

Systematic review of current approaches to prioritise chemical contaminants of emerging concern for research and management in the water industry

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ABSTRACT

Contaminants of emerging concern (CEC), such as pharmaceuticals, hormones and industrial chemicals, pose a significant challenge for the water industry due to their presence in matrices including wastewater and drinking water. This is compounded by a lack of knowledge about their occurrence, environmental fate and/or toxicity, making it difficult to assess and mitigate risks. In this systematic review we investigated approaches used to prioritise CEC in matrices relevant to the water industry for research and management. Most approaches were specific to a geographic location, with fewer studies considering CEC risk at the national or international level, despite CEC being a global issue. Further, most prioritised CEC in surface water, wastewater and drinking water, with few considering recycled water, ground-water or biosolids. The methods used to prioritise CEC varied from a simple screening based on (predicted) persistent, bioaccumulative and toxic (PBT) properties to automated workflows considering many different criteria. A risk quotient (RQ) or equivalent approach, where measured or predicted occurrence data were compared to toxicity data, was the most common method to identify and rank priority CEC. This systematic review identified several limitations when applying existing CEC prioritisation tools for the water industry, with opportunities for prospective prioritisation models outlined.

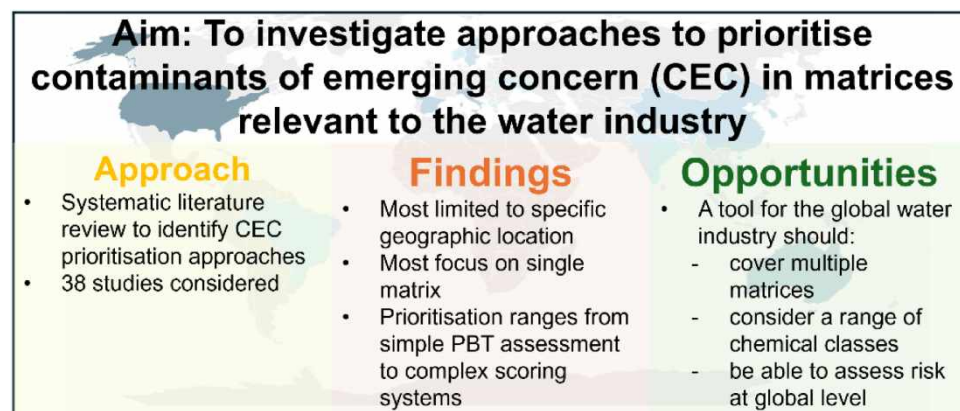
Key words: chemical contaminants, drinking water, ecosystem health, human health, risk, surface water

HIGHLIGHTS

- Ever-present need for the global water industry to identify high risk contaminants of emerging concern (CEC) in water and related matrices.
- Systematic review identified 38 CEC prioritisation studies.
- 58% of studies prioritised CEC at the regional level.
- 84% of studies focused on a single matrix, namely surface water or drinking water.
- Approach covering multiple matrices that can be scaled to global level is needed.

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GRAPHICAL ABSTRACT



INTRODUCTION

Chemical pollution poses a significant threat to both human and ecosystem health (Brack *et al.* 2022). Agricultural and urban runoff can release chemicals to surface waters (Buss & Achten 2025; Yang *et al.* 2025), while increasing consumption of pharmaceuticals and personal care products (PCPs) results in their ubiquitous presence in sewage (Nguyen *et al.* 2018; Ahmed *et al.* 2023) and surface waters (Wilkinson *et al.* 2022). The presence of chemicals in surface waters can also affect drinking water supplies. While a number of sectors contribute to the management of chemical pollution, the water industry is responsible for end-of-pipe treatment and acts as the final barrier before treated water is released to the environment or consumers (Ateia *et al.* 2023). Managing chemical pollution is compounded by the sheer number of chemicals released into the environment, with a recent study finding that close to 20,000 chemical contaminants have been analysed in environmental media over the last 50 years (Muir *et al.* 2023). A small fraction of chemicals have guidelines or standards, but the majority do not. Some of these unregulated chemicals are considered contaminants of emerging concern (CEC) – natural or synthetic chemicals, such as algal toxins, hormones, industrial chemicals and pharmaceuticals, that are present or likely to be present in the environment and may pose a risk to either human or ecosystem health (Diamond *et al.* 2011; Sauvé & Desrosiers 2014). A defining feature of CEC is that the evidence for occurrence, toxicity and/or environmental behaviour is limited.

The lack of knowledge about CEC makes it difficult for the water industry to accurately assess the risk they are managing as part of their operational responsibilities, or to meet the needs of communities for transparent communication regarding potential chemical risks. CEC have been detected in environmental waters worldwide, including in remote locations, such as Antarctica (Li *et al.* 2025; Singh *et al.* 2025). Consequently, there is a need for global, as well as regional, solutions to address the challenge of CEC in water. An understanding of which CEC represent the greatest risk is necessary for effective management and the protection of biodiversity and human health. Therefore, tools to identify and rank CEC based on risk to either human health or ecosystem health can therefore help water utilities develop efficient management strategies and direct resources towards high priority CEC that pose the biggest risk to their operations.

Tools and techniques have been developed to prioritise CEC in matrices relevant to the water industry, such as drinking water, surface water and wastewater, including PikMe (Wennberg *et al.* 2025), RANKVET (Di Nica *et al.* 2015) and ECHIDNA (Neale *et al.* 2023). However, few have specifically focused on supporting the water industry and protecting the availability of safe and healthy water for nature and societies (e.g., de Voogt *et al.* 2009; Neale *et al.* 2023). The available tools use a range of different approaches to identify and rank CEC, with many using a combination of experimental or modelled fate, occurrence and toxicity data, including high-throughput screening data.

Consequently, this review aimed to systematically investigate the different approaches proposed to prioritise CEC in matrices relevant to the water industry, including drinking water, surface water, groundwater, wastewater, recycled water, sludge and biosolids. Factors including location, matrix, candidate list, occurrence and toxicity data, as well as prioritisation approach, were considered. The strengths and limitations of available approaches were identified, along with opportunities for a future CEC prioritisation tool for the global water industry. To our knowledge, no previous studies have systematically reviewed CEC prioritisation approaches based on their applicability to the water industry.

MATERIALS AND METHODS

The systematic quantitative literature review methodology based on Pickering & Byrne (2014) was applied to identify CEC prioritisation studies. Two widely used, comprehensive databases, Web of Science and Scopus, were searched on 10th February 2026. The terms (*prioritisation OR prioritization*) AND (*tool OR database*) AND (*micropollutant* OR 'emerging contaminant*' OR 'contaminant* of emerging concern' OR CEC*) AND (*water OR biosolid* OR sludge*) were searched in 'All Fields' in Web of Science. The terms *prioritization OR prioritisation AND tool OR database AND micropollutant* OR 'emerging contaminant*' OR 'contaminant* of emerging concern' OR CEC AND water OR biosolid* OR sludge* were searched in 'Article title, Abstract, Keywords' in Scopus. No time restrictions were placed on the database search. The search strings returned 69 publications for Web of Science and 56 publications for Scopus. Key information about each identified publication, including author list, title, journal and digital object identifier (DOI), were exported to Microsoft Excel for screening. Forty-four of the studies appeared in both Web of Science and Scopus, with 25 studies only in Web of Science and 12 studies only in Scopus. In addition to the Web of Science and Scopus searches, water industry experts identified an additional 14 studies. This gave a total of 95 unique studies.

The abstract of each paper was screened to ensure that only studies that prioritised CEC in matrices relevant to the water industry were included, with only original peer-reviewed research studies (i.e., no review articles, book chapters or conference papers) and studies in English considered. Any studies that prioritised CEC in biota were excluded, as were studies that prioritised study sites or mixtures, rather than individual CEC. Fifty-five studies were excluded after screening, with the full text of the remaining 40 studies assessed for eligibility. Two studies were excluded after reading the full text, resulting in 38 studies considered in the current review. The identification and screening approach is summarised in Figure S1 of the Supplementary Material. Data were extracted from the 38 studies and recorded in Microsoft Excel. The recorded information included study location, matrix (e.g., drinking water, wastewater), chemical classes, data sources, prioritisation approach, type of toxicity data (e.g., *in vivo*, *in vitro*, predicted) and type of chemical analysis (e.g., targeted analysis, non-targeted analysis). In addition to the systematic review of peer-reviewed publications, CEC prioritisation projects undertaken by the water industry, research organisations and government were discussed. These projects were identified in consultation with water industry experts.

RESULTS AND DISCUSSION

Location and matrix

Thirty-eight CEC prioritisation studies were identified from the systematic review, with the majority originating from the United States, followed by the Netherlands (Figure 1(a)). An overview of all 38 included studies including country, matrix and data source is provided in Table S1. The majority of the studies focused on a specific region or river basin using occurrence data limited to the area of interest (e.g., Deere *et al.* 2021; Zhao *et al.* 2023; Guolo *et al.* 2025). Fewer studies prioritised CEC at the country level, including China and the United States, with occurrence data from sources such as national monitoring programs and the peer reviewed literature used (e.g., He *et al.* 2023; Rosenblum *et al.* 2024; Chatzipanagiotou *et al.* 2026). Figure 1(a) reveals a lack of research in Africa, and only one study in South America. However, two of the studies, which are not captured in Figure 1(a), focused on CEC prioritisation at the global scale (de Voogt *et al.* 2009; Yang *et al.* 2022), while another study focused on Europe (Dulio *et al.* 2024).

Most studies prioritised CEC in water matrices, primarily surface water, drinking water and wastewater (Figure 1(b)). Fewer studies prioritised CEC in groundwater and recycled water, and only one study focused on biosolids. Biosolids, produced from treated wastewater sludge, are applied to land in some countries to improve soil characteristics but can contain elevated levels of CEC (Xue *et al.* 2025). While the sustainable reuse of biosolids is widely acknowledged as a key contributor to circular economy development, its implementation requires robust standards for treatment processes and contaminant mitigation (EEA 2022). The lack of prioritisation approaches for this matrix highlights an important knowledge gap. Further, most of the reviewed studies were specific to a particular water matrix, rather than considering multiple matrices. Ideally, a CEC prioritisation tool for the water industry should consider multiple relevant matrices, but only six studies focused on more than one water matrix, most commonly surface water, drinking water and wastewater. However, some publications do suggest that their workflow can be applied to other environmental matrices (Dulio *et al.* 2024).

Given the focus on surface water and wastewater, most studies prioritised CEC based on risk to ecological health, with fewer studies focusing on human health (Figure 1(c)). Only six studies considered both human and ecological health (de

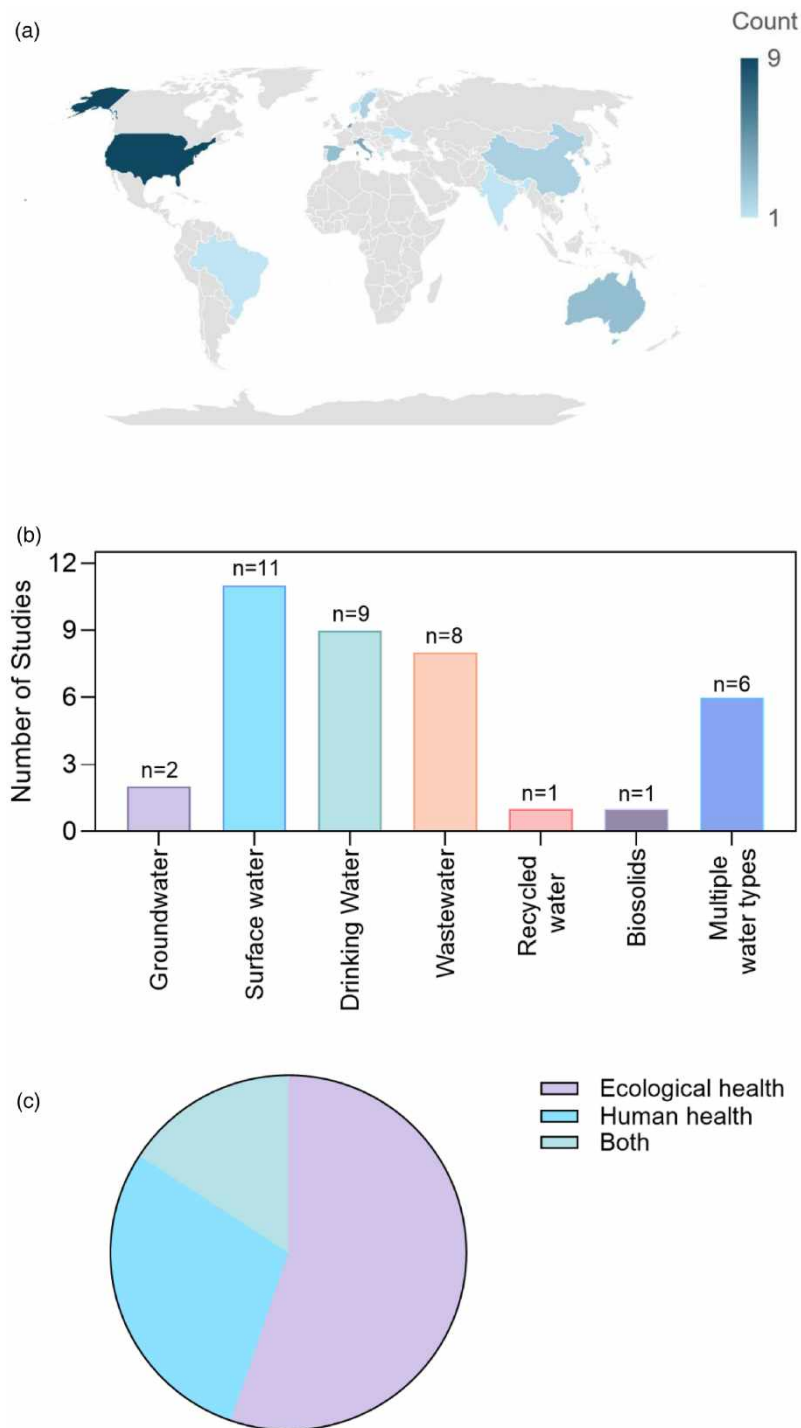


Figure 1 | (a) Location of CEC prioritisation studies (excluding three studies that focused on broader geographical regions or the global scale), (b) matrices covered in CEC prioritisation studies, with *n* indicating the number of studies for each matrix, and (c) whether CEC were prioritised based on risk to ecological health or human health.

Voogt *et al.* 2009; Yang *et al.* 2022; Neale *et al.* 2023; Newmeyer *et al.* 2024; Wennberg *et al.* 2025; Penserini *et al.* 2026). The One Health perspective, where human health is interlinked with animal and ecosystem health, argues the importance of considering both human health and ecological health when assessing the risk of CEC (Wang *et al.* 2024).

Prioritisation candidate list

Different approaches were applied in the literature to select a list of CEC for prioritisation, which is also known as a candidate list. The candidate list in some studies was simply based on what was monitored in the studied matrix (e.g., surface water, wastewater) using targeted chemical analysis (e.g., [Villa *et al.* 2020](#); [Deere *et al.* 2021](#); [Choi *et al.* 2024](#); [Xie *et al.* 2025](#)), while other studies used regulatory databases (e.g., chemical products registered and approved for use) ([Di Nica *et al.* 2015](#); [Gago-Ferrero *et al.* 2018](#); [Serasinghe *et al.* 2022](#)), or existing compound lists (e.g., Water Framework Directive Watchlist, European Chemicals Agency Candidate list of Substances of Very High Concern) ([Been *et al.* 2021](#)). Several studies used a combination of approaches. For example, the candidate list in [Neale *et al.* \(2023\)](#) was based on chemicals in regulation, chemicals detected in water and existing compound lists (e.g. NORMAN Network emerging substances list, US EPA Contaminant Candidate List), as well as new CEC identified in academic reviews (e.g., [Richardson & Kimura 2020](#)). The number of substances in the candidate lists in the reviewed studies ranged from 8 to 1,139,631.

The majority of studies considered a range of different chemical classes (e.g., pharmaceuticals, PCPs, pesticides, disinfection by-products (DBPs), per- and polyfluoroalkyl substances (PFAS), flame retardants (FR), polycyclic aromatic hydrocarbons (PAHs)) (e.g., [Baken *et al.* 2018](#); [Alvarez *et al.* 2021](#); [Lopez-Herguedas *et al.* 2023](#)), though some only focused on a single class, such as pharmaceuticals ([Di Nica *et al.* 2015](#); [dos Santos & Nardocci 2019](#)), PCPs ([Balakrishnan *et al.* 2024](#)) or pesticides ([Serasinghe *et al.* 2022](#); [Xie *et al.* 2025](#)) ([Figure 2](#)). Rather than focusing on individual CEC, the San Francisco Public Utilities Commission prioritised CEC groups, such as algal toxins and industrial and commercial chemicals, with expert review and customer interaction included in the prioritisation approach ([Olson *et al.* 2017](#)). Overall, the substances prioritised in the studies considering multiple chemical classes are diverse with regard to their applications, underlining the importance of including multiple chemical classes in monitoring programs to inform diverse approaches for exposure and risk management. While outside the scope of this systematic review, two of the studies also included microbial pathogens ([Olson *et al.* 2017](#); [Hartmann *et al.* 2021](#)), with [Olson *et al.* \(2017\)](#) identifying microbial pathogens as the highest priority.

Occurrence, toxicity and removal

Occurrence was included as part of the prioritisation process in most studies. Many publications measured CEC concentration as part of the study (e.g., [Kuskopf *et al.* 2020](#); [Nikolopoulou *et al.* 2022](#)), though existing databases (e.g., [Baken *et al.* 2018](#); [Rosenblum *et al.* 2024](#)) and predicted environmental concentrations ([Di Nica *et al.* 2015](#); [Villa *et al.* 2020](#)) were also used ([Figure 3](#)). One exception was [Balakrishnan *et al.* \(2024\)](#), where commonly used PCPs were prioritised based on predicted persistent, bioaccumulative and toxic (PBT) properties only. This is in line with precautionary principles, where measures to reduce environmental degradation should be taken if there are concerns about the fate and toxicity of a contaminant, even when there is limited data ([Gouin 2010](#)). [Serasinghe *et al.* \(2022\)](#) also did not include occurrence data, with pesticides shortlisted for monitoring identified based on approved use in the region of interest, toxicity and lack of

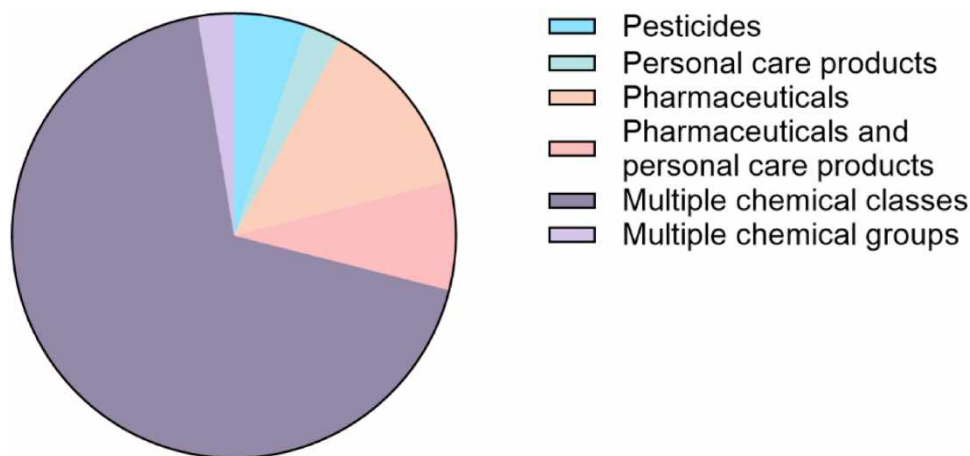


Figure 2 | Overview of chemical classes considered in the CEC prioritisation studies.

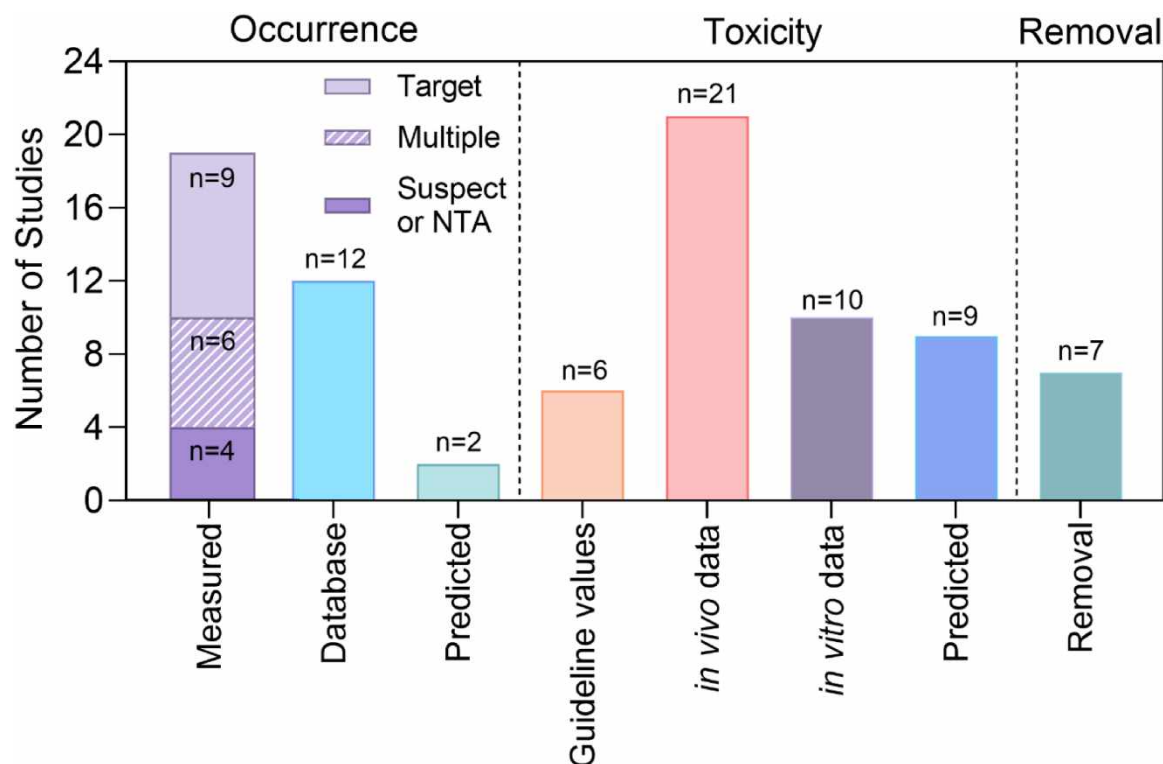


Figure 3 | Overview of the number of studies (*n*) that included occurrence, toxicity and removal as part of the CEC prioritisation process.

routine monitoring. Any unapproved use was not considered in [Serasinghe *et al.* \(2022\)](#), though unapproved pesticides may potentially be used in the region of interest. While targeted chemical analysis is most frequently used, several studies have complemented targeted analysis with non-targeted analysis (NTA) and/or suspect screening ([Been *et al.* 2021](#); [Nikolopoulou *et al.* 2022](#)) or applied NTA or suspect screening alone for CEC prioritisation ([Newmeyer *et al.* 2024](#); [Ekpe *et al.* 2025](#)) ([Figure 3](#)). Parameters such as peak abundance, detection frequency and estimated concentration were used for prioritisation. The advantage of NTA and suspect screening over targeted analysis is that prioritisation is not limited to only known, targeted chemicals, though it is less sensitive and often for only a fraction of the detected features their identity is confirmed to an acceptable confidence level (e.g., Level 1 (confirmed structure), Level 2a and 2b (probable structure) ([Schymanski *et al.* 2014](#))). In the absence of monitoring data, chemical use data, environmental exposure models and (global) water quality models may inform the potential presence of CEC in water bodies.

Toxicity was considered in most CEC prioritisation approaches, with guideline values (e.g., [Baken *et al.* 2018](#); [Nikolopoulou *et al.* 2022](#)), *in vivo* data (e.g., [Osorio *et al.* 2016](#); [Choi *et al.* 2024](#)), *in vitro* bioassay data (e.g., [Blackwell *et al.* 2017](#); [Xie *et al.* 2025](#)) and predicted toxicity data using quantitative structure-activity relationships (QSAR) (e.g., [Gros *et al.* 2017](#); [Deere *et al.* 2021](#); [Wennberg *et al.* 2025](#)) all used to some degree ([Figure 3](#)). When available, (provisional) guideline values or *in vivo* data are preferred. Due to the lack of this type of data for many CEC, prioritisation approaches often need to rely on *in vitro* or predicted toxicity data, which is also in line with the global transition toward the use of animal-free methods for improved translatability to human physiology ([Kienhuis *et al.* 2025](#)). For example, the US EPA CompTox Chemicals Dashboard includes data for over 1,500 bioassays, with over 8,000 chemicals run in some bioassays ([US EPA 2025b](#)). The ecotoxicity data reported included environmental quality standards, predicted no-effect concentration (PNEC) and concentration causing 50% effect (EC₅₀), while toxicity data included preliminary drinking water guideline values and health reference levels. Some studies used a combination of toxicity data types for CEC prioritisation. For example, [Maloney *et al.* \(2025\)](#) used a range of different ecotoxicity data types including water quality guidelines, *in vivo* data, *in vitro* data and predicted toxicity data, with different action categories assigned based on the data type.

Removal was also considered in some studies that prioritised CEC in wastewater and drinking water (e.g., [Gros *et al.* 2017](#); [Sjerps *et al.* 2021](#); [He *et al.* 2023](#); [Neale *et al.* 2023](#)). For example, [Lopez-Herguedas *et al.* \(2023\)](#) included removal efficiency

as part of the scoring criteria for CEC prioritisation in wastewater. While removal was usually based on measured data, [Pronk *et al.* \(2023\)](#) developed indicative rules for the removal of CEC by conventional treatment, oxidation, activated carbon, reverse osmosis and advanced oxidation. These were combined to determine the 'effort index' (i.e., how much effort is required to remove a particular chemical), which was used to prioritise CEC and identified 18 CEC classified as particularly difficult to remove. Other approaches to predict treatment efficacy, such as AquaPriori ([KWR 2026](#)) and Water-Val ([WaterRA 2026](#)), could be potentially integrated into future prioritisation tools.

Prioritisation approach

Given the diversity of prioritisation studies, it is not surprising that many different approaches have been used to rank CEC. Several studies prioritised CEC based on PBT, persistent, mobile and toxic (PMT), or very persistent and very mobile (vPvM) properties (e.g., [Neale *et al.* 2023](#); [Balakrishnan *et al.* 2024](#); [Guolo *et al.* 2025](#); [Wennberg *et al.* 2025](#)). In all cases, CEC that exceeded triggers for all properties were deemed the highest priority for further investigation. The lack of experimental data, particularly for CEC, means that these parameters are typically predicted, commonly using EPISuite ([US EPA 2012](#)) and the CompTox Chemicals Dashboard ([US EPA 2025b](#)). Other proposed approaches include read-across based on structural similarity to group PMT and vPvM CEC ([Chirsir *et al.* 2024](#)), while coupling machine learning with models was proposed to screen PMT and vPvM CEC ([Zhao *et al.* 2022](#)). Structural similarity models, such as the ZZS similarity tool, can also be applied to assess whether the chemical fingerprint of a substance with unknown properties is similar to known Substances of Very High Concern ([Wassenaar *et al.* 2022](#)). Further, [Hartmann *et al.* \(2023\)](#) developed a continuous scoring system for P, M and T potential using modelled parameters, with an overall PMT score grouping chemicals as low to moderate, high or very high P, M and/or T. It should be noted that a limitation of these approaches and tools is that they are not compatible with inorganics, organometals and salts.

In an alternative approach that did not consider toxicity or fate, [Gago-Ferrero *et al.* \(2018\)](#) prioritised CEC in wastewater using the exposure index, which was based on occurrence in products, volume consumed, and usage pattern information available in the National Swedish Product Register.

Many of the reviewed studies ranked CEC based on risk quotients (RQ) or an equivalent approach using measured or predicted environmental concentrations and toxicity data (e.g., [Villa *et al.* 2020](#); [García-Vara *et al.* 2023](#); [Choi *et al.* 2024](#); [Chatzipanagiotou *et al.* 2026](#)). Other terms used in the literature include benchmark quotient ([Baken *et al.* 2018](#)), hazard quotient ([Kuskopf *et al.* 2020](#)), hazard index ([Rosenblum *et al.* 2024](#)) and toxicity quotient ([Alvarez *et al.* 2021](#)). In these studies, the calculation is essentially the same, with the measured or predicted environmental concentration divided by a toxicity threshold, such as a PNEC or (provisional) drinking water guideline. *In vitro* bioassay data from the CompTox Chemicals Dashboard was also used to prioritise CEC based on biological activity ([Alvarez *et al.* 2021](#); [Been *et al.* 2021](#); [Ekpe *et al.* 2025](#)). This was often done using exposure-activity ratios (EAR) based on the environmental concentration and activity concentration at cutoff (AAC) (i.e., defined *in vitro* response threshold) ([Blackwell *et al.* 2017](#)). The RQ approach is typically used to rank CEC for a particular location, so in an effort to identify CEC that posed a risk globally, [Yang *et al.* \(2022\)](#) developed a weighted average risk quotient (WARQ). Using 83 international case studies focusing on different water matrices, the study calculated the WARQ based on both risk intensity (i.e., RQ value grouped into four classes) and risk frequency (i.e., how often a compound had a RQ in a particular class). Fifty-three CEC were recommended for global risk management.

Other studies applied scoring systems to rank CEC, where numbers were assigned based on different criteria including removal efficiency, persistence, bioaccumulation, detected concentration, detection frequency, RQ and/or toxicity (e.g., [de Voogt *et al.* 2009](#); [Gros *et al.* 2017](#); [Deere *et al.* 2021](#); [Hartmann *et al.* 2021](#)). The scores were then summed to determine high priority CEC. For example, [Isaacs *et al.* \(2024\)](#) developed a scoring system for CEC in drinking water with 22 primary criteria covering environmental fate, occurrence in water and potential for release, as well as over 20 score adjustment factors, such as the potential for human exposure and detection frequency. This study developed an automated workflow, with much of the required data available in the CompTox Chemicals Dashboard and other public databases.

Another approach used to prioritise CEC is the Toxicological Priority Index (ToxPi), where a score is derived for a CEC based on toxicity parameters, such as *in vitro*, *in vivo* and/or *in silico* data, as well as other fate and occurrence data ([dos Santos & Nardocci 2019](#); [Zhao *et al.* 2023](#); [Ekpe *et al.* 2025](#)). However, the variables included in ToxPi differ between studies, and careful consideration is needed to optimize variables and their corresponding weighting for a particular prioritisation purpose. [Newmeyer *et al.* \(2024\)](#) used the Cheminformatics Hazard Comparison Module ([US EPA 2025a](#)) to

prioritise CEC in biosolids, with a hazard profile and score generated for each chemical based on both experimental toxicity data and QSAR toxicity predictions. [He *et al.* \(2023\)](#) developed the environmental health prioritization index (EHPI) method to rank CEC in wastewater effluent based on factors including detection frequency, detected concentration, toxicity and removal. Detection frequency and toxicity were assigned a higher weighting in the EHPI due to the relevance of these parameters to wastewater operators. [Penserini *et al.* \(2026\)](#) applied the Typology of Pollutants (TyPol) approach, which clusters CEC based on molecular descriptors, environmental parameters and toxicological parameters, to prioritise CEC in wastewater impacted surface water. The TyPol results were compared to the RQ approach for the same candidate list, with both approaches identifying estrogenic CEC as highest priority.

Other CEC prioritisation approaches

In addition to the approaches identified from the systematic review, several CEC prioritisation projects have been undertaken by research organisations, government and the water industry. For example, Technologiezentrum Wasser (TZW) in Germany completed a project called ‘Hot-Target’ to identify CEC in drinking water that were PMT and unlikely to be removed by ozonation or activated carbon. Of the over 10,000 substances screened, 89 were identified as ‘hot target substances’, with nine assigned the highest exposure and hazard categories (reviewed in [Rüdel *et al.* 2020](#)).

KWR in the Netherlands identifies priority drinking water relevant chemicals and tests the robustness of purification plants ([Puijker *et al.* 2016](#); [Baken *et al.* 2018](#); [Brunner *et al.* 2019](#); [Hoondert *et al.* 2024](#)). From a long-list of substances from, among other sources, RIWA databases and research reports, chemical candidates are prioritised based on exceedance of standard or target values, with further screening based on toxicity, removal during drinking water treatment, physico-chemical properties and practical considerations, like ability to analyse the chemical. Within the Waterwijs Joint Research Programme of Dutch and Flemish utilities, a workflow for detecting emerging chemical threats and assessing their urgency is being developed. The conceptual framework and available underlying tools were recently reported ([KWRW 2025](#)).

The ‘Decision-Making Framework for the Prioritization of Research into Constituents of Concern’ research project, supported by the Water Research Foundation (WRF) and Global Water Research Coalition (GWRC), used a Bayesian Network to help water utilities and other organisations prioritise CEC but does not in itself rank candidate lists of CEC ([Khan *et al.* 2019](#)). From a survey of the water industry, the project identified eleven criteria to be considered, including whether the contaminant is known or suspected to cause acute or chronic health risks and whether there are existing analytical techniques available with suitable limits of detection. Users score each criterion for each chemical, with uncertainty in the criteria scores and weighting of the importance of the criteria to the organisation considered in the final prioritisation. The approach presented in [Neale *et al.* \(2023\)](#) incorporates a module that provides scores to use in the Bayesian Network prioritisation tool.

The ‘Enhanced Source Control Framework for Industrial Contaminants in Potable Reuse’ research project, supported by WRF and California State Water Resources Control Board, focused on 262 industrial chemicals and identified priority contaminants for three conceptual advanced water treatment trains ([Nading *et al.* 2023](#)). An Industrial Contaminant Screening Score (ICSS) that considered both toxicity to human health and removal was used to prioritise the chemicals. The project also proposed an Industrial Contaminant Risk Quotient (ICRQ) using the ICSS and the detected chemical concentration, with specific actions triggered at ICRQ greater than 0.2 and greater than 1.

At the government level, the Minnesota Department of Health (US) has an initiative to prioritise CEC with no or limited human risk information that are present or likely to be present in drinking water in Minnesota ([Minnesota Department of Health 2025](#)). The review considers exposure, such as typical use and potential for release, and health-based guidance values inferred from available *in vivo* data. Members of the public can nominate a CEC for review. Minnesota Department of Health has recently partnered with US EPA to expedite the screening (outlined in [Isaacs *et al.* \(2024\)](#)).

LIMITATIONS AND OPPORTUNITIES

This systematic review has shown that there are many studies and projects that prioritise CEC but the majority of studies are limited to a particular matrix, like surface water or wastewater (e.g., [Choi *et al.* 2024](#); [Maloney *et al.* 2025](#)), though the approaches may be applicable to other matrices. This highlights the need for a CEC prioritisation protocol that covers the broader range of matrices relevant to the water industry. In particular, few studies have applied approaches to prioritise CEC in biosolids and recycled water, highlighting a major knowledge gap. Compared to water matrices, assessing CEC risk

in biosolids is challenging as it is necessary to predict the concentration in biosolids amended soils or the predicted daily intake from food, though there is guidance available on how to estimate these parameters (e.g., Huygens *et al.* 2022).

Most of the identified studies focused on a specific geographic region (e.g., Villa *et al.* 2020; Nikolopoulou *et al.* 2022), though many of the approaches could be transferred from one region to another. Some inputs, such as toxicity and fate parameters, would remain constant, while others, such as detected concentrations, detection frequency and chemical use data, would vary from location to location. Other factors to consider when transferring existing approaches include candidate list selection and analytical capabilities, as well as matrix type. Despite CEC being an issue for the water industry internationally, few studies have assessed risk at a global level. Yang *et al.* (2022) developed the WARQ approach to assess which CEC pose a risk globally, which was based on both risk intensity and frequency in 83 studies that prioritised CEC. Another option would be to develop a tool with international occurrence data, allowing users to select one or more countries of interest and calculate a RQ. This would provide users with a better understanding of the relative risk in their region, as well as indicating whether a particular CEC poses a high risk in many countries (i.e., a global relevant CEC) or whether it is only a risk in one location. In addition to the peer reviewed literature, there are several publicly available occurrence databases, such as UKWIR Chemical Investigations Programme, NORMAN EMPDAT Database and UBA 'Pharmaceuticals in the Environment' database, which could be used to populate such a tool.

CONCLUSIONS

This systematic review aimed to synthesise the various tools and approaches available to prioritise CEC in matrices relevant to the water industry. The available approaches varied greatly, ranging from a simple PBT assessment to scoring systems based on multiple variables and weightings. Availability of experimental data for CEC remains a challenge, with many approaches relying on predicted toxicity and environmental fate values from resources like EPISuite and the CompTox Chemicals Dashboard. Overall, a CEC prioritisation tool for the water industry should ideally cover all relevant matrices, include CEC from a range of chemical classes, as well as pathogens, and have the ability to be scaled to the global level. From this systematic review, it can be concluded that none of the existing, publicly available approaches fully meet these requirements, suggesting further work is required to develop a CEC prioritisation approach tailored to meet the needs of the water industry. Further, an important consideration for any CEC prioritisation tool is ensuring that it stays up to date with any newly identified CEC, such as new chemicals on the market or existing chemicals with new concerns about their risk, as well as capturing any new experimental toxicity, fate and occurrence data. It is essential to ensure that the tool remains relevant and is available to the global water industry to effectively prioritise and manage CEC.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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