the faecal matter and flushwater to the septic tank or packaged treatment system, the other transports the urine to a separate tank. Here the urine is stored to be collected once or twice a year for use as an agricultural fertilizer. An added advantage to separation toilets is that the urine is flushed away using only 0.1L of water, thus conserving water and reducing volumes to be disposed via percolation areas to groundwaters.

Although 90% of the nitrogen in fresh urine is in the form of urea (CO(NH₂)₂), this quickly

dissociates on storage to ammonia/ammonium with a resultant increase in pH from 6.5 to 9.



Local farmers collect the urine and store it centrally or in existing slurry tanks and then spray it directly onto land as a replacement for mineral fertilizers when required. Unlike sewage sludge urine is rich in potassium, making it a suitable replacement for most mineral fertilizers including NPK mixtures (Table 2). Other advantages of urine over mineral fertilizers are that the proportion of directly available nitrogen to plants is larger; there is a very low concentration of heavy metals in urine compared to mineral fertilizers; and finally compared to sewage sludge and treated wastewaters, urine contains relatively few pathogens, that are largely eliminated on storage.

Table 2. Relative proportions of other nutrients and trace elements in urine at a dosage rate to give 100kg of ammonia/ammonium nitrogen per hectare. ⁽²⁾

Component	Unit	Urine
N-tot	Kg/ha	102
NH ₃ /NH ₄ -N	Kg/ha	100
P	Kg/ha	9
K	Kg/ha	28
Hg	g/ha	0.01
Cd	g/ha	0.03
Pb	g/ha	0.3
Cr	g/ha	0.5
Ni	g/ha	1.7
Cu	g/ha	69
Zn	g/ha	5.5

The implications for the protection of sensitive ground and surface waters from isolated dwellings, including hotels, bars, and visitor centres, are significant. The announcement in December 1999, that the use of sodium tripolyphosphate as a detergent builder is to be phased out in Ireland by the industry itself over the next three or four years will largely remove this source of phosphorus. So in this context urine separation appears a sustainable and highly effective nutrient control strategy.

In Sweden there are a number of urine separation projects based on individual houses to entire villages.⁽³⁾ A preliminary study is underway at

TCD to investigate the potential of this simple technology for Irish conditions. Any comments or queries will be gratefully received. Please contact either Nick or Orla (nfgray@tcd.ie or ooconnel@tcd.ie).

(1) Fittschen, I and Hahn, H.H. (1998) *Wat. Sci. Tech.* 38, (6), 9.

(2) Jönsson, H., Stenström, T-A., Svensson, J. and Sundin, A. (1997) *Wat. Sci. Tech.* 35, (9), 145

(3) SNV (1995) *Utdrag ur datoriserade nätverket EVA- Experimentella and miljöanpassade VA-Projekt.* Swedish Environmental Protection Agency.

Nick Gray and Orla O'Connell, Department of Civil, Structural and Environmental Engineering, Trinity College, Dublin.

Ireland's Environment: A Millenium Report

Do you need/want a summary of the current situation regarding the environment in Ireland? If so, a superb report was published by the EPA in April. It is comprehensive, informative and well written. It includes not only scientific information on air, water, waste and habitats, but also broader environmental concepts, and provides a vision for the future. The layout, design, use of tables, maps and figures, and use of colour, are excellent. The publication is a credit to the editors (Larry Stapleton, Mícheál Lehané and Paul Toner) and the contributors – I don't envy whoever has to organise the next report! Copies of the report can be purchased for £15 from the EPA or Government Publications Sales Office.

Editor

The Water Quality of Groundwaters

The following article is Chapter 5 of the EPA publication 'Water Quality in Ireland' 1995-1997 by J. Lucey, J.J. Bowman, K.J. Clabby, P. Cunningham, M. Lehane, M. MacCártaigh, M.L. McGarrigle and P.F. Toner. The maps and appendices mentioned in the article are not reproduced here.

INTRODUCTION

5.1 Groundwater is an important phase of the hydrological cycle and may be defined as subsurface water that occurs beneath the water table in soils and geological formations that are fully saturated. Groundwater flow supplies the baseflow in Irish rivers and is a valuable water resource. In the Local Government (Water Pollution) (Amendment) Act, 1990, an aquifer is defined as "any stratum or combination of strata that stores or transmits groundwater". The aquifers in Ireland have been mapped by the Geological Survey of Ireland (GSI) (1982) and published by the European Commission (these maps are being revised by the GSI and it is anticipated that a new edition will be available in the year 2000). These aquifer maps were digitised by the EPA and are shown on Map 1 in Appendix VI.

5.2 Groundwater is an important national asset. It accounts for about 15 per cent of the total volume of water supplied by public authorities and about 25 per cent of all water supplies (Environmental Research Unit, 1993). It is also the vital for the mineral water industry in Ireland. For these reasons information on the quality of our groundwaters is important.

5.3 Groundwater is generally less susceptible to pollution than surface water because pollutants tend to be retarded or attenuated by filtration and various chemical and biochemical processes in the soil and subsoil. Depending on the aquifer media and water levels, groundwater may move slowly; thus, if aquifers become polluted, the pollution may persist in contrast to rivers where rapid flushing usually occurs. Because groundwater movement is slow when compared to river flows and restoration of quality after contamination is a difficult and often lengthy process, prevention of pollution and maintenance of groundwater quality are important.

GROUNDWATER QUALITY MONITORING

Background

5.4 In the EPA Groundwater Monitoring Programme, monitoring has been classified in three categories:

- 1) representative or basic monitoring;
- 2) user-related monitoring and
- 3) pollutant-related monitoring.

5.5 The representative or basic monitoring is operated on a national basis by the EPA to define the state of groundwater quality, to detect trends in groundwater quality and to determine the causes of any changes in quality that are identified. Monitoring stations within

this basic network have been selected taking into account hydrogeological conditions and groundwater use. The stations in this network are sampled out before the water receives any treatment.

5.6 User-related monitoring mainly consists of monitoring of those drinking water originating as groundwater, as required under the European Communities (Quality of Water intended for Human Consumption) Regulations, 1988. Under these Regulations, all water used for human consumption as well as water used in the food industry, regardless of origin is covered. Monitoring of the water quality is required at the point where it is made available to the consumer.

5.7 Pollutant-related monitoring is intended to detect possible pollutant emissions from landfill sites, septic tank clusters, factories and other waste sources and includes the identification and mapping of potential sources of pollution.

5.8 This is the first time that information on groundwater has been contained in a national water quality report. The information set out below is based primarily on the analysis of samples taken by the EPA at monitoring stations in the representative network as part of the EPA's National Groundwater Quality Monitoring Programme. This programme commenced in 1995 and monitoring is carried out twice a year, to coincide with groundwater levels being at their (1) lowest and (2) highest levels.

5.9 The report contains the results of the analyses of groundwater samples taken in the period 1995-1997 in relation to a number of important parameters and indicates whether they meet the standards set in the Drinking Water Regulations for these parameters. This approach is taken in view of the fact that many groundwaters are taken into supply systems with only minimum treatment.

Assessment of Groundwaters in Ireland

5.10 The following factors explain the general water quality characteristics of Irish groundwaters (Wright *et al.*, 1983):

- a) high rainfall and aquifer recharge, distributed fairly evenly throughout the year;
- b) a shallow water table, ensuring that much of the groundwater re-emerges quite close to its recharge zone, producing short flow-paths within the aquifer;
- c) the predominance of fissured aquifers, leading to rapid flow, minimising water/rock contact;

- d) the widespread occurrence of the Carboniferous limestone, both as an aquifer and as a constituent of Quaternary gravel aquifers;
- e) large recharge and low abstractions ensure steady seaward flow of groundwater, minimising saline intrusion;
- f) most groundwater is drawn from shallow (less than 120 m) aquifers. Deeper aquifers (which might be more mineralised) are largely uninvestigated and unexploited;
- g) limited development of evaporitic facies in sedimentary rocks, leading to some sulphate-rich groundwaters in the north of the country.

Groundwater Chemistry

5.11 Pure water, in a chemical sense, is not found in nature, even in areas remote from development. Natural water contains both dissolved and suspended solids - which may be of organic or inorganic origin - gathered by the water on its way through the atmosphere and from the soil on its way to a stream, river, lake or water table.

5.12 The natural chemistry of groundwater varies. It depends on the chemical nature of the rainwater and the nature of the soil, the subsoils and rocks through which the water passes. Limestone bedrock and limestone-dominated subsoils are common in Ireland and consequently groundwater is often hard, containing high concentrations of calcium, magnesium and bicarbonate. However in areas where volcanic rocks or granites are present and in many sandstone areas, soft water is normal (Daly, 1994).

Sampling Frequency and Numbers of Monitoring Stations in the Period 1995-1997

5.13 The EPA commenced its groundwater monitoring programme in 1995 and undertook one sampling run in 1995, two runs in 1996 and two runs in 1997, giving a maximum of 5 samples in the period 1995-1997 at each sampling location. In excess of 200 samples have been taken in each sampling run, although the number of monitoring stations has varied over the period of this review as sites were either found to be unsuitable for monitoring purposes or sources were no longer in use as the abstraction of water had ceased. However, the number of monitoring stations has increased since the programme commenced in 1995 and is expected to stabilise at around 300.

5.14 As five samples were not taken at all locations in the period 1995-1997, the results, for the major parameters, from four sampling runs were taken as the minimum for the purposes of obtaining representative water quality data for use in this report. This gave an average of 193 samples per run available for analysis for the period of the review.

5.15 Map 1 in Appendix VI indicates the locations of the groundwater monitoring stations covered by this report in relation to the major aquifers. As can be

observed, there is a good distribution of the monitoring stations among the major aquifers, although there is only limited sampling in the south eastern counties. More extensive sampling at groundwater monitoring stations in these counties under the EPA's national groundwater quality monitoring programme will commence in the sampling runs undertaken in 1999/2000.

RESULTS OF ANALYSIS OF GROUNDWATER QUALITY SAMPLES TAKEN IN THE PERIOD 1995-1997

Presentation of Data

5.15 To ensure uniformity in reporting throughout this report, the comments below are made on water quality results in terms of the mean of the sample results at each monitoring station; however, where relevant, individual sample results are also commented upon. A more detailed presentation of the data for selected parameters at each monitoring station is given in the maps 2-8 in Appendix VI.

Ammonia Concentrations

5.16 Ammonia is generally present in natural waters, though in very small amounts, as a result of microbiological activity which causes the reduction of nitrogen-containing compounds (Flanagan, 1992). It has a low mobility in soil and subsoil and its presence in groundwater much above 0.1 mg/l N may indicate direct sewage or industrial contamination. From the viewpoint of human health, significant concentrations of ammonia can indicate the possibility of sewage pollution and the consequent possible presence of pathogenic micro-organisms. Under the EC (Quality of Water intended for Human Consumption) Regulations, 1988 (S.I. No. 81 of 1988), the maximum allowable concentration (MAC) of ammonia is 0.3 mg/l as ammonium which is equivalent to 0.23 mg/l as N. The units for ammonia used below are mg/l N.

5.17 A total of 903 individual samples were analysed for ammonia at 193 monitoring stations. A summary of the data is given in Fig. 5.1 and the ranges of the mean concentrations measured at the individual sampling stations are shown on Map 2 in Appendix VI.

5.18 Mean ammonia levels greater than 0.23 mg/l N were recorded at only ten of the 193 monitoring stations while the bulk (83 per cent) had mean values less than 0.05 mg/l N (Fig. 5.1). The overwhelming number (862) of individual samples had ammonia concentrations less than the MAC value of 0.23 mg/l N. Of the 41 individual samples in which the measured concentrations were greater than the MAC value, 33 were taken at stations where the mean ammonia concentrations were also greater than 0.23 mg/l N. The highest individual ammonia concentration recorded was 1.6 mg/l N.

5.19 These results of the analysis of groundwater samples for ammonia indicates that there was no widespread pollution of particular aquifers although elevated values (i.e. with a mean ammonia concentration >0.23 mg/l N) were found in samples from Cavan, Kerry, Leitrim, Monaghan and Meath. Of the 18 sampling locations that had high ammonia concentrations, 17 were boreholes and the remaining one a spring. This may indicate the need for improved borehole construction techniques or better source protection measures in the vicinity of boreholes.

5.20 Only two of the ten monitoring stations with mean ammonia results above the MAC were free of bacteriological contamination. This indicates organic pollution at the majority of these ten stations and emphasises the need for disinfection of drinking water supplies. Although there is no fixed relationship between high ammonia concentrations and bacterial contamination, a large number of sources that had high ammonia concentrations did have such contamination. It is clear that any drinking water supply source with elevated ammonia levels should be regarded with suspicion pending the results of bacteriological examination.

Nitrite Concentrations

5.21 A total of 548 samples, taken at 159 monitoring stations, were analysed for nitrite. The results are summarised in Fig. 5.2 while the ranges of the mean concentrations measured at the individual sampling stations are shown on Map 3 in Appendix VI. The Drinking Water Regulations specify a MAC for nitrite of 0.1 mg/l which is equivalent to 0.03 mg/l N.

5.22 There was one monitoring station where the mean nitrite concentration was found to be greater than 0.03 mg/l N while 148 of the 159 sampling points had mean concentrations less than 0.01 mg/l N. Of the 548 individual sample results, 519 were less than 0.01 mg/l N with 23 between 0.01 and 0.03 mg/l N. The highest individual nitrite concentration was 0.087 mg/l N.

5.23 As nitrite is an intermediate compound in the oxidation of ammonia to nitrate and therefore not likely to accumulate, high nitrite concentrations would not be expected in waters. This is borne out by an examination of the sample results in the period 1995-1997. Only one source had a mean nitrite concentration greater than the MAC (out of 159 stations) and there were only six individual samples (out of 548 samples) above the MAC value.

Nitrate Concentrations

5.24 Most of the nitrate found in natural waters is of anthropogenic origin, coming from organic and inorganic sources, the former including waste discharges and the latter comprising chiefly artificial fertilisers. Sewage (either of human or animal origin) is rich in nitrogenous matter which, through bacterial action, may ultimately appear in the aquatic

environment as nitrate. The presence of nitrates in groundwater is cause for suspicion of remote sewage pollution or of excess levels of fertilisers or manure slurries spread on land. As pointed out above, high nitrite levels would indicate more recent pollution as nitrite is an intermediate stage in the ammonia-to-nitrate oxidation. Under natural conditions, nitrate is present only in low concentrations - normally in the range 5-9 mg/l of nitrate. Drinking water treatment does not remove nitrate. (Note that the units used below are in terms of molecular nitrate rather than nitrogen equivalent).

5.25 As pointed out in Chapter 2, there are health risks associated with excess nitrate consumption in the human diet. These include methaemoglobinaemia in infants (blue baby syndrome) and potential carcinogenic hazards for the general population (Dorin, 1983). Nitrate itself is not a direct toxicant but is a health hazard because of its conversion in the stomach to nitrite which reacts with blood haemoglobin to cause methaemoglobinaemia. If water contains more than 450 mg/l nitrate, it is unsuitable for consumption by livestock (Freeze and Cherry, 1979).

5.26 Under the EC (Quality of Water intended for Human Consumption) Regulations, 1988 (S.I. No. 81 of 1988), the MAC of nitrate is 50 mg/l (or 11.3 mg/l as N). In the EU Directive 80/778/EEC, a guideline value of 25 mg/l (or 5.65 mg/l as N) is recommended.

5.27 A total of 556 samples were analysed for nitrate. An additional 349 samples were analysed for Total Oxidised Nitrogen (TON) (nitrate plus nitrite). These TON results were converted to nitrate by subtracting nitrite values where available or by assuming that the nitrite levels present were insignificant in comparison to the nitrate levels. This gave a total of 905 individual nitrate samples taken at 193 monitoring stations. The results are summarised in Fig. 5.3 while the ranges of the mean concentrations measured at the individual sampling stations are shown on Map 4 in Appendix VI.

5.28 Mean concentrations of nitrate of 25 mg/l or less were recorded at 155 of the 193 sampling points but exceeded 50 mg/l at five stations. Concentrations greater than 50 mg/l were recorded in 26 individual samples. Of these, 15 were taken at stations where the mean nitrate concentration was also greater than 50 mg/l. The remaining 11 samples were taken at nine stations and had concentrations in the range 50-103 mg/l. The highest individual nitrate concentration was 153.3 mg/l.

5.29 The results of the examination of samples for nitrates indicates that there was no widespread pollution of particular aquifers although elevated values (i.e. with mean concentrations >50 mg/l) were found in Carlow, Kildare, Limerick and Louth. This indicates a local pollution problem, either associated with failure of the protection measures at the groundwater source or with

agricultural practices nearby. However, these high nitrate levels were not, in general, associated with raised concentrations of ammonia or nitrite or by bacterial contamination. All sources with mean nitrate results greater than 50 mg/l should be examined and the source of the problem identified and controlled.

Chloride Concentrations

5.30 Chloride exists in all natural waters, the concentrations varying very widely and reaching a maximum in sea water (up to 20,000 mg/l Cl). Chloride does not pose a health hazard to humans and the principal consideration is in relation to palatability. Where there is a high chloride level there may also be an associated high sodium concentration. Under the EC (Quality of Water Intended for Human Consumption) Regulations, 1988 (S.I. No. 81 of 1988), the MAC value for chloride is 250 mg/l Cl.

5.31 In fresh waters, the sources of chloride include rain water, soil and rock formations, sea spray and waste discharges. Sewage contains large amounts of chloride, as do some industrial effluents. Concentrations vary and what is important is not the absolute level (although one would expect levels below 30 mg/l in uncontaminated groundwater) but rather the relative levels from one sampling period to the next. Because sewage is such a rich source of chloride, a high level or a significant increase may give rise to suspicions of pollution from sewage. However, in coastal areas elevated chloride values may be due to sea spray or salt water intrusion and not necessarily due to pollution (Flanagan, 1992). Saline intrusion in groundwaters is not common in Ireland; the best known example is in the low-lying, karst limestone area east and south of Galway City.

5.32 A total of 886 samples, taken at 189 of the sampling locations, were analysed for chloride. The results are summarised in Fig. 5.4 while ranges of the mean concentrations measured at the individual sampling stations are shown on Map 5 in Appendix VI. Mean concentrations of chloride measured were less than 30 mg/l at 85 per cent (160) of the sampling locations and exceeded 100 mg/l at only three locations. However, mean concentrations were well below the MAC at all points.

5.33 All of the individual samples taken had less than the MAC while in 85 per cent (749), the concentrations were less than 30 mg/l. The highest individual chloride concentration recorded was 195 mg/l Cl; this sample had a sodium concentration of 41 mg/l indicating that the contamination was not due to salt. The location of this sample and of another with raised chloride concentrations are well removed from the coast but in some other cases a seawater effect may have been responsible for the above average chloride content. While some of the samples with raised chloride concentrations also had levels of ammonia or bacterial contamination indicative of organic pollution, this was

not a consistent pattern; thus, chloride content alone is not likely to be a reliable guide to the presence or absence of such pollution.

Phosphate Concentrations

5.34 Phosphorus occurs widely in nature in plants, in micro-organisms and in animal wastes. It is used as an agricultural fertiliser and as a constituent in detergents. The significance of excess phosphorus in water is principally in regard to the phenomenon of eutrophication of lakes and rivers. Phosphorus gaining access to such water bodies, along with nitrogen, promotes the growth of algae and other plants leading to blooms. Its importance in this regard has been recognised in the Local Government (Water Pollution) Act 1977 (Water Quality Standards for Phosphorus) Regulations, 1998 (SI No. 258 of 1998). However phosphorus has not been regarded as a problem in groundwaters as it was considered to be retained in the soil zone and unlikely to penetrate to groundwaters.

5.35 Under the EC (Quality of Water Intended for Human Consumption) Regulations, 1988 (S.I. No. 81 of 1988), the MAC value for phosphorus is 5000 ug/l measured as phosphorus pentoxide; this is equivalent to 2.2 mg/l phosphate expressed as P, the form in which phosphorus is usually measured in waters. It should be pointed out that this concentration is greatly in excess of that likely to cause eutrophication in surface waters. Phosphate has little significance for human health at the levels normally found in water sources and has been dropped as a parameter in the revised directive on drinking water quality (CEC, 1998).

5.36 A total of 833 samples were analysed for phosphate at 189 stations. The results are summarised in Fig. 5.5 while the ranges of the mean concentrations measured at the individual sampling stations are shown on Map 6 in Appendix VI. Mean concentrations of phosphate were less than 0.04 mg/l P at 87 per cent (164) of the sampling points. While mean concentrations between 0.1 and 0.6 mg/l P were measured at four locations, all were well below the MAC. The highest concentration recorded in an individual sample was 0.58 mg/l P. There was little sign of a correlation between raised phosphate concentrations and indications of organic pollution.

5.37 Based on these measurements, it appears that Irish groundwaters generally have phosphate concentrations of less than 0.04 mg/l P and typically are less than 0.02 mg/l P. Thus, as groundwater provides the baseflow in rivers, the inflow from unpolluted aquifers may assist in diluting the phosphorus loadings from other sources.

Iron and Manganese Concentrations

5.38 Iron is present in significant amounts in soils and rocks, principally in insoluble form. However, many complex reactions which occur naturally in ground formations can give rise to more soluble forms of iron which will therefore be present in water passing through

such formations. Background levels vary considerably depending on the rock structure. Excessive concentrations of iron do not cause health problems but are of concern for aesthetic and taste reasons. A groundwater sample may be colourless but on exposure to air, the iron may precipitate out due to oxidation of the soluble ferrous to the insoluble ferric form which appears as a reddish-brown (rust) deposit.

5.39 Manganese is widely found in soils. Like iron, it may be present in solution in groundwaters due to reducing conditions and the excess metal will be deposited as the water is brought to the surface and re-aerated. The principal objection to the presence of relatively large concentrations of manganese in drinking waters is, again, aesthetic due to turbidity and taste, there being little significance for health. It may also cause staining of fabrics.

5.40 Since organic pollution can lead to serious deoxygenation of groundwaters and provide the necessary reducing conditions to bring the two metals into solution, marked increase in levels of iron and manganese can, therefore, be considered indicative of such pollution.

5.41 Under the EC (Quality of Water Intended for Human Consumption) Regulations, 1988 (S.I. No. 81 of 1988), the MACs for iron and manganese, respectively, are 200 µg/l and 50 µg/l; these are equivalent to 0.2 mg/l Fe and 0.05 mg/l Mn.

5.42 *Iron* A total of 730 samples were analysed for iron at 193 stations. The results are summarised in Fig. 5.6 while the ranges of the mean concentrations measured at the individual sampling stations are shown on Map 7 in Appendix VI. There were 43 sampling stations with mean iron concentrations greater than 0.2 mg/l of which 16 had mean concentrations over 1 mg/l. The highest individual iron concentration was 8.48 mg/l Fe.

5.43 *Manganese* A total of 715 samples were analysed for manganese at 193 stations. The results are summarised in Fig. 5.7 while the ranges of the mean concentrations measured at the individual sampling stations are shown on Map 8 in Appendix VI. There were 42 sampling stations with mean manganese concentrations greater than 0.05 mg/l, the bulk of these being in excess of 1 mg/l. The highest individual manganese concentration was 11.6 mg/l.

5.44 These results show that iron and manganese contamination of the groundwaters sampled is relatively common and likely to cause problems for consumers in many cases unless appropriate pre-treatment is used. In general, samples with high concentrations of one metal also had raised concentrations of the other.

Results of Bacteriological Examination of Samples

5.45 From the perspective of human use and consumption of groundwaters, the most important

consideration is the absence of pathogenic organisms, i.e. those organisms capable of infecting or of transmitting diseases to humans. These organisms are not native to aquatic systems and usually require an animal host for growth and reproduction. They can, however, be transported by natural water systems. Many species of pathogens are able to survive in water and maintain their infectious capabilities for significant periods of time. These pathogens include bacteria (e.g. faecal streptococci and *Salmonella*), viruses, protozoa and helminths (parasitic worms).

5.46 The universal indicator organisms for the presence or absence of pathogens originating in sewage are the coliforms, specifically *Escherichia coli*. These bacteria are of definite faecal origin (human and animal). Their presence is proof that faecal contamination has occurred and an indication, therefore, that there is a potential presence of pathogens. Conversely, the absence of these faecal coliforms (specifically the *E. coli* Type 1) must be demonstrated as an assurance of the minimisation of this potential. As all coliform organisms (or organisms which respond to the test conditions) are not of faecal origin, some types being able to grow in soil, a second analysis is carried out for the presence of total coliforms, giving an indication of the general level of microbiological contamination of a water. The latter is a confirmatory test.

5.47 The pollution indicated by the *E. coli* bacteria can come from different sources, e.g. septic tank effluent, farmyard waste or landfill sites. The natural environment, in particular the soils and subsoils, is effective in removing bacteria and viruses by predation, filtration and absorption. A high risk situation can arise where permeable sands and gravels with a shallow water table are present and where fractured rock, particularly limestone, is present close to the surface. These conditions allow rapid passage of contaminated material into the groundwater. While the presence of clayey gravels, tills, and peat will, in many instances, hinder the vertical migration of microbes, preferential flow paths, such as cracks in clayey materials can also allow rapid movement by bypassing the subsoil.

5.48 A total of 537 samples at 125 stations were examined for faecal coliforms. Positive counts were obtained in 185 (34 per cent) of these samples and in 24, the counts exceeded 100/100 ml (Fig. 5.8). Some of the stations at which nil counts were obtained had positive counts on other occasions. Taking a positive faecal coliform count of greater than 10 coliforms/100 ml as a threshold indicator of gross contamination, 98 samples, taken at 48 sites, would be so described. A total of 541 samples at 127 stations were examined for total coliforms of which 284 showed positive counts. Faecal coliforms were not found in all samples with positive total coliform counts.

5.49 The stations which had positive faecal coliform counts above 10 coliforms/100 ml were in Counties

Roscommon (10); Galway (7); Leitrim and Mayo (5 each); Cavan and Sligo (4.); Monaghan (3); Clare, Donegal, Longford and Louth (2 No. in each county) and Kilkenny and Westmeath (1 each). This relatively widespread occurrence of coliform contamination emphasises the importance of disinfection of drinking water drawn from groundwater sources. While the results for this parameter do not necessarily represent the overall national picture, as (1) there was a significant number of samples that were not subjected to bacteriological examination and (2) no samples were taken in the South-East, any indication at all of contamination, however mild, must be regarded as a matter of gravity and the circumstances promptly investigated. This matter has been addressed in detail in the annual reports on drinking water quality published by the Agency (EPA, 1997).

References

- Groundwater Resources of the Republic of Ireland. Published by the EC Commission and prepared by the Geological Survey of Ireland 1982.
- Environmental Research Unit. "Water and Sewerage Needs Study". November 1993.
- EU Groundwater Protection and Management in View of The Sustainable Use of fresh Water Resources Draft Policy Paper 1991 Page 5.
- Wright, G.R., Daly, D., Daly, E.P. "Groundwater Vulnerability and Quality in the Republic of Ireland" Commission of the European Communities. July 1983.
- Daly, D. "Chemical Pollutants in Groundwater: A review of the Situation in Ireland. Geological Survey of Ireland
- Flanagan, P. J. "Parameters of Water Quality. Interpretation and Standards". Second Edition. Environmental Research Unit. October 1992.
- Flanagan, P. J. "Parameters of Water Quality". 2nd. edition Environmental Research Unit. 1990.
- United Nations. "Nitrate Contamination of Aquifers. Evaluation and Control Options. Prepared by G. Dorin. October 1983.
- Freeze, R.A. and Cherry, J.A. "Groundwater". Prentice-Hall 1979.
- Flanagan, P. J. "Parameters of Water Quality". 2nd. Edition (with amendments). Environmental Research Unit. 1992.
- Flanagan, P. J. "Parameters of Water Quality". 2nd Edition (with amendments). Environmental Research Unit. 1992.
- G. Friel and M. Quinn. "STRIDE Environment Sub-Programme Measure 1 Groundwater Assessment in Counties Cavan, Louth and Monaghan". March 1994.
- Peavy, H.S., Rowe, D.R. & Tchobanoglous. "Environmental Engineering". McGraw Hill. International edition 1986.

Article supplied by Mícheál MacCártaigh, EPA

Proceedings of the Environmental Conference: "Water: Is its Quality Deteriorating?", Carrigaline, 4-5 May, 2000

The Proceedings include papers on the following topics: future EU legislation; habitat quality for fisheries; practical approaches to preventing pollution of wells; the current status of water quality in Ireland; water quality in UK, US and Sweden; the origins and effects of phosphate in freshwater; and Cryptosporidium. The Proceedings are now available for £30.00 (post free). Contact Sherkin Island Marine Station, Sherkin Island, Co. Cork. Email: sherkinmarine@eircom.net

IAH (Irish Group) News

Future IAH Technical Discussion Meetings (TDMs)

These meetings are held every year from September to the following June. TDMs are held in the Geological Survey of Ireland and open to all. They start at 18:00 hrs and are preceded by tea/coffee from 17:30 hrs. For further information, contact either Kevin Cullen (01-294 1717) or Donal Daly (01-604 1490). Our line up for the Autumn is as follows:

September 2000: An **Agricultural Practices Course** is due to be held at Johnstown Castle, Co. Wexford in September. In addition to practical field demonstrations, this meeting will consist of technical discussions so there will be no TDM held in the GSI for this month. Details of the course will be circulated to members in the coming weeks.

October: "Ranking Environmental Risks and Hazards using GIS" - a case study using petrol storage facilities in Wales by Richard Cantwell, K.T. Cullen & Co. Ltd.

November: Presentation on the Irish Forest Soils project by Robbie Meehan, Teagasc.

IAH Fieldtrip to the South Munster Synclines - 2000

To avail of the long bright evenings and warm summer days, this years weekend fieldtrip was held in May. Our trip focused on the South Munster Syncline Region of Cork and was led and organised by Geoff Wright and Morgan Burke. A total of 25 people attended the fieldtrip.

On Saturday morning the group assembled at Glounthaune Church (an experience in itself for some of our members). Our first stop was at Carrigtwohill limestone quarry where we were given an opportunity to examine the limestones and to discuss dewatering of the quarry which amounts to approximately 16,000 m³/d. A second limestone quarry was visited at Carrigacrump

which contains one of the best cave systems in east Cork. While some of the cave system has been quarried, it was still possible to examine some smaller caverns and karst features developed in the limestone. The Dower Spring (yielding 6800 m³/d) and other karst springs and swallow holes were visited at a number of locations including Water Rock House, Shanagarry and Poulinahorka. There was also time to visit the water supply schemes of both Cloyne-Aghada and Dungarvan-Ballynamuck. Eugene Daly informed the group that the Dungarvan-Ballynamuck supply was the highest known yield recorded for a borehole in Ireland (13,000 m³/d or 2.5 million gpd).

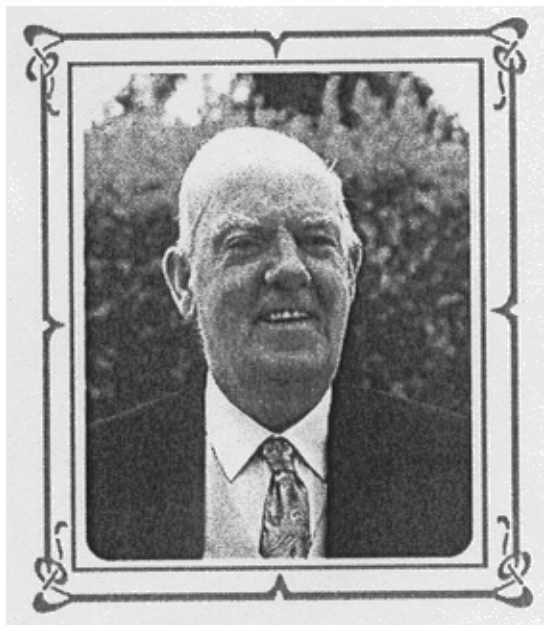
The Sunday morning meeting point was the Natural Energy Centre at the Spa House, Mallow. The Energy centre was introduced by Alex Grassick and our own Colette Cronin spoke of the hydrogeology of the Mallow springs and the geology of surrounding area. Colette informed us that there are 6 warm springs in Munster, the largest of which is Lady's Well which is located adjacent to the Spa House. It was then time to test the temperature of this largest warm spring which averages 22°C (eleven degrees higher than most Irish springs).

Leaving Mallow behind, it was time to head underground and visit the truly spectacular caves of Mitchelstown (well worth a visit for those who have not had the pleasure). Our tour guide lead us through 3 huge caverns, each decorated with wonderful examples of stalagmites and stalactites and other speleothem formations. When we reached our final destination in the cave, known as "The Stage", the acclaimed acoustics of the cavern systems were demonstrated by a bout of yodelling (thanks Kevin!).

Thanks again to all who attended the fieldtrip. It was a superb weekend and a great opportunity to visit some of the karst features and warm springs of the picturesque South Munster Synclines.

Anita Furey, IAH Secretary (afurey@ktcullen.ie) and Morgan Burke, Fieldtrip Secretary (mburke@minerex.iol.ie)

Farewell to John Dunne



On a cold, bright January morning a huge crowd of mourners gathered in John Dunne's adopted home town of Mallow to pay their last respects to one of the foremost figures in Irish well drilling, a man who spanned the huge technological leap forward in well construction - from the manual well-digging of the 1940s to the powerful high-tech drilling machines of today.

In their different contributions to the requiem mass, the parish priest and members of John's family recalled various aspects of his character: his vibrancy, his love of music and singing, his love of books and learning, his encyclopaedic knowledge of the highways and byways of Ireland, his hospitality and openness.

As his parish priest recalled, 'Helpfulness' was John's middle name. Although not a member, John was a great friend and supporter of the Irish Group of IAH from its very beginning, and a regular attendee at our meetings. He was a particular supporter of our Annual Seminar in Portlaoise, and always had a relevant question or comment. "We can always learn something" he used to say. And indeed he was a real example of lifelong learning - at the age of 63 he attended and successfully completed a diploma course in geology at UCC, where he was also a strong supporter of the Cork Geological Association.

The Groundwater Section of GSI will always have good reason to remember John, because the well records he sent to us, and the anecdotal information and advice he so freely offered, have contributed in no small measure to our hydrogeological data bases. As we gathered in Mallow, I recalled a similar cold January morning twelve years earlier in the nearby town of Buttevant, when we said goodbye to David Burdon. John and David were good friends and shared a deep mutual respect. Though different in many ways, they had much more in common than the accident of living in the same part of Ireland and their common interest in groundwater: at a deeper level they were both such encouragers, they were always keen to learn new things, they were both real Christian gentlemen.

To his family we offer our sincerest condolences. As the notice in *The Examiner* said, "He will draw waters from the wells of salvation". Rest in Peace, John. We shall not see your like again.

Geoff Wright, Geological Survey of Ireland

CONTRIBUTIONS FOR THE NEXT ISSUE OF THE NEWSLETTER

Contributions for the next issue should arrive before 1st October 2000 to:

The Editor, GSI Groundwater Newsletter,
Geological Survey of Ireland,
Beggars Bush, Haddington Road, Dublin 4.

**The contributors are responsible for the content of the material in this Newsletter.
The views expressed are not necessarily those of the
Geological Survey of Ireland.**