WATER SECURITY, RISK & SOCIETY

Brief No. 5

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Water Security and Technological Innovation

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Key messages

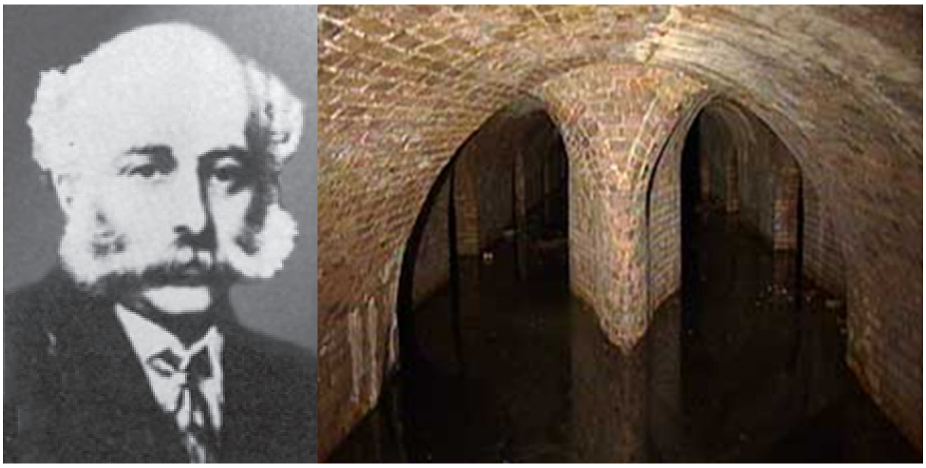
Less than 3% of global water is fresh and it is this tiny fraction that is so vital for our existence. The availability of water has played a vital role in the evolution of man, the way we live and will continue to do so. With the projected increase in global population growth the pressure on freshwater will inevitably increase.

The development of technological solutions for the provision of clean and plentiful supplies of freshwater has been a central feature of successful civilisations and their failure has altered history. For over one hundred and fifty years water engineering in the developed world has provided potable water on demand, with only very occasional failure.

We have grown to assume that the tap at home will always provide as much as we want of clean drinking water. However, with global population growth and the apparently inevitable consequences of climate change the projected short-fall in water needs in the UK in the next 30 years is in the region of 40%.

This demand can only be met by a change in behaviour, better infrastructure, improved efficiency of current methodologies and development of completely new technologies. For instance, the established use of drinking water to flush toilets, water gardens and wash cars is not a sensible use of a vital resource. So the future will require technological innovation to address water supplies, but also good thinking with regards to their exploitation and incorporation in the current infrastructure.

1 Victorian Legacy



Joseph Bazelgette (1819-1891) established our current water treatment systems.

We are fortunate in the UK and most of the developed world in being secure in the knowledge that our domestic water supplies are safe to use and consume. Effective regulation and established technologies ensure that instances of microbial pathogens and chemical contaminants entering our water supplies are rare. In this regard we still owe an enormous debt of gratitude to the Civil Engineers, most notably Joseph Bazalgette, who in the 1860's designed and constructed the water treatment system which is still the blue print for many parts of the world. It is this infrastructure that Victorians put in place that we still largely rely on to ensure waste water is effectively treated and recycled. Indeed the technology has changed little since those pioneering days.

However, the rapidly expanding global population and their tendency to concentrate in mega-cities are putting untold pressure on sewage processing and all aspects of current water treatment systems, which after all were designed for the needs of the past century. Some of the most pressing demands in terms of modern requirements include the need to:

- Reduce the energy/carbon footprint of established water treatment methods or replace them with more efficient alternatives.
- Treat high concentration and toxic industrial effluent, which until recent legislation were disposed to landfill.
- Treat low concentration/trace high impact contaminants, such as hormones derived from excreted contraceptive hormone and other endocrine disruptors.
- Conserve high value resources, such as precious metals (e.g. platinum) derived from street wash-off originating from catalytic converters of vehicles.
- Transform the high organic component waste waters to renewable energy in the form of microbial methane generation.
- Reduce current dependence on centralised national water supply grid and introduce the ability for more localised self-sufficiency.

A water technology at work.

2 Challenges we face

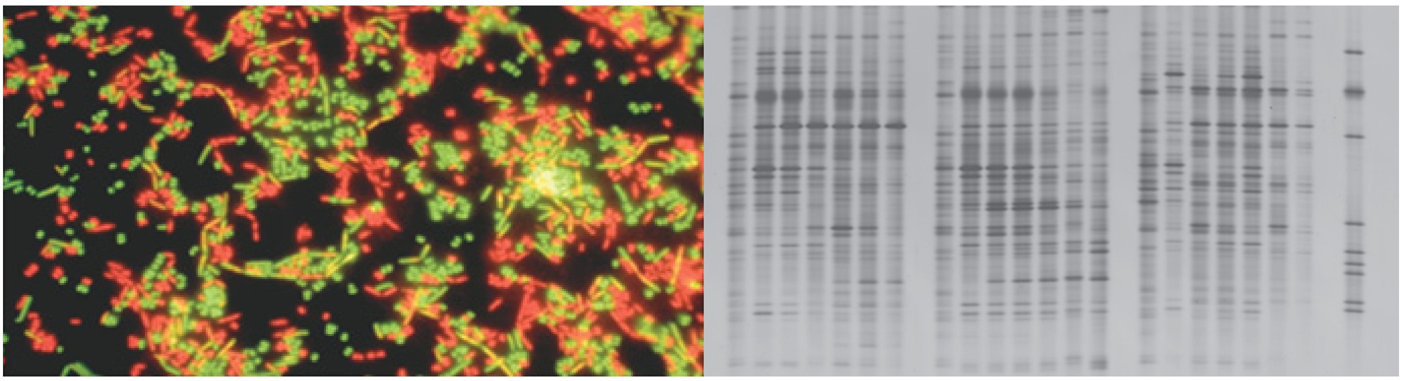
To highlight some of these challenges and the urgent need for new technologies required to maintain water quality in the face of modern day needs are some striking facts. Perhaps the most alarming are plummeting sperm counts, which have on average halved in the past 50 years. This is attributed in large part to the ineffectiveness of current sewage treatment processes to remove the remnants of contraceptive pill excreted in urine. The same hormone contaminants have been attributed to the increased cases of prostate cancer. Similarly, increasing incidence of Parkinson's disease has recently been attributed to the occurrence of industrial solvents in aquifers providing potable water. Added to the concerns of unintentional contamination, is the increasing realisation that the national water supply grid is dependent upon a relatively few strategically vital pumping stations which play a critical role in distributing essential supplies. Targeted debilitation of these stations would disrupt supplies to the millions currently entirely dependent on the national grid supply system. Thus there is drive from Government to develop an infrastructure and accompanying new technologies which will enable more self-sufficiency, decentralisation and the ability to isolate contaminated sources. However, one of the most significant needs in terms of societal security is the urgent requirement for technologies which reduce the high energy/carbon footprint associated with current water purification and distribution systems.

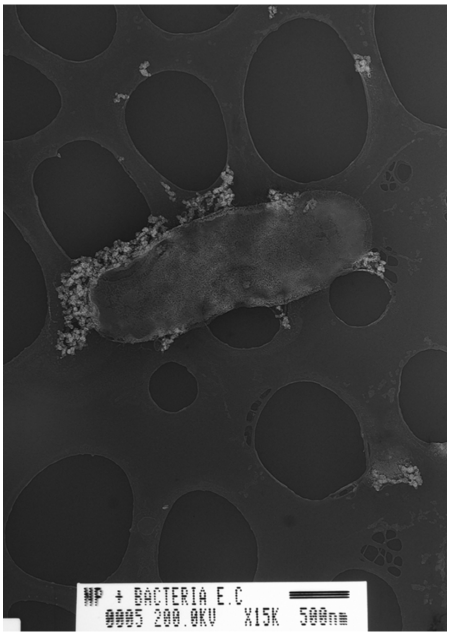
Bacterial biosensors of contamination – contemporary day miners' canaries.

3 Molecular Insights

Fortunately in recent years there have been significant advances in several technological fields that will inevitably impact positively in terms of making current water delivery systems much more secure and energy efficient. For instance, with the introduction of molecular biology, which came with the resolution of the structure of DNA, it is now possible to obtain unique insights into the microbial processes that are so central to water cleaning systems we are so reliant upon. These provide comprehensive assessments of the key functional communities of microorganisms that transform potential toxic sewage and other waste water effluent to clean potable water and renewable energy in the form of methane generation. With such information it is possible to assess the potential efficiency of the treatment system, optimise performance and importantly predict potential failures. A particularly exciting development is the advent of "bacterial biosensors", which are the modern day equivalent of the "miners' canary". With this technology bacteria emit light that can be easily detected when conditions are good. However, as with the canary response, as conditions deteriorate, such as the introduction of a very toxic chemical, light emission decreases in proportion to the degree of toxicity. The potential of this immediate and highly sensitive feedback mechanism holds enormous promise for improving performance, control and pre-empting system failure.

Microscopic and DNA profiling of microbial populations in water.





Attachment of nano-scale iron to a bacterial cell (E.coli).

4 Small World Solutions

An even more recent development and significant step change technology is the introduction of nanotechnology, particularly in the form of nanomaterials. As the name suggests, these materials are manufactured to nano-scale, which significantly alters their physical properties via quantum mechanics, resulting in the dramatic alterations and even introduction of completely new material properties. A striking instance of such property change is gold, which is well known for its inertness, but at the nano-scale becomes a highly reactive and an effective catalyst. Other features that dramatically change at nano-scale include melting points, strength, conductivity and even light emission. The enormous excitement and potential this new technology holds is reflected in the recent award of the Nobel prizes to two UK scientists for "graphene", which is the monolayer building block of graphite. The potential of this nanomaterial and the whole field of nanotechnology in terms of advancing water technology are genuinely very exciting and await exploration. However, work has already started in a range of applications including:

- The application nano-scale iron to treat recalcitrant and toxic industrial solvents in groundwater.
- Nano-scale sensors for real time *in situ* detection of chemical contaminants (organic and metal) and microbial pathogens.
- Nano-filters to remove potentially toxic pesticides/ hormones from potable water.
- Nano-biocides that specifically target and kill off water-borne pathogens.
- Magnetic particles for attachment and manipulation of cells, including those with useful traits and targeted removal of pathogens.
- Self-sterilising containers for on-site generation of potable water.

Microbes have always played a central role in the maintenance of a healthy environment and with growing emphasis on low energy and sustainable systems, their use is likely to grow and impact even more on the water industry. Fortunately microorganisms have exceptional properties which, for instance, enable them to treat toxic waste as nutritional opportunities, so that a disposal problem is transformed to a clean renewable energy opportunity. However, like talented children, if left to their own devises they can wreak havoc and in some cases this can lead to large scale death and famine.

Manipulation, via nanomaterials as indicated in the bullet points above, is one approach of several whereby cross-disciplinary skills and tools from the physical and chemical sciences can be exploited to optimise biological performance. With effective guidance and more engineered control microbes will continue to detoxify water and treat our waste, and work harmoniously with new technologies as they come on board. The key challenge for water technologists today and in the future is to exploit this biological potential even more effectively and scale-up their processes so that they can service the increasing needs of rapidly growing populations. Inevitably this will require the skills of engineers, a discipline trained in methodical thinking which will be applied to vital issues of biological process control and scale-up. However, the application of the disciplined thinking and mind-sets of engineers to biological systems, which are so notoriously unpredictable and stochastic, will require effective multidisciplinary training and a new breed of engineer.