

A1 Results of water chemistry and radionuclide monitoring for 2001–02 Wet season

A1.1 Water chemistry (including radionuclides)

Background descriptions about the nature and sources of mine contaminants reaching ARR streams from the Ranger and Jabiluka mine sites may be found in [section 4 of the main paper](#).

Data are provided [in the accompanying graphs](#) for a number of physical and chemical indicators for three streams on ERA leases. These streams are Magela Creek, which flows immediately east of the Ranger mine, Gulungul Creek, which flows immediately west, and Ngarradj (Swift) Creek which flows east of the Jabiluka minesite. In each case a location upstream and downstream of the minesite were sampled.

A1.1.1 Commentary on Magela Creek monitoring data

Data for a number of variables for the monitoring period show strong concordance between upstream and downstream values (Ra, Ca, pH, turbidity) indicating no detectable mine-related effects. These variables are not significantly enhanced or altered in mine waste waters compared with levels found naturally in Magela Creek.

The most evident difference between the upstream and downstream sites for Magela Creek is the presence of elevated concentrations of uranium (U), magnesium (Mg), and sulphate (SO₄) at the downstream location. These differences are almost entirely due to the contribution from Retention Pond 1 (RP1) mine waste-water overflow to Coonjimba Billabong and thence to Magela Creek. When RP1 ceases to overflow, indicator values at the paired sites converge. Relatively minor contributions from Georgetown Billabong, via Georgetown Creek and Corridor Creek, Djalkmara Billabong releases and washoff from the Magela land application area are also probable, especially early in the Wet season. The concentrations of manganese (Mn) diverge, particularly towards the end of the season. The basin-shaped profile for Mn, particularly at the downstream site, is thought to be due to intrusion of natural groundwater to Magela Creek. The shallow groundwater near the Magela downstream site is known to contain elevated concentrations of soluble Mn. During recessional flow, the groundwater contribution increases as a proportion of total flow, leading to higher values for this element. Although electrical conductivity (EC) is notably higher at the downstream site, this indicator is a less sensitive measure of mine-related contribution than either Mg or SO₄.

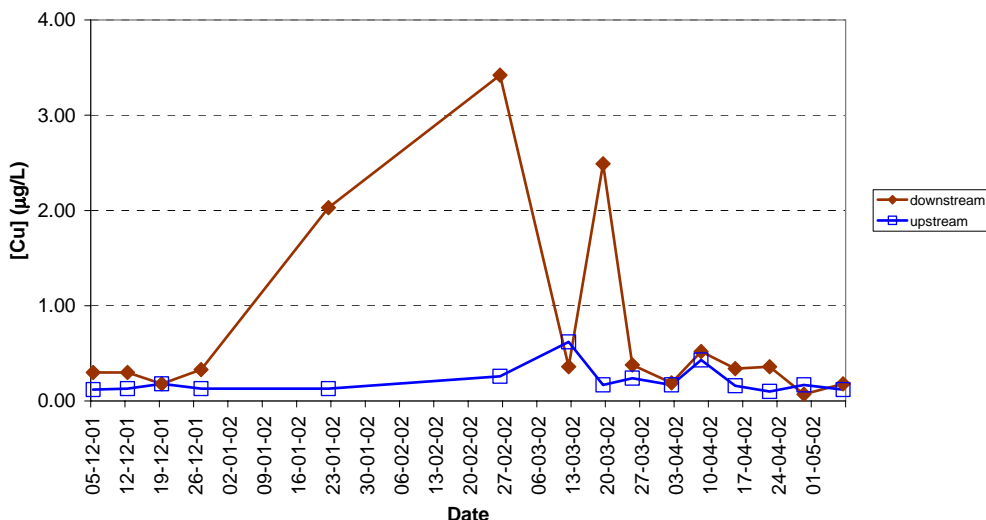
While mine-related changes were evident over the period of monitoring in the 2001-02 Wet season, limits were rarely exceeded for any constituent, indicating no environmental harm arising from mine waste water dispersion.

A1.1.2 Commentary on Gulungul Creek monitoring data

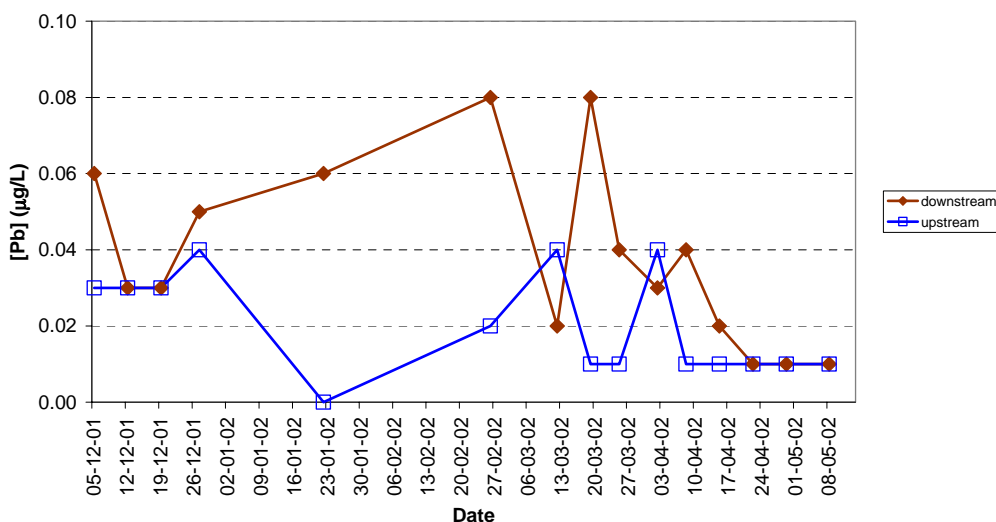
The downstream site at Gulungul Creek has a consistently higher SO₄ concentration than the upstream site. This would normally be interpreted as evidence for mine-related impact. However, the concentration of Mg is not higher at the downstream site whereas elevation would be expected if there was an influence from Ranger mine. This decoupling of Mg and SO₄ suggests that the source of the latter constituent may be the oxidation of sulphide minerals in the catchment, and unrelated to the mine. This interpretation is supported by the generally lower pH at the downstream site, which is the reverse of the observations from Magela and Ngarradj Creeks (and some tributaries of Ngarradj Creek, not shown). Sulphide oxidation is accompanied by a decrease in pH. Gulungul Creek flows through black soils and

associated swamps in the vicinity of Ranger, and these may be a source of low levels of sulphide minerals and some heavy metals. The downstream site shows elevated (though not environmentally significant) concentrations of copper (Cu) and possibly lead (Pb). Charts for these metals are shown below. These (particularly Cu) are not likely to be attributable to the mine, and strengthen the hypothesis that Gulungul Creek receives a measurable indicator input from riparian soils. Gulungul downstream also has a higher U concentration, compared with the upstream site. There is no clear indication of whether this is mine-related or not.

Copper in Gulungul Creek



Lead in Gulungul Creek



A1.1.3 Commentary on Ngarradj Creek monitoring data

The indicators measured for Ngarradj Creek included pH, conductivity, turbidity, uranium, magnesium, manganese, sulphate and calcium. For all indicators, concordance in

concentration values was maintained between the upstream and downstream sites throughout the monitoring season. In no case did values measured at the sites diverge in any significant way. These observations allow a high degree of confidence that no measurable mine-related additions of target indicators were observed during the 2001-02 Wet Season.

The most evident difference between the upstream and downstream sites at Ngarradj Creek is the higher SO_4 concentration at the upstream site. This observation is consistent over the Wet season and mirrors the baseline data of previous years. Full baseline data to the end of the 1999-2000 Wet Season (three years) are contained in leGras et al (2001). The reason is that the west branch of Ngarradj Creek (not routinely sampled), which joins the creek between the two monitoring sites contains lower SO_4 than the main branch. This difference is natural and may be related to spatial differences in the previous estuarine character of this region. This consistent reversal of the typical concentration pattern for SO_4 (upstream indicator concentrations are usually lower than downstream ones) provides a very sensitive indication of whether mine-related SO_4 is entering Ngarradj Creek. The only other significant divergence between the two sites relates to Mg. A basin-shaped profile is evident for Mg measured at both sites, but particularly downstream. As noted above, basin-shaped profiles are usually an indication of groundwater intrusion. Although this effect has been observed in previous years (the baseline period), it was more evident for the 2001-02 monitoring season. This may be due to the 2001-02 Wet Season having below average rainfall, but also a grossly abnormal distribution, where most precipitation fell in January and February. Under these circumstances surface flow will decline much earlier than usual (Ngarradj Creek stopped flowing in early May 2002), but groundwater flows may be much less affected. In this case, Mg-charged groundwater will make a greater contribution to surface flow, and earlier in the season.

A1.2 Radon and radon progeny in air at the monitoring station near the Mudginberri community

The figure shows monthly mean concentrations of radon-222 (Rn-222) in air at 1.5 m height between February 2000 and March 2002. The variation in concentrations between the Wet and Dry seasons can be easily seen from these data. The annual average Rn-222 concentration is 10.5 Bq/m^3 . By comparison, similar stations at DjarrDjarr and the East Alligator Ranger Station recorded annual average radon concentrations of 9.4 and 8.8 Bq/m^3 , respectively. Average radon concentrations vary from year to year and with geographical location depending on a large number of factors, including: distance from the coastline; meteorological parameters such as wind direction and atmospheric stability; soil moisture and porosity; and average soil radium-226 concentration. Few datasets are available for outdoor radon concentrations elsewhere in Australia with which the Mudginberri data can be compared. Data for the United States suggest a mean concentration in the vicinity of 10 Bq/m^3 (Nero, 1988).

Whereas radon concentrations are measured with a continuous monitor over long periods, radon progeny concentrations are measured over one-day periods only. This is because the nature of the available measurement techniques makes radon more amenable to continuous measurement in the field than is the case for radon progeny. At present, 3 readings at the Mudginberri station are available for radon progeny potential alpha energy concentrations (PAEC): 4 , 16 and 83 nJ/m^3 in February, April and May 2002, respectively. As for radon, the increasing values reflect the change from wet to dry seasons, as well as day-to-day variability in meteorological parameters.

Estimation of radon progeny PAEC from radon concentrations

Radon progeny PAEC may be estimated from radon concentrations using the equation:

$$C_{RDP} = f\alpha \cdot E\alpha \cdot C_{Rn}$$

With:

C_{RDP} : Radon progeny potential alpha energy concentration (PAEC), [nJ/m³]

$E\alpha$: PAEC per Bq of Rn-222 in equilibrium with short lived progeny, 5.6 nJ/Bq

$f\alpha$: equilibrium factor

C_{Rn} : radon activity concentration [Bq per m³].

The equilibrium factor is variable. It cannot be less than 0 or more than 1. Akber et al (1990) report values for the Alligator Rivers Region of between 0.2 and 0.5.

Conversion of radon progeny PAEC to a dose rate

The following calculation can be performed to estimate the effective dose resulting from exposure to radon progeny:

$$E_{RDP} = h_{RDP} C_{RDP} t$$

With:

E_{RDP} : effective dose due to the inhalation of Rn decay products [mSv]

h_{RDP} : dose conversion factor

C_{RDP} : Rn progeny PAEC [nJ/m³]

t : inhalation time

The dose conversion factor h_{RDP} recommended in ICRP 65 (1993) is 1.1 nSv/(nJh/m³) (for Rn in equilibrium with progeny).

Estimate of total dose rate at Mudginberri community due to radon progeny

Using the equations discussed above, if we assume an average value of 0.35 for the equilibrium factor, then the average radon concentration of 10.5 Bq/m³ at the monitoring station near the Mudginberri community would translate to a radon progeny PAEC of 21 nJ/m³, and hence to an effective dose rate for full-time occupancy of approximately 0.2 mSv per year. This dose is primarily natural and hence not subject to dose limits.

Contribution from the Ranger minesite

Estimating the contribution from the Ranger minesite to radon and radon progeny concentrations at the monitoring station near the Mudginberri community is difficult because it is certainly much lower than the natural concentrations. An estimate for the period March 1989 to February 1990 using an atmospheric dispersion model gave the contribution to be approximately 0.8 Bq/m³ for radon and 0.8 nJ/m³ for radon progeny PAEC (Martin 2000).

For full-time occupancy at Mudginberri community (365 days per year) a Rn progeny PAEC of 0.8 nJ/m³ converts to 0.0077 mSv, which is less than 1% of the dose limit of 1 mSv per year for a member of the public. The dose limit applies to total dose including all pathways; nevertheless it is plain that the contribution of radon progeny from Ranger to effective dose at Mudginberri is extremely small.

eriss is currently conducting research projects using a set of radon monitors in the field, together with measurements of rates of exhalation of radon from the minesite surface, to improve and update these estimates.

A1.3 References

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