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Heap leach cyanide irrigation and risk to wildlife: Ramifications for the international cyanide management code

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ABSTRACT

Exposed cyanide-bearing solutions associated with gold and silver recovery processes in the mining industry pose a risk to wildlife that interact with these solutions. This has been documented with cyanide-bearing tailings storage facilities, however risks associated with heap leach facilities are poorly documented, monitored and audited. Gold and silver leaching heap leach facilities use cyanide, pH-stabilised, at concentrations deemed toxic to wildlife. Their design and management are known to result in exposed cyanide-bearing solutions that are accessible to and present a risk to wildlife. Monitoring of the presence of exposed solutions, wildlife interaction, interpretation of risks and associated wildlife deaths are poorly documented. This paper provides a list of critical monitoring criteria and attempts to predict wildlife guilds most at risk. Understanding the significance of risks to wildlife from exposed cyanide solutions is complex, involving seasonality, relative position of ponding, temporal nature of ponding, solution palatability, environmental conditions, in situ wildlife species inventory and provision of alternative drinking sources for wildlife. Although a number of heap leach operations are certified as complaint with the International Cyanide Management Code (Cyanide Code), these criteria are not considered by auditors nor has systematic monitoring regime data been published. Without systematic monitoring and further knowledge, wildlife deaths on heap leach facilities are likely to remain largely unrecorded. This has ramifications for those operations certified as compliance with the Cyanide Code.

1. Introduction

Cyanide-bearing solutions associated with gold and silver extraction and recovery processes in the mining industry pose a potential toxicological risk to wildlife interacting with these solutions. It has been documented at tailings storage facilities (Griffiths, 2014a, 2014b; M.E. Smith, 2008; G.B. Smith, 2008; Donato, 1999; Hagelstein, 1997; Sinclair et al., 1997; Adams et al., 2008; Smith et al., 2010) and although not examined, a number of potential risks are associated with heap leach facilities. Heap leach facilities are used to leach metals such as gold (Lottermoser, 2007; Schlitt, 1992; G.B. Smith, 2008; M.E. Smith, 2008; Marsden and House, 2006), silver (Schlitt, 1992; Smith, 2008), copper (Schlitt, 1992; G.B. Smith, 2008; M.E. Smith, 2008; IIED, 2002), and to a lesser extent uranium (Schlitt, 1992) and nickel (G.B. Smith, 2008; M. Smith, 2008), from low grade ore (G.B. Smith, 2008; M.E. Smith, 2008; Eisler and Wiemeyer, 2004) and occasionally milled tailings (G.B. Smith, 2008; M.E. Smith, 2008; Eisler and Wiemeyer, 2004; Thiel and Smith, 2003). Their design and management are known to result in risks to wildlife arising from exposure to cyanide-bearing solutions. These risks are reviewed in the context of compliance with the International Cyanide Management Code (Cyanide Code).

1.1. Wildlife cyanide toxicity

Hydrogen cyanide and other cyanide compounds that liberate free cyanide ions are highly toxic to almost all forms of fauna and flora (Souren, 2000). Cyanide is a fast acting (Environment Australia, 1998, 2003; Staunton and Jones, 1989) and the toxicity is related to the inverse of the bond strength of metal atoms and cyanide ligands (Staunton and Jones, 1989; Klenk et al., 1996; Sadler, 1990). Sodium cyanide causes death in fauna by inhibiting enzyme reactions that prevent oxygen flow to the blood (US EPA, 1994). Within seconds of inhalation or ingestion cyanide can, if the absorption rate is greater than the detoxification rate (Eisler, 2000), produce reactions such as rapid asphyxiation (Eisler, 2000; Wiemeyer, 1986) and incapacitation (Eisler, 2000) and leading to death (Eisler, 2000; Wiemeyer, 1986) within minutes (Eisler, 2000). Acute, sub-lethal exposure to cyanides are readily metabolised in the body with minimal long-term effects (Donato and Smith, 2007; Henny et al., 1994; Ma and Pritsos, 1997; Minerals Council of Australia, 1996; Smith and Mudder, 1995).

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Biota readily absorb cyanide compounds (Klenk et al., 1996) and poisoning may occur due to inhalation of dust and mist, ingestion, absorption through mucous membranes and absorption through direct contact with intact skin (Wiemeyer, 1986; Henny et al., 1994; Minerals Council of Australia, 1996; Reece, 1997; Ryan and Shanks, 1996). The poison action of cyanide is similar regardless of the route response (Environment Australia, 2003). Laboratory lethal toxicity of essentially free cyanide complexes to birds has been reported (Reece, 1997; Eisler, 1991; Barcroft, 1931; Davis, 1981). In the field, the critical measure is the environmental resilient weak-acid-dissociable cyanides of which copper cyanide complexes is a major component in mine waste solutions (Donato et al., 2007). A concentration below 50 mg/L weak-acid-dissociable cyanide in mine waste solutions has been reported as safe to wildlife (Henny et al., 1994; Hagelstein and Mudder, 2001; International Cyanide Management Institute, 2012a). Field observations of wildlife at tailings storage facilities have identified that ingestion of solutions is the only lethal pathway (Griffiths, 2014a; Adams et al., 2008; Smith et al., 2010). Cyanide is not resilient in carcasses and therefore they are readily scavenged by other wildlife (Donato, 1999).

1.2. Wildlife deaths on heap leach facilities

Wildlife deaths on heap leach facilities have been reported by not in detail of extent and species composition (Henny et al., 1994; Eisler, 1991). At a heap leach facility in South Dakota, USA, exposed collection ditches, resembling streams, attracted songbirds, mainly Common Crossbill (*Loxia curvirostrata*) and Pine Siskins (*Carduelis pinus*) killing 573 birds (Parish, 1989). Although these ditches were then covered with crushed rock, deaths still occurred when cyanide-bearing solution pooled on the top of the rock (Parish, 1989). A heap leach operation in the Northern Territory, Australia, killed 32 ducks in one evening (Donato, 1999). In the first dry season (primarily May to June) of a heap leach operation in west Africa, 554 bird fatalities were recorded including swifts, swallows, nightjars and the raptors; buzzards, goshawks and hobbys (AngloGold Ashanti, 2016).

2. Operation of cyanide-bearing heap leach facilities

Heap leach facilities are extensively used in Africa (Eagle Environmental, 2008), North (Golder Associates Inc, 2010) and South America (Geoengineers Inc, 2009) and a number of these operations are Cyanide Code certified. A heap leach facility is constructed using an impermeable base (Eisler and Wiemeyer, 2004; Thiel and Smith, 2003; Bartlett, 1998; Hornsey, 2010; Majdi et al., 2007, 2009; Breitenbach, 2000) with a geomembrane (G.B. Smith, 2008; M.E. Smith, 2008; IIED, 2002; Hornsey, 2010; Majdi et al., 2009; Breitenbach, 2000), or less commonly as a standalone composite liner (Thiel and Smith, 2003) or compacted clay. Typically collection pipes, usually constructed from HDPE, are laid directly over the liner to improve heap drainage followed by a granular soil layer to protect the system during ore stacking (Hornsey, 2010). Ore is either piled in lifts from run-of-mine or specially prepared by crushing and sometimes agglomeration (Schlitt, 1992; G.B. Smith, 2008; M.E. Smith, 2008; IIED, 2002; Thiel and Smith, 2003; Breitenbach, 2000). The heap is irrigated with cyanide-bearing solution which can be either sprayed onto the heap (Schlitt, 1992; Marsden and House, 2006; IIED, 2002; Eisler and Wiemeyer, 2004) or by drip irrigation (Marsden and House, 2006; Eisler and Wiemeyer, 2004). Drip irrigators can be buried under coarse material to limit evaporation and reduce wildlife exposure. Free cyanide, pH-stabilised, is typically irrigated at a concentration between 50 and 500 mg/L (Marsden and House, 2006; Bartlett, 1998; NICNAS, 2010). The cyanide percolates through the heaped ore dissolving gold (Lottermoser, 2007; Marsden and House, 2006; Eisler and Wiemeyer, 2004), silver (Lottermoser, 2007) and other desirable metals.

Leaching cycles are usually between 30 and 120 days (G.B. Smith, 2008; M.E. Smith, 2008; Breitenbach, 2000) to several months (Eisler and Wiemeyer, 2004). Following collection usually by the pipes from underneath the heap, the leachate containing gold and other desired metals is drained from the heap leach pad and transferred to the process ponds (Schlitt, 1992). These transfer solutions and process pond solutions contain variable cyanide concentrations but are typically above 50 mg/L WAD cyanide concentration. Cyanide resilience in the initial irrigation solutions is provided by elevated pH (usually above pH 10) and may be stabilised by metallo-cyanide complexes in impregnated collection solutions.

2.1. International cyanide management cyanide code

The Cyanide Code is a voluntary program for gold and silver mining companies, producers and transporters of cyanide to encourage industry-wide responsible use and management of cyanide (International Cyanide Management Institute, 2012a). The primary objectives of the Cyanide Code are the protection of human health and the reduction of environmental impacts associated with the use of cyanide in the gold and silver mining industry. To maintain certification under the Cyanide Code an operation is to be audited by third-party independent auditors on a triennial basis. The issue of wildlife deaths from interaction with tailings system cyanide-bearing mine waste solutions has essentially been eliminated from Cyanide Code-compliant operations, but remains a contentious issue at non-signatory operations. Wildlife interaction and cyanide monitoring protocols of tailings systems have been developed and widely implemented in Australia as leading practice (Griffiths, 2014a; M.E. Smith et al., 2008; G.B. Smith et al., 2008; Adams et al., 2008; Smith et al., 2010; Donato and Smith, 2007).

Specifically, the objective of Standard of Practice 4.4 is as follows: Implement measures to protect birds, other wildlife and livestock from adverse effects of cyanide process solutions. For an operation to be compliant, an auditor must be satisfied that the objective of the standard of practice is met, and to be recertified an auditor must be satisfied of continual compliance over the triennial audit period. *"One of the few numerical guidelines is a 50 mg/L cyanide concentration limit for exposure of birds"* p 31 (International Cyanide Management Institute, 2012b), other wildlife and livestock. *"This recommended limit applies solely to water in tailings impoundments, heap leach facilities and other open ponds and impoundments to which wildlife has access. This recommended limit also applies to solution ponds and open solution trenches or ditches at a heap leach pad, as well as leach solution ponded on the surface of a leach pad due to poor infiltration"* p 32 (International Cyanide Management Institute, 2012b).

The Cyanide Code prescribes that *"an operation apply leach solutions in a manner designed to avoid significant ponding on the heap surface"* p 35 (International Cyanide Management Institute, 2012b). It is however recognised within the Cyanide Code *"the fine content of some ore will restrict infiltration and promote ponding of leach solution on the surface of a heap leach facility. While this cannot always be completely eliminated, and some level of ponding can be expected, operations should take appropriate measures to limit excessive ponding that provides an attractive water source for birds"* p 35 (International Cyanide Management Institute, 2012b).

The Cyanide Code goes on to state, *"The Cyanide Code does not establish a numerical standard for what level of ponding is considered to be excessive, but each operation should determine this itself"* p 36 (International Cyanide Management Institute, 2012b).

Operations are to make their own interpretations on what is significant or excessive ponding and determine the attractiveness of a water source. This has typically been interpreted by operations and auditors, as volume or surface area of ponding, essentially meaning size.

A review of all Cyanide Code certified heap leach operations summary audit reports (see www.cyanidecode.org (International Cyanide Management Institute, 2015, 2015)), demonstrates that auditors, on justifying full compliance, use the size terminology regarding