Australian Government
Department of Agriculture, Water and the Environment
Supervising Scientist

Ammonia in Surface Water — Rehabilitation Standard for the Ranger uranium mine

Water and sediment theme

Preface

The Supervising Scientist developed this Rehabilitation Standard to describe the requirements to protect aquatic ecosystems outside of the Ranger Project Area in the Alligator Rivers Region of the Northern Territory from the effects of ammonia in surface water.

This document is part of a series of Rehabilitation Standards for the Ranger uranium mine. It may be updated as additional relevant knowledge becomes available.

This Standard should be cited as follows:

Supervising Scientist 2021. Ammonia in Surface Water — Rehabilitation Standard for the Ranger uranium mine (version 1.1). Supervising Scientist Branch, Darwin, NT. http://www.environment.gov.au/science/supervising-scientist/publications/ss-rehabilitation-standards. Cited [Date].

1. General elements

Scope

1.1 The Rehabilitation Standards for the Ranger uranium mine have been developed in accordance with section 5c of the *Environment Protection (Alligator Rivers Region) Act 1978* and are advisory only.

1.2 The *Environmental requirements of the Commonwealth of Australia for the operation of the Ranger uranium mine* (Environmental Requirements) (Australian Government 1999) specify the environmental objectives for the rehabilitation of the Ranger uranium mine.

1.3 The Supervising Scientist's Rehabilitation Standards quantify the rehabilitation objectives and recommend specific values based on the best available science that will ensure a high level of environmental protection. These values can be used to assess the achievement of, or progress towards, the rehabilitation objectives, some of which may not be reached for a significant period of time.

1.4 Until it can be determined that the rehabilitation objectives have or will be reached, there will be an ongoing need to ensure environmental protection during and after rehabilitation, through continued water quality monitoring, including the comparison of water quality data with relevant water quality limits.

Objective

1.5 There is currently no agreed acceptable level of effect to the environment surrounding the Ranger Project Area. In the absence of agreement, the Rehabilitation Standard for ammonia in surface water aims to protect the biodiversity and health of aquatic ecosystems outside of the Ranger Project Area. This includes ecosystems upstream of the mine given that poor water quality within the Ranger Project Area could form a barrier to the movement of aquatic organisms. If an acceptable level of effect is agreed, this standard will be updated accordingly.

Application

1.6 This Rehabilitation Standard should be applied in Magela and Gulungul creeks at the boundary of the Ranger Project Area, downstream from the Ranger uranium mine.

1.7 Given the potentially long time frame between the completion of rehabilitation and the peak delivery of contaminants to surface water, this Rehabilitation Standard will most likely be used to assess predicted ammonia concentrations from modelled scenarios. Ongoing surface water and groundwater monitoring will be required after rehabilitation to continue to ensure the environment is being protected and to validate and assess confidence in the models.

2. Relevant requirements

Environmental Requirements

2.1 The primary environmental objectives in the Environmental Requirements require that surface waters or groundwater arising from the Ranger uranium mine do not result in any detrimental change to biodiversity or impairment of ecosystem health outside of the Ranger Project Area, including during or following rehabilitation. This Rehabilitation Standard is relevant to the Environmental Requirements listed in Box 1.

Aspirations of Traditional Owners

2.2 The Mirrar Traditional Owners desire that operations at the Ranger uranium mine should not result in any change to the natural water quality of surface waters outside of the Ranger Project Area (Iles 2004). Specifically, as stated in Garde (2013):

> …the waters contained within all riparian corridors, (i.e. rivers and billabongs), must be of a quality that is commensurate with non-affected riverine systems and health standards. The principle of 'as low as reasonably achievable' should not apply to these areas. Instead, the standard of rehabilitation must be as high

as is technically possible and level of contamination must be as low as technically possible.

Box 1: Ranger Environmental Requirements relevant to the Ammonia Rehabilitation Standard

1 Environmental protection

1.1 The company must ensure that operations at Ranger are undertaken in such a way as to be consistent with the following primary environmental objectives:

- (a) maintain the attributes for which Kakadu National Park was inscribed on the World Heritage list
- (b) maintain the ecosystem health of the wetlands listed under the Ramsar Convention on Wetlands (i.e. the wetlands within Stages I and II of Kakadu National Park)
- (d) maintain the natural biological diversity of aquatic and terrestrial ecosystems of the Alligator Rivers Region, including ecological processes.

1.2 In particular, the company must ensure that operations at Ranger do not result in:

- (a) damage to the attributes for which Kakadu National Park was inscribed on the World Heritage list
- (b) damage to the ecosystem health of the wetlands listed under the Ramsar Convention on Wetlands (i.e. the wetlands within Stages I and II of Kakadu National Park)
- (d) change to biodiversity, or impairment of ecosystem health, outside of the Ranger Project Area. Such change is to be different and detrimental from that expected from natural biophysical or biological processes operating in the Alligator Rivers Region.

3 Water quality

3.1 The company must not allow either surface or ground waters arising or discharged from the Ranger Project Area during its operation, or during or following rehabilitation, to compromise the achievement of the primary environmental objectives.

3. Recommended values for ammonia

3.1 To protect aquatic ecosystems outside the Ranger Project Area in accordance with the rehabilitation objectives, predicted water quality at the boundary of the Ranger Project Area, reported as 72-hour moving averages, should not exceed the recommended values for the parameters shown in Table 1.

Table 1 Rehabilitation standard for ammonia in surface water

Parameter	Location	Rehabilitation standard [a]
Dissolved total ammonia nitrogen	In Magela and Gulungul creeks at the boundary of the Ranger Project Area, downstream of the Ranger mine	0.4 mg/L

[a] Calculated conservatively to be protective at the upper 90th percentile for temperature (32°C) and pH (6.4) of Magela Creek

4. Scientific basis

Guidelines and standards used to develop the recommended values

4.1 The rehabilitation standard for ammonia is based on the site-specific guideline value derived from laboratory-based effects data, using the procedures recommended in the previous and current Australian and New Zealand guidelines for fresh and marine water quality (ANZECC & ARMCANZ 2000, ANZG 2018) and associated methods subsequently revised by Batley et al. (2014) and Warne et al. (2018).

4.2 Given the ecological importance of the region surrounding the Ranger uranium mine, the rehabilitation standard for ammonia has been derived to provide the highest level of protection: at least 99% of species according to the national water quality guidelines (ANZECC & ARMCANZ 2000, ANZG 2018).

Scientific evidence summary

4.3 Ammonia is used during the processing of uranium ore. It is present at high concentrations in the Ranger uranium mine process water; approximately 900 mg/L total ammonia nitrogen. Ammonia presents a risk to the aquatic environment surrounding the Ranger uranium mine because it will be present at high concentrations in tailings and concentrated brine that will be disposed of in the mine pit voids. Ammonia may be mobilised under certain conditions and leach from the buried tailings and brine and enter surrounding surface water through groundwater egress after rehabilitation.

4.4 In solution, ammonia toxicity is caused by both ammonia and the ammonium ion, with ammonia being more toxic (USEPA 2013). Ammonia readily dissolves in water where it will ionise to form the ammonium ion. The extent to which this occurs depends on the pH and temperature, and to a lesser extent, other dissolved ions present in the water. Higher pH and temperature decreases ionisation (Emerson et al. 1975). Emerson et al. (1975) derived speciation equations to predict the speciation of ammonia in solution based on water pH and temperature. These speciation equations can be used to adjust toxicity estimates for individual species and subsequent guideline values for pH and temperature.

4.5 In Magela Creek stream channel, the natural baseline concentration of ammonia varies, with a median of 0.01 mg/L total ammonia nitrogen, a 5th percentile of 0.005 mg/L total ammonia nitrogen and a 95th percentile of 0.015 mg/L total ammonia nitrogen (derived from combined upstream and downstream data, n = 142). The ammonium ion is the dominant species in Magela Creek water (pH ~ 5.0 to 6.5) with the percentage of ammonia being < 0.25% of the total ammonia nitrogen concentration (Emerson et al 1975).

4.6 The ANZECC & ARMCANZ (2000) 99% species protection default guideline value for ammonia in freshwater is 0.32 mg/L total ammonia nitrogen at pH 8, which is based on the toxicity of ammonia to temperate species. This value increased to 0.88 mg/L total ammonia nitrogen when adjusted for the conditions of Magela Creek (pH 6.4). However, research has been published showing that tropical species are more sensitive to ammonia toxicity compared to temperate species, indicating that the default guideline value may be under-protective for tropical freshwater ecosystems. Similarly, the toxicity of ammonia may be increased in Magela Creek due to the low ionic strength of the water (Mooney et al. 2018a).

4.7 The Supervising Scientist studied the toxicity of ammonia on local aquatic species in the laboratory between 2014 and 2017. In this period, more than 26 laboratory experiments using eight local species were conducted at conditions representative of

Magela Creek. The potential for increased toxicity due to local water quality conditions in Magela Creek water was accounted for through the use of Magela Creek water as a diluent during laboratory toxicity tests (median pH ~ 6.0, *n* = 76,432; temperature range 27–31°C; and low concentrations of dissolved ions) (Mooney et al. 2018a, Mooney et al. 2018b, Kleinhenz et al. 2018). This testing confirmed that the toxicity of ammonia to local species was typically higher than that reported in previous studies for temperate species and other water types.

4.8 The results of these studies were used to derive a site-specific guideline value for ammonia. The nationally accepted species sensitivity distribution approach for deriving water quality guideline values (ANZECC & ARMCANZ 2000, ANZG 2018) was used to calculate a site-specific guideline value for ammonia that aims to protect 99% of species in the environment. The value was then adjusted to 0.4 mg/L total ammonia nitrogen based on the methodology of Emerson et al. (1975) and as recommended by Mooney et al. (2018a, 2018b), reflecting the upper 90th percentile pH of 6.4 (*n* = 76,432) and temperature of 32°C (*n* = 76,432) of Magela Creek. This adjustment represents the worst-case scenario for ammonia toxicity in Magela and Gulungul creeks, allowing an additional margin of protection.

4.9 Based on the evidence from the laboratory studies, 0.4 mg/L total ammonia nitrogen is recommended as the rehabilitation standard for ammonia. This value is equivalent to the European Union's (2006) national/regional ammonia water quality guideline value of 0.2 mg/L total ammonia nitrogen at pH 7 and 20°C (Appendix A). Alterations to the standard may be required if the pH and temperature of a water body exceed the threshold values calculated for Magela Creek (pH 6.4 and 32°C). A matrix is provided in Appendix A to undertake this alteration.

5. Future knowledge needs

5.1 Rehabilitation planning can only be based on the best available information at a given time, but this should not preclude the continual improvement of the knowledge base and its subsequent application where possible.

5.2 The Supervising Scientist, through its Key Knowledge Needs, has identified the knowledge required to ensure appropriate management of the key risks to the environment from the rehabilitation of the Ranger uranium mine. For ammonia, these knowledge needs are shown in Table 3.

Table 3 Key Knowledge Needs for Ammonia in surface water

ER Link	Key Knowledge Need	Questions
Biodiversity and human health	WS7. Determining the impact of chemical contaminants on aquatic biodiversity and ecosystem health	WS7A. Are current guideline values appropriate given the potential for variability in toxicity due to mixtures and modifying factors? WS7C. Are current guideline values appropriate to protect the key groups of aquatic organisms (e.g. flow-dependent insects, hyporheic biota and stygofauna) that have not been represented in laboratory and field toxicity assessments? WS7F. Can a contaminant plume in creek channels form a barrier that inhibits organism migration and connectivity (e.g. fish migration, invertebrate drift, gene flow)?

6. References

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Appendix A

The site-specific 99% species protection guideline value of 0.23 mg/L total ammonia nitrogen (at pH 7.0 and 20°C) adjusted to a range of pH and temperatures using the speciation equations of Emerson et al. (1975).

Table 2 Total ammonia nitrogen in mg/L adjusted for temperatures from 20 to 32°C and pH from 6.0 to 8.0

pH	**20°C**	**21°C**	**22°C**	**23°C**	**24°C**	**25°C**	**26°C**	**27°C**	**28°C**	**29°C**	**30°C**	**31°C**	**32°C[a]**
6.0	2.30	2.14	1.99	1.85	1.73	1.61	1.50	1.40	1.30	1.22	1.14	1.06	0.99
6.4[a]	0.91	0.85	0.79	0.73	0.68	0.64	0.59	0.55	0.52	0.48	0.45	0.42	0.39
6.5	0.73	0.68	0.63	0.59	0.55	0.51	0.47	0.44	0.41	0.39	0.36	0.34	0.31
7.0	0.23	0.22	0.20	0.19	0.17	0.16	0.15	0.14	0.13	0.12	0.11	0.11	0.10
7.5	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.04	0.03	0.03
8.0	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01

[a] The upper 90th percentiles for pH and temperature in Magela Creek are 6.4 and 32°C, respectively. Therefore, these water quality conditions formed the basis of the ammonia rehabilitation standard.