

Bellarine Peninsula: Legacy and emerging contaminant sampling and analysis (2018–2019)



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Summary

In 2018, concerns about historical use of organochlorine pesticides (dieldrin) in the Bellarine Peninsula area and their effects on the health of local communities were expressed and reported in media together with potential cluster of cancers on the Bellarine Peninsula. The Chief Health Officer's (DHHS) review found no evidence of higher rates of cancer in any geographical areas within the Bellarine Peninsula. Despite this advice, community concern has continued.

This report by EPA provides an assessment of pesticides, PFAS, metals and selected industrial chemicals contaminant concentrations in surface soils in areas of the Bellarine Peninsula region and in water and sediments in the Barwon River catchment to further inform assessment of the potential risk for exposure to these environmental contaminants.

EPA found that all samples had contaminant concentrations below available health-based guidelines for soil and recreational water. Sediment contaminant concentrations were generally lower than those in soils, and while not directly comparable, were also below human-health guidelines for soils. Background concentrations of organochlorine insecticides, notably dieldrin, and all other analysed contaminants were below human health guideline values across the Bellarine Peninsula area. These results should reassure the community, as the analysis indicates that the risk of exposure to these contaminants of concern is low in this setting.

Background and aims

EPA is responsible for understanding and advising on potential human health risks and environmental impacts from exposure to legacy and emerging contaminants in the environment. In June 2018, EPA tested 19 Victorian wetlands and waterfowl for per- and polyfluorinated alkyl substances (PFAS). Results showed elevated perfluorooctane sulfonate (PFOS) + perfluorohexane sulfonate (PFHxS) concentrations in a few wetlands when compared against ecological guideline values (PFAS NEMP, 2018), and waterfowl breast and liver tissue exceeded consumption limits (FSANZ, 2017). EPA subsequently issued advice to hunters to limit consumption of waterfowl from Hospital Swamp and nearby areas (EPA 2019).

In 2018 there was also public concern in the Bellarine Peninsula area about a suggested link between organochlorine insecticides (dieldrin) and public health impacts (DHHS 2019). Various media reported a potential cluster of cancers on the Bellarine Peninsula related to historical use of dieldrin. Like other parts of Victoria, residential areas of the Bellarine Peninsula have previously been used for agriculture. Most organochlorines were banned in Victoria in the 1980s, however they are very resistant to degradation and so will persist at low levels for decades. Dieldrin is classified as probably carcinogenic to humans (Grade 2A), based on the most recent evaluation and review in 2016 of risk of cancer from environmental factors by World Health Organisation's International Agency for Research on Cancer (IARC). This classification is based on limited evidence for breast cancer in humans and sufficient evidence for liver cancer in experimental animals. The media coverage was based on speculation about high numbers of cancer cases and potential links with dieldrin on the Bellarine Peninsula, resulting in understandable concern in the local community. Victoria's Chief Health Officer initiated a review of cancer incidence rates. The report found no evidence of higher rates of cancer assessed in any geographical areas within the Bellarine Peninsula (DHHS 2019).



At a community forum in February 2019, EPA presented summaries of dieldrin concentrations from samples collected at sites across the Bellarine Peninsula through historical audits and EPA's emerging contaminants sampling program (Sardina et al 2019). Subsequently, EPA conducted additional sampling of surface soils in the Bellarine Peninsula as well as water, sediment and soil samples from the Barwon River catchment in June 2019. This sampling provided more data on the nature and extent of legacy (e.g. organochlorine insecticides) and emerging contaminants (e.g. PFAS). These results have allowed for a more comprehensive review of the concentrations and range of contaminants that were present in environmental samples in the Bellarine Peninsula area and has helped EPA to understand the potential for human exposure. The analysis in this report provides further evidence about environmental concentrations of key contaminants (most notably dieldrin) and the potential risk for human exposure to the chemicals targeted.

Sampling and analytical methods

EPA collected the most recent samples for water, sediment and soil on 6 and 7 June 2019. Sampling sites included four aquatic sites (water, sediment and soil) and four public areas (soil), shown in Figure 1.

The sampling design was to identify the type and spatial extent of the contaminants of concern (Table 1). The focus was on freshwater, sediment, and soil samples at locations representing different land-uses along the Barwon River and Bellarine Peninsula catchment.

Two soil (non-composite) samples were collected at each site for organochlorine analysis. An additional composite soil sample was collected at each site for emerging contaminant analysis. Soil samples from the top 10 cm were collected from unvegetated soil using a stainless-steel trowel. At the four aquatic sites, water and sediment samples were collected for organochlorine and emerging contaminant analysis. Water samples were collected from the edge at a depth of 5-10 cm below the surface. Sediment samples were collected from the top 2 cm of sediment in shallow water using the container lid.

Samples were analysed by the National Measurement Institute for a range of contaminants of concern (Table 1). Sample results for pesticides in water, sediment and soil from June 2019 are presented, as well as the results of previous EPA sampling in the Geelong region in April and June 2018 (Sardina et al 2019, unpublished data).

Table 1 – List of analytes measured

Pesticides	Industrial chemicals
<ul style="list-style-type: none"> Insecticides: Organochlorines, Organophosphates, Synthetic pyrethroids Herbicides: Glyphosate, Triazines, Urea Fungicides (various) 	<ul style="list-style-type: none"> Chlorinated hydrocarbons Per- and poly-fluorinated alkyl substances (PFAS) Phenols, ethers, amines nitroaromatics and nitrosamines Phthalate esters (e.g. dibutyl phthalate, diethylhexyl phthalate) Polybrominated diphenyl ethers (PBDEs) Polycyclic aromatic hydrocarbons (PAHs) Short chain chlorinated paraffins (SCCP)
<ul style="list-style-type: none"> Metals (totals) 	
<ul style="list-style-type: none"> Al, As, Ba, Be, B, Cd, Co, Cr, Cu, Hg, Li, Mn, Se, Mo, Ni, Pb, Sb, Sr, Sn, Th, Ti, V, Zn 	
<ul style="list-style-type: none"> Other 	
<ul style="list-style-type: none"> Total organic carbon 	



Figure 1 - Bellarine Peninsula sampling site map

Results were compared against a combination of:

- Australian guidelines for PFAS (PFAS NEMP 2018)
- Default aquatic ecosystem, drinking and recreational water quality guideline values and sediment quality guidelines for fresh and marine waters (ADWG, 2011; ANZG, 2018; SEPP Waters 2019; NHMRC, 2008)
- National Environmental Protection (Assessment of Site Contamination) Measures (NEP(ASC)M, 2013) for human health investigation levels (HILs).

Organic contaminants in sediments were normalised to 1% total organic carbon for comparison with guidelines (ANZG 2018). In the absence of Australian guidelines, PBDEs in sediment and soils were compared with Canadian Federal Environmental Quality Guidelines for PBDEs and SCCP (Environment Canada 2013, 2016) for protection of aquatic life.

Summary of Bellarine contaminant sampling (2018–2019)

Results

Several organic chemical groups, including pesticides and PFAS, in waters and/or sediments in the Barwon River catchment, and soils from the Bellarine Peninsula were detected (Table 2).

Table 2 – Summary of chemical groups detected in water, sediment and soils from sites and maximum analyte concentrations. HGV – health (human) guideline value; n/a – Not Applicable (no sample/no guideline value).

Chem group	Matrix	Max analyte	Max conc.	Max site	HGV
Pesticides	Water	Simazine – herbicide	0.41 µg/L	Upper Barwon R	3.2 µg/L
	Sed.	Dieldrin-insecticide	0.072 mg/kg	Upper Barwon R.	n/a
	Soil	Dieldrin-insecticide	0.04 mg/kg	Upper Barwon R.	6 mg/kg
PFAS	Water	PFOS	0.025 µg/L	Hospital Swamp	0.07 µg/L
	Sed.	PFOS	0.0089mg/kg	Lower Barwon R.	n/a
	Soil	PFOS	0.0091mg/kg	Reedy Lake	1 mg/kg
Metals	Water	Zinc	25 µg/L	Reedy Lake	n/a
	Sed.	Zinc	190 mg/kg	Lower Barwon R.	n/a
	Soil	Zinc	160 mg/kg	Lower Barwon R.	n/a
PBDEs	Sed.	BDE-99	5.5 ng/g	Lower Barwon R.	n/a
	Soil	BDE-209	4.4 ng/g	Lower Barwon R.	1 mg/kg
PAHs	Sed.	None	<0.1 mg/kg	n/a	n/a
	Soil	Fluoranthene and	1.2 mg/kg	Drysdale Reserve	*10 mg/kg
SCCP	Sed.	Total SCCPs C ₁₀ -C ₁₃	<0.1 µg/g	n/a	**1.8 mg/kg
	Soils	Total SCCPs C ₁₀ -C ₁₃	0.13 µg/g	Barwon River	n/a

*health investigation level (HIL) for total PAHs; ** Canadian guidelines for sediment

Chemical analyses detected low concentrations of:

- insecticides dieldrin and pp-DDE in sediment/soil and triazine herbicides atrazine and simazine in water (Appendix, Table 3)
- PFAS (PFOA, PFHxS and PFOS) in waters, sediments and soils (Appendix, Table 4)
- metals (all 23 detected except for thallium) in all matrices at all sites, with highest concentrations found in Reedy Lake (Appendix, Table 5)
- PAHs (fluoranthene and pyrene) were detected in one soil sample from Drysdale Reserve (both 1.2 mg/kg and well below the Health Investigation Level of 10 mg/kg for sum of PAHs) (Table 2)
- PBDEs (most notably the congeners pentaBDE – BDE-99 and 100) in sediment/soil in Lower Barwon River (Appendix, Table 6)
- SCCPs (C₁₀-C₁₃ as total SCCPs) in one Barwon River soil sample (0.13 µg/g); all other sites below reporting limits (<0.1 µg/g), below recommended Canadian guidelines of 1.8 mg/kg for sediment with concentrations normalised to 1% organic carbon (Environment and Climate Change Canada 2016) (Table 2).

No compounds from the following chemicals groups were detected in any sample:

- fungicides
- herbicides (e.g. glyphosate), other than triazines
- organophosphate, synthetic pyrethroid or carbamate insecticides
- phenols, phthalates, ethers, chlorinated hydrocarbons, amines, nitroaromatics and nitroamines.

Rinsate blank and bottle blank samples showed no contamination, and duplicate samples indicated acceptable quality control limits.

Summary of Bellarine contaminant sampling (2018–2019)

All chemicals were below human-health investigation levels (HILs) in soils and recreational water quality guidelines in waters (NHMRC, 2008). There were some chemicals (such as PFAS) which exceeded default guideline values for ecological protection. The concentrations of all the detected compounds are listed in the Appendix, Tables 3 – 6 (see below).

All pesticide concentrations were below human-health guidelines in waters, sediments and soils. Pesticides in water samples were below the 95% level of species protection for freshwater ecosystems (Table 2). Concentrations of two organochlorine insecticides (dieldrin and p'p-DDE; adjusted to 1% organic carbon) exceeded the sediment quality guideline values (SQGV) for ecosystem protection.

Thirteen PFAS congeners were detected (Appendix, Table 4). Only PFOA, PFHxS and PFOS currently have accepted Australian guidelines (PFAS NEMP, 2018). Concentrations in soils and sediments at Lower Barwon River and Reedy Lake had detectable concentrations of PFOA (<0.001 to 0.066 mg/kg) and PFOS (0.0029 to 0.0091 mg/kg). PFAS was not detected in sediments or soils at other sites. PFHxS was not detected in any samples. Water samples at all sites exceeded the ecological 99% level of species protection default guideline value applied for PFOS bioaccumulation (0.00023 µg/L).

Metals concentrations in waters were generally below ecological guidelines for all metals, except cadmium (0.11 µg/L) in Reedy Lake, copper (2.1 to 2.9 µg/L) at all sites, and zinc (11 and 25 µg/L, respectively) in Lower Barwon River and Reedy Lake. Metals concentrations in sediments exceeded ecological guidelines for arsenic, lead, mercury and nickel, but were below the human-health guidelines (Appendix, Table 5). Soil metal concentrations were all less than ecological guidelines except for manganese and zinc and all were well below human-health guidelines (Appendix, Table 5).

Concentrations of PBDEs in soils and sediment were detected at two sites, with low concentrations in Upper Barwon River sediment and higher concentrations in Lower Barwon River sediment and soil samples (Appendix, Table 6). These PBDEs from the Lower Barwon had a sum of 13.98 ng/g. Concentrations in soils were well below NEPM Health Investigation Levels (HILs) of 1 mg/kg. For PBDEs in sediments, only pentaBDE 99 exceeded the Environment Canada guidelines (2013).

Discussion

EPA's sampling results showed that dieldrin and PFAS concentrations in the Barwon River catchment and the Bellarine Peninsula present a low risk to humans, with all water concentrations below drinking and recreational water quality guidelines, and all soil concentrations below HIL A (Residential) and HIL C (Recreational, Public Open Space) (Appendix, Tables 3 – 6).

The health-based investigation levels used nationally for residential use of soil (HIL A)_take into account the most sensitive scenario for risk assessment purposes, using conservative assumptions whereby exposure is prolonged and children may be more highly exposed through daily incidental ingestion of soil and dust. For reference, exceedance of HILs does not necessarily imply that a site is unsafe, but does indicate that further investigation may be warranted.

The highest concentrations of chemicals were detected in aquatic sites Upper Barwon River for (pesticides in water, sediment and soil) and Lower Barwon River (PFAS in sediments) exceeding ecosystem protection levels. Each chemical group is discussed below in further detail.

Metals

Metal concentrations in soils were below human-health guidelines. Several metals (Cd, Cu, Zn) exceeded default guideline values (DGVs) for ecosystem protection in waters at all sites, suggesting potential impacts to aquatic biota. Measurements for metals are based on total concentrations (rather than just the soluble and more readily bioavailable sub-component), which can overestimate toxicity if compared directly with water quality guidelines. As such, comparisons to these guidelines should be taken as a worst-case scenario (Appendix, Table 5). Arsenic is normally naturally elevated in coastal sediments and alluvial soils in Port Phillip Bay and any accumulation in biota has previously been found in non-toxic organic forms (Harris et al 1996). There are likely to be multiple industry and urban sources of metals in the Lower Barwon River and Reedy Lake sediments. Concentrations of arsenic, lead, mercury and nickel in the Lower Barwon River and Reedy Lake slightly exceeded sediment quality guideline value (SQGVs) (Table 4; ANZG 2018). Potential impacts to sediment-ingesting biota from elevated metals (arsenic, lead and nickel) are unlikely to impair tolerant organisms, however concentrations could possibly impact other sensitive species in high-diversity ecosystems such as the Lake Connewarre wildlife reserve downstream of Reedy Lake and Hospital Swamp.

Pesticides

Concentrations of pesticides currently registered for use were low. While residues of legacy organochlorine (OC) insecticides (dieldrin and p,p'-DDE) remain present bound to sediments, concentrations were not detected in the water. Despite being banned or restricted for several decades, residual OCs are still detected in the environment. Concentrations of OC insecticides (dieldrin and p,p'-DDE; adjusted to 1% organic carbon) exceeded (SQGV) but were less than the SQG-High, suggesting concentrations of the legacy organochlorine insecticides measured in the Upper Barwon River may have potential impacts on sediment-ingesting and benthic organisms (ANZG 2018). It is recognised that these chemicals are toxic and have bioaccumulative potential. Waterfowl tissue concentrations in composite samples tested during an earlier program from Reedy Lake, however, detected the OC insecticide dieldrin in livers, at concentrations (0.018 mg/kg) substantially below the food residue limits for poultry of 0.2 mg/kg of dieldrin relevant to human consumption (FSANZ, 2017).

PFAS

PFOS exceeded current guideline values for 99% level of aquatic species protection but was below 95% level of species protection DGVs in all water samples, and was below human-health guidelines in all soils (Appendix, Table 4). There are potential impacts from PFOS to the environment via bioaccumulation and biomagnification (with potential exposure for humans via consumption) through the food web. Waterfowl were last collected downstream in the Barwon River catchment in Hospital Swamp and Reedy Lake in June 2018. Concentrations of PFOS + PFHxS in waterfowl at Hospital Swamp exceeded trigger points for investigation of meat and offal and EPA advised limiting human consumption (EPA 2019, publication 1734).

PBDEs

Concentrations of PBDEs at most sites were lower or not detected in sediments or soils (except in the Lower Barwon River) compared with sediments sampled by EPA in 2018 (Sardina et al, 2019). Concentrations were low in background and residential areas in Melbourne, Ballarat and Geelong (ranging from less than the Limit of Reporting (LOR) to 1.5 ng/g). PBDE concentrations in the Geelong industrial location (Cowies Creek, 0.22 ng/g) was lower than concentrations in industrial sediments from Ballarat (29 ng/g) and Melbourne (33 ng/g) (Table 5; Sardina et al, 2019). Industrial sites are a key source of PBDEs (Sardina et al, 2019), especially waste facilities and electronics recycling (McGrath et al, 2018). Biosolids from sewage waste are also a potential source of PBDEs from agriculture (Clarke and Smith 2011). In the Lower Barwon River, BDE-99 slightly exceeded the Canadian sediment quality guidelines (Environment Canada, 2013), which are derived from fish tissue guidelines and biota-sediment accumulation factors. Environment Canada (2013) suggest concentrations of this BDE congener have potential to bioaccumulate in benthic organisms, although bioaccumulation in higher consumers is unlikely to be high with a concentration of 1.1 ng/g (adjusted to 1% total organic carbon) compared against the guideline of 0.4 ng/g (adjusted to 1% total organic carbon) (Appendix, Table 6).

Conclusions

Based on the analysis of sediments, soils and waters in June 2019, EPA has not identified human exposure risks in the Barwon River catchment and Bellarine Peninsula area from legacy organochlorine pesticides such as dieldrin, current use pesticides, metals, PFAS or PBDEs or other compounds tested. Sampled contaminants were below available health-based guidelines for soil and recreational water. Sediment concentrations were generally lower than in soils, and while not directly comparable were below respective human-health guidelines for soils. Background concentrations of organochlorine pesticides, notably dieldrin, were low across the Bellarine Peninsula area.

Contaminants detected in this study were comparable with earlier sampling in 2018 from other waterways across Victoria (including the Barwon River and its surroundings), with similar concentrations (Sardina et al, 2019). Compared with mean and maximum concentrations measured in 2018, concentrations of chemicals detected in this study were relatively comparable, with generally slightly lower concentrations in waters for some of the herbicides and PFAS, and slightly higher concentrations in sediments and/or soils for some PFAS, insecticides and PBDEs. This sampling included a substantial number of contaminants, which can serve as a guide for future sampling in the Bellarine to limit analysis to those previously detected chemicals along with other emerging contaminants with potential for health or ecosystem effects. Future sampling efforts should consider ecosystem effects and bioavailable concentrations.

Overall, this analysis shows that the human health risk from exposure to the contaminants measured is low. No chemical concentrations exceeded the recreational water quality guidelines, indicating that waters are suitable for recreational uses such as rowing and kayaking. Ecosystem protection standards are typically much lower than human health standards because of constant exposure to organisms like fish. Periodic monitoring to evaluate temporal changes and assess new and emerging contaminants, sources and fate and their potential for impacts remain important to consider for future sampling.

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Appendix

Table 3. Summary of pesticide compounds detected in Bellarine Peninsula samples (April 18 and June 2019) compared with guidelines.....	Page 10
Table 4. Summary of PFAS compounds (PFHxS, PFOS and PFOS) detected in Bellarine Peninsula samples (June 2019) compared with current guidelines.....	Page 11
Table 5. Summary of metals detected in Bellarine Peninsula samples (June 2019) compared with guidelines.....	Page 12
Table 6. Summary of key PBDEs congeners detected in Bellarine Peninsula samples (June 2019) compared with guidelines.	Page 13

Summary of Bellarine contaminant sampling (2018–2019)

Table 3. Summary of pesticide compounds detected in Bellarine Peninsula samples (April 18 and June 2019) compared with guidelines.

	MATRIX	WATER				SEDIMENT					SOIL					
	ANALYTE	Atrazine	Simazine	Dieldrin	pp-DDE	Atrazine	Simazine	Dieldrin	pp-DDE	TOC	Atrazine	Simazine	Dieldrin	pp-DDE	TOC	
	LOR	<0.1	<0.1	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<0.01	
UNITS	µg/L	µg/L	µg/L	µg/L	mg/kg	mg/kg	mg/kg	mg/kg	%TOC	mg/kg	mg/kg	mg/kg	mg/kg	%TOC		
Drinking water standard ^a	WATER	20	20	0.3*	9 (DDT)	-	-	-	-	-	-	-	-	-	-	
Recreational water quality ^u		200	200	3	90	-	-	-	-	-	-	-	-	-	-	
Ecological 99% protection ^u		0.7	0.2	-	-	-	-	-	-	-	-	-	-	-	-	
Ecological 95% protection ^u		13	3.2	-	-	-	-	-	-	-	-	-	-	-	-	
Ecological 90% protection ^u		45	11	-	-	-	-	-	-	-	-	-	-	-	-	
Ecological ULS protection ^u		-	-	0.01	0.03	-	-	-	-	-	-	-	-	-	-	
Sediment Default Guideline Value ^u	SED	-	-	-	-	-	-	2.8 µg/OC	1.4 µg/OC	-	-	-	-	-	-	
Sediment Guideline Value-High ^u		-	-	-	-	-	-	7.0 µg/kgOC	7.0 µg/kgOC	-	-	-	-	-	-	
NEPM HILs (Rec. C - Public Open Space) ^u	SOIL	-	-	-	-	-	-	-	-	-	400	-	10*	400**	-	
NEPM HILs (Residential A) ^u		-	-	-	-	-	-	-	-	-	320	-	6*	240**	-	
NEPM EILs (Conservation Areas) ^u		-	-	-	-	-	-	-	-	-	-	-	-	3 †	-	
	MAX	0.13	0.41	<0.01	<0.01	<0.001	<0.001	0.072	0.024	5.9	<0.001	<0.001	0.04	<0.01	30.3	
SITE	AREA	DATE	Atrazine	Simazine	Dieldrin	pp-DDE	Atrazine	Simazine	Dieldrin	pp-DDE	TOC	Atrazine	Simazine	Dieldrin ‡	pp-DDE	TOC
Upper Barwon River	Central Foothills and Coastal Plains (Slightly to moderately modified)	June 2019	0.13	0.41	<0.01	<0.01	<0.1	<0.1	0.072mg/kg 60µg/kgOC	0.024mg/kg 20µg/kgOC	1.2	<0.1	<0.1	0.04	<0.01	5.0
Moorabool River		April 2018	<0.1	<0.1	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	4.0	<0.1	<0.1	<0.01	<0.01	6.1
Cowies Creek		April 2018	<0.1	0.11	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	-	<0.1	<0.1	<0.01	<0.01	-
Lower Barwon River		June 2019	<0.1	0.22	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	5.1	<0.1	<0.1	<0.01	<0.01	5.2
St Augustines Lagoon	Riverine wetland (Slightly to moderately modified)	April 2018	<0.1	<0.1	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	1.8	<0.1	<0.1	<0.01	<0.01	3.9
Reedy Lake		June 2019	<0.1	0.12	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	5.9	<0.1	<0.1	<0.01	<0.01	30.3
		June 2018	Trace	<0.1	<0.01	<0.01	<0.1	<0.1	<0.01	Trace	-	<0.1	<0.1	<0.01	<0.01	-
Hospital Swamp		June 2019	<0.1	<0.1	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	1.1	<0.1	<0.1	<0.01	<0.01	5.4
		June 2018	<0.1	<0.1	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	-	<0.1	<0.1	<0.01	<0.01	-
Drysale Rec Reserve	Public Open Space	June 2019									<0.1	<0.1	<0.01	<0.01	11.0	
Ocean Grove Community Reserve												<0.1	<0.1	<0.01	<0.01	8.7
Barwon Heads Community Reserve												<0.1	<0.1	0.01	<0.01	3.6
Wallington Reserve												<0.1	<0.1	0.01	<0.01	6.4

Notes:

Guidelines: a, b Australian Government Department of Health, 2017; c NEP(ASC)M 2013; d ANZG 2018

*Sum of Dieldrin + Aldrin; ** HIL for DDT + DDE + DDD; † EIL for DDT used in absence of other guidelines; ‡ GeoMean (including LOR) for Dieldrin (3 replicates)

Maximum concentration in bold (for each chemical); Half LOR of either PFHxS or PFOS used to calculate Sum shown in grey

Trace = detected between LOR and LOD; <LOR = not detected

Grey shading - no sample for that matrix

Summary of Bellarine contaminant sampling (2018–2019)

Table 4. Summary of PFAS compounds (PFHxS, PFOS and PFOA) detected in Bellarine Peninsula samples (June 2019) compared with current guidelines.

			WATER				SEDIMENT				SOIL				
			ANALYTE	PFOA	PFHxS	PFOS	PFOS + PFHxS	PFOA	PFHxS	PFOS	PFOS + PFHxS	PFOA	PFHxS	PFOS	PFOS + PFHxS
GUIDELINES			LOR	<0.001	<0.001	<0.002	<0.002	<0.001	<0.001	<0.002	<0.002	<0.001	<0.001	<0.002	<0.002
			UNITS	µg/L				mg/kg				mg/kg			
Drinking water standard ^a				0.56	0.07	0.07	0.07	-	-	-	-	-	-	-	-
Recreational water quality ^b				5.6	2	2	2	-	-	-	-	-	-	-	-
Ecological 99% protection ^c			WATER	19	-	0.00023	-	-	-	-	-	-	-	-	-
Ecological 95% protection ^c				220	-	0.13	-	-	-	-	-	-	-	-	-
Ecological 90% protection ^c				632	-	2	-	-	-	-	-	-	-	-	-
NEMP HILs (Public Open Space) ^c			SOIL	-	-	-	-	-	-	-	-	10	-	1	1
NEMP Interim Soil –Eco. indirect exposure) ^c				-	-	-	-	-	-	-	-	-	-	0.01	-
MAX				0.0043	0.0058	0.025	0.0255	0.0026	<0.001	0.0089	0.0094	0.0066	<0.001	0.0091	0.0096
SITE	AREA	DATE	PFOA	PFHxS	PFOS	PFOS + PFHxS	PFOA	PFHxS	PFOS	PFOS + PFHxS	PFOA	PFHxS	PFOS	PFOS + PFHxS	
Upper Barwon River	Central Foothills and Coastal Plains (Slightly to moderately modified)	June 2019	0.0043	0.0055	0.0048	0.0053	<0.001	<0.001	<0.002	<0.002	<0.001	<0.001	<0.002	<0.002	
Lower Barwon River		June 2019	0.0036	0.0034	0.0060	0.0065	0.0026	<0.001	0.0089	0.0094	0.0066	<0.001	0.0029	0.0034	
Reedy Lake	Riverine wetland (Slightly to moderately modified)	June 2019	0.0024	0.0058	0.0049	0.0054	<0.001	<0.001	0.0044	0.0049	0.0013	<0.001	0.0091	0.0096	
Hospital Swamp		June 2019	0.0032	0.0048	0.0250	0.0255	<0.001	<0.001	<0.002	<0.002	<0.001	<0.001	<0.002	<0.002	
Drysale Rec Reserve	Public Open Space	June 2019									<0.001	<0.001	<0.002	<0.002	
Ocean Grove Community Reserve		June 2019									<0.001	<0.001	<0.002	<0.002	
Barwon Heads Community Reserve		June 2019									<0.001	<0.001	<0.002	<0.002	
Wallington Reserve		June 2019									<0.001	<0.001	<0.002	<0.002	

Notes:

Guidelines: a, b Australian Government Department of Health, 2017; c HEPA 2018

Half LOR of either PFHxS or PFOS used to calculate Sum shown in grey <LOR = not detected

Maximum concentration in bold (for each PFAS congener for each matrix)

Grey shading - no sample for that matrix

Summary of Bellarine contaminant sampling (2018–2019)

Table 5. Summary of metals detected in Bellarine Peninsula samples (June 2019) compared with guidelines.

	MATRIX	WATER											SEDIMENT										SOIL																		
	ANALYTE	As	B	Cd	Cr _{total}	Cu	Pb	Mn	Hg	Ni	Ag	Zn	Sb	As	Cd	Cr _{total}	Cu	Pb	Hg	Ni	Ag	Zn	TOC	As	B	Cd	Cr _{total}	Cu	Pb	Mn	Hg	Ni	Ag	Zn	TOC						
	LOR	<1	<1	<0.1	<1	<1	<1	<1	<0.1	<1	<1	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.2	<0.5	<0.5	<0.5	<0.01	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.2	<0.5	<0.5	<0.5	<0.5	<0.01						
	UNITS	µg/L											mg/kg										mg/kg																		
GUIDELINES																																									
Drinking water standard ^a		10	4000	2	50'	2000	10	500	1	20	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-					
Recreational water quality ^b		100	8000	20	500'	4000	100	5000	10	200	1000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Ecological 99% protection ^d	WATER	0.8'	90	0.06	0.01'	1	1	1200	0.06'	8	0.02	2.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Ecological 95% protection ^d		13'	370	0.2	0.4'	1.4	3.4	1900	0.6'	11	0.05	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Ecological ULS protection ^d		-	-	-	3.3^	0.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Sediment Quality Guideline Value ^d	SED	-	-	-	-	-	-	-	-	-	-	-	2	20	1.5	80	65	50	0.15	21	1	200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Sediment Quality Guideline - High ^d		-	-	-	-	-	-	-	-	-	-	-	25	70	10	370	270	220	1	52	3.7	410	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NEPM HILs (Rec. C - Public Open Space) ^c		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	300	20000	90	300	17000	600	19000	80	1200	-	30000	-						
NEPM HILs (Residential A) ^c	SOIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	4500	20	100	6000	300	3800	40	400	-	7400	-						
NEPM EILs (Urban Res/Public Open Space) ^c		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50+	-	-	630^	85	270+	220	-	30	-	130	-						
	MAX	13	350	0.11	1.9	2.9	1.4	530	0	9.5	-	25	1.4	38	0	33	32	62	0.55	28	0	190	5.9	48	28	<0.5	21	24	59	810	0.2	53	0	160	30.3						
SITE	AREA	DATE	As	B	Cd	Cr _{total}	Cu	Pb	Mn	Hg	Ni	Ag	Zn	Sb	As	Cd	Cr _{total}	Cu	Pb	Hg	Ni	Ag	Zn	TOC	As	B	Cd	Cr _{total}	Cu	Pb	Mn	Hg	Ni	Ag	Zn	TOC					
Upper Barwon River	Central Foothills and Coastal Plains (Slightly to moderately modified)	June 2019	13	90	<0.1	<1	2.2	<1	25	<0.1	3.3	NS	5.4	0.69	12	<0.5	9.2	28	6.7	<0.2	5.2	NS	33	1.2	39	4.7	<0.5	21	13	12	490	0.2	16	NS	66	5.1					
Lower Barwon River		June 2019	9.4	93	<0.1	1.9	2.7	1.3	34	<0.1	3.3	NS	11	1	37	<0.5	33	32	51	0.27	28	NS	190	5.1	15	5.7	<0.5	19	21	21	230	<0.2	37	NS	160	5.2					
Reedy Lake	Riverine wetland (Slightly to moderately modified)	June 2019	6.7	350	0.11	<1	2.9	1.4	530	<0.1	9.5	NS	25	1.4	38	<0.5	32	23	62	0.55	20	NS	49	5.9	48	28	<0.5	17	14	59	810	<0.2	17	NS	53	30.3					
Hospital Swamp		June 2019	5.2	270	<0.1	<1	2.1	<1	180	<0.1	3.4	NS	3.3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.1	12	27	<0.5	21	12	20	220	<0.2	29	NS	38	5.4					
Drysale Rec Reserve	Public Open Space	June 2019																							3.3	5.3	<0.5	16	24	15	310	<0.2	53	NS	80	11.0					
Ocean Grove Community Reserve		June 2019																							36	1.7	<0.5	13	4.3	6.4	83	<0.2	8.9	NS	37	8.7					
Barwon Heads Community Reserve		June 2019																							9.2	8.4	<0.5	18	4.6	6.7	110	<0.2	11	NS	11	3.6					
Wallington Reserve		June 2019																							17	3.2	<0.5	21	11	14	140	<0.2	23	NS	31	6.3					

Notes:

Guidelines: a, b Australian Government Department of Health, 2019; c NEP(ASC)M 2013; d ANZG 2018; e NEP(ASC)M 2013

<LOR = not detected; NS = not sampled or analysed; Total Metals Unadjusted for bioavailability

Maximum concentration in bold (for each chemical)

Half LOR of either PFHxS or PFOS used to calculate Sum shown in grey

Grey shading - no sample for that matrix

Metals were only analysed for total metals; where Guidelines for Total Metal were unavailable ' = As (V); Cr(VI), Hg(inorganic); ^ for As (III); Cr(III)

Sediment Quality Guidelines: Total metals (no speciation or bioavailability)

Soil Quality Guidelines: *assumes fresh contamination (NEP(ASC)M EILs)

Summary of Bellarine contaminant sampling (2018–2019)

Table 6. Summary of key PBDEs congeners detected in Bellarine Peninsula samples (June 2019) compared with guidelines.

		MATRIX	SEDIMENT								SOIL							
			ANALYTE	triBDE (BDE-28+33)	tetraBDE (BDE-47)	pentaBDE (BDE-99)	pentaBDE (BDE-100)	hexaBDE (BDE-153)	decaBDE (BDE-209)	ΣPBDEs*	TOC	triBDE (BDE-28+33)	tetraBDE (BDE-47)	pentaBDE (BDE-99)	pentaBDE (BDE-100)	hexaBDE (BDE-153)	decaBDE (BDE-209)	ΣPBDEs*
GUIDELINES		LOR	<0.002	<0.02	<0.01	<0.004	<0.001	<0.2	Variable†	<0.1	<0.002	<0.02	<0.01	<0.004	<0.001	<0.4	Variable†	<0.1
		UNITS	ng/g								ng/g							
NEMP HILs (Public Open Space) ^a		SOIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2 mg/kg	-
NEPM HILs (Res. A) ^a		SOIL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1 mg/kg	-
**Environment Canada FSeQG ^b		SED	44	39	0.4	0.4	440	19	-	-	-	-	-	-	-	-	-	-
		MAX	0.046	2.9	5.5	1.1	0.84	0	13.98	5.9	<0.01	0.54	0.85	0.17	0	4.4	7.7	30.3
SITE	AREA	DATE	BDE-28+33	BDE-47	BDE-99	BDE-100	BDE-153	BDE-209	ΣPBDEs*	TOC	BDE-28+33	BDE-47	BDE-99	BDE-100	BDE-153	BDE-209	ΣPBDEs*	TOC
Upper Barwon River	Central Foothills and Coastal Plains (Slightly to moderately modified)	June 2019	<0.02†	<0.06†	<0.04†	0.019	<0.001	<0.5	0.2	1.2	-	-	-	-	-	-	-	5.1
Lower Barwon River		June 2019	0.046	2.9	5.5	1.1	0.84	<2†	13.98	5.1	<0.01†	0.54	0.85	0.17	<0.006†	4.4	7.7	5.2
Reedy Lake	Riverine wetland (slightly to moderately modified)	June 2019	<0.02†	<0.06†	<0.04†	<0.04	<0.004†	<0.5	<0.9†	5.9	-	-	-	-	-	-	-	30.3
Hospital Swamp		June 2019	<0.004	<0.02	<0.02	<0.04	<0.002	<0.6	<0.9†	1.1	<0.002	<0.02	<0.01	<0.004	<0.002	<0.4	0	5.4
Drysale Rec Reserve	Public Open Space	June 2019																
Ocean Grove Community Reserve		June 2019																
Barwon Heads Community Reserve		June 2019																
Wallington Reserve		June 2019																

Notes:

Guidelines: a NEP(ASC)M 2013; b Environment Canada Federal Sediment Quality Guidelines (FSeQG) 2013

Half LOR of either PFHxS or PFOS used to calculate Sum shown in grey

<LOR = not detected

*ΣPBDE - Sum of BDE congeners excluding decaBDEs and LOD values

TOC - Total Organic Carbon

**Values normalized to 1% organic carbon

†LOD raised more than 2x (LODs based on corrected labelled surrogate recoveries)

Maximum concentration in bold (for each PFAS congener for each matrix)

Grey shading - no sample for that matrix