Contaminants in floodwaters – Victoria 2022

Fate and transport of legacy and emerging contaminants and environmental DNA

Summary report | August 2025

EPA Victoria (Science Division) in collaboration with SES Victoria and Natural Hazards Research Australia

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Introduction

Background

The Environment Protection Authority Victoria (EPA) has taken a lead on identifying flood risks as a serious, ongoing and potentially growing concern. The results of this study form one part of a broader strategy in which the EPA is spearheading collaborations with partners and stakeholders to identify, understand and mitigate our future flood risks.

Key advice of EPA remains to avoid contact with floodwaters wherever possible. Remember that any flooded waterway might be carrying dangerous contaminants. The ongoing work of EPA and the findings of this report strongly support this advice.

What is the Flood Impacted Waterways study?

EPA, the Victoria State Emergency Service (VICSES), and Natural Hazards Research Australia are working together to better understand issues and concerns related to environmental contaminants during the major floods experienced by Victorians during October to December 2022. To better understand the presence and risk associated with flood-borne contaminants, EPA collected water and sediment samples from 21 lake and river system sites over 33 days during the major floods experience across Victoria (Figure 1). Samples were analysed for 780 anthropogenic and natural contaminants, including legacy contaminants (e.g. trace metals such as lead, per- and poly-fluoroalkyl substances ‘PFAS’) and emerging contaminants (e.g. pharmaceuticals, personal care products, endocrine disrupting chemicals ‘EDCs’). Two biotic indicators of human wastewater contamination (E. coli and environmental DNA ‘eDNA’) were also quantified, along with standard physiochemical water measurements (e.g. pH, EC, turbidity). The resulting dataset currently comprises over 40,000 measured values. It is the most comprehensive study of floodwaters and sediments ever undertaken globally.

Why is the study important?

Given the increased frequency of high magnitude floods in response to shifts in climate patterns, there is an increasing community interest in understanding the impacts of flooding beyond the immediate hydrological damage of the flood. Of particular concern is flood-induced mobilisation and distribution of contaminants: both emerging and legacy. This critical study enables EPA and its agency partners to better identify hazards and contaminant risks associated with flooding and to provide evidence-based advice to support community actions. These data will provide EPA with world-leading knowledge and insight into contaminant risks and necessary responses to major flood events.

What are the outcomes for EPA and VIC SES?

The data study has the following key outcomes:

- Unprecedented knowledge of the presence and risks of emerging contaminants to human health and the environment from flood events;
- World-leading state of knowledge on the presence of chemicals and compounds in floodwaters;
- Evidence-based decision making for flood-impacted communities that will guide future sampling campaigns and community advice;
- Improved understanding around future-targeted monitoring for contaminants during flooding, and on flood-impacted landscapes (floodplains, low lying land, high value water systems),

especially where food production occurs and bioaccumulation risks are present in domestic and native animals.

- In addition to this summary report, EPA has published the full study as an open access research article in a leading international science journal (https://pubs.acs.org/doi/10.1021/acs.est.4c03875).

Methods and approach

Sampling method and laboratory analysis

Site Selection: Sampling of naturally flooded water systems was opportunistic. Widespread flooding across Victoria in late 2022 allowed selection of urban, peri-urban, rural and remote locations during and after the flood event. The predominant focus was on impacted main river systems, but lakes were also sampled given they are important receiving environments. The wide variety of locations means the study data can be considered as characteristic of the Victorian landscape.

Methods: The methods for sample collection, handling, transport, storing, and quality assurance and control were consistent with EPA, national and international best practice and standards: EPA publication IWRG 701 (2009) and PFAS National Environmental Management Plan (NEMP 3) (2023). Emerging contaminants were determined using USEPA 8270, USEPA 537 and USEPA-821-R-11-007, Pesticide Analytical Manual (1999), AS4479, USEPA 3050, 200.7, 6010, 200.8 and 6020 methods at the Leeder Analytics (Melbourne) and ALS (Melbourne). The eDNA assessments were conducted by EnviroDNA (Melbourne).

Sites: The key study sites were in waterways that feed the Murray River system (15 sub-sites), Maribynong River (3 sub-sites) and the Snowy River (3 sub-sites) (Figure 1).

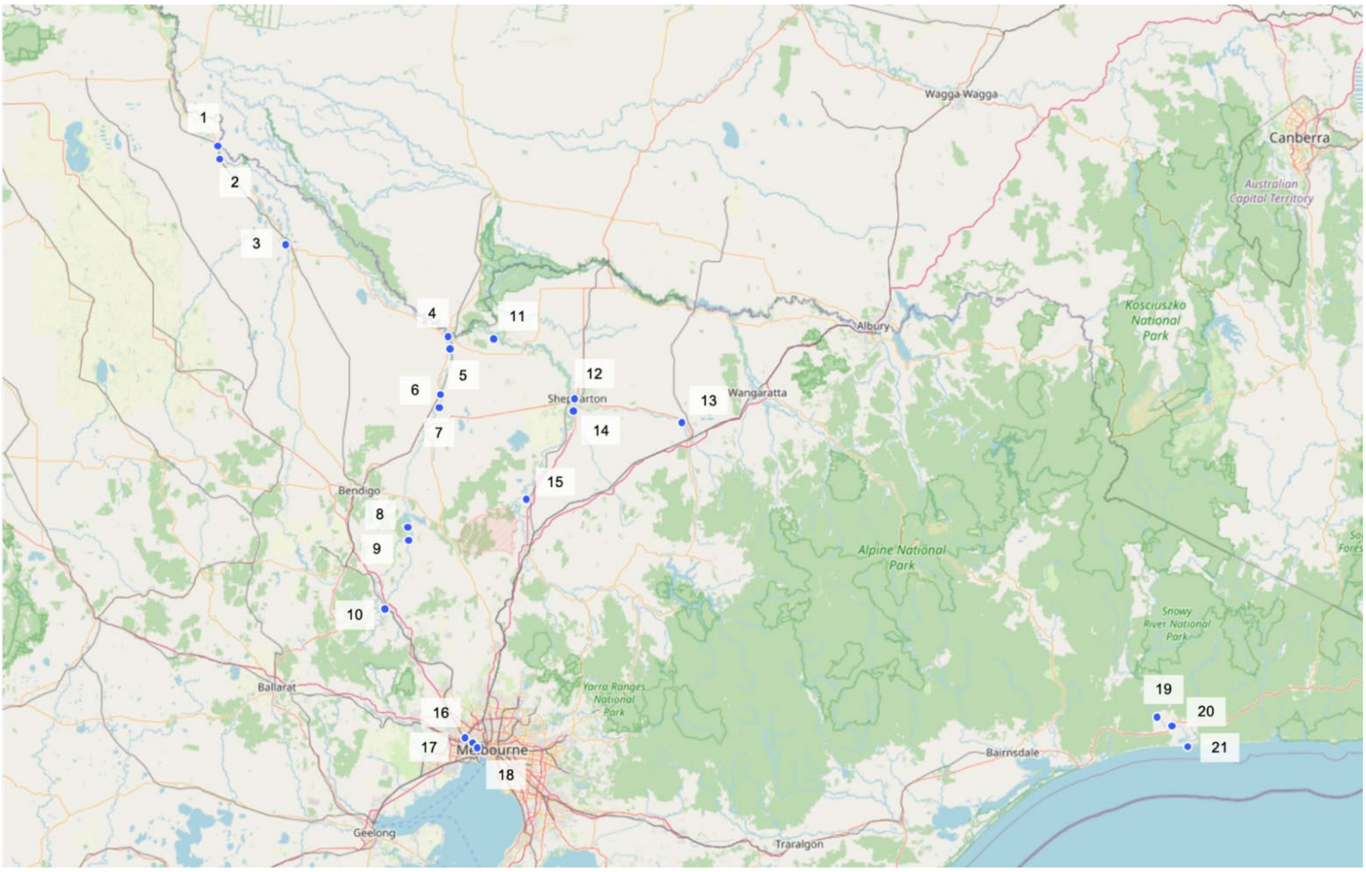


Figure 1. Blue points indicate sampling sub-sites located on waterways that feed into the Murray River Catchment (1-15), Maribynong River (16-19) and Snowy River (19-21). Map data copyrighted OpenStreetMap contributors and available from https://www.openstreetmap.org.

Results

Seventeen (of 21) sites are key focus sites, and were more heavily targeted for sampling. The sampling study encompassed both surface water (in river and lakes) and sediments (deposited on banks during the floods). However, as analysis and evaluation of sediments is still being finalised, this report is based on data from surface floodwaters only.

Of the 780 contaminants analysed, 81 were detected in water at focus sites (Table 1). The most commonly detected contaminants were fungicides (in 94.1% of sites), PFAS (in 94.1% of sites), a class of 'forever chemicals' used in various applications, phthalates, a class of compounds with known endocrine disrupting effects (18.988.2% of sites), and polycyclic aromatic hydrocarbon (PAHs), a class of naphthalene-based compounds with known toxic effects (82.4% of sites). The PFAS and phthalates data are examined in more detail below (see: Overview of Results), as these are contaminants of key concern.

Table 1. Summary of substances detected in water.

Group[1]	Substances detected	Min[2] (μgL^{-1})	Median (μgL^{-1})	Max (μgL^{-1})	Mean (μgL^{-1})	Sites (n)	Detections (n)	Percent Detects

EDC	1	<0.01	0.03	0.04	<0.01	17	5	29.4%
Fungicides	15	<0.01	0.01	0.30	<0.01	17	16	94.1%
Herbicides	8	<0.01	0.01	0.11	0.014	17	17	100.0%
Insecticides	3	<0.01	0.01	0.03	<0.01	17	12	70.6%
Metals	19	<0.05	1	76000	33.8	17	17	100.0%
PAHs	5	<0.01	0.01	0.84	0.014	17	14	82.4%
PFAS	6	<0.0002	0.0002	0.012	0.0002	17	16	94.1%
- PFOS	1	<0.0002	0.0004	0.0018	0.0004	17	16	94.1%
Phthalates	8	<0.01	0.01	1.8	0.014	17	15	88.2%
Pharmaceuticals	1	<0.005	0.003	0.050	0.003	17	4	23.5%
TPH (all lengths)	4	<1.0	1	760	22	17	17	100.0%

[1] EDC: Endocrine disrupting chemicals with known toxic and developmental effects. Fungicide: Agrichemicals for control of fungal pests. Herbicides: Agrichemicals for control of weeds. Insecticides: Agrichemicals for control of insect pests. Metals: Elemental metals (however note that this category includes naturally occurring metals such as calcium and sodium, as well as metals originating from human activities). PAHs: Naphthalene-based substances with known toxic effects. PFAS: Per-and polyfluoroalkyl substances: highly persistent and pervasive. Phthalates: Esters of phthalic acid with known endocrine disrupting effects. Pharmaceuticals: Pharmaceutical, antibiotic and personal care products. TPH: Total petroleum hydrocarbons: (C6-C36). [2] Values at or below the practical quantifiable limit are indicated by 'less than' notations. Note that one well-established contaminates group was detected but is not shown on the table (Anions; N and P compounds; 76% of sites).

Overview of Results

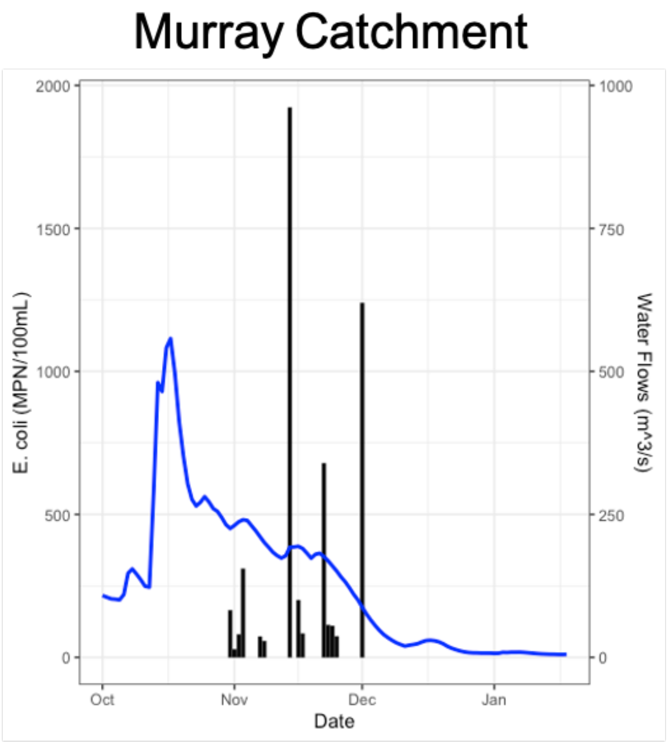
Where guidelines are available, only one synthetic compound (perfluoro-octane sulphonate 'PFOS') exceeded current human health or environmental guidelines. Overall, flood water concentrations tended to be quite low, even when compared with previous EPA data (e.g. https://www.epa.vic.gov.au/about-epa/publications/1879) for the same contaminants.

Relatively low concentrations of some contaminants in floodwaters are not surprising due to the effects of dilution. The substantial volume of water in the system has to be taken into account when considering flood contaminants. Although any given litre of floodwater might have relatively low concentrations of a particular contaminant, the total cumulative contaminant load from all litres of water in a flood can be quite high. Consequently, flood researchers recommend converting concentrations to a Mass Flux to account for hydrology and large flow volumes experienced during floods. Mass Flux is the total mass of a substance passing through a given point on a watercourse. This important data conversion step is ongoing and will be included in the final report to better characterise the impacts of floods.

Contaminants in Water: Contaminants were selected based on their potential to cause known harm to human health or the environment and/or their potential to become a contaminant of emerging concern. Emerging contaminants have the potential to cause known or suspected ecological and/or human health effects.

PFAS and phthalates are among the key contaminants of concern in this study. Overall, the levels observed were below guidelines, except for one class of PFAS. A total of 88% of PFOS samples exceeded its guideline (99% species protection; 0.00023 μgL^{-1}) with concentrations ranging from 0.0002 μgL^{-1} to 0.0018 μgL^{-1}. PFOS was above detection limits in 42 of 47 sites tested. Although no longer used in Australia, PFOS is very resistant to breaking down in the environment. It can originate, for example, from older landfill and industrial sites, in addition to its historical use as a fire-fighting retardant, especially near airports and military installations. For phthalates, the highest value was for di-iso-octyl phthalate (0.81 μgL^{-1}). The primary use of this phthalate is to keep plastics soft and more malleable. Any soft plastic can leech this (or similar) phthalates. This can include plastic tubing in agricultural settings, but also soft consumer plastics that enter the environment more generally. Even though this phthalate has no current guidelines, di-iso-octyl phthalate (DIOP) is known to cause foetal malformations, late-stage litter loss, and serious liver disease (in mice). Although levels detected were below what is likely to cause toxicity in humans, EPA's advice is to avoid ingesting flood water because of risks associated with contaminants like DIOP. There is emerging evidence that suggests phthalates are more severely toxic to aquatic life (invertebrates, fish, algae) when multiple phthalate species are combined. This remains a developing area of research, and a point of interest for EPA.

E. coli in water: E. coli is a bacterium that lives in the human gut. It is one of the most commonly used indicators for untreated or insufficiently treated sewage water entering environmental waters. Figure 2 shows simplified data presentations in which all water flows for samples in the broad Murray River catchment and lower Maribynong River have been averaged from Oct 2022 to Jan 2023 (blue line). This is plotted against averaged *E. coli* results for the same rivers in the same time period. Note that peaks in *E. coli* do not immediately follow the peak in waterflow. Instead, there is a lag of maximum risk. The data shows that *E. coli* exposure post-flood was evidently at its highest after peak flooding: a time when water levels were receding. This highlights the importance of EPA's standard public safety advice: please remember to stay out of flood waters, even if those waters are receding.



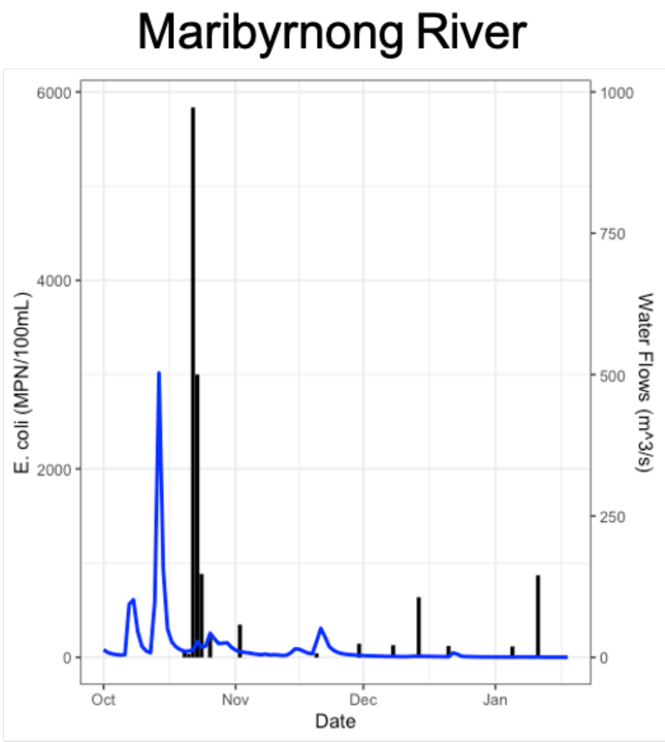


Figure 2. *E. coli* (black bars; Most Probable Number (MPN) per 100 mL) and water flows (m^3/s) from Oct 2022 to Jan 2023. Left: Combined from rivers in Murray River catchment. Right: Combined from urban Maribyrnong River sites (in greater Melbourne). Guidelines are that E. coli should not exceed 260 MPN/100mLin recreational water.

Environmental DNA (eDNA): Measurement of DNA directly from the environment presents a new and exciting opportunity to elevate EPA monitoring of microorganisms to world-leading standards, and beyond, moving EPA monitoring to new horizons. eDNA is an area that is in the midst of transitioning from being purely research focused, to having practical and important applications in the real world. Instead of culturing one or two bacterial species for identification, a whole suite of bacteria in a sample can be identified. This is important as some disease-causing bacteria are not easily cultured, and might be missed by traditional lab methods. Such data can potentially provide insight into a river's 'microbial health'. In the same way that human gut health benefits from a diversity of bacteria, a healthy river should have a similarly rich microbial flora. eDNA analysis has identified 163 bacterial families, 260 genera and 328 species. Order Bacteroidales, which is thought to be a highly reliable human sewage bioindicator was identified in 20 river samples in the Broken, Campaspe, Goulburn, Murray and Snowy Rivers. Other similar flood-linked trends in the data are also evident. For example, bacterial species that are potential pathogens (i.e. have the capacity to cause disease) were most diverse earlier in the sampling window, and declined from Nov 7 to Dec 1 2022, coinciding with moderate-to-declining flood waters. The eDNA results provide a different insight into possible disease risk, when compared to E. coli alone. It is plausible that the risk profile of E. coli specifically, is different to the broader risk profiles of pathogenic species more generally. Resolving the exact relationship between disease causing bacteria and flooding requires further investigation. Work will be needed to better understand the causal and environmental factors underlying these responses, but there are early indications that flooding might influence bacterial diversity. in water. Precisely how and why remains to be unravelled, but will be addressed in the final report.

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