Factsheet

Global Water Research Coalition

Effect Based Monitoring in Water Safety Planning

Factsheet for legislators

This factsheet provides key elements to promote regulatory uptake of Effect Based Monitoring (EBM) for drinking water risk assessment, along with classic chemical methods.

This document is developed within the GWRC project Effect Based Monitoring in Water Safety Planning. This collaborative project between GWRC, KWR Water Research Institute, Veolia, Suez, UFZ and Griffith University addresses the implementation of in vitro bioassays for monitoring the effect of micropollutants in water and wastewater treatment installations at a global scale, profiling experiences and case-studies from Europe, Australia, North America, Asia and South Africa.

What is the issue?

Water resources may contain a great number of trace organic pollutants, including pesticides, personal care products (PCPs), pharmaceuticals and disinfection byproducts (DBPs) at very low concentrations, and their potential mixture effects. This is a challenge for (drinking) water safety as traditional chemical-by-chemical analysis cannot capture the whole picture. Most existing water quality legislations have not overcome this challenge. As such, only a small portion of the total chemical load is detected, and water safety is not fully assessed.

How can this be overcome?

Scientists now recommend combining targeted chemical analysis and Effect-Based Methods (EBMs) for better water quality risk assessment (1). EBMs have known great scientific developments in the last ten years, and are now commercially available to measure early adverse effects of complex aqueous mixtures, even at low concentrations.

Existing water quality legislation

The Policy for Water Quality Control for Recycled Water of the California State Water Boards is the only body that recommends using bioanalytical screening tools with guidance for interpretation and response actions (2).

EBM has been acknowledged by regulatory agencies such as the WHO (3). The Australian Guidelines for Water Recycling (4) and the Australian Drinking Water Guidelines (5) also clearly acknowledge the potential of EBM, but do not provide explicit guidance use.

This GWRC project and the Dutch Water Quality Knowledge Impulse (6) aim to by developing protocols and support documents.

Broader support from regulatory authorities is strongly needed to support EBM use and better water safety risk assessment.

What are Effect-Based Methods (EBMs)?

Effect-Based Methods (EBM) provide complementary information about biological effects and link water quality with risk assessment.

In vitro bioassays (e.g., typically mammalian or human cell lines) and well plate-based in vivo assays (small organisms) can detect the effect of all active chemicals in a sample extract, including both known and unknown chemicals, and can account for mixture effects. This gives a measure of the active chemicals, according to different types of biological responses (estrogenicity, oxidative stress, genotoxicity…).

EBM are complementary to existing chemical analysis: they detect the effect of all active chemicals, but cannot identify the individual chemicals present.

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Using EBM to verify drinking water safety

EBM should be used in addition to chemical analysis to detect bioactive chemical contaminants in a water sample. In a risk-based approach, EBM can be used at the drinking water treatment plant to screen produced drinking water and verify water safety. If screening shows significant bioactivity, additional analysis is recommended to identify relevant control measures. Other targets could be set, for instance using EBMs for evaluation of specific treatment performance, or for risk assessment of water resources.

In frameworks such as WHO Water Safety Plans, EBMs can be applied to several modules for source- to-tap risk assessment: system assessment, validation, operational & verification/compliance monitoring (7). **The way to go may be to include EBMs in supporting R&D programs** and test applicability for verification monitoring to start.

How can EBMs be used for drinking water safety?

Answers to the following questions and more (test selection, sampling, sample preparation, sensitivity, quality control) are developed in (8).

> Should a single bioassay or a battery be used?

A single bioassay cannot capture all effects. A battery of assays is recommended to assess different biological modes of action. This project recommends tests on a quarterly or biannual basis, with bioassays indicative of:

- Activation of the estrogen receptor (ER), to detect estrogenic activity,
- Activation of the aryl hydrocarbon receptor (AhR), as an indicator of xenobiotic metabolism,
- Oxidative stress response that is activated after damage by chemical stressors,
- Genotoxicity due to genotoxic chemicals in raw water or potential formation of genotoxic DBPs in the water production scheme.

As developments progress, additional or different bioassays may be recommended, such as androgen receptor (AR), glucocorticoid receptor (GR), peroxisome proliferator-activated receptor (PPAR).

> What about EBM result interpretation?

EBMs provide a sum effect of the micropollutants in a water sample for each mode of action. The Bioanalytical Equivalent Concentration (BEQ) relates the effect of a water sample to the effect of the bioassay reference compound. To assess water quality, the bioassay response as a BEQ is compared to an Effect-Based Trigger value (EBT) for the protection of human health (9).

> What if EBM results show bioactivity?

BEQ results should be interpreted as follows (9, 10):

If BEQ < EBT
No action is required; risks are considered negligible. The frequency of testing can be reduced if results remain below EBT after a few campaigns.

If BEQ > EBT
Further action is required if confirmed after laboratory quality control validation and re-testing.

BEQ < 10×EBT
More frequent monitoring is recommended until BEQ is less than EBT.

BEQ > 10×EBT or
EBT < BEQ < 10xEBT for more than 6 to 12 months
Further action is required:

1) Health Authorities should be informed;
2) an effort should be made to try to identify the chemicals contributing to the effect;
3) optimization of the treatment process should be considered.

This is applicable where the effect may be explained by a few chemicals. Toxicant identification is not feasible for assays where the response is triggered by many low potency chemicals (e.g., oxidative stress response). For these assays the cytotoxicity response can be compared with the cytotoxicity EBT (9).

> Are laboratories easy to find?

As this is a newer field of science, the number of expert and certified laboratories remains limited. However, as the application of EBMs increases, so will commercial laboratory capabilities to meet the demand. For now, samples can be processed in chemistry laboratories and then safely shipped to the appropriate laboratories.

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> What about costs?

Overall, costs are in the same order of magnitude as trace chemical screening methods. The decision to use EBMs should be based on effectiveness and water safety rather than cost alone. Applied as a first screening step, EBMs can help refine and reduce the number of samples and chemical classes to monitor using different targeted chemical methods.

Perception of EBMs

In the course of the project, the GWRC project team ran a survey on EBM perception and willingness for implementation among a global panel of water sector stakeholders. The survey gathered 63 responses from 19 countries and 32 companies or institutes.

The majority of survey participants (75%) stated that EBM would **improve water quality monitoring and public confidence in drinking water.** Most (80%) think that EBM can support risk assessment and management, complementary to targeted chemical analysis. They would recommend in vitro bioassays and consider them to be very cost effective. Some key barriers were given: lack of support from regulatory authorities, lack of guidelines from experts, and costs.

Now what?

Science provides in depth evidence of EBM relevance and reliability to ensure drinking water safety, along with existing chemical analysis. Commercial labs around the world are implementing methodologies and making them available to all. Water sector experts assert EBMs would improve water quality monitoring, and that biological tests would support public confidence in drinking water. **EBMs may also be used for other water systems, such as wastewater treatment or water reuse.**

There are strong incentives from governments (Australia, California) and institutions such as WHO and the EU to review Water Quality Management Frameworks to better assess emerging water contaminants that are not adequately covered by existing guidelines and regulations. **Yet, adoption in legislation is limited.**

Due to the ever growing number of chemical contaminants in the aquatic environment and the increasing demand for recycled water, managers are in need of novel strategies to assess water safety.

EBMs are currently the most promising and cost-effective methods to address these challenges and increase public confidence in the quality of drinking and/or recycled water.

Broader support from regulatory authorities is strongly needed to support the use of EBMs and enhance laboratory capabilities.

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Please check project's webpage for further info

www.kwrwater.nl/en/projecten/effect based-monitoring-in-water-safety-planning.

References

(1) Brack W. et al (2019) *Environ Sci Eur* 31, 74 & European Collaborative Project SOLUTIONS (2018)
(2) Water Quality Control Policy for Recycled Water | California State Water Resources Control Board
(3) World Health Organization, *Potable reuse: guidance for producing safe drinking-water*. 2017, Geneva
(4) www.waterquality.gov.au/guidelines/recycled -water
(5) www.nhmrc.gov.au/about-us/publications/australian -drinking-water-guidelines
(6) Water Quality Knowledge Impulse www.stowa.nl/kennisimpuls
(7) Neale P. A. et al (2022) *J Water Health* (2022) 20 (12) & www.sleutelfactortoxiciteit.nl/key-factor-toxicity-introduction
(8) Neale P.A. et al (2023) Environ Sci & Technology (submitted)
(9) Neale PA, Escher BI, de Baat ML, Enault J, Leusch FDL.(2023) Effect-Based Trigger Values Are Essential for the Uptake of Effect-Based Methods in Water Safety Planning. *Environ Toxicol Chem.* 2023 Mar;42(3):714-726.
(10) Leusch F. D. L. and Snyder S. A. (2015) *Environ. Sci.: Water Res. Technol.* 2015,1, 606-621

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