

Executive Summary

The Drinking Water Inspectorate commissioned this review to identify all relevant, robust studies that investigate pharmaceutical concentrations in raw or treated water, or factors affecting those concentrations. This summary of existing knowledge will be taken forward and used for the systematic evaluation of the potential for different pharmaceuticals to reach water.

There are about 3000 pharmaceuticals registered in the UK and approximately 5000 substances listed as human pharmaceuticals were sold over the counter in the UK in 2004. Consumption of active pharmaceutical ingredients in industrial countries is estimated to be between 50 and 150 g per person per year, with fewer than 50 compounds making up 95% of the total amount of active pharmaceutical ingredient consumption. In addition to the consumption of drugs for health care, there is also significant consumption of 'illegal' drugs due to both recreational consumption and drug addiction, and for enhancement of sporting performance.

The observed concentrations of pharmaceuticals in raw wastewater indicate that the major source of pharmaceuticals to the environment is via sewage treatment works effluent. Sewage treatment works use a wide range of processes, e.g. primary screening, biological filtration, and anaerobic digestion, and these are considered in detail in this report. Reported removal rates for pharmaceuticals vary considerably between and within studies. In addition, concentrations of some compounds have been found to increase during the treatment process, probably as a consequence of the transformation of conjugates back to the parent compound. As well as the variances that can be ascribed to differences in process type and sewage treatment works configuration, other factors, such as heavy rainfall and seasonality, have been shown to confound interpretation of removal rate efficiency.

Drinking water treatment works use a wider and technically more advanced range of processes, but again these are not specifically designed to remove pharmaceuticals and several compounds have been reported in finished drinking water in different parts of the world. Although no clear quantitative structural relationships have been determined that describe the degree of removal of a pharmaceutical during treatment processes, it is clear that the structure and nature of individual compounds are key parameters in determining the efficiency of removal. Only a few pharmaceuticals are oxidised to smaller molecules by chlorine or chlorine dioxide, but for those pharmaceuticals containing amino or phenolic moieties a complete oxidative degradation can be expected. Most non-polar organic compounds are the best candidates for the removal by activated carbon but the removal rate may depend on the age of the carbon. Neutrally charged pharmaceuticals are well removed from water using an oxidant such as ozone or ultraviolet radiation. Reverse osmosis has been shown to be a particularly effective process for removing a wide range of pharmaceuticals but is an energy-intensive process. Removal of pharmaceuticals by drinking water treatment works processes was significant for almost all of the pharmaceuticals studied when the treatment process included ozonation and activated carbon. This combination, together with the more conventional DWTW processes, can result in removal rates of >90% for a wide variety of pharmaceuticals.

Very limited data were available for the concentrations of pharmaceuticals or illegal drugs in UK drinking waters, but data from the rest of Europe and the USA have

shown that concentrations in finished drinking water at treatment works are generally =100 ng.l⁻¹. Data for UK rivers and streams has shown that median concentrations of pharmaceuticals are almost always =100 ng.l⁻¹.

Five drinking water treatment works scenarios based on UK catchments were used for deterministic and probabilistic modelling to estimate concentrations in UK drinking waters. The model was based on the simple approach developed by the European Medicines Agency (EMA) for estimating concentrations of pharmaceuticals in surface waters. Exposure ratios based on comparison of the estimated concentrations with the minimum therapeutic dose were used to determine the significance of the model outputs for pharmaceuticals and illegal drugs.

Worst-case modelling showed that even in the scenario with the highest estimated concentrations, the exposure ratios (comparison of the minimum therapeutic dose to the estimated intake from drinking water) for most of the major used pharmaceuticals and illegal drugs were significantly greater than 1000 and provided a high safety margin. Only 10 substances produced exposure ratios less than 1000 and four of these were illegal drugs. In only one case was the exposure ratio less than 100 and this was the special case, using a combined total for all NSAIDs at the lowest minimum therapeutic dose. It therefore appears that even in this worst case situation there is no significant risk from pharmaceuticals discharged to drinking water sources.

The use of probabilistic modelling provided a more realistic estimate of likely concentrations in drinking water and showed that, as expected, the estimated concentrations for all except one substance were significantly lower than the estimated concentrations from the worst case (deterministic model). Using the mean concentrations from the probabilistic model, all of the substances have exposure ratios significantly greater than 100 and only tetrahydrocannabinol also has an exposure ratio less than 1000. It therefore appears that this more realistic worst case probabilistic modelling confirms that there is no significant risk from pharmaceutical usage.

Recommendations

The accuracy of the estimates of usage for the illegal drugs is unknown and since many of them produced some of the lowest exposure ratios it would be appropriate to revisit estimates of usage. In addition, since they were assigned nominal, very low, minimum therapeutic doses it would also be appropriate to search for data to provide more realistic estimates. In addition it would be useful to collate data on the percentage of active ingredients in cannabis that are absorbed during use in order to obtain a better estimate of the quantities of tetrahydrocannabinol that might be available to reach wastewater.

Some pharmaceuticals produce significant quantities of metabolites which are excreted and enter the environment via sewage treatment. Worst case modelling of these metabolites for major use pharmaceuticals would be worthwhile to determine their exposure ratios.

In view of the dearth of measured data on the concentrations of pharmaceuticals and illegal drugs in UK drinking waters it would be prudent to carry out a small scale survey. This survey could be guided by the findings from this report and address

those substances that have the lowest exposure ratios, the highest predicted concentrations and substances of potentially high public perception of hazard such as cytotoxic drugs, depending on the available analytical methodology. In addition, the monitoring could be carried out in the catchments that provided the scenarios with the highest estimated concentrations or where there is reason to believe that there may be a particular hotspot.