How effective are water treatments in removing toxic effects of micropollutants? A literature review of effect-based monitoring data

GWRC project « Effect-based monitoring in water safety planning » - WP4

Jérôme Enault[1*], Jean-François Loret[1], Peta A Neale[2], Milo L De Baat[3], Beate I Escher[4], Faten Belhadj[5], Stefan AE Kools[3], Geertje J Pronk[3], Frederic DL Leusch[2]

[1] SUEZ – CIRSEE (France); * jerome.enault@suez.com ; [2] Griffith University - Smart Water Research Centre (Australia); [3] KWR Water Research Institute (Netherlands); [4] Helmholtz Centre for Environmental Research - UFZ (Germany); [5] Veolia Research & Innovation (France).

GWRC Project « EBM in WSP »

The Global Water Research Coalition (GWRC) project "Effect Based Monitoring in Water Safety Planning (WSP)" is a collaboration between GWRC, KWR, Veolia, Suez, UFZ and Griffith University. The project addresses the implementation of bioassays for monitoring of micropollutants in water and wastewater treatment installations at a global scale, profiling experiences and case-studies from Europe, Australia, North America and South-East Asia. Three other presentations summarise work from this project at this conference: Effect-based monitoring in global water safety planning (platform presentation), Perception & barriers to implementation (poster), and Water Safety Plan protocol development (poster).

Introduction

Wastewater, environmental and drinking water contain, to different extents, a complex mixture of micropollutants, including pharmaceuticals and personal care products, pesticides and industrial compounds. Regulations and risk assessments associated with these water matrices usually consider individual chemicals. This approach fails to account for the mixture effects of the many chemicals that are present.

Effect-based monitoring (EBM) using *in vitro* bioassays and well plate-based *in vivo* assays can be applied in parallel to chemical analysis, in order to detect the mixture effects of all active chemicals present in a sample, including unknown ones. Therefore, these tools are usually described as a useful complement to individual chemical analysis.

The objective of this study was to review the published literature on the application of EBM in the water cycle and use the published data to characterize (i) the extent of bioanalytical concentrations observed in different water matrices, (ii) their compliance with existing ecological and human health EBTs, (iii) the ability of water treatment to reduce these biological effects.

Method

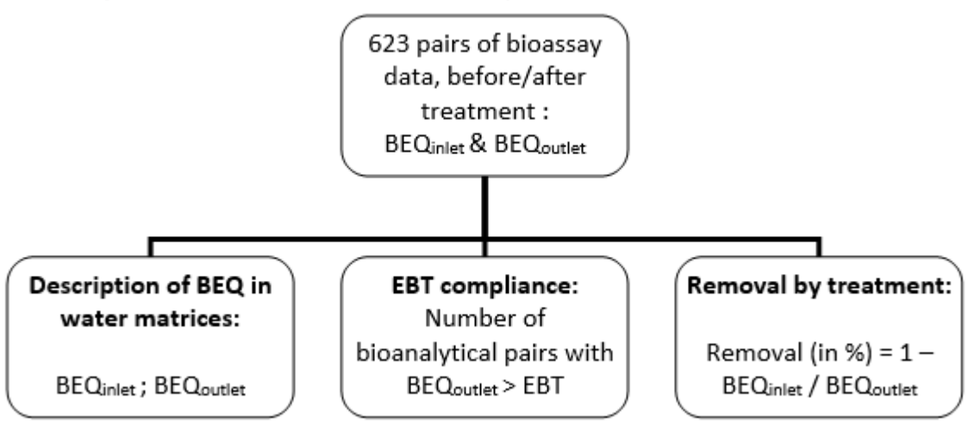
The method applied consisted of four successive steps:

1) **Selection of the publications** based on four criteria: sampling points (at least inlet and outlet of the DWTP/WWTP), sample preparation (with SPE), EB analysis (at least one *in vitro* bioassay), and result expression (quantitatively, as BEQ).

2) **Data extraction** from 37 publications meeting the criteria.

3) **Data clustering** of the 623 pairs of results (treatment inlet/outlet) based on 4 types of water treatment schemes (DW and WW, conventional and advanced) and 17 biological endpoints investigated (agonism/antagonism of hormones receptors, genotoxicity, xenobiotic metabolism, oxidative stress…)

4) **Result expression,** in three different ways:



Abbreviations

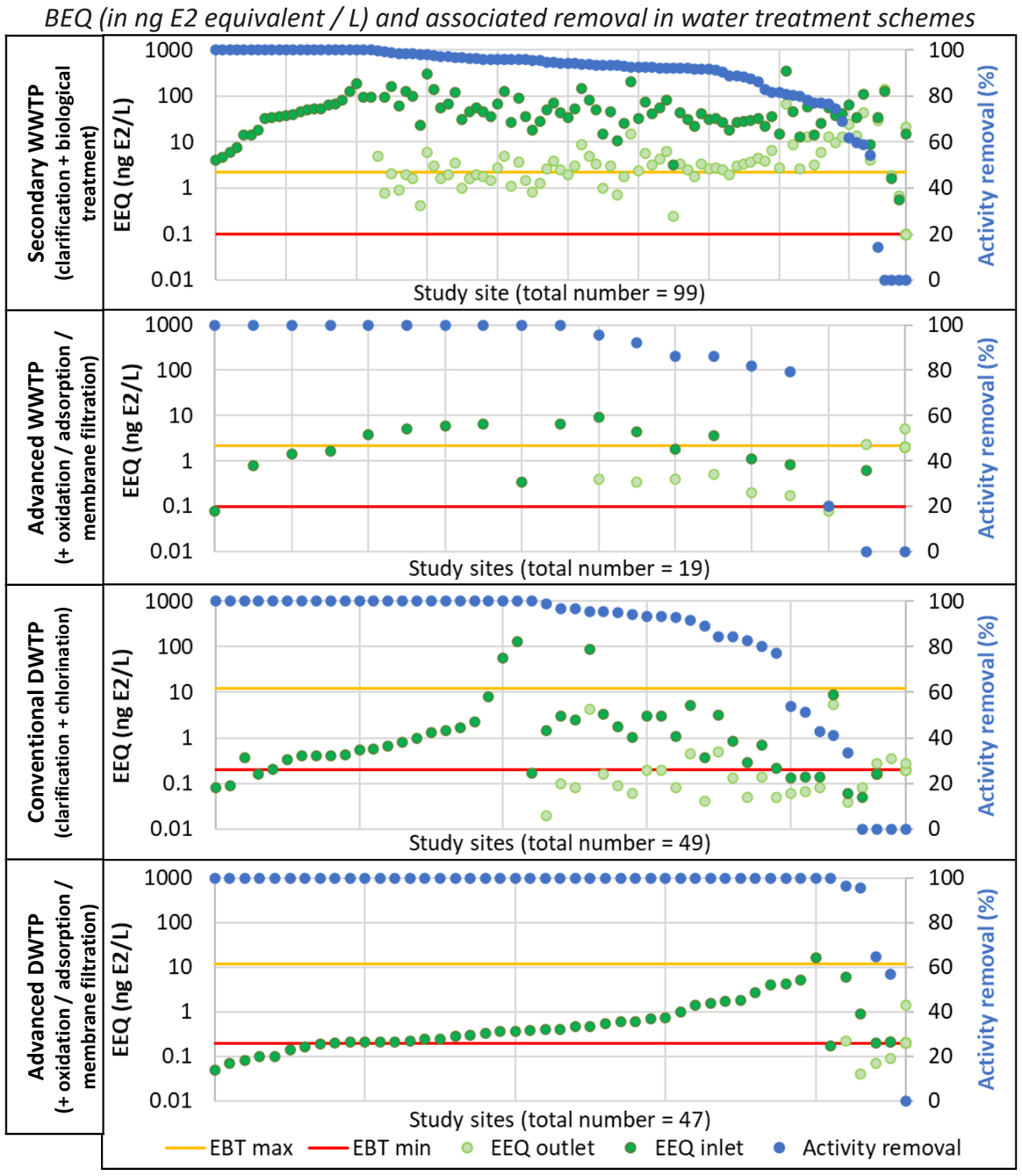
BEQ: Bioanalytical equivalent concentration
EB: Effect-based ; EBM: Effect-based monitoring
EBT: Effect-based trigger value
EEQ: estradiol equivalent concentration
ER: Estrogen receptor ; E2: 17β-estradiol
SPE: Solid phase extraction
DW: Drinking water
DWTP: Drinking water treatment plant
WW: Wastewater
WWTP: Wastewater treatment plant

Results

Most published studies originate from a few countries (12), mainly Australia (33%). Most available results are associated with secondary WW treatment (48%), the most studied endpoint being the ER agonism (34%), whose results are presented graphically in the figure below.

Overall, environmental risks associated with ER activation in WW effluents are higher than health risks in DW. This is explained by lower removal by the treatments, higher BEQs in effluents, and lower EBTs. As a consequence, 76% of investigated secondary WWTP effluents exceed the lowest proposed EBT. Even with a ten-fold dilution in the receiving water body, 64% would still be above this EBT. For DWTPs, except in some specific contexts, ER agonistic activity was either undetected at the outlet, or below the lowest EBT.

BEQ (in ng E2 equivalent / L) and associated removal in water treatment schemes



Conclusions

This review provides a mapping of mixture effects, here exemplified by estrogenicity, in the water cycle, which may help in defining priorities of action to better control micropollutants and their biological effects. It also demonstrates the potential of these bioassays to assess water safety and the effectiveness of water treatment in removing estrogenicity, which makes them a useful tool in the framework of Water Safety Plans. Similar effect and toxicity reductions were reported for other biological endpoints. These results will be presented in an upcoming publication available on the GWRC website.

Overall, the available data show that toxic effects resulting from environmental pollutants appear to be well eliminated by drinking water treatments, even with conventional schemes. However, oxidative stress and genotoxicity (data not shown) generated by chemical disinfection of drinking water deserve closer attention. Wastewater treatment seems to be less effective in removing toxic effects, compared with drinking water treatments. Most effects in wastewater effluents present values above the existing ecological trigger values. Consequently, priority should be given to a better treatment of wastewater in order to better protect the environment and DWTP resources.

www.globalwaterresearchcoalition.net

Global Water Research Coalition

Acknowledgment

This project was funded by PUB – Public Utilities Board, Stowa- Foundation for Applied Water Research, Water Research Australia, the Water Research Commission and the Water Services Association of Australia. In-kind support was kindly provided by Veolia Research and Innovation, SUEZ, and KWR.

References of WP3 reports (available on the GWRC website)

(1) WP3.2: Medium-to-high throughput bioanalytical tools and decision-making tool for selection of bioassays.

(2) WP3.3: Sampling strategies and sample pre-treatment options and decision-making tool for selection of sampling methods

(3) WP3.4: Effect-based trigger values for different water quality classes considering hazards for human and the environment health