European Commission

Science for Environment Policy

'Green' decontamination methods for 1,4-dioxane (solvent linked to cancer, found in paints and cosmetics) offer promise of cleaner water

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Source: Zhang, S., Gedalanga, P.B., Mahendra, S. (2017). Advances in bioremediation of 1,4-dioxane-contaminated waters. *Journal of Environmental Management.* 204: 765–774. DOI:10.1016/j.jenvman.2017.05.0.

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The chemical 1,4-dioxane, a solvent suspected of causing cancer, is very difficult to clean up once it enters the environment. However, hope is offered by recent scientific developments that use plants, bacteria and fungi to decontaminate water resources. Scientists provided a round-up of these 1,4-dioxane bioremediation techniques in a recent analysis.

Of emerging concern, 1,4-dioxane has been found widespread in ground- and surface water, from where it can enter drinking water. Most studies into its environmental proliferation have been conducted in the USA, but there is increasing evidence of its environmental presence in Europe[1].

It is used as a solvent in products including paints and oil and can be found as a residue in cosmetics and personal-care products. Historically, it was used as a stabiliser in 1,1,1-trichloroethane (TCA), another solvent of concern to human health and the environment. TCA was phased out under the Montreal Protocol as an ozone-depleting substance, but persists in the environment.

The International Agency for Research on Cancer (IARC) considers 1,4-dioxane to be potentially carcinogenic to humans. Currently, there is insufficient research evidence of its effects on humans but it is known to increase the occurrence of tumours in animal studies, which raises concerns for human health.

The researchers present a summary of studies investigating bioremediation techniques for 1,4-dioxane-contaminated waters. Bioremediation is a 'green' technology which uses natural processes to destroy or remove pollutants, or make them safe, in land and water.

The chemical 1,4-dioxane is challenging to remediate with more conventional technologies, such as stripping away volatile compounds with heat or an air stream, because it has unique properties and often occurs with other contaminants. These new bioremediation methods are in the early stages of development, but accompanied by further research, they are already transitioning out of the laboratory and into 'real world' situations to become sustainable and cost-effective technologies in the future, the researchers suggest.

One form of bioremediation is phytoremediation, which uses plants to remove environmental contamination. One study found that poplar trees could soak up (through their roots) around 54% of 1,4-dioxane in nine days from tanks containing water with a contamination level of 23 milligrams per litre (mg/L). Another lab-based study used poplar trees in combination with bacteria to speed up the degradation. This method decreased starting concentrations of 100 mg/L until 1,4-dioxane was below the detection limit of 1 mg/L, in 45 days.

Microbes are also used in bioremediation. The researchers identify 27 different microbes, or groups of microbes, which have been used in studies to clean up 1,4-dioxane in water. Most are bacteria, but two examples of fungi have also been identified.

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1. For example: Karges, U., Becker, J., Püttmann, W. (2018). 1,4-Dioxane pollution at contaminated groundwater sites in western Germany and its distribution within a TCE plume. *Science of the Total Environment*. 619–620: 712–720. DOI:10.1016/j.scitotenv.2017.11.043.

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'Green' decontamination methods for 1,4-dioxane (solvent linked to cancer, found in paints and cosmetics) offer promise of cleaner water *(continued)*

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The majority of these microbial methods fall into two camps: metabolic and co-metabolic biodegradation. Using metabolic methods, the microbe feeds on 1,4-dioxane as a source of carbon and energy, growing as a result and breaking down the chemical. A recently investigated example is the bacterium *Pseudonocardia carboxydivorans* RM 31, which one study found was able to break down 1,4-dioxane at a rate of 31.6 milligrams per litre per hour (mg/L/hr). With co-metabolic methods, the microbe does not feed off the 1,4-dioxane. Instead, another carbon source is introduced which, in turn, causes the microbe to produce an enzyme that degrades the primary carbon source along with 1,4-dioxane. Enzymes that have been explored by researchers include 1,4-dioxane monooxygenase (MO), propane MO, 1-butane MO, toluene MO and tetrahydrofuran MO.

To develop these bioremediation methods into workable techniques, research is needed in several areas. For example, scientists need to explore the significant effects of specific environmental conditions on the degradation of 1,4-dioxane, such as other contaminants, pH and nutrients.

An effective treatment also needs to be able to continuously remove contamination, from flowing river water, for example. A single technology may not be sufficient to achieve this, and so the researchers recommend using bioremediation as part of a series of treatment methods. Research is needed to identify the best combination of treatments, which could also include advanced chemical oxidation, adsorption and electrolysis processes.