BIRDS ASSOCIATED WITH THE TAILINGS STORAGE FACILITY AND SURROUNDS OF A SOUTH AFRICAN GOLD MINE

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ABSTRACT

As part of the 'International Cyanide management code for the manufacture, transport, and use of cyanide in the production of gold', companies voluntarily commit towards keeping the weak-acid-dissociable (WAD) cyanide concentrations in tailings below 50 $mg.l^{-1}$. Day and nighttime observations were made in winter at the tailings storage facility (TSF) of the Mponeng mine of AngloGold Ashanti, and extensive surveys of the surroundings were made for mortalities. The cyanide levels never exceeded 50 $mg.l^{-1}$ WAD. No dead birds or mammals were found.

Twenty-five bird species were recorded in and around the TSF and the associated return water dams (RWDs), with 20 occurring only in the surrounding grasslands or RWDs, and five (four wader species and a sand martin) on the TSF.

The wading birds were most likely feeding on dead insects from the pond surface, as they adjusted their locations according to wind direction. Other birds actively avoided the TSF water, possibly suggesting a locally learned behaviour. Whether this avoidance will also hold for migratory birds or natal dispersal of local birds in summer necessitates further investigation. A better understanding of the TSF–wildlife interactions would lead to improved measures to reduce environmental risks.

Key words: ICMI, insects, WAD cyanide, waders

1. INTRODUCTION

Tailings storage facilities (TSFs) are a well-known component of the altered landscapes of many parts of South Africa, and indeed most gold mining areas of the world. In South African gold extraction, sodium cyanide is used to dissolve the gold forming $Au(CN)_2$ from crushed ore in leach tanks. The gold is then extracted from this solution activated carbon, and much of the liquid is then reused. The residue slurry contains the fine gangue materials, as well as toxic cyanide residues in various forms. This slurry is then pumped on the TSFs where the particles settle out. After sedimentation, the supernatant water is drawn down to return water dams (RWDs) via penstocks, from where the water is recycled for re-use. The temporary ponds of standing water on the TSFs and RWDs attract wildlife, particularly birds where they come into contact with cyanide (Read, 1999). This can lead to mortality including migratory birds (UNEP 2006; Donato et al., 2007), and some have been recorded in the U.S.A. (Eisler, 1991; Eisler & Wiemeyer, 2004) and Australia (Read, 1999). A frequently cited publication reports 9512 mortalities between 1986 and 1991 in Nevada, of which 91% were birds covering more than 91 species, 7% were mammals including bats and carnivores (including endangered mammals), and the remainder were made up by frogs and reptiles (Henny, Hallock & Hill, 1994).

A global initiative, developed in consultation with the United Nations Environment Programme (UNEP) in collaboration with the International Council on Metals and the Environment, led to the 'International cyanide management code for the manufacture, transport, and use of cyanide in the production of gold'; in short, the Code, is administered by the International Cyanide Management Institute (ICMI). It is an industry voluntary programme to which companies subscribe and are audited against (ICMI 2007). Regarding wildlife, companies are audited against a maximum of 50 $mg.l^{-1}$ weak-acid-dissociable (WAD) cyanide in the liquid or tailings solutions on the TSFs; a level generally assumed to be appropriate for wildlife protection (Donato et al., 2007; ICMI 2007), although effects in birds at lower levels of exposure have been found (Pritsos & Ma, 1997; Brasel, Cooper & Pritsos, 2006). We could trace no published information on how wildlife interacts with gold mining TSFs in Africa. In this survey, we investigated the contact patterns and any signs of toxicity or mortalities of wildlife in relation to the TSF of AngloGold Ashanti Mponeng Mine in the North–West Province as part of an ICMI external audit of the mine. Results of the audit can be seen at (ICMI, 2007).

2. METHODOLOGY

Location and Observations

The Mponeng TSF (26°27’S, 27°23’E) is of a raised embankment, upstream type, with a side-hill valley embankment, and is located on a south-east facing slope of a hill, surrounded by grasslands and small *Acacia* stands (Fig. 1). The surface area is 90 ha, and about 6000 tons of tailings with 64% water content are deposited every day. RWDs and reservoirs, some with substantial reed beds, are located further down the slope. The northern side of the TSF is not embanked, and the shore is therefore natural veldt with no artificial barriers keeping small wildlife away, although fences restrict access of cattle and people.

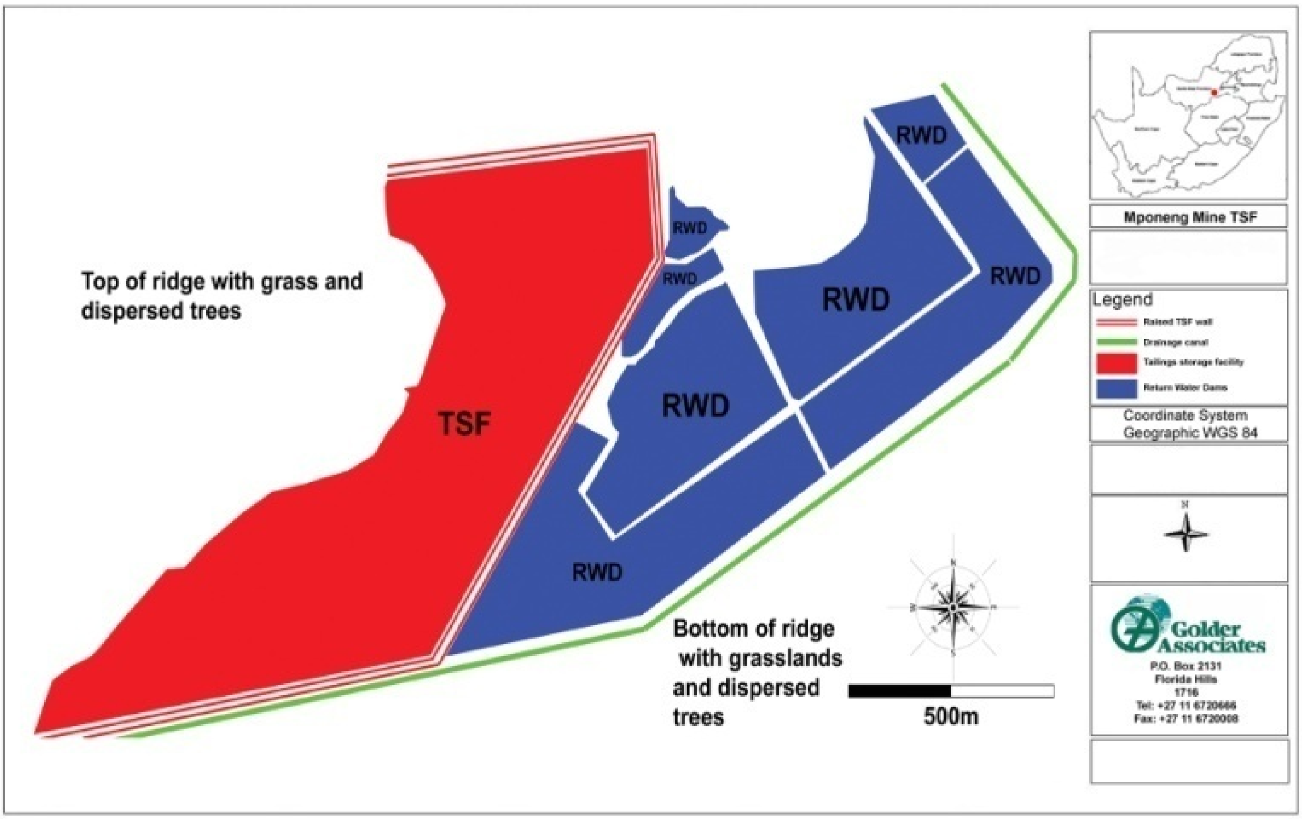

Figure 1. Schematic representation of the study area

Sixty hours of observations were made in four 12-h stints (06.00–18.00 hours) on 4 days (one on a Saturday to observe possible racing pigeons), and one additional day–night observation (12.00–24.00 hours) between 23 and 28 May 2006, using binoculars (8 x 25), a telescope (40 x 50) and night vision equipment (2.5 x 50). Species, activities and individual length of time in contact with tailings solution were recorded. Birds in the surrounding landscape and at RWDs were recorded from good observation spots on the TSF wall or from the shoreline. The maximum number per species seen at any given period (or from established territories for the larks and chats) is reported, as concurrent tracking of individuals was not possible and averaging over days would not reflect activity.

The surrounding areas were investigated for wildlife mortalities, especially areas used by birds for roosting, as well as areas where old bird nests were found.

3. RESULTS

Cyanide concentrations measured in the pumped slurry at the extraction plant never exceeded 50 $mg.l^{-1}$ WAD cyanide during any of the observation periods. During the surveys, daytime conditions for observations were excellent with little wind or dust, but the night-time temperature dropped to below freezing. Although the area was searched extensively for carcasses that may have been caused by cyanide poisoning, none were found. Twenty five bird species were recorded in and around the TSF and the RWDs, with 20 occurring only in the surrounding grasslands or RWDs, and five on the TSF, in close contact with standing water (Table 1). None were Red Data Book species for South Africa. Because the surveys were carried out during winter, no migratory birds were present. We did not see any racing pigeons, although, on similar mining locations (but without cyanide) we noticed these birds landing to take a quick drink. No birds were seen during the night survey.

Four bird species were recorded regularly utilizing the TSF (Table 1). All were observed wading along the lee shoreline of the ponds, exhibiting typical feeding behavior (Fig. 2). The only other species we observed utilizing the TSF water was the brown-throated martin; two individuals were seen drinking water in flight on one occasion. Kittlitz's plovers and three-banded plovers were present almost the entire day feeding (running and pecking) along the shoreline of the ponds on the TSF, whereas blacksmith lapwings would spend about 16–22 min per individual (Table 1), also showing typical feeding behaviour along the lee shoreline, before returning to the grassland area to the north of the TSF. Cape wagtails would forage on the shoreline for short periods (up to 15 min) before moving away for extended periods. Assuming that individuals return more than once per day to forage on the TSF, individual Kittlitz's plovers, three-banded plovers (Fig. 2), blacksmith lapwings and Cape wagtails were estimated to spend c. 360, 300, 150 and 100 min day^{-1} $individual^{-1}$, respectively, on the TSF (Table 1). The brown-throated martin probably had <1 min day^{-1} $individual^{-1}$ in contact with TSF water, and that was for in-flight drinking. During the survey, we noticed dead insects and insect remains on the TSF pond water surface. It was noticeable during the study that birds from the areas surrounding the TSF did not utilize the TSF at all, resulting in a very sharp behavioural and species ecotone, with feeding waders on the TSF, and all other birds active around it. Although there were granivorous birds in the grassland area of the RWDs, which also regularly drank water from the RWDs, granivorous species neither were recorded in the grassland area immediately adjacent to the TSF (in a band of c. 50 m), where the tailings came into direct contact with the grasslands, nor were they found to drink water from the TSF. Striped mouse, *Rhabdomys pumilio*, vlei rat, *Otomys irroratus*, and yellow mongoose, *Cynictis penicillata*, were only seen during the day, but neither any interaction with TSF water nor any tracks on the soft tailings were observed.

Table 1. Species, types of contact and contact time recorded during the survey.

Common Name	Scientific Name	Surrounds	RWDs	TSF	TSF activity	TSF contact time (min-max/individual)	Estimated daily individual contact time
Reed Cormorant	*Phalacrocorax coronatus*		2				
Yellow-billed Duck	*Anas undulata*		7				
African Purple Swamphen	*Porphyrio madagascariensis*		2				
Red-knobbed Coot	*Fulica cristata*		14				
Kittlitz's Plover	*Charadrius pecuarius*	16		16	Wading/feeding	35–114 min	360 min
Three-banded Plover	*Charadrius trichollaris*	8		8	Wading/feeding	28–48 min	300 min
Blacksmith Lapwing	*Vanellus armatus*	6		6	Wading/feeding	16–22 min	150 min
Rufous-naped Lark	*Mirafra africanoides*	12					
Sabota Lark	*Mirafra sabota*	14					
Spike-heeled Lark	*Chersomanes albofasciata*	2					
Brown-throated Martin	*Riparia paludicola*	6		6	Drinking	5 s	>1 min
Mountain Wheatear	*Oenanthe monticola*	7					
Familiar Chat	*Cercomela familiaris*	6					
Ant-eating Chat	*Myrmecocichla formicivora*	2					
Desert Cisticola	*Cisticola aridulus*	3					
Chinspot Batis	*Batis molitor*	1					
Cape Wagtail	*Motacilla capensis*	12		12	Wading/feeding	4–15 min	100 min
Cape Longclaw	*Macronyx capensis*	2					
Common Fiscal	*Lanius collaris*	3					
Bokmakierie	*Telophorus zeylonus*	1					
White-browed Sparrow Weaver	*Plocepasser mahali*		16				
Southern Masked Weaver	*Ploceus velatus*		34				
Southern Red Bishop	*Euplectes orix*		12				
Laughing Dove	*Streptopelia senegalensis*	23					

Yellow-crowned Bishop	*Euplectes afer*	3

4. DISCUSSION

The top of TSFs is harsh and cold in winter, the light grey surface reflects sunlight (Fig. 2), and it can be very windy and dusty, partially explaining the low numbers of birds we observed. Bird species richness was considerably higher in the area below and to the south and east of the TSF, due to the RWDs. Waterfowl such as yellow-billed duck, redknobbed coot, and African purple swamphen occurred only on the RWDs (Table 1). The lack of food and nesting sites in the TSF area, due to the (presumed) sterility of the water, would make this area highly unsuitable. Granivorous species are known to need a daily water supply (Maclean, 1990); therefore these species were initially thought to be at high risk from drinking cyanide-containing TSF water. We found, however, that granivorous species (Table 1) did not utilize the TSF for drinking at all, and almost exclusively restricted their movements to the area to the south and southeast of the TSF. Hardly, any granivorous birds were recorded in the grassland to the north of the TSF, although some old southern masked weaver nests were found a considerable distance to the north in some A*cacia* trees, indicating their presence during the summer. This may be due to a lack of sufficient nesting sites immediately to the north of the TSF, or an effect of the cyanide-containing water itself, that has caused the birds to select areas that are closer to cleaner water in the RWDs. Similarly, laughing doves were also absent in the area to the north of the TSF, but were common in the areas to the south and southeast.

Only five bird species utilized the TSF while the other species, although a very short distance away, seemed to actively avoid the area. The absence of any granivorous birds on the northern grasslands does, however, suggest a locally learned behaviour of the resident birds. The sharp distribution and behavioural ecotone observed were such that it suggests either a drastic difference in visual environmental cues that cause birds to prefer the cleaner RWDs, a locally learned behaviour, or a combination of both. However, little support for a learned avoidance behaviour of a specific area is available from literature. Chickens did not associate visual cues on the ground with elevated ammonia levels in air (Jones, Wathes & Webster, 2005), although breeding waterfowl preferred less acidic lakes in Canada, but this was probably due to lack of insect prey in acidic water(Parker, Petrie & Sears, 1992; Scheuhammer et al., 1997).

However, mechanisms for selective habitat use based on dietary and spatial awareness (Forbes, 1998), behavioural changes to changing environments (Wingfield, 2003) (wind direction and daily changes in water surface levels on the TSFs in this case), and the responses of animal movement in altered landscapes (Fahrig, 2007), may explain the behavior patterns observed. If a locally learned behaviour pattern was the case (and this is hypothetical only), it would imply that in summer, when migrants return and when natal dispersion of non-migrants occurs, increased contact with the TSF water may be expected. An observation supporting a possible locally learned behaviour would be the presence of the wading birds on the TSF that have obviously habituated to the almost constant presence of people and noise, but the finches and weavers, although quite capable to adjust to similar disturbance in urban areas, did not. This, in turn, indicates that the introduction of any bird scaring measures (Allen, 1990; Read, 1999) would have to contend with the already existing disturbances, possibly minimizing its long-term effectiveness.

As remarked in the Results section, we saw insects on the pond water. The reason for the presence of the wading birds on the TSF would most likely be the presence of food, as they exhibited typical wader foraging behaviour. Although we did not test for the presence of any native macro-invertebrates in the water or sediment, this seems unlikely due to the high pH and conductance, cyanide, and fluctuating water levels throughout the day. The best explanation is that flying insects are attracted and land on the water and are then incapacitated (either due to cyanide, high pH, or other factors), and that the birds collect these from the water surface or at the shore/water interface (Fig. 2). The birds were seen to adjust their feeding areas according to wind direction, mostly, to forage on the lee side, supporting the deduction that wading birds feed on extraneous insects. The birds were specifically seen picking at objects on the surface of the water and shore/water interface (as the water recedes, insects would become lodged on the edge), and not pecking into the sedimented tailings surface or underneath the water surface, a normal foraging behaviour on natural mudflats.

This aspect, as far as we could ascertain, has not been reported before. The flying insects would probably be both terrestrial and aquatic in origin, but this needs further testing. The same insects would also land on the other (less toxic) water bodies in the area, but the shallow shoreline, possibly better visibility of prey and predators, and easier access (no fringe vegetation), could combine to attract the wading birds we observed to the TSF.

The same combination of factors might also be the reason for the avoidance by other birds. Natural pans (shallow temporary ponds with little or no fringe vegetation), however, do attract the same species that actively avoided the TSFs, as well as the waders (own observations). Obviously, there are many aspects that need further investigation. The four wading species that came into contact with the TSF pond water, sediment and prey (Table 1), did not show any obvious symptoms of cyanide toxicosis (Eisler, 1991), such as panting, eye blinking, salivation and lethargy.

Figure 2. Kittlitz' Plover wading on the shoreline of the TSF

Although the sediment and water would contain cyanide at <50 mg.l^{-1} WAD, it would appear that either the concentrations were too low to have had any noticeable effect on birds, or that the birds were not ingesting or taking up (through the skin) enough cyanide to have caused an immediate adverse effect during single or multiple visits (Table 1). We presumed that the same birds returned to the TSFs every day, based on experience from regular wetland counts. No birds, besides the brown-throated martin, were actually seen to be drinking water, and the method of feeding exhibited by the other birds, namely, picking insects up off the water surface on the lee shoreline, would indicate that very little of the water from the TSF is actually ingested by birds. This factor, when combined with the fact that animals can ingest and metabolize small amounts of cyanide over a period of time (Brasel et al., 2006), may explain why none of the birds on the TSF appeared to show any symptoms of cyanide toxicosis. Furthermore, cyanide is destructured (broken down) very easily and quickly by a number of natural mechanisms (*inter alia* biodegradation, pyrodegradadtion and photodegradation). The most important of these mechanisms on the TSF would be photodegradation, which would be very effective on a TSF due to the amount of sunlight, the shallow depth of the water allowing sunlight to pass to the bottom and, once deposition of the silt has occurred (which is usually the case by sunrise on this TSF), the clarity of the water. No mortalities were observed after intensive searches on successive days. However, if any carcasses were present, they would be difficult to spot in the long grass. Furthermore, a number of mongoose as well as dogs from the nearby settlement were noted in the area; these animals would likely scavenge dead bird and mammal carcasses, thereby reducing the chances of finding any. Although the possibility of mortalities can therefore not entirely be excluded, and its incidence in summer might increase due to returning migrants and natal dispersal, this aspect needs further investigation. Because the TSF water contains WAD cyanide that will dissociate at low pH in the bird stomach [pH 1.8–3.0 (Duke et al., 1975)], the onset of any symptoms and death might be delayed. The chances of finding any carcasses nearby would be reduced as birds could fly some distance before the cyanide takes effect. Dosing racing pigeons at an equivalent of 50 mg.l^{-1} CN) (using NaCN) in 10 ml of water (1.25 mg kg)1 body mass) and greater (to 2.0 mg.kg^{-1} body mass), reduced flying times significantly over distances of 105 km and greater, but without any obvious cyanide-linked mortalities (Brasel et al., 2006). As the levels in the tailings were <50 mg. l^{-1} WAD at all times during this survey, it was unlikely that any mortality occurred during this period. It must be noted however, that few of the birds observed during the study drank appreciable amounts of water from the TSF; this would have added to the risk. Many possibilities remain, and the indication of a 'behavioural ecotone' possibly based on learned avoidance behaviour suggests negative effects, although there is lack of reports on such behaviour in the literature. Such avoidance patterns might provide clues that can be used in minimizing bird exposure to cyanide. The RWDs with their reed beds, in close proximity to the TSF, probably provided a preferred water source and refuge for birds. A number of contact scenarios are still possible. We mainly concentrated on birds during a cold winter (possibly curtailing some behaviours), but there might be additional patterns of exposure and associated factors during warmer periods that need investigation. These include studies on wildlife interactions in spring and summer, identification of food items and their origin, levels of WAD and other chemicals at contact points, night-time activities on TSFs, investigation of other bird behaviours such as nesting on tailings (TSF workers suggested that plovers might do so), and better characterization of the biodiversity associated with the whole TSF system.

We conclude, and concur with Donato et al. (2007), that a better understanding of the interactions of wildlife with potentially toxic TSFs would lead to better measures, practices and strategies whereby contact and exposure can be minimized, and thereby reducing the environmental risks associated gold mining operations. The point of learned birds avoiding the TSF and associated water on the TSF due to learned behavior may be a contentious issue, which is impossible to resolve within the time frame of a study such as this. There may be other visual or environmental cues that may cause birds to avoid the top of the TSF. These may include lack of trees for perches or nesting, lack of vegetation for cover from predators and the sterility of the system due to the replacement of the water and upper lay of sediment on an almost daily basis. Some studies have indicated salinity as being a factor that reduces diversity and abundance on TSFs, however we disagree that salinity in itself will have such a marked effect in bird diversity and abundance. Barberspan Bird Sanctuary has a very high salinity but is designated as an Important Bird Area (IBA) due to the high diversity and abundance of birds (especially waterfowl) present. We feel that further long term specialist studies are required in order to determine whether deaths do occur due to the presence of cyanide in the water on TSFs, these studies can also include the collection of carcasses, in order to determine whether or not the deaths were actually the result of cyanide poisoning by means of chemical analysis of tissue. These studies would be especially useful if conducted on tailings storage facilities with varying environmental factors such as vegetation cover on the slopes etc in order to obtain a better understanding of the cue if any that would attract birds to - or repel bird from the tailings storage facility. The area covered by such a study would also need to be increased in order to determine if birds are dying further away from the TSF after succumbing to cyanide toxicity. The monitoring of the area for carcasses, collection of carcases for analysis and recording of fatalities can be conducted by the mine personnel, provided they undergo a sufficient amount of training to this regard. We recommend that the training for this include basic bird identification, handling of dead animals and the possible health risks that are associated with this activity (especially zoonotic and other diseases) and the handling preservation and transportation of the carcases for analysis.

5. ACKNOWLEDGEMENTS

This study was funded by AngloGold Ashanti. Boetie van den Heever, Marie Schlechter and Greg Rehbok of Anglo-Gold Ashanti are thanked for their support in many ways. No restrictions were placed on planning, access, information, or deductions.

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