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22 March 2022

Scott Hayes-Stanley
Director
Wulguru Technical Services
Suite 3, Level 1
559 Flinders Street
Townsville, QLD 4810

Dear Mr Hayes-Stanley,

C&R Consulting Pty Ltd (C&R) recently completed a waste rock characterisation report (C&R, 2022[1]) for the Wirralie Gold Mine (WGM), for Wulguru Technical Services (WTS), to support WGM's progressive rehabilitation and closure plan (PRCP). It is understood that, following the review of this document, the Department of Environment and Science (DES) raised concerns about contaminants within the tailings storage facility (TSF) at WGM. The issues related to the potential for the formation of moderately/highly saline waters and the potential mobilisation of elevated cadmium and selenium levels. The salinity matter was addressed in the letter from C&R (dated 17 March 2022) which stated:

"Based on the above assessment it is suggested that risk associated with salinity from the waste rock (including tailings) at WGM is considered low/moderate with the potential of brackish runoff/infiltration."

Therefore, this letter aims to address the concerns of DES around the potential for elevated levels of cadmium and selenium to mobilise and transport to receiving environments.

Table 8 in C&R (2022) details the recorded levels of various analytes (including cadmium [Cd] and selenium [Se]) from up to four kinetic leach experiments. It should be noted that the results in successive columns are cumulative. Therefore, when the results for cadmium are reviewed for each individual leach fewer exceedances of guideline values are noted. For instance, in TSF01 with a comparison contaminant limit of 0.01 mg/L, leach 0 has a level of 0.00690 mg/L and leach 1 a concentration of 0.01100 mg/L (i.e. exceeding the contaminant limit). However, when the certificate of analysis (COA) sheet for leach 1 is examined (in Appendix B of C&R, 2022), the value given is 0.00410 mg/L. That is the fluid passing the material for leach 1 only produced 0.00410 mg/L dissolved cadmium, a level compliant with the contaminant limit. Similarly, analyses of the fluids actually passing through in leaches 2, 3 and 4 respectively were 0.00180, 0.00130 and 0.00080 mg/L, all compliant with the contaminant limit.

For cadmium in TSF 03, the initial level was 0.3430 mg/L, with 0.02910.mg/L added in leach 1 and a further 0.01080 mg/L in leach 2 to give a cumulative total of 0.07490 mg/L. All the individual values

[1] C&R (2022). *Wirralie Gold Mine: Waste Rock Characterisation*. Report prepared for Wulguru Technical Services.

and the cumulative levels are non-compliant with the contaminant limit, leach 2 only slightly at 0.01080 mg/L.

Similar data for selenium indicate comparable trends. For TSF 02 (contaminant limit of selenium is 0.02 mg/L) an initial compliant level of 0.0200 mg/L for leach 0 is supplemented by 0.0050 mg/L in leach 1 to give a cumulative total of 0.0250 mg/L. This level of supplementation is also observed in leaches 2, 3 and 4 to give a final cumulative total of 0.0400 mg/L. Thus, although cumulative totals may be non-compliant, all individual leach results meet the contaminant limit of 0.0200 mg/L.

For TSF 03 the cumulative data for leaches 0, 1 and 2 are 0.030, 0.060, and 0.070 mg/L respectively (refer to Table 8 in C&R, 2022) with individual additions of 0.030 and 0.010 mg/L for leaches 1 and 2. The initial level and the first leach (both 0.030 mg/L) are non-compliant with the contaminant limit of 0.020 mg/L. The increase from leach 1 to leach 2 (of 0.010 mg/L) is compliant with the contaminant limit. The levels of selenium in these samples from TSF 03 may show a degree of correlation with iron in the fluid.

A recent review of cadmium in soils and groundwater (Kubier *et al*., 2019[2]) indicates that in groundwaters cadmium mainly occurs as the divalent cation and is mobilised in oxic, acidic conditions. The sorption of cadmium is enhanced by the presence of hydrous oxy-hydroxides (iron, aluminium, manganese and silicon), clay minerals and organic matter. Its mobility is further influenced by pH, redox and the ionic strength of the solution. The association of cadmium with the zinc sulphide (sphalerite) is well documented as is the existence of cadmium chloride and cadmium sulphate solution species in the associated fluids

Generally, the mobility of dissolved cadmium is high but its adsorption by the hydrous oxy-hydroxide species (which usually occur as colloids) and/or clay minerals may limit its mobility and bio-availability. The hydrous oxy-hydroxides of iron, aluminium, manganese and silicon as well as clay minerals (smectite, kaolinite and illite) are present in the materials of the WGM TSF. Therefore, it is likely that they will moderate the mobility of cadmium in the system.

A review by Gebreeyessus and Zewge (2018[3]) on environmental issues associated with selenium indicates that the mobility and bio-availability of this element is complex. Recorded selenium may occur in the environment in several forms:

- as selenide, the divalent anion;
- as the element selenium;
- as the quadrivalent species which is present in the divalent anion selenite ($Se0_3^{2-}$); and
- as the hexavalent species which is represented by the divalent anion selenate ($Se0_4^{2-}$).

Selenium speciation in acidic and reducing conditions reduce organic selenites to elemental selenium whereas alkaline oxidising conditions favour the formation of selenates in the environment. The solubility of both selenites and selenates in water means that selenium in leachates from soils is favoured under oxic (i.e. oxygenated), alkaline conditions. Selenides are insoluble and are favoured under wet, anoxic conditions. Similar to cadmium, the adsorption of selenites and selenates to hydrous oxy-hydroxides of iron, aluminium and possibly manganese, as well as clay minerals will restrict mobility of these species. Selenium mobility may also be reduced by micro-biological interactions.

[2] Kubier, A., Wilkin, R.T.,and Pichier, T. (2019). Cadmium in soils and groundwaters: A review. *Applied Geochemistry*, **108**: 1-16.
[3] Gebreeyessus, G.D., and Zewge, F. (2018). A review on environmental selenium issues. *Springer Nature. Applied Sciences*. Published on line 22 November 2018.

Given that the leach solutions are only of low to moderate salinity (not moderate to high) and the presence of hydrous oxy-hydroxides of iron, aluminium, manganese and silicon, as well as clay minerals (smectite, kaolinite and illite) in the TSF, leachate from the material within the TSF is considered low to moderate risk.

Regards,

Dr. Christopher Cuff

Principal Scientist/Geochemist – Director
C&R Consulting Pty Ltd