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WATER QUALITY – a Water Company Perspective

Clive Harward
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At Anglian Water, we're putting water at the heart of a whole new way of living, encouraging everyone to Love Every Drop.

We supply water and wastewater services to more than six million domestic and business customers in the east of England and Hartlepool.

Our population has grown by 20% in the last 20 years, but we still provide the same amount of water today as we did in 1990 – almost 1.2 billion litres every single day – by minimising leaks and encouraging customers to use water wisely.

Our region stretches from the Humber north of Grimsby to the Thames estuary and then from Buckinghamshire to Lowestoft on the east coast. Our 112,833 km of water and wastewater pipes supply and transport water across an area of 27,500 square km.

We're the largest water and wastewater company in England and Wales by area.

DRINKING WATER QUALITY AND HEALTH

Safe drinking water is fundamental to public health and we take our responsibilities for supplying water which is safe, clean and wholesome extremely seriously.

Wholesome drinking water is defined in regulations and has to meet stringent microbiological, aesthetic, physical and chemical standards; not just as it leaves the water treatment works but right up to the point of consumption – usually the kitchen tap, and this brings a whole set of challenges and risks in itself.

Compliance with drinking water standards is extremely high at 99.96%. However the small number of compliance failures is often associated with issues outside a water company's direct control. The most common cause of compliance failures are associated with the impact that customers' premises have on the quality of the water leaving their tap. This can be due to the plumbing system, fittings and devices used in the home, for example taps, water softeners, storage tanks, incorrectly installed rain water harvesting and solar heating systems.

We work closely with WRAS – the Water Regulations Advisory Scheme – to help ensure that products and fittings that are approved for use do not have a negative impact on water quality. We are also a founding member of WaterSafe, the national approved plumber scheme which brings together all the UK approved plumber schemes under a single umbrella so that customers can find a trained, competent plumber to carry out work in a way that will not affect the quality of water.

. . . 1.2 billion litres every single day . . .

The next most common cause is pollution from agricultural sources, for example pesticides. While many of these substances can be removed by our treatment processes, some pesticides, for example metaldehyde (used to control slugs), would cost billions of pounds to remove. In these cases a combination of controls and regulations are needed, as well as a catchment based approach to help prevent the pollution at source.

BEHAVIOURAL CHANGE

Our Love Every Drop strategy is about securing water supplies for local people and businesses, promoting local knowledge about water use and climate change, and changing how people think about and use water.

We currently have two behaviour change campaigns supporting this strategy. Keep it Clear aims to reduce pollution incidents from sewer blockages, and Drop 20 encourages customers to reduce their water use by 20 litres per day and has contributed to saving 60 Ml of water in 2012.

Half of the blockages in Anglian Water's sewer network are avoidable, caused by people putting unflushable items (wipes

. . . supplying water which is safe, clean and wholesome . . .

and sanitary waste) and fats, oils and grease (FOG) down toilets and sinks. 60% of sewer flooding in homes and environmental pollution incidents are as a result of a blockage. By reducing avoidable blockages we reduce the risk of these incidents.

We undertook extensive research with our target audience – householders and food serving establishments (FSEs) to understand current behaviours and the barriers and motivators for change. We then devised interventions to make it easy for customers to act.

Each location starts with a personalised mailing to customers giving advice on how to dispose of FOG and unflushables responsibly. Outdoor and local media advertising and a community engagement programme is then undertaken through a long-term partnership with a lead voluntary organisation – the local messenger that residents "know and trust".

We also work with restaurants and food outlets to advise them on the correct way to dispose of fats, oils and grease.

Overall the programme is achieving sustained behaviour change with an average of 51% blockage reduction achieved across the eight locations targeted to date, compared to previous years.

Our water efficiency behaviour change campaign, Drop 20, focuses on the benefits of simple changes in behaviour to reduce water consumption, from fixing dripping taps (saving 3 litres a day) to spending two minutes less in the shower (16 litres). Using billboards, radio adverts, leaflets and conducting roadshows we are encouraging everyone to take part, and have already given away 5,000 water butts to make it easy for customers to act.

ENVIRONMENTAL WATER QUALITY

As science develops we are able to detect more substances in the environment at lower levels. The real challenge is to evaluate their ecological impact, and determine whether they present a risk to public health and therefore need to be controlled. Recent studies have focused on potentially eco-toxic, persistent or bio-accumulative substances.

Environmental policies have reduced exposure to harmful environmental contaminants in air, water and food over the decades. However, some contaminants are still a problem, and several new health risks are emerging. For example, new chemicals, products and changing lifestyle all play a part.

. . . the local messenger that residents "know and trust" . . .

European legislation sets out a list of substances such as metals and pharmaceuticals which present a significant risk to or via the aquatic environment. The substances, such as metals and pharmaceuticals, are designated as Priority Substances (PS) or Priority Hazardous Substances (PHS), and are required to be monitored in the environment.

In early 2012 the European Commission proposed the addition of new substances to this list. This proposal recommended two hormones (17alpha-ethinylestradiol (EE2), 17beta-estradiol (E2)) and a painkiller (Diclofenac) be added (among others). The excretion of such compounds by humans is recognised as the main source of these pharmaceuticals, as they enter rivers via discharges from wastewater treatment plants.

In order to understand the prevalence and fate of these substances in wastewater, a national study was commissioned by the water industry and supported by regulators, known as the Chemical Investigations Programme (CIP) from 2009 to 2013. Over 70 substances were monitored at 162 treatment plants, with over 200,000 samples analysed.

The study showed that the vast majority of substances were removed during conventional wastewater treatment. However the level of reduction from the process depended on a number of factors, such as the type of treatment employed. Achieving higher levels of removal to meet proposed environmental standards are likely to be particularly challenging. Experience within the water industry has shown that a technology that is successful at one site, or for one substance, is not necessarily successful for another. Also the costs to remove these substances at treatment plants run into billions of pounds and generate significant carbon emissions.

This means that alternative control measures, such as product substitution or more advertising of pharmaceutical take-back schemes need to be explored, to prevent pollution at source.

JOINED UP POLICY MAKING

Overall water quality in the UK is very high. However there are a number of factors beyond the direct control of water companies that can have a detrimental impact. We need joined up policy, and concerted action by all parties, to tackle these environmental challenges. Policy needs to prevent pollution at source rather than rely on expensive and unsustainable treatment to remove it.

EU chemicals legislation (REACH) contains mechanisms suited to controlling substances at source, which is hugely important. However REACH assesses only environmental impacts not drinking water impacts. In our experience prevention is better than cure, and therefore we would like to see products assessed for their impact on drinking water quality as well as on the environment before being approved for market.

Standards setting the level of chemicals allowed in water must be based on strong evidence, taking account of the full environmental impact alongside financial and carbon costs. We would like to see a detailed regulatory impact assessment before the introduction of any new standards for the permissible levels of priority substances in the environment.

. . . Standards must be based on strong evidence . . .

WATER PURITY – MYTHS AND CHALLENGES

Kevin Prior MBA FRSC FCIWEM CChem CSci CWEM
Chair, Royal Society of Chemistry Water Science Forum

INTRODUCTION

Water purity is a complex term and is often approached in a subjective manner.

What are we talking about: water contamination or perhaps environmental pollution? In the United States, the EPA defines "pure" water as water free from all types of bacteria and viruses. In the UK drinking water has to be "wholesome". But there is more to purity than just that.

Water is a compound made up of hydrogen and oxygen, so pure water would be water that contains nothing but hydrogen and oxygen. However, pure water of this sort does not normally exist except in the controlled environment of a laboratory. Even in a laboratory pure water is hard to come by. For example, bacterial contamination of purified water can cause major problems in the laboratory. Even if organic and inorganic chemical impurities are removed down to the limits of detection, bacterial growth can still occur, even though very pure water provides an extremely harsh environment with apparently negligible nutrient content. To avoid metallic contamination of the water, laboratory water purifiers are constructed using plastics. The bacteria can use these materials that are in contact with the pure water as a carbon food source to sustain them, and then when they die they release further contaminants into the water. If this bacterial growth is not minimised, it can cause significant difficulties in the day-to-day operation of the laboratory.

WHAT DO PEOPLE MEAN BY "PURE WATER"?

From a drinking water standpoint, most references to "pure water" emphasise bacteria content and not the chemical contaminant concentrations.

There is no such thing as pure water. The very concept of 'pure' water is misleading. Pure water does not exist in nature. Water is the universal solvent. Even as it falls to earth as rain it picks up particles and minerals in the air. And as soon as it hits the ground it captures minerals from the soil and rock upon which it lands and then makes its way into streams and rivers.

Most water will contain certain ions, such as calcium and magnesium, even if it is just a trace amount. These minerals are the ones that define whether water is hard or soft, and they play a role in taste.

Water supply companies achieve healthy water by identifying the unhealthy contaminants in their water and then taking action to remove them. Consumers can further purify if they wish.

The public discussion about water will switch from the notion of 'pure' to 'healthy'. 'Healthy' water is attainable, whereas pure water is not. And just what is healthy water? 'Healthy' water has a pH that does not adversely affect human biological processes; the optimum appears to be between pH 7 and pH 8. Harmful contaminants such as disinfection by-products eg trihalomethanes, and any harmful chemicals or metals, whether man made or naturally occurring, have been identified and removed with the appropriate treatment.

WHAT DOES A WATER SCIENTIST MEAN BY "PURE WATER"?

From a water scientist's perspective, water purity is considered within the context of its anticipated use. Drinking water should be wholesome and meet all regulatory requirements whereas water destined for use by industry, agriculture or horticulture should be "fit for use". The quality standards are determined for the most part by the user. In the case of environmental waters they would be expected to have achieved good (ecological) status as described in the EU Water framework Directive.

WHAT IS REQUIRED TO DETERMINE ACHIEVEMENT OF THOSE CRITERIA?

In order to determine if water has achieved the required standards the following measures are required. There must be:

- Appropriate evidence based quality standards
- Appropriate risk based monitoring and testing
- By accredited laboratories
- With competent technical staff

All these need to be reviewed at appropriate intervals.

Examples of evidence based quality standards include World Health Organisation's drinking water standards and UK Environmental Quality Standards.

EUROPEAN DRINKING WATER DIRECTIVE

This Directive (98/83/EC) concerns the quality of water intended for human consumption and forms part of the regulation of water supply and sanitation within the European Union. The Directive protects human health by laying down healthiness and purity requirements which must be met by drinking water within the Community. It applies to all water intended for human consumption apart from natural mineral waters and waters which are medicinal products.

In setting contaminant levels the Directive applies the precautionary principle. For example, the EU contaminant levels for pesticides are up to 20 times lower than those in the WHO drinking water guidelines, because the EU directive not only aims at protecting human health but also the environment.

WHO CONTAMINANT LEVELS

The WHO contaminant levels are already set so that there would be no potential risk if the contaminant was absorbed continuously over a person's lifetime. EU drinking water standards and cases where these standards are temporarily exceeded by a small margin should be interpreted in this context.

WHO specifies health related guideline values rather than one fixed blanket limit, irrespective of substance toxicity.

For example WHO states "Because of their low toxicity, the health-based value derived for AMPA [1] alone or in combination with glyphosate is orders of magnitude higher than concentrations of glyphosate or AMPA normally found in drinking water under usual conditions. The presence of glyphosate and AMPA in drinking water does not represent a hazard to human health. For this reason, the establishment of a formal guideline value for glyphosate and AMPA is not deemed necessary." This also applies to metaldehyde where many millions of pounds have been spent trying to remove totally harmless levels.

SAMPLING AND TESTING

Within the UK there exists a risk based regulatory sampling and inspection system for both drinking water and environmental waters and aquatic emissions.

The analytical laboratories are accredited to ISO/IEC 17025:2005 General Requirements for the Competence of Testing and Calibration Laboratories.

In addition Drinking Water Laboratories are required to comply with the Drinking Water Technical Standards (DWTS) issued by the DWI (in England and Wales) and DWQR (in Scotland). DWTS is necessary in addition to ISO 17025 to ensure fit for purpose results.

These standards also set out the required competencies of people involved in determining if the necessary standards have been met. Demonstration that the competencies have been achieved and verified by a third party can be done by gaining relevant profession accreditations such as Chartered Chemist (CChem) status within the Royal Society of Chemistry. Other scientific based professional registers accreditations include those granted by the Science Council.

The Professional Registers consist of the three designations below:

Chartered Scientist (CSci) is a well-established award, with over 15,000 scientists having achieved it since its launch in 2004. Candidates will typically be in senior scientific or managerial roles, qualified to at least QCF level 7 and applying their knowledge in their roles.

Registered Science Technician (RSciTech) is a new award to provide recognition for those working in technical roles.

Registered Scientist (RSci) is a new award to provide recognition for those working in scientific and higher technical roles.

WATER SECURITY

Water quantity as well as quality (purity) has also to be taken into account when considering water security or sustainability.

For water to be considered renewable it has to be used at less than the regeneration rate. In other words, renewable resources are limited. The faster you use them the quicker they run out. As demand for water rises combined with increasing urbanisation, alternatives to removing water from the environment have to be considered.

> "the reliable availability of an acceptable quantity and quality of water for health, livelihoods and production, coupled with an acceptable level of water related risks"
>
> Mike Muller, Graduate School of Public and Development Management University of the Witwatersrand South Africa

The options for increasing water availability in urban areas include:

- Rain water harvesting
- Aquifer recharge
- Affordable sanitation
- Desalination and similar processes
- Reuse and recycling

There are existing regulatory quality standards for:

- Drinking (potable) water standards
- Environmental standards
- Environmental emissions

While there are no regulations covering the quality of reused water, the British Standards Institute (BSI) has produced some guidelines for both greywater and rainwater reuse. For the first time, guidance introduces embedded water quality parameters for water reuse applications. Compliance with these parameters is designed to ensure public health is not compromised.

The guidelines in BS 8525 have taken the standards included in the Bathing Water Directive and developed values based on detailed research into specific applications where greywater is to be used.

The guidance recommends that whilst frequent water sampling is not necessary, it is good practice to observe water quality during maintenance checks. There is more detailed information in the Environment Agency publication *Greywater for domestic users: an information guide.*

The Water Sciences Forum within the RSC role in ensuring water purity and water security is non-partisan and to act as an "honest broker."

Water Scientists should identify the evidence needs and gaps, enable debate, and help influence policy.

CONCLUSION

Water Purity means "not harmful." Scientists and technologists cannot impose solutions on citizens which guarantee water purity. Water Policies need to be based on sound science and evidence to be successful. Consumers, citizens, politicians and scientists must all work together to achieve success.

Reference

1 Aminomethylphosphonic acid

MURKY WATERS: phosphorus mitigation to control river eutrophication

Professor Helen Jarvie
Centre for Ecology & Hydrology, Wallingford.

Professor Helen Jarvie is a Principal Scientist in Water Quality at the Centre for Ecology and Hydrology, Wallingford, and Adjunct Professor in Fluvial Sciences at the University of Arkansas, USA.

Eutrophication (enrichment of waters with phosphorus (P) and nitrogen (N), causing nuisance excessive growth of aquatic plants), is one of the biggest causes of surface water quality impairment, and is of pressing national and global concern. Eutrophication can cause reductions in plant biodiversity and toxic algal blooms; loss of dissolved oxygen (from the death and decay of large amounts of plant biomass), resulting in death of fish and invertebrates; increases in costs of water treatment for potable supply; and reduced amenity value of our rivers, lakes and coastal areas. Of particular concern are nuisance algal blooms and P is often the limiting nutrient for freshwater algal growth. This means that P inputs to rivers from sewage and agriculture can be particularly problematic in stimulating algal growth. Our UK lowland rivers are particularly vulnerable to eutrophication, owing to the high population density and intensive agriculture, which generate large fluxes of nutrients to our rivers. This is exacerbated by high demands for water abstraction for domestic supply, industry and irrigation which, coupled with climate variability and a move to drier summers, reduces river flows and the capacity for rivers to dilute and attenuate these nutrient inputs at times of greatest eutrophication risk. Over the last few decades, reducing P inputs to rivers has become the main international strategy for limiting freshwater eutrophication and is a key target for the EU Water Framework Directive, in order to achieve "Good Ecological Status" in our rivers.

Upgrades to treatment of sewage effluent (which strip P from the final effluent before discharge into rivers) have yielded some dramatic improvements in river P concentrations over the last couple of decades. The Centre for Ecology & Hydrology's River Thames Initiative studies have shown how P stripping from final sewage effluent has reduced P concentrations in rivers across the Thames basin. For example, on the River Kennet in the upper Thames catchment, P stripping at Marlborough sewage works in 1997 resulted in a dramatic reduction in baseline ambient P concentrations from c 0.6 to c 0.08 milligrams per litre.

To mitigate agricultural P inputs, best management practices have been adopted, which address P source controls (eg the rate, method and timing of P applied as fertilisers or manure) and transport controls (eg conservation tillage, contour ploughing and riparian buffers). Although these have been very successful in reducing P concentrations in field runoff, there has often been disappointingly little improvement in downstream water quality as a result of agricultural remediation. More widely, despite decades of P-based mitigation, many restoration programmes have not yet achieved the expected

. . . not yet achieved the expected ecological improvements . . .

magnitude and extent of water quality and ecological improvements, for example, in Chesapeake Bay, the Great Lakes, or the Gulf of Mexico. This disappointing response to P remediation has puzzled catchment managers, but two important factors are starting to emerge:

Firstly, the continued long-term release of P from 'legacy P' stores. Legacy P stores have accumulated in soil, river sediments, wetlands, riparian floodplains, lakes, groundwater and estuaries, as a result of inefficient use of P in past and on-going land-use management. Annually, only around 20-30% of P applied to agricultural land as fertilizer or manure is exported directly out of the watershed (through P loss from the soil in runoff when it rains and removal of P in grain and animal produce). The remaining 70-80% of the applied P enters catchment and water body P stores, which build up over time and release 'legacy' P, as the P storage capacity becomes saturated, or after changes in land use, land management or wastewater treatment. This means that, even when remediation measures reduce P inputs, P release from legacy stores can mask downstream improvements in water quality. The variable residence and recycling times of P within these terrestrial and aquatic stores suggest that the legacies of past land-use management may continue to impair future water quality over timescales of years or decades.

Secondly, ecological responses do not necessarily conform in simple and predictable ways to reduced P concentrations. Algal response can become decoupled from P concentrations during remediation. The example from the River Kennet illustrates the challenges we face: before the upgrades to effluent treatment, the baseline P concentrations in the river downstream were c 0.6 milligrams per litre, but there was healthy chalk stream ecology, including abundant macrophyte (higher plant) growth which provides an important habitat for fish and invertebrates. However, within a couple of years of effluent remediation (which resulted in a seven-fold decrease in baseline river P concentrations), attached algae had proliferated and shaded out the macrophytes, resulting in a major degradation in the aquatic ecology. This response to dramatically lowered P concentrations seems counter-intuitive, but this is just one of numerous examples, where P remediation does not always yield the desired ecological outcomes, even when targets are met. While increasing P concentrations can increase algal biomass, it does not necessary follow that by, reducing P concentrations, recovery will follow the same trajectory. These are complex and inter-linked ecological systems and it is often difficult to ascertain the cause of these unexpected ecological responses. For example, P concentrations may not have been reduced sufficiently to reach the critical thresholds for algal growth limitation, and there are other ecosystem feedbacks and drivers that can come into play. Grazing by invertebrates provides a 'top-down' control on limiting algal growth. Reducing the invertebrate grazing pressure, for example by stocking rivers with fish (such as brown trout), which predate on the invertebrate grazers, can result in proliferation of algae. There are also important physical habitat controls; for example, cutting down riparian tree cover increases light availability to the river, which can also promote algal growth. Similarly, channel management, which impedes river flow and reduces water flow velocity can also promote algal accrual while standing waters such as lakes and canals may seed algal growth within rivers to which they drain. Correspondingly there are extremes in flow that come with the climate instability that the UK is experiencing. In this context, extreme drought conditions may be particularly problematic and very difficult to address within environmental management. Further, there are other co-limiting nutrients, such as nitrogen, to consider. While P has an important role in promoting nuisance algal growth, if we want to reduce the impacts of eutrophication, we also need to consider a wider range of controls, including physical habitat, other nutrients and top-down controls linked to food web (invertebrate and fish


(a)


(b)

WHICH DO YOU PREFER?

These photographs challenge our perception about what constitutes 'Good Ecological Status':

(a) This appears to be the cleanest of the three water bodies, and is used for boating and recreation. However, the lack of algal growth is actually a consequence of upstream industrial discharges, which result in the presence of a mix of heavy metals and organic micro-pollutants, including herbicides, which limit algal growth.

(b) This is a canal, which receives very high phosphorus (P) inputs from sewage effluent (with canal water P concentrations at c 2 milligrams per litre), but supports a high diversity of aquatic plants, and is classed as a 'Site of Special Scientific Interest' in terms of reed bed habitat.

(c) Visually, this appears to have the worst water quality. However this highly turbid river, with high levels of phytoplankton (floating algae), actually has the highest ecological classification in terms of macroinvertebrate biodiversity score.

So appearances can be deceptive; these photographs illustrate (i) the divergence between quantitative measures of chemical and ecological status and the aesthetic appearance of our rivers and (ii) the need to open up the dialogue for wider community consultation to assess what sort of river environments we want, that are achievable and that we are willing to pay for.


(c)

Source: I. J. Bateman, University of East Anglia; see Bateman, I.J et al. (2006) Journal of Agricultural Economics, Vol. 57, 221–237.

interactions), to promote more resilient ecosystem functioning.

We also need to consider what sort of river environments are desirable to the wider community and also achievable and affordable. Many of our rivers have been physically impacted by human activity over many hundreds of years. The River Basin Management Planning process (required under the EU Water Framework Directive), is helping to engage wider stakeholder involvement in identifying how water quality impairment impacts communities and what constitutes healthy river environment. This dialogue is of great importance because there can be considerable divergence between what is visually perceived as good water quality and an attractive river environment, and the quantitative measures used to define "Good Ecological Status" (see accompanying Figure 'Which do you prefer?'). Initiatives such as the Catchment Restoration Fund and the rise of third sector organisations such as the Rivers Trusts are also helping wider community engagement by promoting campaigns to restore and protect river environments. These include a broader remit of restoring a wider range of ecological functions and services, including aquatic and riparian habitat management. Such approaches not only benefit the aesthetic and amenity value of river environments but also promote more tightly coupled nutrient cycling, and ecosystem resilience to perturbations.

In conclusion, we face an "inconvenient truth" that P-based nutrient mitigation, long regarded as the key strategy in eutrophication management, in many cases has not yet yielded the desired improvements in water quality and reductions in nuisance algal growth in rivers and their associated downstream ecosystems. However, the complex recovery trajectories & lags in response to remediation are not an excuse to do nothing; nor are they an excuse to impose more restrictions on any one stakeholder. To address legacy P, the priority must now be to 'draw-down' existing P legacies and prevent future legacy P build-up through source controls, which balance P inputs and recycling more efficiently. Nutrient (including P) mitigation is just one important part of a larger toolbox of measures to promote more resilient river ecosystem functioning. Simple, pragmatic, and easily applicable management tools linked to public perceptions of "good" water quality are also needed, and policies on eutrophication control need to be based on best-available scientific understanding. However, while science can help decision makers, the decisions cannot be taken within science: decisions about allocation of resources and priorities for remediation need to be made within the context of wider societal goals, and balancing competing demands for environmental improvement, food security, depletion of easily-mined mineral P reserves and increasing costs of fertilizer production, and the development of sustainable and vibrant rural and urban communities and economies.

For more information, see:

Jarvie, H.P., Sharpley, A.N, Withers, P.J.A, Scott, J.T., Haggard, B.E., Neal, C. (2013). Phosphorus mitigation to control river eutrophication: murky waters, inconvenient truths and 'post-normal' science. *Journal of Environmental Quality*, 42, p295-304.

HOW WELL IS WATER?

Recently, **Dan Osborn**, from the Natural Environment Research Council spoke to the All Party Parliamentary Group on Water about the global context of water and the progress UKWRIP members are making to address growth and resilience issues associated with water.

Water represents an opportunity for growth because every business, household and person needs water no matter where in the world they are. The UK has an excellent research track record in water and an excellent reputation for delivering high quality drinking water and waste water management. But this is no time to rest on our laurels. The challenges from environmental change, population growth and demographic developments (such as ageing) mean that the UK must examine critically its water security position and take the opportunities presented by a global need to supply water and deploy and refurbish the technologies and infrastructure that does so. Great research needs to be taken up by innovators and innovations need to lead to marketable products and new ways of managing water resources. The new products and services will have to take account of the extreme variations in rainfall that lead to floods on the one hand and droughts on the other that will be a continuing and perhaps increasing feature of the UK "waterscape". Thus, the Government Chief Scientific Adviser chairs the UK Water Research and Innovation Partnership which aims to help private, public and third sectors address both the water security challenge and the national and international economic growth and social development opportunities. Recently, Dan Osborn spoke to the All Party Parliamentary Group on Water about the global context of water and the progress UKWRIP members are making to address growth and resilience issues associated with water.

> . . . increasing feature of the UK "waterscape" . . .

THE GLOBAL ECONOMIC AND BUSINESS CONTEXT

The World Economic Forum annually assesses risks to the world economy on an annual basis and water has risen near the top of the tree (see http://www.weforum.org/reports/global-risks-2013-eighth-edition). Water supply is seen as the top societal risk and many of the other top risks are linked to water. Failure to take action to address such issues could cost at least $250bn for water supply alone. Overall, water issues rank alongside the challenges (and opportunities!) that climate change presents. The magnitude of the risk is, in turn, equivalent in many respects to those posed by the lack of liquidity and the financial crisis itself.

. . . global water market is worth about $500bn . . .

Business opportunities in water (and other natural systems on which we depend without often realising the importance of that dependence) have been recognised in the UK by the Ecosystems Market Task Force (EMTF) and the World Business Council for Sustainable Development (WBSCD). In its 2050 Vision (see: http://www.wbcsd.org/vision2050.aspx) WBSCD call for externalities such as carbon, water and ecosystem services more broadly to be incorporated into market thinking and practices. The global water market is worth about $500bn annually and grows as the population and its expectations do.

The EMTF was funded by Defra and for its specialist aspects by the Natural Environment Research Council. EMTF said (recommendation 5) that implementing appropriate measures set out under its section on "Water cycle catchment management: integrating nature into water, waste water and flood management was important to UK businesses and society" could lead to savings of about £5bn. Views of stakeholders and business on such matters can be seen at (http://www.youtube.com/playlist?list=PLDKjigqXww5hWDCKQMVA2CSUhV-DaEkUS).

THE ENVIRONMENTAL CONTEXT

The UK as a whole could not be more aware of the variability in weather and rainfall patterns that have happened over the past few years. There have been dramatic swings from drought to flood, low rainfall to high. Impacts have been many and various with farmers and city-dwellers all suffering shocks as water has disappeared and then reappeared – sometimes in unexpected places.

This variability is something we may have to get used to because of where the UK is located in the flow of global air masses and ocean currents. Research supported by Research Councils UK is helping understand this variability. Recent initiatives cover both flooding, drought and intense rainfall events.

UK WATER RESEARCH AND INNOVATION PARTNERSHIP (UKWRIP)

Despite the importance of water to the UK, the degree to which this resource varies in availability and recent findings showing that about 65% of the water the UK depends on for food and manufactures is water originating overseas, the way UK businesses approach water innovation and the creation of new business opportunities is less well tied into the outputs and outcomes from research than it is in other countries.

. . . growing interest in water and waste-water . . .

UKWRIP (chaired by the Government Chief Scientific Adviser) was formed to see whether links between research, innovation and the market place could be improved. UKWRIP has the twin aim of helping (a) improve the UK's water security and (b) the UK get a larger share of the global water market. UKWRIP members are from the private, public (research and innovation; policy and regulation) and third sectors. Private sector groups cover the utilities, the supply chain and those business sectors that have a major reliance on water (farming, retailers). A full account of UKWRIP set out in 2011 can be found at: (http://www.bis.gov.uk/assets/bispartners/goscience/docs/t/11-1390-taking-responsibility-for-water).

UKWRIP is meeting a range of members' needs as it is the only UK forum in which all interested parties can meet to identify issues and organise actions. There are network opportunities; Action Groups (business, infrastructure, food, water use, climate and environment); ways to lower barriers on the road from research to innovation and a study in hand to see how other countries succeed in getting innovative products and services into the market place. This will recommend what steps the UK needs to take if it wants to emulate best practice.

There is a growing interest in water and waste-water in an urban context where the UK could take a global lead if the right kinds of investments in demonstration facilities can be achieved. This may need support from both the public and private sector and there are models to base action on in other business sectors such as energy. UKWRIP's Infrastructure Action Group (funded by UKWIR – the water utilities research arm) has already reported on where the major priorities should be in this kind of area.

UKWRIP private sector members have pointed to a lack of training opportunities in water and very swiftly this has been addressed by the Research Councils opening opportunities for post-graduate training in water and infrastructure. The strong private sector involvement in multi-disciplinary bids to Doctoral Training Centres funded through the Engineering and Physical Science Research Council signals a new approach to the UK's water security and economic growth is gaining momentum.

. . . dramatic swings from drought to flood . . .

WATER PURITY: Microbial Aspects, Especially Cryptosporidium

Professor Rachel Chalmers
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Despite the fact that the most common and widespread health risk associated with drinking water globally is microbial contamination, water purity is an expectation in the UK: we do not expect our drinking water to transfer infections and make us ill. However, there are occasions and settings where infections may occur; water of poor quality can cause outbreaks, and contributes to background rates of disease, whether this is through water used for drinking, domestic purposes, food production or recreation.

Cryptosporidium is a microbial contaminant, a protozoan, which has caused drinking and recreational waterborne outbreaks of gastrointestinal illness (cryptosporidiosis) in the UK and elsewhere. This protozoan has a complex life cycle and infection can cause cryptosporidiosis in animals (especially young livestock) as well as humans, resulting in large numbers of the "oocyst" stage being shed in their faeces. Although usually self-limiting, symptoms can be prolonged (often 2 weeks, sometimes longer) and unpleasant. There is a growing body of evidence that long-term adverse health effects may also arise following Cryptosporidium infections, such as irritable bowel syndrome. For some severely immunocompromised patients, infection can have devastating results, including chronic diarrhoea and infection of the hepto-biliary tree leading to liver failure. There is no proven specific therapy for cryptosporidiosis in these patients.

Contracted mainly by person-to-person or farm animal contact, Cryptosporidium can also be spread through food or water. Ingestion of even single numbers of oocysts has a high probability of causing illness. Historically, more drinking waterborne outbreaks in the UK were caused by Cryptosporidium than any other pathogen. One reason for this is because it is resistant to chlorine which controls most other pathogens. However, following the introduction of regulatory continuous monitoring for Cryptosporidium at high-risk water treatment works in England and Wales in 1999 the occurrence of drinking waterborne outbreaks of cryptosporidiosis decreased: structured surveillance conducted since 1992 shows that the proportion of Cryptosporidium outbreaks linked to drinking water before the regulatory change (34% of 62 outbreaks) was substantially greater than after (4% of 132 outbreaks) (Figure). There is also evidence of beneficial impact in a reduction of sporadic cases of cryptosporidiosis in the spring, when combinations of rainfall events and seasonal occurrences in animal husbandry (eg calving, lambing) contributed to contamination of water supplies with human-infectious strains. It is notable from the Figure that while drinking waterborne outbreaks have declined, outbreaks linked to recreational waters have increased; swimming pools are now the most common settings associated with Cryptosporidium outbreaks. Here, secondary disinfection (UV, ozone, for example) as well as both swimming pool user and operator awareness of Cryptosporidium are proven interventions that need to be promulgated in the UK. Notably, there are no specific regulations governing swimming pools in the UK.

To return to drinking water, where contamination and outbreaks can have far-reaching

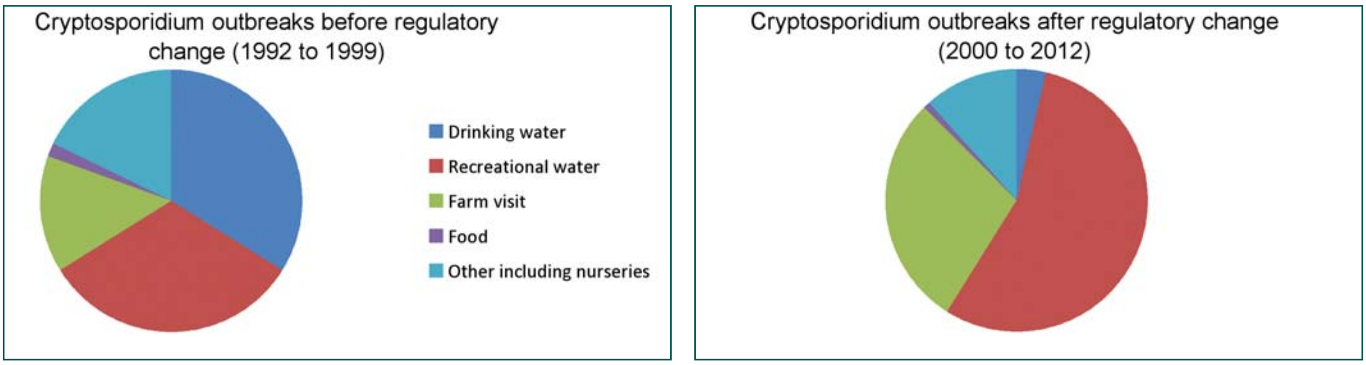

Figure: Proportion of reported Cryptosporidium outbreaks by setting or vehicle (Public Health England and Public Health Wales data) effects, affecting large numbers of people and industries that use mains water (food and health care to name but two). Those 1999 regulations, which relied heavily on end-point testing, have since been replaced with broader drinking water quality regulations that in 2007 introduced new provisions for risk assessment and risk mangement, based on WHO water safety plan methodology outlined in the WHO water quality guidelines. A fundamental ethos of the WHO guidelines is that water quality should promote public health. This is translated in practical fashion by the adoption of water safety plans, providing a risk-based approach supported by evidence-based awareness of potential vulnerability of the source water and supply to contamination, underpinned by effective preventative management. Water safety plans comprise:

- a system assessment to determine whether the drinking-water supply (from source through treatment to the point of consumption) as a whole can deliver water of a quality that meets the health-based targets;
- operational monitoring of the control measures in the drinking-water supply that are of particular importance in securing drinking-water safety;
- management plans documenting the system assessment and monitoring plans and describing actions to be taken in normal operation and incident conditions, including upgrade and improvement, documentation and communication.

The plans are supported by a system of independent surveillance that verifies that the above are operating properly.

A management approach that places the primary emphasis on preventing or reducing the entry of pathogens into water sources and reducing reliance on treatment processes for their removal is the preferred strategy. As a faecally-derived contaminant, Cryptosporidium can arise from farmed or wild animals through direct contamination of source waters with dung, indirect through slurry and run-off, or from people via sewage. With this in mind, it is critical for Cryptosporidium control that multiple barriers are in place to secure the safety of drinking water supplies. These include protection of water sources, proper selection and operation of a series of treatment steps, mainly effective filtration supplemented by UV disinfection where necessary, and management of distribution systems to maintain and protect treated water quality. Where one or more of these barriers are absent or fail, outbreaks of cryptosporidiosis may, and indeed have, occurred. Current testing identifies the oocysts, only as "genus Cryptosporidium" regardless of whether they are alive or dead, or of a species that infects and causes illness in humans or not. Yet additional tests for the resolution of species, which improve the risk assessment by including infectivity potential for humans, have been shown to be of added-value. This is a specialist molecular test provided by reference laboratories. More aspirational is current research as part of the AQUAVALENS project, led by the University of East Anglia and funded by EU Framework 7 (www.aquavalens.org), investigating the further development of assays based on whole genome sequencing data, to improve the accuracy of testing for waterborne pathogens.

One area of particular difficulty in source water quality management arises as many aspects are often outside the direct responsibility of the water supplier, for example where catchments and source waters are beyond the drinking-water supplier's jurisdiction. Thus, it is essential that a collaborative multiagency approach be adopted to ensure that agencies with responsibility for specific areas within the water cycle are involved in the management of water quality. Communication has been identified by the Chief Inspector of Drinking Water as one area for improvement.

Improved control of drinking waterborne cryptosporidiosis can be, and continues to be, achieved within the current regulatory framework. Nevertheless, there may still be a background risk in some mains supplies requiring a high level of vigilance throughout the system. Furthermore, many private water supplies are poor quality, and recent estimates of risk of Cryptosporidium infection, and likelihood of diarrhoea, from very small supplies are unacceptably high especially among children. There are health benefits to be gained from improving the quality of such supplies, a goal underpinning regulations introduced in England and Wales in 2010.

Globally, the impact of Cryptosporidium has been brought into sharper focus recently. The Global Enteric Multicenter Study (GEMS) has identified that in children under 5 years in sub-Saharan Africa and south Asia, most attributable cases of moderate-to-severe diarrhoea were due to just four pathogens including Cryptosporidium. Interventions targeting these pathogens could substantially reduce the burden of moderate-to-severe diarrhoea. However, the world remains off-track to meet the Millennium Development Goals sanitation target, which requires reducing the proportion of people without access from 51 per cent to 25 per cent by 2015.

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