Summary

i Reasons

Volatile Organic Compounds (VOCs) are compounds that contain, at least, the element carbon and one or more element from hydrogen, oxygen, sulphur, phosphorus, silicon, nitrogen or halogens, and have a high vapour pressure at room temperature. VOCs have a wide range of uses in many industries as solvents, chemical intermediates and components of paints and varnishes. Additionally, many have a diverse range of historical uses that may have resulted in significant releases to the environment. Fourteen VOCs on the US Environmental Protection Agency's (EPA's) 3rd Chemical Contamination List (CCL3) have been identified for further investigation; 1,2-dichloropropane, dichloromethane, aniline, benzylchloride, 1,3-butadiene, 1,1-dichloroethane, nitrobenzene, oxirane methyl, 1,2,3-trichloropropane, urethane, ethylene oxide, formaldehyde, o-toluidine and quinonline.

ii Objectives

1. Review existing literature on VOCs, and summarise data on occurrence in the environment including water sources and treated water, toxicity, physico-chemical properties and removal in water treatment;

2. Identify the quantities used and manufactured in England and Wales and the industries that use them;

3. Determine the possible routes into the water system;

4. Estimate the likely concentrations found in raw and treated water;

5. Compare estimate of potential exposure via drinking water with appropriate toxicological end points; and

6. Compare potential drinking water intakes of VOCs with other routes of exposure.

iii Benefits

This project provides a better understanding of the potential risks of contamination of drinking water supplies by these VOCs, and allows determination of whether exposure to these substances via drinking water poses a risk to human health. It also provides guidance to water companies on the factors that may need to be considered in their risk assessments of VOCs.

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iv Conclusions

Detailed toxicological reviews considering oral, dermal and inhalation exposure have been conducted on fourteen VOCs within this report. These reviews identified a number of gaps within the toxicological databases for these chemicals, particularly in regards to dermal toxicity data. However, Tolerable Daily Intakes (TDIs) via the oral and inhalation routes have been derived for all fourteen VOCs, and dermal TDIs have been derived where appropriate.

VOC	Oral TDI	Dermal TDI	Inhalation TDI
1,2-Dichloropropane	14 µg/kg bw/day	14 µg/kg bw/day	66 µg/m³
Dichloromethane	6 µg/kg bw/day	30 µg/kg bw/day	124 µg/m³
Aniline	7 µg/kg bw/day	No TDI derived	6 µg/m³
Benzylchloride	6 µg/kg bw/day	No TDI derived	27 µg/m³
1,3-Butadiene	5 µg/kg bw/day	No TDI derived	2 µg/m³
1,1-Dichloroethane	475 µg/kg bw/day	475 µg/kg bw/day	3620 µg/m³
Nitrobenzene	5 µg/kg bw/day	50 µg/kg bw/day	0.7 µg/m³
Oxirane methyl	17 µg/kg bw/day	No TDI derived	71 µg/m³
1,2,3-Trichloropropane	2 µg/kg bw/day	2 µg/kg bw/day	1.7 µg/m³
Urethane	0.07 µg/kg bw/day	0.07 µg/kg bw/day	250 µg/m³
Ethylene oxide	15 µg/kg bw/day	No TDI derived	60 µg/m³
Formaldehyde	Tolerable Concentration: 2600 µg/l	1380 µg/kg bw/day	0.06 µg/m³
o-Toluidine	150 µg/kg bw/day	8 µg/kg bw/day	67 µg/m³
Quinoline	25 µg/kg bw/day	25 µg/kg bw/day	19 µg/m³

Due to the gaps in these data, it was considered appropriate to assess the potential health concerns from exposure to VOCs from the consumption of drinking water and bathing and showering on the basis of the total contribution from each route (oral, dermal and inhalation) as a single oral litre-equivalents per day value.

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VOC	Total Intake (l-eq/day)
1,2-Dichloropropane	4.47
Dichloromethane	4.39
Aniline	2.37
Benzyl chloride	3.86
1,3-Butadiene	8.72
1,1-Dichloroethane	4.85
Nitrobenzene	2.70
Oxirane methyl	2.25
1,2,3-Trichloropropane	3.28
Urethane	2.00
Ethylene oxide	2.54
Formaldehyde	2.78
o-Toluidine	2.54
Quinoline	2.63

Three types of models have been developed to estimate the concentrations in drinking water; a surface water model; a diffuse source groundwater model; and a point source groundwater model. The results of the surface water model and the diffuse source groundwater model were combined to provide an extreme worst-case scenario of a drinking water treatment works that is supplied by a river that also receives a significant proportion of flow from a groundwater source.

These models produced estimated concentrations in final drinking water that were used to calculate estimated daily exposures which were compared to the oral TDIs to determine the Risk Characterisation Ratios (RCRs) for each of the VOCs.

- An RCR of less than 1 would indicate that there is unlikely to be a concern following exposure to that VOC in drinking water at the concentrations predicted by the model.

- An RCR of greater than 1 indicates that it is not possible to preclude adverse health effects following exposure to a VOC in drinking water at the concentrations predicted in the model.

All of the VOCs considered in this study had RCRs significantly below 1. Therefore, none are anticipated to be of concern to human health.

VOC	Risk Characterisation Ratio
1,2-Dichloropropane	0.0000759
Dichloromethane	0.00175
Aniline	0.0015
Benzyl chloride	0.0000264
1,3-Butadiene	0.00416
1,1-Dichloroethane	0.00000566
Nitrobenzene	0.00495
Oxirane methyl	0.000616
1,2,3-Trichloropropane	0.000118
Urethane	0.00138
Ethylene oxide	0.000384
Formaldehyde	0.000225
o-Toluidine	0.00000304
Quinoline	0.0000582

However, it should be noted that these TDIs are based on the assumption of a threshold level for an adverse health effect; the weight of evidence indicates that 1,3-butadiene and ethylene oxide are both genotoxic *in vivo*, and are both considered to be Group 1 carcinogens (i.e. carcinogenic to humans) by the International Agency for Research on Cancer (IARC). Therefore, there is theoretically no 'safe' level for these chemicals, and it would be appropriate to ensure that their concentrations in drinking water are as low as reasonably practicable.

v Suggestions

This project was commissioned to provide an understanding of the significance of exposure to VOCs in drinking water. The available literature data and the results of exposure modelling suggest that the concentrations of VOCs in drinking water are very low, and with regards to non-carcinogenic endpoints, are likely to be at concentrations below those of health concern.

However, there are several gaps within the data that, if addressed, may aid in the validation of the model and in supporting this conclusion. Therefore, the following suggestions and considerations are made based on this report:

- The most significant data gap within this report is a lack of information on the current volumes of VOCs manufactured and used within England and Wales. Additional information would significantly aid in the development of the model, and may enable the development of models to assess the risks to drinking water supplies in specific regions.

- The available data on the occurrence of these VOCs are also limited. As such, while the results from the model have generally been consistent with reported environmental and drinking water concentrations, it has not been possible to fully validate the results of the model. Further information on the occurrence of these VOCs in the environment would aid in the determination of the reliability of the model predictions.

It has not been possible to derive tolerable daily intakes via all three of the routes considered within this project (oral, dermal and inhalation) for a number of chemicals due to a lack of relevant toxicological data. To overcome this, route-to-route extrapolations have been applied to derive as many tolerable daily intakes as possible, and a multi-route exposure approach developed. This is considered to be a conservative approach; however, if additional toxicological data were to become available, it would be appropriate to reconsider this approach in the light of these additional data.

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