Australian Government
Department of Health, Disability and Ageing
Australian Industrial Chemicals Introduction Scheme

Zinc and zinc manufacturing byproducts

Evaluation statement (EVA00177)

16 December 2025

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Subject of the evaluation

Zinc and zinc manufacturing byproducts

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Reason for the evaluation

An evaluation or assessment recommended further evaluation of specific issues related to the chemical(s).

Parameters of evaluation

In 2024, AICIS completed an evaluation of the environmental fate and effects of zinc ions, which may be released into the environment from the industrial uses of zinc containing substances in Australia (AICIS 2024a). Elevated levels of zinc above national guideline values were detected in some areas in Australia. The manufacture of zinc metal was identified as an industrial use of chemicals that may contribute to these elevated levels.

The primary manufacture of zinc is through the refining of zinc containing mineral concentrates. This evaluation considers the environmental risks associated with zinc and zinc-containing substances that are emitted from industrial facilities that refine zinc concentrate into zinc metal.

Emissions from zinc ore mining activities, secondary zinc processing facilities, such as those recycling zinc scrap, and historical contamination are not considered in this evaluation.

Summary of evaluation

Summary of introduction, use and end use

The primary manufacture of zinc metal in Australia occurs at 2 facilities: Townsville in Queensland, and Hobart in Tasmania. Manufacture of zinc oxide (calcine), that is used to produce zinc metal, is manufactured at a facility in Port Pirie, South Australia. Based on National Pollutant Inventory (NPI) data and environmental monitoring data, these 3 facilities are major point sources of zinc emissions to the Australian environment. Chemicals in this group are products or byproducts of the primary manufacture of elemental zinc via refining of zinc concentrates.

Zinc metal is listed on the 2006 Australian High Volume Industrial Chemicals List (HVICL) with a total reported introduction of 100,000–999,999 tonnes per annum.

Environment

Summary of environmental hazard characteristics

Although zinc is an essential trace element for all living organisms, excessive environmental zinc concentrations are of concern as they can overwhelm homeostasis and result in adverse effects on aquatic and terrestrial life.

It is not currently possible to categorise the environmental hazards of metals and other inorganic chemicals according to standard persistence, bioaccumulation and toxicity (PBT) hazard criteria.

Environmental hazard classification

These chemicals satisfy the criteria for classification according to the Globally Harmonised System of Classification and Labelling of Chemicals (GHS) for environmental hazards. The evaluation does not consider classification of physical hazards and health hazards:

Environmental Hazard	Hazard Category	Hazard Statement
Acute Aquatic	Acute aq. – Cat. 1	H400: Very toxic to aquatic life
Chronic Aquatic	Chronic aq. – Cat. 1	H410: Very toxic to aquatic life with long lasting effects

Summary of environmental risk

The primary environmental concern for chemicals in this group is the potential for release of zinc(2+) ions to aquatic environments from production at primary zinc refining facilities. Current practices and facilities result in the release of zinc to all environmental compartments, leading to elevated zinc levels in natural waters, sediments and biota. This is of concern because bioavailable zinc(2+) ions can become toxic at elevated levels.

The primary manufacture of zinc metal occurs at refineries in Townsville and Hobart. The manufacture of zinc oxide (calcine) that is used to produce zinc metal occurs at the Port Pirie smelter. The environmental risk was characterised by reviewing environmental monitoring data at these sites and comparing zinc concentrations against relevant guideline values in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZ Water Quality Guidelines) for natural waters and sediments. Environmental monitoring data from within the last 5 years was available for most compartments. All sites are subject to state environmental authorities or Environment Protection Authority (EPA) licences/permits, and the requirements therein have been considered in this evaluation statement.

Significant historical contamination at the Port Pirie and Hobart sites are also a source of zinc emissions to the environment. Although emissions arising from past zinc contamination are beyond the parameters of this evaluation, it can be difficult to distinguish between current and historical sources in the monitoring data.

At the Townsville refinery, zinc is mainly released via emissions to air from point sources, which are deposited to soils and surface water. In 2020, zinc concentrations in Cleveland Bay surface waters were in the range of 2–138 µg/L. In Sandfly Creek, which receives treated water discharge, sediment concentrations of zinc were close to, or exceeded the upper sediment guideline value closest to the release point. Zinc sediment concentrations decreased to below the default guideline value at the mouth of the creek where it enters Cleveland Bay. This presents a potential risk under high flow events, where sediments above the zinc guideline value could be flushed into Cleveland Bay, releasing bioavailable zinc.

The environmental authority covers monitoring and reporting of zinc in surface waters, sediments and groundwaters. Trigger values and objectives are given for zinc in released treated water, receiving waters and sediments. Groundwater trigger values are to be developed. All exceedances must be assessed and followed up with appropriate actions to minimise environmental harm.

At the Port Pirie refinery, zinc is released primarily to air and water. Almost 90% of air emissions are from fugitive sources, e.g. slag stockpiles, manual handling and transport (NPI n.d.). Zinc-contaminated water is discharged to surrounding marine waters via First Creek.

In coastal and marine waters adjacent to the Port Pirie facility, maximum concentrations exceed the 80% protection level. Zinc concentrations in marine surface waters are greatest near the First Creek discharge point and decrease with distance, indicating that effluent discharge is the source of zinc contamination. Sediment concentrations of zinc follow the same trend, exceeding the upper sediment guideline for zinc at the discharge point and decreasing with distance. Available data from sediment cores also indicate that ongoing deposition of zinc to the sediment compartment has not decreased since the 1970s. This information suggests that there may be risks to aquatic organisms at this location.

The EPA licence for the Port Pirie refinery specifies a notification value for treated waters discharged to First Creek. The licence does not specify monitoring requirements or investigation trigger levels for zinc in surrounding marine water or sediments. Based on the above evidence of zinc concentrations exceeding guideline values in water and sediment compartment, the current practices and regulations do not appear to ensure protection of the marine ecosystem surrounding Port Pirie. Further environmental risk assessment and ongoing management are required to reduce risks posed to the marine ecosystem by zinc in water and sediment at this site.

At the Hobart refinery, zinc is primarily released to water. Treated waters are discharged to the River Derwent. Treated waters include wastewaters produced via current practices, captured stormwater and extracted contaminated groundwater.

Surface water and sediment zinc concentrations are greatest in samples adjacent to the refinery and decrease with increasing distance. Surface water concentrations closest to the refinery exceed the 80% protection level for marine ecosystems. Sediment concentrations are also much higher than the upper sediment guideline. However, since 2007 environmental monitoring has shown decreasing zinc concentrations in surface waters and sediments, which has been attributed to remediation and management efforts.

The EPA permit for the Hobart refinery stipulates a limit for zinc concentration in discharged waters. Monthly monitoring of surface waters and annual monitoring sediment zinc concentrations and publicly available reports are required. If an incident occurs, the EPA must be notified within 24 hours, and all reasonable and practicable action must be taken immediately to minimise any adverse environmental effects from the incident.

Proposed means for managing risk

Environment

The environmental risks identified in this evaluation resulting from zinc primary manufacturing should continue to be managed and mitigated by the relevant state regulatory authorities. Where potential risks have been identified, further investigation should be undertaken and, if necessary, risk management approaches should be strengthened to reduce the risk. Such management should be supported by ongoing environmental monitoring programs for all impacted environmental compartments.

The routine collection and publication of environmental and biomonitoring data from all facilities that manufacture zinc metal and for all impacted environmental compartments is recommended to assist in formulating facility specific risk management measures.

Conclusions

The conclusions of this evaluation are based on the information described in this evaluation statement.

The Executive Director is satisfied that the identified risks to the environment from the introduction and use of the industrial chemicals can be managed. This is provided that all requirements are met under environmental, workplace health and safety and poisons legislation as adopted by the relevant states and territory and the proposed means of managing the risks identified during this evaluation are implemented.

Note:

1. Obligations to report additional information about hazards under *section 100* of the *Industrial Chemicals Act 2019* apply.
2. A person introducing these chemicals should be aware of their obligations under environmental, workplace health and safety and poisons legislation as adopted by the relevant state or territory.

Supporting information

Rationale

In 2024, AICIS completed an evaluation of the environmental fate and effects of zinc ions that may be released into the environment from the industrial uses of zinc-containing substances in Australia. Elevated levels of zinc above national guideline values were detected in some areas in Australia. The manufacture of zinc metal was identified as an industrial use of chemicals that may contribute to these elevated levels (AICIS 2024).

The primary manufacture of zinc is through the refining of zinc-containing mineral concentrates. The process involves the deliberate and/or incidental formation of zinc metal and 8 zinc-containing substances that are listed on the Australian Inventory of Industrial Chemicals (the Inventory). The production of these chemicals during manufacture of zinc metal is expected to contribute to total zinc emissions in Australia. Zinc metal is manufactured at 2 sites in Australia: Townsville in Queensland and Hobart in Tasmania. Manufacture of zinc oxide (calcine), that is used to produce zinc metal, is manufactured at a facility in Port Pirie, South Australia.

This evaluation will consider the environmental risks arising from zinc metal manufacture and its associated byproducts.

Chemical identity

The 9 chemicals in this group consist of target products, process intermediates and byproducts from the primary manufacture of zinc metal. Except for zinc, zinc oxide and zinc sulfate, the remaining 6 compounds have the characteristics of a UVCB (unknown, of variable composition, complex reaction products, or of biological origin).

Slags are refining products that are separated during roasting and consist primarily of zinc, iron, calcium and oxides of silicon and zinc (NCBI n.d.-a; The Editors of Encyclopaedia Britannica n.d.).

Leach residues are the byproducts of leaching calcine zinc ore concentrates with sulfuric acid (NCBI n.d.-b; REACH n.d.-f).

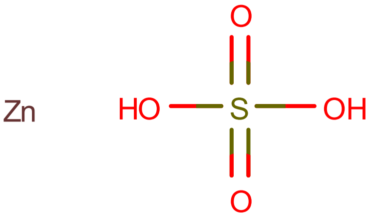
Zinc flue dust is a byproduct of roasting of zinc ores consisting primarily of zinc, lead and iron and impurities of up to 16 other elements (REACH n.d.-e).

Slimes and sludges result from cleaning the anodes and electrolysing cells in an electrolytic zinc plant. They consist primarily of lead oxides, manganese oxides, and calcium sulfate, with zinc sulfate residues (REACH n.d.-d).

Drosses are a scum formed on the surface of molten zinc and zinc alloys (REACH n.d.-a). They consist of solid oxide-coated globules of zinc that precipitate during the cooling of molten zinc in air. They form by reactions between molten zinc and loose particles of iron. Drosses can also contain traces of iron, copper, chlorine, lead and aluminium (Goodwin 2012; REACH n.d.-a).

CAS number	7440-66-6
CAS name	Zinc
Molecular formula	Zn
Molecular weight (g/mol)	65.40
Associated names	-
SMILES (canonical)	[Zn]

CAS number	1314-13-2
CAS name	Zinc oxide (ZnO)
Molecular formula	ZnO
Associated names	C.I. 77947
Molecular weight (g/mol)	81.39
SMILES (canonical)	O=[Zn]
Representative structure	

CAS number	7733-02-0
CAS name	Sulfuric acid, zinc salt (1:1)
Molecular formula*	$ZnSO_4$
Associated names	Zinc sulfate
Molecular weight (g/mol)*	163.48
SMILES (canonical)*	[Zn].O=S(=O)(O)O
Representative structure*	

Additional chemical identity information

* This chemical is a salt and has been represented according to CAS nomenclature/identity conventions.

CAS number	69012-36-8
CAS name	Slags, zinc sinter reduction
Molecular formula	Unspecified
Associated names	Spent slags, zinc fuming
Molecular weight (g/mol)	-
SMILES (canonical)	-

Additional chemical identity information

Zinc furnace residues which consist primarily of iron, calcium and oxides of silicon and zinc.

CAS number	69012-63-1
CAS name	Flue dust, zinc-refining
Molecular formula	Unspecified
Associated names	Baghouse dust Boiler ash, slag fuming Zinc furnace baghouse dust
Molecular weight (g/mol)	-
SMILES (canonical)	-

Additional chemical identity information

Byproduct of refining of zinc ores consisting primarily of zinc, lead and iron.

CAS number	69012-70-0
CAS name	Leach residues, zinc ore-calcine

Molecular formula	Unspecified
Associated names	Lead sulfate residue
Molecular weight (g/mol)	-
SMILES (canonical)	-

Additional chemical identity information

Byproduct of leaching calcined zinc ore concentrates with sulfuric acid. Residues consist primarily of lead sulfate with other calcium and iron salts and SiO_2.

CAS number	Leach residues, zinc ore-calcine, zinc cobalt
CAS name	69012-72-2
Molecular formula	Unspecified
Associated names	Zinc cobalt precipitate
Molecular weight (g/mol)	-
SMILES (canonical)	-

Additional chemical identity information

Residue from treatment of calcined zinc ore concentrates with antimony trioxide, zinc dust, lead oxide and copper sulfate. Consists primarily of zinc and a composite of metallics: cobalt, copper and lead.

CAS number	Slimes and sludges, zinc sulfate electrolytic
CAS name	69012-43-7
Molecular formula	Unspecified
Associated names	Cell sludge, electrolytic zinc Electrolytic zinc residue
Molecular weight (g/mol)	-
SMILES (canonical)	.

Additional chemical identity information

Product resulting from cleaning anodes and electrolysing cells in an electrolytic zinc plant with zinc sulfate. Consists primarily of oxides of lead and manganese and calcium sulfate.

CAS number	Zinc, dross
CAS name	69011-50-3
Molecular formula	Unspecified
Associated names	Zinc furnace dross Zinc skimmings
Molecular weight (g/mol)	-
SMILES (canonical)	-

Additional chemical identity information

A scum of oxide-coated globules of zinc that forms on the surface of molten zinc and zinc alloys.

Relevant physical and chemical properties

Elemental zinc is a brittle metal at ambient temperature with a density of 7.14 g/cm^3 at 20°C and a melting point of 420°C (Schwab et al. 2015). Atmospheric corrosion of zinc results in poorly soluble hydrated basic carbonates that form a surface film that protects against corrosion (Goodwin 2012; Schwab et al. 2015). Zinc carbonate is described as poorly soluble but, in the presence of acids, will form zinc(2+) ions (Schwab et al. 2015). The standard reduction potential of zinc (-0.76 V) often means that zinc will be reduced to zinc(2+) ions in the presence of many other metals (Goodwin 2012).

The following table provides water solubility data for zinc metal (powder form), zinc oxide, zinc sulfate and zinc present in leach residues, slimes and sludges and drosses.

Chemical	Solubility (mg Zn_{diss}/L)	Reported Test Conditions*	Source
Zinc (powder)	0.1	OECD TG 105, pH > 6.93 to < 8.57 20°C	(REACH n.d.-c)
Zinc oxide	2.9	OECD TG 105, pH > 6.07 to < 6.55, 20°C	REACH (n.d.-b)
Zinc sulfate	577,000	25°C	NCBI (n.d.-c)
Leach residues, zinc ore calcine, zinc cobalt	862	OECD TG 105, pH > 5.78 to < 6.43, 20°C	REACH (n.d.-f)

Chemical	Solubility (mg Zn_{diss}/L)	Reported Test Conditions*	Source
Slimes and sludges, zinc sulfate electrolytic	28	OECD TG 105, pH > 2.28 to < 2.32, 20°C	REACH (n.d.-d)
Zinc, dross	0.032 (calc)	OECD T/Dp, pH 6, 1 mg/L loading, 28 days (calculated from 100 mg/L, 7 day results)	REACH (n.d.-a)

*OECD T/Dp: OECD Transformation and Dissolution protocol is designed to determine the rate and extent to which metals and sparingly soluble metal compounds can produce soluble available ionic and other metal-bearing species in aqueous media under a set of standard laboratory conditions representative of those generally occurring in the environment (UNECE 2017).

No physical or chemical property data was identified for zinc slags or zinc flue dust. However, based on their descriptions and their formation, they can be classified as zinc-containing inorganic solids. These UVCBs are a mixture of zinc metal and zinc oxides with various impurities (Nowińska and Adamczyk 2023). Flue dust can contain impurities of up to 16 other elements (REACH n.d.-e). Therefore, the solubilities of zinc metal and zinc oxide (0.1–2.9 mg Zn_{diss}/L) can be used as conservative estimates of the solubilities of these substances.

Introduction and use

Australia

Primary zinc processing for the manufacture of zinc metal occurs at 3 locations in Australia. Zinc metal and other chemicals in this group are introduced (imported or manufactured) at high volumes. The major use of zinc metal is in corrosion protection, particularly galvanising.

Zinc metal is manufactured in Australia using sulfide-rich zinc ore concentrates (Sinclair 2005). Hobart and Townsville refineries process zinc ore concentrates and/or zinc oxide/calcines to produce zinc metal. Whereas Port Pirie uses zinc-rich slag resulting from processing lead ore concentrates in the Port Pirie refinery. Zinc-rich wastes from the Hobart zinc refinery produce zinc oxide (calcine) that is then sent back to the Hobart refinery to produce zinc metal (Geoscience Australia n.d.; Sinclair 2005).

Zinc metal is listed on the 2006 Australian High Volume Industrial Chemicals List (HVICL) with a total reported introduction of 100,000–999,999 tonnes per annum (NICNAS 2006). In 2022 to 2023, reported volumes of refined zinc produced in Australia were 424,000 tonnes (DISR 2024).The Townsville refinery reports a production of 230,000 tonnes zinc metal annually (Sun Metals n.d.). In 2016, the Hobart refinery reported a production volume of 236,000 tonnes zinc metal (Nyrstar n.d.).

Of the remaining chemicals covered in this evaluation, only zinc oxide (CAS RN 1314-13-2) and zinc sulfate (CAS RN 7733-02-0) have reported Australian introduction volumes of 100–999 tonnes and 1,000–9,999 tonnes per year, respectively (NICNAS 2006). However, for the purpose of this evaluation these chemicals are process intermediates, and these volumes are expected to be representative of uses outside the scope of this evaluation.

Many UVCB byproducts produced in the primary manufacture of zinc metal are recycled in the manufacturing process or placed into long term on-site storage for future reprocessing.

International

In 2019, 13.5 million tonnes of special high-grade zinc (99.995% purity) was produced internationally (International Zinc Association n.d.).

In the European Union, zinc metal is registered under Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) legislation at volumes of 1,000,000–10,000,000 tonnes annually (REACH n.d.-f). Zinc oxide is registered at volumes of 100,000–1,000,000 tonnes annually (REACH n.d.-g). Zinc sulfate is registered at volumes of 10,000–100,000 tonnes annually (REACH n.d.-a).

In the USA, between 2016 and 2019 the nationally aggregated volumes for zinc metal and zinc sulfate were 454,000–2,270,000 tonnes per year, respectively (US EPA 2020). Between 2016 and 2019, 227,000–340,000 tonnes of zinc oxide were produced annually (US EPA 2020). In 2019, 24,000 tonnes of zinc dross and 11,000 tonnes of leach residue, zinc ore-calcine were produced (US EPA 2020).

Existing Australian regulatory controls

A detailed evaluation of the regulatory status of zinc in Australia and internationally is outlined in the *Environmental fate and effects of zinc ions evaluation* (AICIS 2024a). The details below outline the regulations and standards that are relevant to the processes of refining and manufacturing zinc metal in Australia.

Environment

Zinc and zinc compounds are subject to reporting under the Australian National Pollutant Inventory (NPI). Under the NPI, emissions of zinc and zinc compounds are required to be reported annually by facilities that exceed substance, fuel, and electricity usage thresholds (NPI 2015). Reportable emissions include direct release to air, surface water, and land, and indirect releases from fuel combustion and other ancillary activities (NPI 1999). Discharges to groundwater are included in emissions to land. Discharges to tailing facilities are not reported, but emissions from these facilities are reportable.

For surface waters, very high reliability default guideline values have been published for zinc in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZ Water Quality Guidelines) (ANZG 2018a). To protect 95% of species in a *slightly to moderately disturbed* ecosystem, the guideline value is 8 µg Zn/L for both fresh and marine waters. The same guideline values should be used for *highly disturbed systems,* but exceptions can be made in cases where the default guideline value is too stringent. In these cases, the 80% species protection levels can be applied, 31 µg Zn/L and 21 µg Zn/L for fresh and marine waters, respectively (ANZG 2018a). However, the ANZ Guidelines note that *highly disturbed systems should still be subject to* adaptive management and continual improvement that aim to maximise future ecological value.

Groundwater investigation levels are 8 µg Zn/L and 15 µg Zn/L for fresh and marine waters, respectively (Commonwealth of Australia 2013).

For sediments, the recommended default sediment quality guideline value is 200 mg Zn/kg dry weight (ANZG 2018b). An upper guideline value of 410 mg Zn/kg dry weight is used as an indicator of potential high level toxicity effects. The upper guideline value should only be used as an indicator of potential high level toxicity problems, not as a guideline value to ensure protection of ecosystems (ANZG 2018b).

For soils, added contaminant limits for zinc were taken from the *National Environment Protection (Assessment of Site Contamination) Measure 1999* (Site Contamination *NEPM).* The added contaminant limits have been developed to protect soil-dwelling species (Commonwealth of Australia 2013). Ecological investigation limits (EILs) represent the level above which further investigation or evaluation is required and are the sum of the added contaminant limit and ambient background concentration at the site. For urban residential/public open space land use soils, the added contaminant limit for fresh contamination (contaminant present for < 2 years) is 20–330 mg added Zn/kg and 70–1,300 mg added Zn/kg for aged contamination (contaminant present > 2 years) (Commonwealth of Australia 2013). A soil specific added contaminant limit is chosen from these ranges based on measured soil pH and cation exchange capacity.

State Regulatory Controls – Queensland

In Queensland, the state government issues environmental authorities, that regulate environmentally relevant activities, through the *Environmental Protection Act (1994)*. The environmental authority for the zinc refinery in Townsville mandates monitoring for zinc in refinery-affected surface waters, groundwaters, and sediment. Monitoring sites include locations both on-site and up to 5 km downstream (Queensland Government 2021).

Under the environmental authority, water used in processes on-site must be stored in bunded areas and/or the process pond system. All stormwater from the refinery area must be collected and directed to the stormwater pond system. The release limit for zinc in waters discharged from the stormwater pond system is 15 mg Zn/L (total). Discharges must only occur at a designated discharge point, unless during a flooding event. A trigger value of 15 µg Zn/L (dissolved) applies to marine surface waters in the surrounding environment. If exceeded, a report on the cause and actions taken to prevent environmental harm must be completed within 3 months by the facility and provided to the environmental authority.

The environmental authority requires that site specific groundwater trigger levels and contaminant limits are developed according to methodology in the ANZ Water Quality Guidelines. An annual groundwater monitoring report is also required.

For sediments, a trigger level of 200 mg Zn/kg and limit of 410 mg Zn/kg applies. These concentrations are equivalent to the low and high guideline values in the ANZG Sediment Quality Guidelines, respectively (ANZG 2018b).

There is no limit for zinc in point source air emissions or ambient air.

Exceedances of these limits described above that are caused by activities at the site must be reported to the environmental authority within 14 days, followed by a report detailing the cause and actions taken to prevent or mitigate environmental harm.

State Regulatory Controls – South Australia

In South Australia, emissions from the Port Pirie refinery and multi-metal recovery plant are regulated under the *Environment Protection Act (1993)*, through an operating licence issued by the Environment Protection Authority of South Australia (EPA South Australia 2023).

Under the operating licence, wastewater discharged from the sedimentation ponds to First Creek is subject to wastewater discharge notification values for various metals. For zinc, the notification value is 5 consecutive exceedances of 1,400 µg/L, based on daily measurements. Exceedances of the notification value must provide notification to the public and EPA SA within 72 hours, followed by a report detailing the cause and actions taken to prevent or mitigate environmental harm.

The refinery is also required to develop a wastewater improvement plan, including identifying sources, concentrations and loads of metals (including zinc) leaving the premises, identifying pathways and volumes of metal-contaminated water leaving the premises, and developing a plan to mitigate and/or minimise the load of metal leaving the premises.

There is no limit for zinc in point source air emissions or ambient air.

State Regulatory Controls – Tasmania

In Tasmania, emissions from the Hobart zinc refinery are regulated under the *Environmental Management and Pollution Control Act (1994)*, through a land use permit that has been varied by Director, Environment Protection Authority of Tasmania (EPA Tasmania 2024).

Under the permit, there is a limit of 5.00 mg Zn/L in water discharged from site, unless discharged during a storm event. Zinc concentrations are monitored in daily composite samples of water at the nominated discharge point for treated surface and wastewaters. Groundwater is extracted and treated before discharge into the estuary. Groundwater is monitored on a biennial basis.

Zinc concentrations in surface waters and sediments of the River Derwent Estuary are monitored monthly and annually, respectively. The permit does not stipulate regulatory limits for these samples, but measured concentrations are compared to the 80% protection level ANZ Water Quality Guidelines.

Under the *Environmental Management and Pollution Control Act (1994),* if an incident occurs the EPA must be notified within 24 hours. Under the permit, all reasonable and practicable action must be taken immediately to minimise any adverse environmental effects from the incident, an investigation report to be conducted within 30 days of the notification, and a publicly available environmental review must be conducted annually.

There is no limit for zinc in point source air emissions or ambient air.

International regulatory status

United Nations

Wastes containing zinc compounds are listed in Annex I to the Basel Convention Controlling Transboundary Movements of Hazardous Wastes and their Disposal (UNEP 1989).

Canada

“Particulate matter containing metals that is released in emissions from zinc plants” is listed under Schedule 1 (the Toxic Substance List) of the *Canadian Environmental Protection Act 1999* (Government of Canada n.d.).

An environmental Code of Practice for base metal smelters and refineries includes primary zinc manufacture (Environment and Climate Change Canada 2019). From June 2018, existing mines must not exceed a maximum monthly concentration of 0.5 mg Zn/L in water effluent. Water effluent from new mines (opened after 2019) must not exceed 0.4 mg Zn/L from June 2021 (Environment and Climate Change Canada 2019). The Code of Practice also recommends that discharged waters will not cause surface waters to exceed the maximum ambient water quality objective of 30 µg Zn/L (Environment and Climate Change Canada 2019).

United States of America

The Environmental Protection Agency (US EPA) lists zinc as a Priority Pollutant under the *Clean Water Act 1972*. For zinc, the nationally recommended acute ambient water quality criteria in freshwater and seawater are 120 and 90 µg Zn/L, respectively (US EPA 1995).

Environmental exposure

Zinc metal is a primary product manufactured at the zinc refineries in Hobart and Townsville. Zinc oxide (calcine) is produced at the Port Pirie refinery and then transported to the Hobart refinery for the manufacture of zinc metal.

Generally, production of zinc metal consists of ore concentration, where zinc ore is crushed and floated, followed by roasting, leaching, purification and electrolysis. This process is used at the refineries in Hobart and Townsville. At Port Pirie, feed material undergoes slag fuming instead of roasting because feed material consists of zinc rich wastes and residues, as well as ore concentrate (Nyrstar 2020).

Emissions from zinc ore mining activities and secondary zinc processing facilities, such as those recycling zinc scrap, are not considered in this evaluation.

Roasting/Slag fuming
Zinc ore primarily occurs as a sulfide mineral. The refineries in Hobart and Townsville use roasting to remove the sulfur by oxidising zinc sulfide to zinc oxide, also called calcine. The gas stream is passed through scrubbers and electrostatic mist precipitators to recover additional zinc oxide and remove contaminants before being released to the atmosphere (Sinclair 2005).

At Port Pirie facility, slag fuming is used instead of the normal roasting step outlined above. Slag fuming uses a feed material that is a mixture of ore concentrate, and zinc rich leach residue generated during the leaching step at the Hobart refinery. The slag fuming process consists of heating zinc rich material in a furnace, vaporising zinc from the slag, which is oxidised to zinc oxide and captured as zinc oxide fume.

Particulate zinc is released to air during these steps when fumes are vented through stacks. Facilities reduce this emission source by passing fumes through baghouses to capture this particulate material, but not all particulate matter is captured. Zinc slags produced at this step can also release particulate zinc to air and soils if not stored in closed conditions. Depending on the prevailing weather conditions and local geography, particulate bound zinc can be carried away from the refinery and deposited to soil and water compartments.

Zinc oxide (calcine) from roasting and slag fuming then undergoes leaching, purification, electrolysis and casting to produce zinc metal (Khartcyzov et al. 2023; Nyrstar 2020; Sinclair 2005).

Leaching & Electrolysis
Roasting and slag fuming produces a solid commonly called calcine. This solid is primarily zinc oxide, but also contains zinc ferrite, zinc silicate, residual sulfur and other metals,

including cadmium, copper, arsenic, antimony, cobalt, germanium, nickel, and thallium (Sinclair 2005). A purified zinc sulfate solution is produced via series of leaching steps using sulfuric acid. This step also produces a solid leach residue that can contain up to 15% zinc depending on the process (Sinclair 2005). While a closed process, zinc sulfate solution can enter the environment through leaks and spills during this step.

Zinc rich leach residues are purposely produced at the Hobart zinc refinery, then sent to the associated lead-zinc refinery at Port Pirie, where additional zinc oxide (calcine) is recovered by slag fuming (Nyrstar 2020; Sinclair 2005).

Zinc is then extracted from the purified zinc sulfate solution by electrowinning, a specialised form of electrolysis. An electric current is passed through the solution that causes zinc to deposit onto cathodes. Slimes and sludges containing residue zinc sulfate are produced at this step, resulting from cleaning the anodes and electrolysing cells.

Zinc remaining in leach residues and slimes/sludges from the electrolysis step may enter the water compartment through controlled release of treated waters. Each facility captures these waste products in treatment ponds, where concentrations of zinc and other contaminants are reduced to the thresholds stipulated in their site license/permit. Treated waters are then released through authorised release points into waterways adjacent to the sites. Zinc also enters groundwater via spills during normal processes and leaks from treatment ponds.

Particulate zinc in leach residues can also enter the air, soil and water compartment during transport and storage of the residues. Facilities reduce this by transporting and storing these residues under closed conditions.

Casting

Finally, zinc is stripped from the cathode, melted in a furnace and cast into slabs (10-25 kg) or blocks (1,000–2,000 kg) of zinc metal. During the melting process, zinc oxide dross forms at the surface via direct oxidation and/or decomposition of residual zinc sulfate reacting with molten zinc. Dross is allowed to build up as a blanket layer to restrict oxidation of the molten zinc. This dross is periodically removed via raking. The dross is allowed to cool before milling to separate fine oxide from metallic zinc. The metallic zinc is re-melted, and the fines are passed through a bag filter. Zinc dross can also be used as a feed stock in slag fuming to recover additional zinc.

National Pollutant Inventory (NPI) reported emissions

Primary zinc production is one of the highest industry sources of zinc emissions to the Australian environment as indicated by the NPI data. Approximately 1,100 tonnes of zinc and zinc compounds were released into the Australian environment from all reporting facilities in 2023-24. Reported emissions from refining facilities accounted for approximately 175 tonnes of total reported zinc emissions. Reported zinc emissions from these refining activities consisted of 53 tonnes to air, 122 tonnes to water, and 65 kg to land (NPI n.d.). These emissions were produced by 3 facilities: Townsville (22 tonnes), Port Pirie (63 tonnes) and Hobart (90 tonnes).

Distribution of NPI 2023-24 emissions varied between environmental compartments at each facility. Total air emissions at the Hobart refinery were approximately ~6.6 tonnes, with roughly equal contributions from point and diffuse sources. At the Port Pirie refinery, diffuse sources were much greater (24 tonnes) compared to point sources (9 tonnes). In contrast, the Townsville refinery reported much greater emissions from point sources (24.8 tonnes) compared to diffuse sources (0.4 tonnes). Emissions to water were reported at the Hobart (84 tonnes) and Port Pirie (36 tonnes) refineries, with no emissions to land reported. Whereas at the Townsville refinery, no emissions to water were reported, and a small emission to land (0.074 tonnes) was reported. This variation is likely a result of differing processes and storage facilities at each site.

Historical contamination

The refineries at Port Pirie and Hobart have been in operation for over 100 years. Because of this, significant historical contamination at these zinc manufacturing sites is also a major source of zinc emissions to the environment (DEP 2020; Vandeleur 2020). At the Hobart refinery, it is known that zinc and zinc compounds enter surface waters via leaching of on-site contaminated groundwaters and is an ongoing source of contamination to the River Derwent Estuary.

In contrast, the refinery in Townsville has only been in operation since 1999 (TropWater 2020). Prior to 2009, there was no requirement to monitor environmental concentrations of zinc. Measurements taken in 2009 indicated that historical contamination caused by the refinery was present.

However, the environmental impacts from historical zinc contamination are beyond the parameters of this evaluation.

Environmental fate

The environmental fate of zinc compounds emitted during the primary manufacturing of zinc metal is site specific.

The Townsville refinery is on the edge of a tidal floodplain that empties into Sandfly Creek and a mangrove estuary that enters Cleveland Bay. The site experiences a seasonal (wet/dry) tropical climate. Sandfly Creek is an estuarine waterbody that is part of a broader floodplain and wetlands surrounding the refinery (TropWater 2020).

The Port Pirie refinery sits within a typical temperate system adjacent to coastal and marine environments in Germein Bay on the eastern shore of the Spencer Gulf (Vandeleur 2020). The refinery is situated on the Port Pirie River and effluent is discharged to First Creek, both of which flow into the Spencer Gulf (Ferguson 1983; Lafratta et al. 2019).

The Hobart refinery is located on the western bank of the River Derwent Estuary and experiences a cool and temperate climate with variable rainfall. The refinery discharges treated effluent into the River Derwent, which flows into the Tasman Sea (DEP 2020).

Chemicals in this group are expected to be released into the atmosphere, surface waters, soils and sediments where they are expected to release zinc(2+) ions. A detailed account of the environmental fate of zinc(2+) ions is available in the AICIS evaluation “*Environmental fate and effects of zinc ions*” (AICIS 2024). A summary of the environmental fate relevant to the Townsville, Port Pirie and Hobart locations is presented below.

Speciation, partitioning and mobility

Zinc compounds are released to all environmental compartments during the primary manufacture of refined zinc metal. Zinc and zinc compounds are emitted to air bound aerosols that will enter water and soil compartments via wet and/or dry deposition. Zinc and zinc compounds will enter the water compartment directly via release of treated effluents to natural waters, from which it will deposit to the sediment compartment. Release of zinc from the sediment and soil compartments to water can also occur under changing physico-chemical conditions.

Each of the zinc refineries in Australia are adjacent to estuarine and marine environments and close to busy shipping ports. Therefore, the greatest influencing factors on the fate of zinc(2+) ions are fluctuations in pH, salinity, dissolved organic matter (DOM), and physical disturbances of sediment.

In marine water, approximately 55% of total zinc is in the dissolved phase and 45% attached to suspended particles. Of the dissolved phase, approximately 80% is the zinc(2+) ion at typical salinity (35 ppt) and pH (pH 8.1). Concentrations of zinc(2+) ion will typically increase with decreasing pH and/or salinity. (ANZG 2021). At higher pH, zinc hydroxides become the major species. At higher salinities, sulfate and chloro-complexes become the major species (Eisler 1993). These species are less soluble and will increase the partitioning of zinc to the sediment (ANZG 2021).

Most dissolved zinc in natural waters will partition to sediments. Zinc in aquatic environments is adsorbed onto iron and manganese oxides, clay minerals, or organic materials (Eisler 1993). Dissolved zinc also precipitates as zinc hydroxide, sulfide, carbonate, insoluble organic complexes and with iron and manganese oxyhydroxides (ATSDR 2005; Eisler 1993). The extent of zinc sorption depends on pH and salinity. Zinc will sorb more readily at pH > 7 and low salinity. Inorganic zinc compounds also precipitate more readily at higher pH (ATSDR 2005). Zinc species may be dissolved or desorbed from sediments as pH decreases or salinity increases (ATSDR 2005) and under anoxic conditions (ANZG 2021). Zinc may also be remobilised when sediments are oxidised due to disturbance by organisms or during flooding events (Zoumis et al. 2001).

In the atmosphere, zinc is mainly bound to aerosols in an oxidised form. Zinc then partitions to soil and water via wet and/or dry deposition (ATSDR 2005).

Bioaccumulation

Zinc is essential to all organisms (ATSDR 2005; WHO 2001). The bioaccumulation of zinc is a complex area because of its essentiality. Some degree of accumulation is normal and does not necessarily signify contamination issues. Zinc does not generally biomagnify through food chains (ATSDR 2005; WHO 2001).

Bioaccumulation of zinc is described more thoroughly in *Environmental fate and effects of zinc ions* (AICIS 2024).

Environmental transport

Zinc compounds that are emitted to the atmosphere can be transported over long distances via association with particulate matter, which are then deposited via wet and/or dry deposition (ATSDR 2005). This is evident in elevated zinc concentrations in soil up to 15 km from the Port Pirie refinery (Cartwright et al. 1977).

The zinc(2+) ions released from water soluble salts to natural waters are expected to largely partition to sediments, limiting long-range mobility. This is reflected in environmental concentrations decreasing with increasing distance from the refineries in this evaluation (DEP 2020; Vandeleur 2020).

Environmental monitoring

Environmental concentrations of metals are usually measured by methods that cannot distinguish between source chemicals. Sources of elevated metal concentrations are generally inferred from exposure scenarios that are likely to influence the affected sites. We note that historical activities may also be a source of zinc contamination at these sites, particularly where facilities have been in operation for a long period of time. Presented below are zinc concentrations measured in the water and sediment in the receiving environments of the Townsville, Port Pirie and Hobart refineries. Similar measurements for soil zinc concentrations could not be identified due to limited environmental monitoring data.

The following table summarises key reported aquatic zinc concentrations around the Townsville, Port Pirie and Hobart refineries. Zinc concentrations are reported as dissolved mean, maximum and minimum concentrations. Where several studies were available, values are from the most recent or most comprehensive studies. Relevant trigger values from ANZ Water Quality Guidelines are described in the note below the table. All mean values exceed the relevant guideline values:

Location	Mean (µg/L)	Maximum (µg/L)	Minimum (µg/L)	Source
Townsville - Freshwater	24	138	< 5	TropWater (2020)
Townsville - Marine	12[a]	28[a]	< 0.08-2.5[b]	[a]TropWater (2020) [b]Jones et al. (2000)
Port Pirie - Marine	22.3	87.9	5.2	Vandeleur (2020)
Hobart - Marine	65[c]	70[c]	~5[d]	[c]Nyrstar (2025) [d]DEP (2020)

8.0 µg/L, 95% species protection for marine water, ANZ Water Quality Guidelines default guideline value
21 µg/L, 80% species protection for marine water, ANZ Water Quality Guidelines default guideline value

The following table summarises key reported zinc sediment concentrations around the Townsville, Port Pirie and Hobart refineries. Sediment concentrations are total concentrations or bioavailable concentrations as measured by passive sampling (diffusive gradients in thin-films). Where several studies were available, values are from the most recent or most comprehensive studies are presented in the table below. Relevant trigger values from ANZ Water Quality Guidelines are described in the note below the table. All mean values exceed the relevant guideline values:

Location	Mean (mg/kg)	Maximum (mg/kg)	Minimum (mg/kg)	Source
Townsville	640	1,900	34-62	TropWater (2020)
Port Pirie	17,000	62,000	10.7	Kastury et al. (2023)
Port Pirie	-	910 (bioavailable)	-	Kastury et al. (2023)
Hobart	5,500	53,000	72	Hughes et al. (2022)

200 mg/kg, low sediment quality guideline value, ANZ Water Quality Guidelines default sediment guideline value
410 mg/kg, high sediment quality guideline value, ANZ Water Quality Guidelines default sediment guideline value

Townsville

The Townsville refinery is required to carry out an annual *Receiving Environment Monitoring Report* (REMP). This includes regular sampling for contaminants of concern in surface soils, sediments, surface waters, and groundwater in locations both on-site and in the surrounding ecosystem that could potentially be impacted by refinery activities.

Atmospheric releases of zinc are monitored by measuring zinc precipitation rates based on dust deposition of zinc enriched dust in locations that are not linked with any existing or known aquatic exposure pathways. In general, annual zinc precipitation rates are greatest in sites adjacent to the roasters and decreases with increasing distance (TropWater 2020).

In 2009, zinc values were typically greater than 200 mg/kg (low sediment quality guideline) in Sandfly Creek sediments. This exceedance continued downstream from the mouth of a drainage discharge point for about 4 km (TropWater 2020). In January 2020, a maximum sediment concentration of 1,850 mg/kg was recorded in Sandfly Creek downstream of the authorised release point. Sediment zinc concentrations decrease with increasing distance falling below low sediment quality guideline value (200 mg/kg) at the mouth of Sandfly Creek (TropWater 2020). Between 2019 and 2020, zinc concentrations increased in sediments downstream of the authorised release point. But overall, sediment concentrations have been trending downwards since 2017. Beds of *Typha* sp. (aquatic grasses) growing in Sandfly Creek downstream of the authorised release point trap a large proportion of fine sediment and their adsorbed metals. This currently acts as a sink for metals but has the potential to be a significant source of metals into the surrounding environment if this sediment is disturbed and the associated metals are released (Queensland Government 2020). Between 2012 and 2019, zinc concentrations in coastal mudflats and adjacent Cleveland Bay sediments have mostly remained below 200 mg/kg (low sediment quality guideline value), with some exceedances in mudflat sediments in 2018 (TropWater 2020).

Dissolved zinc concentrations in Cleveland Bay surface waters between 1975 to 1979 ranged between < 0.08–2.5 µg/L (Jones et al. 2000). Monitoring of fresh and marine surface waters are routinely monitored in the REMP. The most recent report from 2020 reported a mean zinc concentration of 24 µg/L (< 5–138 µg/L) measured across various non-tidal (nominally fresh) waters surrounding the refinery. Zinc concentrations in Cleveland Bay marine surface waters were < 5–28 µg/L, with an average of 12 µg/L (TropWater 2020).

In 2020, groundwater zinc concentrations ranged between < 0.001–658 mg/L (JACOBS 2019). The groundwater modelling report indicates that there is potential discharge of contaminated groundwater to Cleveland Bay. Currently, only surface water zinc concentrations are used to infer impacts of zinc to intertidal mudflats and coastal waters. But groundwater discharge does not always cause detectable changes in the overlying water column, which could mean that adverse effects to sediment-dwelling organisms are not being captured (Queensland Government 2020; TropWater 2020).

Concentrations in leaves of mangroves adjacent to site range from 21–106 mg/kg in 2019. Typically, zinc concentrations were highest in mangroves closest to the refinery (TropWater 2020).

Current biota monitoring data was not identified. Concentrations of zinc in Cleveland Bay biota have not been measured since 1998, prior to the commencement of refinery activities in 1999 (Chariton and Hejl 2024).

Port Pirie

High metal concentrations near the Port Pirie River mouth can be explained mainly by deposition of atmospheric emissions released via refinery stacks and direct effluent discharges into the river until 1939. Prevailing south-east winds likely distributed metals from atmospheric emissions and fugitive dust towards the river mouth (Lafratta et al. 2023).

In the 1980s, reported dissolved zinc concentrations ranged from 4,300 µg/L at the refinery outflow point in First Creek, to 14 µg/L at the mouth of First Creek into Spencer Gulf, to < 10 µg/L 5km into the Spencer Gulf (Ferguson 1983). In 2020, measured zinc concentrations in surface waters were lower. Average surface water concentrations were 22.3 µg/L, with a maximum concentration of 87.9 µg/L, measured in First Creek, and a minimum concentration of 5.2 µg/L, measured near Port Germein (~16 km from the refinery). While these concentrations are much lower, the concentrations in and near First Creek exceed 8.0 µg/L, the 95% species protection guideline value for marine waters (Vandeleur 2020).

Sediment concentrations within the Port Pirie River mouth and First Creek are consistently high. In 2018-19, all samples within a 10 x 10 km^2 area adjacent to the refinery were greater than the high sediment guideline value of 410 mg/kg, with a maximum recorded concentration of > 21,000 mg/kg in the Port Pirie River (Vandeleur 2020). High concentrations of zinc in seagrass and mangrove sediments have also been reported (Kastury et al. 2023; Lafratta et al. 2023). In 2017, the maximum zinc concentration was reported as 2,149 mg/kg in seagrass sediment near the mouth of First Creek, which decreases to < 60 mg/kg in the sites approximately 12 km from First Creek and the refinery (Lafratta et al. 2023). Using sediment cores from seagrass meadows, zinc concentrations have been shown to significantly increase since the establishment of the refinery (Lafratta et al. 2023). Following the construction in 1972 of dams and settling ponds and redirection of all effluent discharge to First Creek, zinc accumulated up to 4 times faster in front of where

First Creek enters Spencer Gulf. Sediment cores showed that between 1972 to 2017, ~1,900 tonnes of zinc accumulated in the seagrass sediment, predominately in front of First Creek. This represents 60% of total zinc accumulated in the sediment since refinery operations began (Lafratta et al. 2023).

Similar patterns of zinc in mangrove sediment within 1km of the refinery are also reported. In 2019, zinc concentrations in mangrove sediments were as high as 62,067 mg/kg adjacent to the refinery, but decreased to 39.5 mg/kg in mangrove sediment 17 km from the refinery (Kastury et al. 2023). This higher zinc concentration compared to Vandeleur (2020) may be attributed to the zinc binding to iron and manganese plaques on mangrove roots surfaces (Kastury et al. 2023). Bioavailable zinc in sediment pore water was reported to be between 914 to 2,710 µg/L in the sites closest to the refinery. High bioavailability of zinc is also demonstrated by elevated concentrations of zinc in mangrove leaves. Zinc concentrations of 187 to 528 mg/kg were measured in the leaves of mangroves within 2 km of the refinery, compared to 26 to 43 mg/kg in mangroves 43 km from the refinery (Kastury et al. 2023).

Hobart

Environmental monitoring conducted around the zinc refinery indicates that zinc is released primarily to the water compartment, with small releases to the atmosphere. The main source of zinc contamination to the River Derwent Estuary is from contaminated groundwater beneath the zinc refinery. While historical contamination is responsible for the high zinc concentrations in groundwater, the greatest concentrations are measured in groundwater below currently operational facilities. This prevents distinguishing between current and historical exposure. Between 2016 and 2019, approximately 120 tonnes of zinc per year was emitted to the estuary via groundwater. In the same period, emissions from air, outfall and stormwater contributed less than 12.5 tonnes/year (DEP 2020).

Between 2022 and 2024, zinc concentrations in groundwater below the refinery ranged from 43 µg/L to 430 g/L. The most significant contamination was measured in bores that were within and downgradient of buildings where the leaching, purification and electrolysis steps occur (Nyrstar 2025).

Between 2022 and 2024, average zinc concentrations in surface waters adjacent to the site were 65.26 µg/L and a maximum of > 100 µg/L (Nyrstar 2025). This is an increase on both the previous reporting period (50.99 µg/L 2019-2021) and the 10 year average (53.09 µg/L 2015-2024). Across all monitoring sites, average zinc concentration in surface waters was approximately 35 µg/L (Nyrstar 2025).

Sediment cores sampled throughout the estuary showed zinc concentrations peaked at 61,275 mg/kg in the 1970s and have decreased to an average of 4,158 mg/kg, with a modern maximum of 19,687 mg/kg in surface sediments (Hughes et al. 2022).

To monitor bioavailability to organisms, oysters are deployed throughout the estuary then retrieved to measure the concentration of accumulated zinc. Concentrations of zinc in deployed oysters throughout the River Derwent Estuary are highly variable. Between 2019 and 2024, concentrations varied between < 500 mg/kg to > 3,500 mg/kg (Nyrstar 2025). Typically, zinc concentrations were highest in oysters deployed adjacent to the refinery. Five year rolling zinc concentrations in muscle tissue of wild-caught flathead have shown a slight increase from 5 mg/kg (2006-2010) to 7.5 mg/kg (2012-2018) (Nyrstar 2022).

Elevated zinc in surface soils surrounding the refinery were identified in the 1980s and determined to be caused by dust blown from the refinery. Soil sampling surveys in the 1990s showed that elevated levels of zinc were limited to the upper 50 mm of soil, with the majority in the upper 20 mm (EPA Tasmania 2009). A follow up survey in 2008 showed that zinc concentrations had not significantly changed (EPA Tasmania 2009; McLaughlin 2009).

Environmental effects

Organisms require a minimum level of zinc for essential functions. However, excessive environmental zinc concentrations can overwhelm homeostasis and result in adverse effects on aquatic and terrestrial life. While sensitivity of aquatic organisms varies between taxa, zinc toxicity is predominantly caused by free zinc(2+) ions. Therefore, zinc toxicity will be highest when environmental conditions favour free zinc(2+) ion speciation. The most important toxicity modifying factors for zinc in marine environments are pH, salinity, and dissolved organic carbon. Maximum zinc toxicity in marine waters is expected in waters with high salinity, acidic to circumneutral pH, and low dissolved organic carbon concentrations.

Effects on aquatic life

The acute and chronic toxicity of zinc to marine aquatic organisms is outlined in the technical brief for the current ANZ water quality guidelines for zinc in marine water (ANZG 2021). Typically, juvenile stages of invertebrates and fish are the most sensitive organisms to zinc (ANZG 2021).

Effects on sediment-dwelling life

The toxicity of zinc in sediment is outlined in the *Environmental fate and effects of zinc ions evaluation* (AICIS 2024). Typically, the most sensitive sediment-dwelling organisms are those that are exposed to zinc through the aqueous and dietary phases e.g. epibenthic deposit feeders (King et al. 2006a; King et al. 2006b).

Predicted no-effect concentration (PNEC)

The primary environmental effects of chemicals in this group are expected to be caused by the release of bioavailable zinc(2+) ions. Zinc and zinc compounds are expected to be released to all environmental compartments from the identified zinc refineries. Given that each of the zinc refineries are coastally located, guidelines for marine waters and sediments are considered. Guideline values for soil and freshwaters were previously detailed in *Environmental fate and effects of zinc ions evaluation* (AICIS 2024).

In place of PNECs for marine waters and sediment compartments, the default guideline values from the ANZ Water Quality Guideline have been used. These values represent thresholds above which further assessment of potential toxicity may be required to ensure environmental quality. For *slightly-moderately disturbed* freshwaters waters, guideline values of 8.0 µg/L and 31 µg/L are applied for the protection of 95% and 80% of species, respectively (ANZG 2021). For *slightly-moderately disturbed* marine waters, guideline values of 8.0 µg/L and 21 µg/L are applied for the protection of 95% and 80% of species, respectively (ANZG 2021). In sediments, the recommended default sediment quality guideline is 200 mg Zn/kg dry weight. An upper guideline value of 410 mg Zn/kg dry weight is used as an indicator of potential high level toxicity effects (ANZG 2018b).

In place of a PNEC for the soil compartment, the ecological investigation level for zinc from the Site Contamination NEPM has been used. In soils, the added contaminant limit for fresh contamination (contaminant present for < 2 years) is 20–330 mg added Zn/kg and 70–1,300 mg added Zn/kg for aged contamination (contaminant present > 2 years) (Commonwealth of Australia 2013).

Categorisation of environmental hazard

Persistence, bioaccumulation and toxicity (PBT)

It is not currently possible to categorise the environmental hazards of metals and other inorganic chemicals according to standard persistence, bioaccumulation, and toxicity (PBT) hazard criteria. These criteria were developed for organic chemicals and do not take into consideration the unique properties of inorganic substances and their behaviour in the environment (UNECE 2007).

Therefore, an environmental hazard categorisation according to domestic PBT criteria has not been performed for chemicals in this group.

GHS classification of environmental hazard

The aquatic hazards of zinc metal, zinc oxide and zinc sulfate have been classified based on the most conservative acute toxicity value for the soluble zinc(2+) ion in freshwater (17 µg/L). This is in accordance with the classification procedure for metals and metal compounds under the GHS (AICIS 2024; UNECE 2017). The aquatic hazards associated with chemicals in this group are dependent on their capacity to release zinc(2+) ions at concentrations that exceed identified acute toxicity thresholds. All substances in this evaluation are classified as Acute Aquatic Category 1 and Chronic Aquatic Category 1.

For zinc metal, transformation/dissolution data exceeds the most sensitive acute toxicity values for zinc(2+) ions in freshwater (AICIS 2024).

For zinc oxides, after correcting for molecular weight, solubility data exceeds the most sensitive acute toxicity values for zinc(2+) ions (AICIS 2024).

For zinc sulfate, after correcting for molecular weight, solubility data exceeds the most sensitive acute toxicity values for zinc(2+) ions (AICIS 2024).

Transformation/dissolution data is available for zinc dross, leach residues, and slimes and sludges. All zinc concentrations after 7 days at the low loading rate exceeds the most sensitive acute toxicity values for zinc(2+) ions (AICIS 2024).

For the remaining UVCB materials, there is insufficient solubility data available to classify their aquatic toxicity hazards according to the procedure above. Instead, these chemicals are conservatively assumed to release concentrations of zinc(2+) ions that exceed relevant ecotoxicological endpoints.

It is preferable to classify the hazard posed by metals and metal compounds using measured solubility data or transformation/dissolution data determined in accordance with the OECD Transformation and Dissolution Protocol (UNECE 2017). Should data from either of these methods become available that supports a lower hazard classification, some chemicals may be reclassified where appropriate.

Environmental risk characterisation

The production of chemicals in this group can release bioavailable zinc(2+) ions to the environment. Although zinc is an essential trace element, excessive zinc can have adverse effects on organisms.

The primary manufacture of zinc metal in Australia occurs at 2 facilities: Townsville in Queensland, and Hobart in Tasmania. Manufacture of zinc oxide (calcine), that is used to produce zinc metal, is manufactured at a facility in Port Pirie, South Australia. Current practices and facilities result in the release of zinc to all environmental compartments, leading to elevated zinc levels in natural waters, sediments, soils and biota.

The following table summarises the measured environmental concentrations of zinc compared to the default Australia quality guideline values for freshwater, marine water and sediment:

Compartment	Mean dissolved Zn (µg/L)	Sediment Zn (mg/kg)
Townsville - Freshwater	24	-
Townsville - Marine	12	640
Port Pirie - Marine	22.3	17,000
Hobart - Marine	65	5,500
95% species protection level freshwater quality guideline	8.0	-
80% species protection level freshwater quality guideline	31	-
95% species protection level marine water quality guideline	8.0	-
80% species protection level marine water quality guideline	21	-
Low sediment quality guideline	-	200
Upper sediment quality guideline	-	410

At the Townsville refinery, zinc is mainly released via emissions to air, which is deposited to soils and surface water. Zinc is emitted to air primarily from point sources (stacks). Around the Townsville refinery, average zinc concentrations in marine waters slightly exceeded the 95% protective guideline value and freshwater values exceeded the 95% protective guideline value. In Sandfly Creek, which receives rainwater runoff and/or stormwater overflow during heavy rainfall events, sediment concentrations of zinc were close to or exceeded the upper sediment guideline value closest to the release point, decreasing to below the default guideline value where it enters Cleveland Bay. This presents a potential risk under high flow events, where sediments above the zinc guideline value could be flushed into Cleveland Bay, releasing bioavailable zinc.

At the Port Pirie refinery, zinc is released almost equally to air and water. Three quarters of air emissions are from fugitive sources, e.g. slag stockpiles, manual handling and transport. Zinc-contaminated water is discharged to surrounding marine waters via First Creek.

In coastal and marine waters adjacent to the Port Pirie facility, mean dissolved zinc concentrations exceed the 80% protection level for marine ecosystems in the ANZ Water Quality Guidelines. Zinc concentrations in marine surface waters are greatest near the First Creek discharge point and decrease with distance, indicating that effluent discharge is the source of zinc contamination.

Sediment concentrations of zinc adjacent to the Port Pirie refinery follow the same trend, initially exceeding the upper sediment guideline then decreasing with distance from the refinery. Available data from sediment cores also indicate that ongoing deposition of zinc to the sediment compartment has not decreased since the 1970s. Although there may be some mitigation of zinc toxicity by the formation of relatively stable complexes, measured bioavailable zinc concentrations still exceed the upper sediment guideline. This information suggests that there may be risks to aquatic organisms at this location.

At the Hobart refinery, zinc is primarily released to water. Treated waters are discharged to the River Derwent. Treated waters include wastewaters produced via current practices, captured stormwater and extracted contaminated groundwater.

Surface water and sediment zinc concentrations are greatest in samples adjacent to the refinery and decrease with increasing distance. Surface water concentrations closest to the refinery greatly exceed the 80% protection level for marine ecosystems. Sediment concentrations are also much higher than the upper sediment guideline. Recent environmental monitoring has shown decreasing zinc concentrations in surface waters and sediments, which has been attributed to remediation and management efforts.

Current management – Townsville

For Townsville, the environmental authority covers monitoring and reporting of zinc in water releases, groundwaters and sediment. Trigger values and objectives are given for zinc in receiving waters and sediment. A groundwater trigger value is under development. These trigger values are or will be generally consistent with national guidelines.

In 2019, the environmental authority issued a "*notice to conduct or commission an environmental evaluation*". This was on the grounds that “an activity being undertaken at the premises is causing, or is likely to cause, environmental harm” (Queensland Government 2019). This notice required a thorough investigation into the contamination and its source in stream sediments and groundwater impacted by the refinery. In the evaluation provided by the refinery, the environmental authority noted that there is potential discharge of contaminated groundwater into Cleveland Bay, the risk from zinc-contaminated sediment should be investigated, and the bioavailability of zinc in sediments, soils and groundwater to biota requires further investigation (Queensland Government 2020).

Current management – Port Pirie

For Port Pirie, the EPA licence covers a wastewater discharge notification value for water releases to First Creek. Exceedances must be publicly reported.

The current licence also includes a wastewater improvement plan that includes identifying sources, concentrations and loads of metals (including zinc) leaving the premises, identifying pathways and volumes of metal-contaminated water leaving the premises, developing a plan to mitigate and/or minimise the load of metal leaving the premises. The facility licence does not stipulate monitoring requirements or investigation trigger levels for zinc in the surrounding marine water or sediments.

Further environmental risk assessment and ongoing management are required to reduce risks posed to marine ecosystems by zinc compounds in water and sediments at this site. Zinc concentrations in marine surface waters are greatest near the First Creek discharge point and decrease with distance, indicating that effluent discharge is the source of zinc contamination. Sediment concentrations of zinc follow the same trend, exceeding the upper sediment guideline at the discharge point and decreasing with distance. Available data of from sediment cores also indicate that ongoing deposition of zinc to the sediment compartment has not decreased since the 1970s.

Current management – Hobart

For Hobart, the environmental permit covers a wastewater discharge limit for water releases to the River Derwent. The Permit also requires ongoing monitoring in estuarine water, sediment and biota, with results reported annually.

A groundwater management plan is also required to reduce groundwater contamination and isolate impacted groundwater from the River Derwent. Between 2022 to 2024, approximately 309 tonnes of zinc was recovered from groundwater. Across the 123 bores that are monitored for zinc, 10 bores showed an increasing or probably increasing trend, 19 were decreasing or probably decreasing and the remaining 94 bores showed no trend or had insufficient data for trend analysis (Nyrstar 2025).

While concentrations of zinc in surface waters adjacent to the refinery showed an increase in the latest reporting period, zinc concentrations in ambient waters have shown a general decrease between 2007 and 2020 across the estuary. This has been attributed to site remediation and management activities, flushing and diluting of zinc during high discharge period between 2018 and 2020, and gradual burial of highly contaminated sediments with relatively cleaner overlying sediments (DEP 2020). This demonstrates that effective management practices are critical in monitoring the environmental risk of zinc over time to enable efficient and effective responses to any increases in potential environmental exposure to zinc.

Uncertainty

This evaluation was conducted based on information that may be incomplete or limited in scope. The most consequential areas of uncertainty for this evaluation are:

- Environmental concentrations were taken from a range of sources, across different sampling campaigns using different methodology. This limits ability to track trends over time.
- Exceedances of guideline values discussed in this evaluation require further assessment of site specific conditions and zinc bioavailability to determine risk to the environment. In the absence of this information, the potential for environmental risk has been noted. Should data become available that indicates low risk, the outcome of this evaluation may change.
- Significant historical contamination, particularly at the Port Pirie and Hobart sites, continues to be a source of zinc emissions to the environment. While emissions from historical contamination are beyond the parameters of this evaluation, it is not possible to distinguish between zinc contamination from current and past emissions based on available information.

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