HOW CLEAN IS YOUR WATER?

Many of the drugs we take end up in the water system.

Geoff Watts investigates the implications

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Every year in the United Kingdom we spend upwards of £10bn (€13bn; \$20bn) on medicines. And where do they go? Down the drain, literally. Out of the bladder, through the sewage system, and into the rivers. Some drugs—unwanted or out of date—bypass the bladder and are flushed straight down the toilet. Either way, does it matter? To fish and other organisms living in the thin chemical soup that emerges from the sewage treatment plants it does; there is evidence of harm to aquatic ecosystems, particularly from endocrine disrupting chemicals such as ethinylestradiol, which is used in many oral contraceptives. For humans, protected by the purification technology that river water goes through before it re-emerges from the kitchen tap, the answer might seem to be no. But how well founded is this assumption?

In March this year the US news agency Associated Press announced the results of an investigation into drugs and the water supply.¹ “A vast array of pharmaceuticals—including antibiotics, anti-convulsants, mood stabilizers

and sex hormones—have been found in the drinking water supplies of at least 41 million Americans,” it claimed. The inquiry found trace quantities of these drugs in the drinking water supplies to 24 metropolitan areas from southern California to northern New Jersey.

A typical press scare? Maybe. But the evidence was enough to prompt two US politicians to arrange a senatorial hearing. This took place on 15 April and saw the US Environmental Protection Agency lambasted for its alleged complacency.² The agency responded that it was taking the issue seriously, and that it was “drastically expanding the scope” of its testing of drinking water across the nation.

In Europe too there have been reports of medicines in drinking water. A researcher at the Technical University of Berlin’s Institute of Food Chemistry found drugs in samples of Berlin tap water.³ A group based at the European Union’s Joint Research Centre in Italy has detected various chemical and medicinal products in drinking water from the Lake Maggiore area.⁴ Last year pharmacologist

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Clockwise from top left: sampling water near the intake pipes for a waterworks on the river Po in Italy; a technician standing in the empty holding tank of a waste water treatment plant—the large orange cones are floats; a chemist testing water from a river for excessive levels of pollution

Abby Collier of the University of Hawaii reviewed all the reports she could locate on drugs in various water systems in Europe and America.⁵ Between them the reports identified 10 drugs in treated drinking water. The amounts were low, but the findings undermine any comfortable assumption that water treatment plants can be counted on to remove all contaminants.

The possible hazard of discharging a bewildering variety of chemicals into the sewers has not gone unnoticed by the regulatory authorities. For the past couple of years the European Medicines Evaluation Agency has required companies seeking a licence for a new product to include environmental impact data.⁶ But these regulations do not operate retrospectively.

Analysing the problem

One British scientist with an interest in water purity is Andrew Johnson, an environmental microbiologist at the Centre for Ecology and Hydrology in Wallingford. Given the paucity of measurements of environmental contaminants you might imagine that he spends his time in domestic kitchens or in the field collecting and analysing water samples. Not so. Searching for chemicals present at low concentrations in sometimes remote locations is costly and difficult. At this stage he thinks it more sensible to use what we already know to create predictive models. When potential problems have been identified you can go and look for hard evidence.

From a knowledge of the per capita consumption of a medicine, and the proportion that is excreted from the body, Dr Johnson calculates the amount of it entering the sew-

age treatment system. Using a mix of results from the laboratory simulation of sewage digestion, actual measurements taken in sewage plants, and informed speculation he can then predict how much of a drug will be discharged into rivers and is free to enter a drinking water plant.

“The natural river flow available to dilute what comes out of sewage works in the UK, particularly in England, is one of the lowest in Europe”

One obvious objection to this modelling is the number of assumptions it has to make. Dr Johnson concedes that there may be question marks, but he points out that the hydrological models used to predict water flow in rivers are widely used by the industry and seen as robust. “When it comes to working out the concentration of a chemical in water, this dilution effect is usually the most important factor.”

As for water purification, the UK Drinking Water Inspectorate⁷ is confident that the country’s “sophisticated treatment processes

... installed to remove pesticides and other organic substances from source waters are equally effective at removing minute traces of pharmaceutical residues." Maybe so, but the findings quoted by Abby Collier and others make it clear that some systems are less than perfect for at least some drugs.

Mindful that cytotoxic drugs have a particular potential for damage, Johnson has modelled the release of fluorouracil into the environment.⁸ He has calculated its likely concentration in the inflow to a drinking water treatment plant extracting from a river downstream of a heavily urbanised area. If the Drinking Water Inspectorate

is correct, any residual fluorouracil will be removed. However there are no data to prove this. So what if the drug isn't removed?

Potential for harm

Even if all the drug remained it would still be at a concentration many orders of magnitude lower than the therapeutic dose. This sounds reassuring, at least as far as adults are concerned. But what of a fetus? In Dr Johnson's worst case scenario an 11-13 week fetus might be exposed to a dose 2800-280 000 times less than the therapeutic amount. Again this sounds comforting—until you take into account what Andreas Kortenkamp, head of the Centre for Toxicology at the London School of Pharmacy, calls the "cocktail" effect of mixing different drugs. "It's possible that several chemicals together can have an action even though they're present at levels at which each one individually would not induce an effect. That's why chemical risk assessments that focus on single chemicals can be misleading."

Professor Kortenkamp's view is supported by some Italian work published a couple of years ago.⁹ It concluded that combinations of drugs at nanogram per litre levels can significantly inhibit embryonic cells growing in vitro.

The dearth of relevant experimental data in this area is not altogether surprising. As

Dr Collier points out,⁵ many drugs—and not least cytotoxic agents—are developed and tested for their short term actions. "The clinical dose of a medication is the concentration in the human body that causes a measurable biological effect in a short time frame (usually minutes to hours) and it is likely that long term, low doses act more subtly and possibly through different pathways." She adds that "subclinical doses can cause effects at the cellular and organ system level, even though they may not change physiological parameters."

Cleaning up

For reasons of geography and population density, the natural river flow available to dilute what comes out of sewage works in the UK, particularly in England, is one of the lowest in Europe. No other freshwater environment, says Dr Johnson, is more exposed to pharmaceuticals. But the cost of beefing up treatment plants would be high. A more sensible approach might be to demand pretreatment of the effluent from hospitals. This would not be without problems. It could even mean asking patients having what would otherwise be outpatient treatment with cytotoxic drugs to remain in the hospital for an extra 12 or 24 hours to ensure that the bulk of the drug was excreted into the hospital's own drains, not into those of the wider community.

On a global scale it may be the newly emerging mega cities of countries such as China that face the greatest problems. Their use of water and of medicines is on the increase. "Urban populations are growing rapidly in many parts of the world," says Dr Johnson, "and there's already pressure on water resources. Where they are getting their water may not be far removed from where they are discharging their sewage."

Until now much more attention has been focused on pesticides and non-pharmaceutical chemicals—rightly, because these almost certainly pose greater threats to the environment than drugs. In itself this is no reason to let pharmaceuticals off the hook.

Nevertheless, some people will argue that Dr Johnson is trying to create a scare for nothing. His response? "You could say that our role as scientists is to sit on our hands until a crisis blows up in our face, to be reactive. Or you could think about issues that have occurred in the past, like endocrine disruption, and ask yourself if there are other chemicals out there that may be having effects that we've not yet looked for."

The issue of environmental contamination by drugs is one that falls within an emerging subsection of the green movement known as "sustainable pharmacy." Its ambitions include the development of drugs that degrade rapidly in the environment. John Sumpter, professor of ecotoxicology in Brunel University's Institute for the Environment, attended a recent conference on the topic held in Germany. This, he notes, included a good turnout from the major drug companies.

Whether or not drugs in drinking water are potentially harmful to human health is an empirical question that can be investigated by science. But experience of a variety of issues from genetic modification to the effects of low level radiation shows that science is not the only or necessarily the dominant factor in policy making. As Professor Sumpter points out, the issue raises problems of public perception. Will people be concerned about drugs in their water supply? And might they want them removed? He thinks the answer in both cases is likely to be yes.

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Checking waste water in Hampshire, England, is clean enough to join unpolluted water sources