URBAN WATER QUALITY MANAGEMENT

Arising challenges of contaminants of emerging concern in OECD countries

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Introduction

We use chemicals for various beneficial purposes, such as crop protection, flame retardation, food conservation or disease recovery. Over 345.000 chemicals are registered and regulated via national and international authorities globally (CHEMLIST), new chemicals enter the market continuously, and the global volume of production of chemicals grows faster than the global human population. These chemicals and their transformation products can enter into the aqueous environment as a consequence of emissions in all stages of their life cycle. Major environmental entry routes are household and industrial effluent treatment plants, agricultural run-off and infiltration into groundwater, incidental spills.

As analytical capabilities to detect the presence of chemicals in the water increase, stakeholders in the water cycle become more aware of the presence of many chemicals in waste water effluents, surface waters, ground waters and drinking waters. The toxicological relevance of complex environmental mixtures is heavily debated, especially related to potential endocrine disruption. Consumers express concerns regarding chemical contamination of drinking water and the topic of water pollution is increasingly mentioned in media. The presence of chemicals within surface water impacts the ecosystem and the food chain. There is evidence for stresses on ecosystem and human health at local to global scales. For these reasons, there is a drive to put additional effort in measures preventing that chemicals enter the water cycle, and to reduce exposures and effects.

Chemicals of emerging concern have as common properties that they are not commonly monitored, there are indications of their presence in environment, they are likely to be toxic and persistent, so there is a potential to pose risks. However, there is scarce information available on these risks, and there are no regulatory criteria or norms.

Increasing analytical possibilities

Analytical techniques are strongly increasing. A recent example is the use of liquid chromatography-high resolution mass spectrometry (LC-HRMS) suspect screening. For the prioritization of more than 5200 anthropogenic chemicals authorized on the European market, such a large scale liquid chromatography-high resolution mass spectrometry (LC-HRMS) suspect screening study was used (Sjerps et al 2016).

Included in the suspect list are chemicals applied in industry in volumes above 1000, and from 100 to 1000, tons per year in Europe, as registered under the REACH legislation. In addition, substances of very high concern (SVHC) as defined under REACH for their carcinogenicity, mutagenicity, reproductive toxicity, persistency or bioaccumulative properties are included (CMR and PBT). Furthermore included are chemicals authorized under the Plant Protection Product Regulation and Biocidal Product Regulation.

Finally, human and veterinary pharmaceuticals as authorized under the EU Directives 2001/83/EC and 2001/82/EC are included.

The prioritization is based on occurrence in 151 water samples including effluent, surface water, ground water and drinking water. The suspect screening linked over 700 detected compounds with known accurate masses to one or multiple suspects. Using a prioritization threshold and removing false positives reduced this to 113 detected compounds linked to 174 suspects, 24 compounds reflect a confirmed structure by comparison with the pure reference standard. The prioritized compounds and suspects are relevant for detailed risk assessments after confirmation of their identity.

Only one of the 174 prioritized compounds and suspects is mentioned in water quality regulations, and only 20% is mentioned on existing lists of potentially relevant chemicals. This shows the complementarity to commonly used target-based methods.

The semi-quantitative total concentration, expressed as internal standard equivalents of detected compounds linked to suspects, in effluents is approximately 10 times higher than in surface waters, while ground waters and drinking waters show the lowest response. The average retention time, a measure for hydrophobicity, of the detected compounds per sample decreased from effluent to surface and groundwater to drinking water, confirming the occurrence of more polar compounds in drinking water. The semi-quantitative total concentrations exceed the conservative and precautionary threshold of toxicological concern. Therefore, adverse effects of mixtures cannot be neglected without a more thorough risk assessment.

Assessment of human health risks

The detection of many new compounds in surface water, groundwater and drinking water raises considerable public concern, especially when human health based guideline values are not available it is questioned if detected concentrations affect human health. In an attempt to address this question, provisional drinking water guideline values were derive for a selection of 50 emerging contaminants relevant for drinking water and the water cycle (Schriks et al 2010). For only 10 contaminants, statutory guideline values were available. Provisional drinking water guideline values were based upon toxicological literature data. The maximum concentration levels reported in surface waters, groundwater and/or drinking water were compared to the (provisional) guideline values of the contaminants thus obtained, and expressed as Benchmark Quotient (BQ) values. We focused on occurrence data in the downstream parts of the Rhine and Meuse river basins.

The results show that for the majority of compounds a substantial margin of safety exists between the maximum concentration in surface water, groundwater and/or drinking water and the (provisional) guideline value. The present assessment therefore supports the conclusion that the majority of the compounds evaluated pose individually no appreciable concern to human health.

Despite the absence of any concern to human health, drinking water remains a major point of consumer concern and some residual uncertainties need further exploration. For example, drinking water guideline values are developed using toxicity information for single compounds. Hence, the long-term cumulative dose-additive or synergistic effects of low concentrations of contaminants co-occurring as mixtures on human health and potentially sensitive sub-populations remain currently unknown.

Effluents and surface waters mirror our lifestyle

In effluents and surface waters, pharmaceuticals and illicit drugs (Thomas et al., 2012) used by the population can be traced back. In a Rhine catchment study (Ter Laak et al., 2010), pharmaceuticals were frequently monitored in the Rhine delta in a 6-yr period. Concentrations were used to calculate annual loads transported by the Rhine at Lobith. These loads were compared to the annual sales upstream of Lobith. This mass balance approach shows that substantial fractions (1.1% to 70.4%) of the 20 most frequently observed pharmaceuticals sold in the Rhine catchment area are recovered in the Rhine at Lobith. The recovered fraction is generally higher for the more polar pharmaceuticals. This is explained by the fact that the hydrophobicity of a chemical correlates with (the need for) degradation in the human body, removal during waste water treatment and from the aqueous phase in the environment.

Increasing effectivity of interventions by placement of treatment

For human pharmaceuticals, sewage treatment plants (STPs) are a major point of entry to surface waters. The receiving waters provide vital functions. Modelling the impact of STPs on susceptible functions of the surface water system allows for a spatially smart implementation of abatement options at, or in the service area of, STPs. In a nation-wide scale for the Netherlands (Coppens et al., 2015), the impact of point source emissions on susceptible functions for all 345 Dutch STPs and nine rivers from neighbouring countries were modelled for Dutch surface waters under two extreme discharge conditions. Monitoring data of 7 locations along the rivers Rhine and Meuse fall mostly within the range of modelled concentrations. Half of the abstracted volumes of raw water for drinking water production, and a quarter of the Natura 2000 areas (European Union nature protection areas) hosted by the surface waters, are influenced by STPs at low discharge. The vast majority of the total impact of all Dutch STPs during both discharge conditions can be attributed to only 19% of the STPs with regard to the drinking water function, and to 39% of the STPs with regard to the Natura 2000 function. The prioritized STPs together bear the majority of the cumulative impact.

Attributing water treatment technologies to STPs as one of the possible measures to improve water quality and protect susceptible functions can thus be done in a spatially smart and cost-effective way, using consumption- or emission- based detailed hydrological and water quality modelling.

Modelling effectivity of abatement options– industrial, care, agriculture & industry sector

Abatement strategies are various interventions with the objective to reduce chemical loads in water systems, thereby reducing the concentration, exposure and adverse effects for man and environment and increasing the possibilities to safely use the water for a variety of services.

Abatement options for contaminants of emerging concern can be categorized according to their relevance for various stages in the chemicals' life cycle, from ex ante interventions during design and authorization to ex post ones after emission. Such a life cycle might span large spatial and time scales. The majority of environmental emissions takes place during the use and disposal phase.

Systematic evaluation of the life cycle of chemicals and the current regulations involving chemicals currently is lacking, which triggers the concept of a beneficial overview of potential abatement strategies. Early in the chemical life cycle, non-technological abatement options that are relevant on large spatial scales dominate, while later in the life cycle technological options relevant at regional scale dominate. While the options early in the cycle are comparable for various use types, they are more differentiated towards a specific use later in the cycle. The various sectors involved (agriculture and subsectors as greenhouses and livestock farming, healthcare sector, producing industry, water sector, households) for the different uses of chemicals could benefit by cross-sectoral learning, and higher co-development of a coherent implementation and investment program to reduce emissions, improve recycling, and improve water quality.

An efficient abatement strategy combines options in various stages of the life cycle, and uses both preventive and curative options. A focus on preventive options early in a chemical's life cycle, may deliver the most long-term and large-scale benefits. However in view of the current high and growing demand for chemicals by society, it is considered inevitable to use also emission-reduction and curative abatement options later in the chemical's life cycle. Furthermore, the implementation of technological options later in the life cycle may provide a cost-price related stimulus that enhances consideration for implementing lower-net-cost abatement options earlier in the chemical life cycle.

Solutions-focused risk assessment

Improvement of environmental quality by implementing sets of abatement options can be expressed in terms of decreased concentrations, improved ecological quality or better possibilities to use the water system services (e.g. for drinking water production, food production, recreation).

Alternative packages of abatement strategies may be evaluated whether, when and where they substantially contribute this quality. It can be foreseen that the use of impact oriented output presentation techniques can facilitate the evaluation of various alternative sets of abatement strategies vis a vis the current situation. More preventive and global approaches can be compared to more curative and local approaches.

References

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