# A new water-purifier

In some parts of the world, the drinking water may contain potentially harmful quantities of various organic contaminants.

Such areas are rare in Australia, but concentrations of organic compounds in excess of the World Health Organisation's guidelines have been measured in drinking water from parts of South Australia. Paradoxically, many of these compounds are formed by the very process we use to disinfect our water.

Groundwater drawn on for town supplies, especially in areas of the United States and Europe, may also be polluted by the proximity of industrial-waste disposal sites. Pesticides and herbicides from croplands are other sources of contamination of drinking-water supplies.

Householders in affected areas can install charcoal filters to remove the contaminants, but these, unfortunately, have their drawbacks. Now Dr Ralph Matthews, a CSIRO scientist in the Division of Energy Chemistry, has designed and built an effective alternative — a solar or electrically powered water-purifier for home use that actually destroys these organic compounds.

But how, in the first place, does the essential process (performed by our water authorities) of removing bacteria and algae from water generate unpleasant compounds, which, although they occur in minute amounts, are causing increasing concern in some countries?

It is simply that the chlorine used to disinfect water undergoes chemical reactions with naturally occurring organic compounds.

These complex compounds, such as humic and fulvic acids, form by bacterial action on organic matter and are common in river water and can also be generated in reservoirs before the water is disinfected. They are relatively harmless themselves, but in 1974 it was discovered that, when combined with chlorine, they can form a class of chloro-organic compounds called trihalomethanes (THM) — and these have been shown to cause cancer in animals.

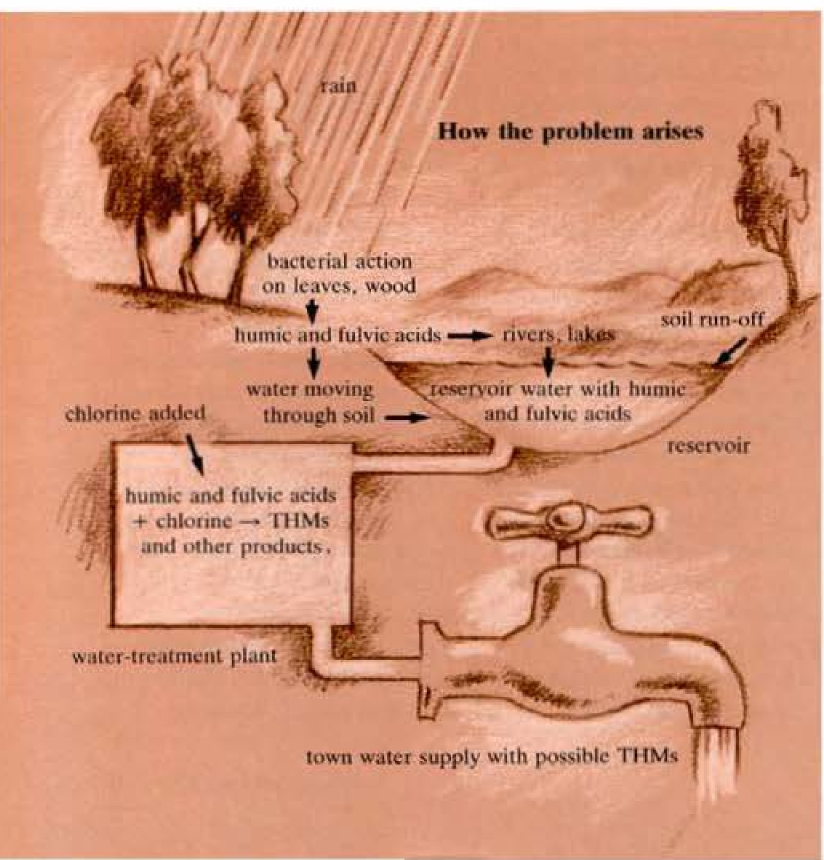
The trihalomethanes include many compounds, but probably the most widespread and important is chloroform ($CHCl_3$), which is used extensively in industry as well as its better-known use in anaesthesia. Bromoform, dibromochloromethane, and bromodichloromethane may also form following the reaction between chlorine and humic and fulvic acids, especially if the water contains bromides, and so may also be present in drinking water.

A way of removing some of these humic and fulvic acids — the essential precursors to THM formation — does exist; it relies upon flocculation during the water treatment process (see *Ecos* 31). Although this greatly improves the water, especially its turbidity and colour, some of the organic acids remain, and so small quantities of THMs still form upon chlorination.

If chlorine must be applied before water treatment — and this is often necessary to prevent algal growth in the reservoir — THMs form before flocculation. Unfortunately, although flocculation removes their precursors, it cannot remove the THMs themselves to a significant degree.

In the United States, the Environmental Protection Agency, concerned at the possible threat to human health, has set a recommended maximum concentration of 100 $\mu$g of trihalomethanes per litre of drinking water. (The World Health Organisation sets an even lower level of 30 $\mu$g per litre.)

Australia currently has no recommended limit. Indeed, few data on THM levels in Australia have been published, although routine monitoring takes place in some areas. The Australian Water Resources Council, in conjunction with the National Health and Medical Research Council, is currently revising its guidelines on drinking water, and may establish criteria for certain compounds such as THMs. It would then be up to the individual States to adopt and enforce these.




In South Australia, figures from the State Water Laboratory show that THM levels in Adelaide's water, averaged for the 5 years to 1982, varied from 205 to 337 $\mu$g per litre depending on the sampling point. (Since then, to reduce these levels, the practice of chlorinating the water before flocculation treatment has been suspended, as an experiment, in some areas.)

Even higher values have been recorded in some South Australian country areas — the highest being in a sample of water from the Yorke Peninsula, which yielded a THM concentration of 1120 $\mu$g per litre.

The causes of the State's problem with THMs are really threefold. Firstly, run-off from croplands into reservoirs gives a high level of the organic precursors of THMs; secondly, a significant fraction of the water supply comes from the Murray River, and this can be high in humic and fulvic acids too. Thirdly, to fulfil the microbiological standards, large amounts of chlorination are often necessary.

Sydney, by contrast, generally has THM levels well within the WHO guidelines, because only small quantities of humic and fulvic acids occur in its water.

In the United States, scientists have reported that many drinking-water supplies routinely exceed the government limit by significant amounts. Concern over potentially contaminated drinking water has led many Americans to buy a water-purifier for home use — or to buy expensive bottled water from shops.

Alternatives to chlorination as a means of disinfection do exist. The most promising of these involve using ultraviolet light or ozone. However, both have their drawbacks and, although the ultraviolet light method has recently improved in efficiency, chlorine still remains the disinfectant of choice.

Clearly, trihalomethanes and any other potentially harmful contaminants should be removed from any water in which they occur in concentrations that could constitute a long-term risk. But that's not easy; even distilling the water will not rid us of THMs, as they are volatile and will evaporate with the water.

Fortunately, charcoal filters can do the job. Many organic impurities, such as THMs, will adsorb, or stick, to the surface of fine charcoal granules. Eventually, of course, these cover all the charcoal grains, so the filter is saturated and ceases to work effectively, and a new one must be installed.

A major drawback of these filters lies in the inconvenience of having to determine when saturation has occurred. But despite their problems, a small market for charcoal filters for home use does exist in Australia and a much larger one exists in the United States.

The device developed by Dr Matthews offers a neater solution. For many years scientists have known that titanium dioxide (now well known as a semi-conductor) becomes a powerful oxidising agent when exposed to near-ultraviolet light. Put simply, this means that, when illuminated, titanium dioxide acquires the ability to force any available molecules of oxygen to combine with an organic (carbon-containing) compound, thus producing carbon dioxide and water.

In the 1970s, scientists found that even stable organic materials such as polychlorobiphenyls could be destroyed if they were put in water with some titanium dioxide powder and illuminated with ultraviolet light.

How does titanium dioxide

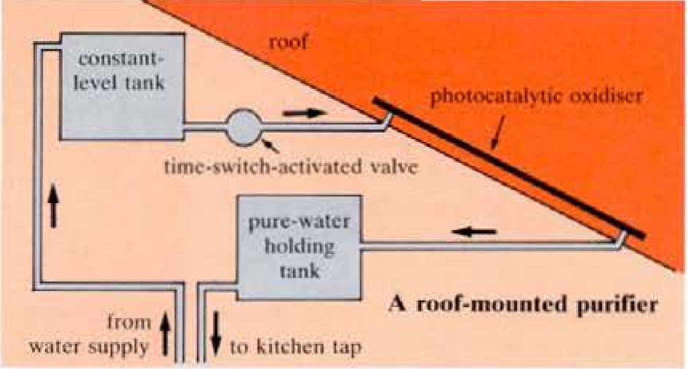
work to catalyse the oxidation of often complex organic compounds? It seems that the energy in the short-wavelength light pushes electrons out of the titanium. The areas of positive charge that remain we can think of as the 'holes' where the electrons once were. It is these holes that confer the oxidising ability on the catalyst; their positive charge enables them to suck electrons away from other compounds, and this removal of electrons is essentially oxidation.

Since Dr Matthews became interested in the photocatalysis of organic impurities, he has experimented on the oxidation of various organic compounds, and has investigated whether sunlight can be used as an energy source to activate the titanium dioxide.

Sunlight at sea level contains about 5% of its energy in the waveband suitable for this photocatalysis, and Dr Matthews and scientists overseas found that it certainly could drive the oxidation reactions.

With his discovery that each organic compound tested was converted to carbon dioxide, and that 14 litres of heavily contaminated water per day could be 90% purified using a 20-watt UV lamp, Dr Matthews realised that this method could offer a new way of decontaminating home water supplies. He also wondered whether solar power could make the process of water purification much cheaper.

Experiments showed that 1 sq. m of solar panels in temperate latitudes could collect enough of the near-ultraviolet to allow the titanium dioxide, with continuous operation during daylight, to purify 10–50 L of water per day. Moreover, the water passes through the panels, which warm it and make the reaction more efficient. The water is then collected in a receiving




**A solar-powered water-purifier for home kitchen use. The water entering the purifier should first pass through a filter to remove suspended matter that may deposit on the titanium dioxide catalyst and lower its efficiency.**

container in the kitchen, where it cools to room temperature.

Unlike the charcoal in filters, on which the contaminants remain stuck and saturation eventually occurs, the titanium dioxide catalyst effectively destroys the compounds and can continue in use for far longer.

Of course, it must be understood that the titanium dioxide is not killing or removing bacteria. Any micro-organisms must be killed in the usual way by chlorination or another effective method. However, the compounds resulting from the use of chlorine, along with any other unpleasant long-lived organic compounds from the chemical industry, are oxidised away.

However, Dr Matthews, and researchers overseas who had also realised the potential of this process, faced a snag: in order to work, the titanium dioxide must be in the water as a powder, and nobody relishes the thought of drinking water laced with pulverised semi-conductor.

Accordingly, Dr Matthews looked for, and found, a process whereby he could fix the titanium dioxide to an inert support without changing its catalytic properties. The support is incorporated into a portable device, which allows water to flow through it and over the catalyst. This little purifier can run on either electrical or solar power. In the case of the former, an ultraviolet lamp is included.

Dr Matthews is patenting his titanium dioxide purifier. He sees it as having a large-scale potential in the United States, where about 5% of households currently use charcoal filters. These filters range in price from about $30 to $100 and the central cartridge lasts about 3 months. Our Australian-designed device will probably cost about the same, but will last far longer. If electrically powered, its lifetime will be that of its UV lamp. If solar-powered, it should function for many years, the limit to its life span being a slow build-up of material on the catalyst.

For the future, Dr Matthews sees the possibility of more uses for his device than just purifying drinking water for unfortunate Americans or Australians living in areas with high levels of organic contaminants.

Particularly pure water is important for many industries. In this case, the water would be cleared of particles and bacteria by conventional means, and then the titanium dioxide device would destroy any organic molecules present, however small their numbers. These molecules might not necessarily be toxic like THMs, but could interfere with the manufacturing process.

Ultra-pure water is vital in the manufacture of semi-conductors and pharmaceutical products. It is also now becoming more important in the food and beverage industry and even in large power generators, where contaminants may build up on the inside of steam turbines, leading to corrosion.

But for the moment Dr Matthews has his sights set on the American domestic market for household drinking-water-purifiers, which has an estimated worth of about $20 million per year. If he can find a company willing to develop and market his device, there seems little doubt that, with its efficiency and long life, it could become a serious competitor with the popular carbon filters.

His hopes are receiving indirect support from the United States Environmental Protection Agency, which is examining charcoal water-filters. Its preliminary findings suggest that claims by the filter manufacturers as to what is absorbed and how long the filters last are exaggerated. Furthermore, old saturated charcoal filters can create the problem of adsorbed materials leaking back into the water. The beauty of Dr Matthews' light-catalysed process is that harmful organic pollutants are totally destroyed.

*Roger Beckmann*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