Levels of Heavy Metals and Cyanide in Soil, Sediment and Water from the Vicinity of North Mara Gold Mine in Tarime District, Tanzania.

A Report Presented to CCT by

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Summary

Heavy metal and Cyanide leakage from Gold mine projects is a challenge that mining companies face the world over. All gold mine companies that properly assume their responsibility of good practice take steps to ensure that people and the environment are safer from their operations. During the present study we have observed heavy metals and Cyanide that are higher than International and National standards. Although the extent of spread can not be estimated it is obvious that people and the environment in the vicinity of North Mara Gold Mine (NMGM) are exposed to heavy metals and Cyanide pollution thus to the dangers associated with these chemicals. These chemicals find their way into human body through direct ingestion of contaminated food, drinking water or air and their health problems are of major concern.

Outcry of people surrounding Gold mine projects about pollution has been a characteristic of many mining projects in Tanzania, NMGM project being one of them. This short study was initiated by religious leaders as a way of responding to such outcry. During the study samples of water, sediments/soil were collected and analysed for four heavy metals Nickel, Cadmium, Lead and Chromium using Atomic Absorption Spectrometer AAS, while CN analysis was analysed using pyridine; pyrazolone method as described by Allen (1989). We also recorded pH levels. The study was carried in Kwimanga, Kwinyunyi, between Kwimanga and Kwinyunyi, River Tighite and Nyabigena. Observed levels of Cyanide were then compared to standards by WHO, Tanzanian and US Environmental Protection Agency (EPA).

In overall terms, observed concentrations for all, almost all parameters were higher than the standards used. These observations therefore suggest that both heavy metals through Acid Mine drainage (AMD) and Cyanide were leaking from waste rock piles and tailing dam, respectively. Generally therefore, people living in the study area are in danger of suffering pollution effects of heavy metals and Cyanide as stipulated in the literature. Water samples taken from River Tighite indicate that Ni, Pb, and Cr, were 260, 168 and 14 times higher this year than it was observed in the year 2002 suggesting that humans and other living organisms in the area are highly vulnerable from pollution resulting from current gold mining activities of North Mara Gold Mine.

Background Information

Gold mine industry in Tanzania has risen since the first large scale gold mine began operations in 1998. The main focus for gold mining has been on the greenstone belts around Lake Victoria where about 90% of gold is produced. It is the vision of the government of Tanzania that by the year 2025 the mineral sector will be contributing 10% of GDP (URT, 1997). In recent days however there have been voices from the public especially communities living closer to mining areas that gold mining has become a nuisance to their wellbeing. There have been claims for example that both Geita Gold Mine and North Mara Gold Mine at some points discharged wastes into nearby rivers that are used as source of drinking water by nearby villagers http://paguntaka.org/2008/08/21/gold-mining-exploration-companies-%E2%80%98pollute-drinking-water%E2%80%99-at-north-mara-gold-mine-in-tarime-district/. Bitala (2008) reported higher levels of heavy metals in the soil and plants collected in Nyakabale a village in the vicinity of Geita Gold Mine. Most recently The Gold Mining companies however, in several occasions have denied. On 8th May 2009 people living around North Mara Mining Project raised their voices about chemical spills that were impacting surrounding villages of Kewancha, Nyangoto and Nyabigena sending the villagers into panic. This sorrow news was reported by local media, Daily News of 13 June 2009 in reference to the spill incidence that occurred on 8th may 2009. According to Chacha Benedict Wambura the Executive Director of the Foundation HELP in Musoma, the spill polluted the nearby Tigithe River leaving thousands of residents without water for domestic use. According to William Kasanga of the WWF Mara River Basin Conservation, following this spill a family of five people got sick after eating fish from Tighite River (Tanzania Daima, 13th June 2009). On the other hand, the Barrick Gold mine Authority admitted over the pollutant leak from tailing ponds into rivers, farms and pasture land (Daily News, 13th June 2009). Based on people's outcry in the area religious leaders commissioned a team of scientists to look into the contents of the spills. Specifically the scientists were required to (1) establish the levels of heavy metals and Cyanide in water, soil and sediments (2) compare these levels with WHO and any other local or international standards and (3) compare with levels that were available in the year 2002 when large scale mining started. It needs to be pointed out here that before 2002 mining was being conducted by small scale miners.

For the purpose of this study the team analysed the levels of four heavy metals namely Cadmium (Cd), Chromium (Cr), Nickel (Ni) and Lead (Pb) and Cyanide (CN).

Do effluents from Gold mine have something to worry about?

In line with people's concerned, this study was conducted based on two important facts about Gold mine effluents/pollutants:

1. *Some of existing cases of environmental disastrous resulting from gold mining effluents in other parts of the world*

The first reason of why we carried out this study lied on the fact that there are so many examples that show that pollution from gold mining real occurs.

i. About 130,000 cubic meters of cyanide-tainted water flowed into the Lupes, Somes, and eventually into the Tisza and Danube rivers in Romania and Hungary respectively, covering over 400 kilometers (Nicolas, 2004).

ii. In Australia, despite government assurances that the Timbarra Gold Mine was a world best-practice mine, there were overflows from the toxic wastewater ponds into the surroundings. Other disasters in Australia occurred earlier in 1995, when a failure to monitor cyanide levels at the North Parkes copper-gold mine caused the death of over a thousand birds. Again in the year 2002, cyanide spill near Granite Gold Mine in the Australian Northern Territory killed more than 400 birds and kangaroos (Nicholas, 2004).

iii. In the year 2004 Barrick Gold (half owner of Lake Cowal gold mine) was under scrutiny when the government report found that a large area around the Kalgoorlie Super Pit Fimiston tailings dam was hit by increased salinity, heavy metal contamination, cyanide contamination and elevated cyanide levels in the groundwater in Western Australia (Nicholas, 2004).

iv. According to the Gold Album (http://www.moles.org), ten miners were killed by cyanide spill after collapse of a tailing dam at the Harmony mine in South Africa in 1994.

v. In 1992 cyanide and heavy metal leakage from the Summitville gold mine killed all aquatic life along a 27 kilometer stretch of the Alamosa River in the San Juan Mountains of southwestern Colorado.

vi. In another incidence in 1997 failure of a leach pad structure at the Gold Quarry mine in Nevada released about a million liters of cyanide-laden wastes into two streams, killing over 11,000 fish along 80 km stretch of the Lynches River.

vii. In 1995 More than 3.2 billion liters of cyanide-laden tailings were released into Essequibo River in Guyana when a dam collapsed at the Omai gold mine. Studies by the Pan American Health Organization indicated that all aquatic life in the four kilometer long stream from the mine to the Essequibo River was killed.

viii. In Vietnam, cyanide leakage from tailing polluted the central Quang Nam province causing public health hazard. Many residents complained over skin irritation and itching when using stream water. People living around for some years have been reported to give birth to deformed and retarded children (Weitzel, 2006).

2. *Heavy metals and cyanide causes health problems and impacts the environment negatively*

Gold mine produce pollutants namely, heavy metals from waste rock piles, Cyanide and

other gaseous materials such Sulphur dioxide (SO_2), Carbon mononxide (CO), Carbon dioxide (CO_2) to mention but a few. Heavy metal comes as Acid Mine Drainage (AMD) from wastes rock especially those containing Possible Acid Forming materials (PAF). Association of ill health and heavy metal pollution is a well-researched and reviewed area. Biotoxicity symptoms caused by heavy metal ingestion include gastrointestinal disorders, diarrhea, stomatitis, tremor, hemoglobinuria, ataxia, paralysis, vomiting and convulsion, depression, and pneumonia. The nature of biotoxicity being toxicity (acute, chronic or sub-chronic), neurotoxic, carcinogenic, mutagenic or teratogenic and may lead to death of an individual (Jarup, 2003). Furthermore, mortality from cancer of the lung, stomach, and respiratory tract has been reported (Eisler, 2004). It has been documented also that consumption of foods stuff contaminated by Lead, Arsenic and Cadmium causes serious depletion of body stored iron, vitamin C., and other essential nutrients leading to decreased immunological defense, intrauterine growth retardation, impaired psycho-social faculties and disability associated with malnutrition (Iyengar and Nair 2000). Cyanide hazards to humans, fish, wildlife, and livestock are well documented. Immense kills of freshwater fish by cyanide wastes have been reported several times (EPA 1989). According to Federation of American scientists Cyanide is deadly to human even in small dose. A small amount of cyanide can result in rapid breathing, restlessness, dizziness, weakness, headache, nausea, vomiting, and increased heart rate. Prolonged exposure or a larger dose (hydrogen cyanide, 1 part in 500) in an enclosed space could lead to convulsions, low blood pressure, and decreased. Other includes heart rate, loss of consciousness, lung injury, and death in 8-10 minutes. Depending on the exposure duration, survivors may have some heart and brain damage. Lord *et al.* http://www.fas.org/programs/ssp/bio/factsheets/cyanidefactsheet.html. It may also affect the thyroid gland, which may cause cretinism (retarded physical and mental growth in children), or enlargement and over activity of the gland. It is based on these negative impacts that have necessitated the establishment of the Cyanide Code, a voluntary program for the Gold mine industry to promote responsible management of cyanide used in gold mine, enhance the protection of human health and reduce the potential for environmental impacts. Although this code requires Gold mine companies to be audited by an independent auditor on their adherence to these requirements, North Mara has never been audited (International Cyanide Management Institute, 2006). North Mara Gold Mine is registered under the Cyanide code.

North Mara Gold Mining Project

This project is located in northwestern Tanzania in Tarime district, about 15km south of Kenyan border, 15km northwest of Serengeti National Park and 60km east of Lake Victoria. The project involves sequential development of Nyabirama and Nyabigena deposits by open-pit mining: drilling, blasting, excavation and road haulage of ore and waste. Processing of gold bearing sulfide rocks is done by conventional carbon-in-leach (CIL) technology in which Cyanide is used for gold amalgamation. Runoff materials from processing plant and other mining activities are held in earth raw water and tailing dams that are supposed to be constructed in such a way that leakage is prevented. This technology according to Nicholas (2004) is not water tight as often tailing dams leak or breaks releasing their contents into the environment. Therefore any Gold mine project in

the world that undertakes sound environmental practices (SEP) should be concerned with leakage or spills of Cyanide and ARD from Possible Acid Forming waste rocks (PAF).

Material and Methods

Sampling of soil, sediments and water

A total of 54 of soil/sediment and water and samples were collected from 27 points in five sites namely Kwimanga, between Kwimanga and Kwinyunyi, Kwinyunyi, river Tighite and Nyabigena around North Mara Gold Mine project. At each site hypothesis guided sampling procedures was used whereby observations for changes in physical characteristics such as color, texture, odor, and deposition were considered as indicators for pollution. For each material samples were taken in triplicates one of them fixed with Sodium hydroxide for Cyanide analysis. The degree of alkalinity or acidity (pH) of each sample was measured using pH meter as it is known that pH influences the solubility of heavy metals. The solubility of heavy metals decrese with increasing pH and vice versa. Furthermore, pH also influences the degradation of Cyanide. All samples were well preserved under cool condition before laboratory analysis.

Laboratory Analysis

Analysis was carried out at the University of Dar es Salaam.

(1) Soluble Heavy metal in soil and sediments were analyzed by using atomic absorption spectrometer (AAS) after dissolution in 1M Ammonium acetate following (Allen 1989) protocol. Water samples were analysed by similar method after pretreatment with 0.1% Hydrochloric acid.

(2) Total Cyanide (soluble + stable) were analyzed by using pyridine; pyrazolone method as described by Allen (1989).

Data obtained were compared with National and International standards to see whether or not they were within the recommended range thus safer to human health and the environment in general.

Results

Table 1 presents level of heavy metals, Cyanide and pH in soil/sediment. Levels of heavy metals except Ni were highest at Kwinyunyi (site C) where Cr ranged from 21.4 – 33.4mg/kg, Cd 6.4 - 11.7mg/kg, Pb 21.8 – 32.4mg/kg and Cyanide 0.63 – 0.84mg/kg. Of all the heavy metals assessed Ni gave the highest record ranging from 301.6 at B_4 to 11200mg/kg (in other words 11.2g/kg of soil) at Nyabigena (site E_1). Presence of Cyanide in the soil was recorded at Kwimanga (0.112 – 0.116mg/kg), an area between Kwinyunyi and Kwimanga (0.08 – 0.13mg/kg) and highest at Kwinyunyi where it ranged between 0.63 - 0.84mg/kg. Cyanide was not detected in the other sites. Soil pH indicated that at Nyabigena the soil was strongly acidic, slightly alkaline in river Tighite, neutral to alkaline between Kwimanga and Kwinyunyi but alkaline at Kwimanga.

Table 1: Concentrations of heavy metals, Cyanide ($mgkg^{-1}$) and pH in soil/sediment in the study

SITEA (Kwimanga)	Cr	Cd	Ni	Pb	CN	pH
A1	4.5	2.1	462.7	3.4	0.112	7.84
A2	3.2	1.4	401.7	2.4	0.113	8.22
A3	3.6	2.2	382.8	2.9	0.116	8.22
SITE B (between Kwinyunyi and Kwimanga)						
B1	3.43	3.6	312.4	21.7	0.13	7.82
B2	2.11	3.4	326.6	21.8	0.11	7.36
B3	2.51	4.6	341.4	21.6	0.09	8.01
B4	3.3	3.2	301.6	31.6	0.05	7.24
B5	4.3	3.6	321.0	32.3	0.12	2.14
B6	2.8	2.8	362.2	21.4	0.08	7.84
SITE C (Kwinyunyi)						
C1	33.4	11.7	601.7	21.8	0.65	7.34
C2	29.4	9.5	582.2	31.0	0.63	7.14
C3	27.6	6.4	501.4	30.7	0.75	8.27
C4	30.7	7.2	452.2	32.4	0.82	8.22
C5	21.4	7.8	611.8	25.7	0.84	7.35
C6	26.4	8.4	602.4	21.8	0.73	7.14
SITE D (River Tighite)						
D1	17.6	3.4	712.2	12.2	ND	7.41
D2	8.4	2.4	652.2	1.7	ND	7.62
D3	2.6	1.1	603.4	0.9	ND	6.87
D4	2.2	0.9	641.7	1.2	ND	7.86
D5	3.4	1.7	612.2	1.1	ND	7.14
D4	2.9	1.6	690.9	1.1	ND	7.66
SITE E (Nyabigena)						
E1	0.7	4.8	11200.0	17.6	ND	3.46
E2	3.1	3.2	1204.0	21.4	ND	3.17
E3	3.6	5.2	942.8	22.2	ND	3.22
E4	3.7	4.4	261.7	7.8	ND	3.34
E5	3.8	3.2	642.7	1.1	ND	3.81
E6	3.2	3.3	521.7	1.1	ND	3.74

On the other hand Table 2 shows the concentration of heavy metals and Cyanide in water, and water pH. Based on this observation Cr was detected in water sampled collected only from three sites namely; Kwinyunyi, river Tighite and Nyabigena. Generally, levels of heavy metals with exception of Ni were lower in water than in soil samples. Water samples from Nyabigena had Ni levels that could be compared with levels obtained in soil samples. Water pH depicted values that could be compared to those in soil samples at

each site. As in the soil samples Cyanide was detected only at Kwimanga where it was lowest (0.001mg/kg), highest between Kwinyunyi and Kwimanga (0.011 - 0.076mg/kg) and intermediate at Ikwinyunyi (0.0412 – 0.062).

Table 2: Concentrations of heavy metals and CN (mgL^{-1}), pH of water from tailing and waste rock in surrounding villages around North Mara Gold Mine

SITE A (Kwimanga)	**Cr**	**Cd**	**Ni**	**Pb**	**CN**	**pH**
A_1	ND	0.4	41.0	ND	0.001	8:70
A_2	ND	0.8	32.3	ND	0.001	8.33
A_3	ND	0.6	52.1	ND	0.001	
SITE B (Between Kwinyunyi and Kwimanga)						
B_1	ND	0.8	42.2	ND	0.076	8.13
B_2	ND	0.4	31.4	ND	0.052	7.61
B_3	ND	0.2	31.2	ND	0.011	8.16
B_4	ND	0.2	30.1	ND	0.012	8.21
B_5	ND	0.4	32.2	ND	0.013	8.17
B_6	ND	0.6	37.3	ND	0.014	8.22
SITE C (Kwinyunyi)						
C_1	20.9	4.9	320.6	23.5	0.062	7.68
C_2	6.1	2.3	94.1	ND	0.0412	7.44
C_3	14.2	2.2	136.7	124.8	0.064	7.63
C_4	2.5	4.3	370.1	ND	0.043	7.64
C_5	2.4	3.5	101.1	ND	0.061	7.58
C_6	6.1	2.3	94.1	ND	0.060	7.21
SITE D (River Tighite)						
D_1	2.14	0.25	26.14	2.16	ND	7.21
D_2	3.14	0.14	20.16	1.17	ND	7.14
D_3	2.01	0.16	15.22	1.18	ND	7.13
D_4	2.16	0.12	15.26	1.17	ND	7.11
D_5	2.00	0.17	15.13	1.17	ND	7.16
D_6	2.17	0.13	17.22	2.00	ND	7.12
SITE E (Nyabigena)						
E_1	7.2	3.1	1205.6	7.5	ND	2.41
E_2	8.2	2.2	1212.7	1.7	ND	2.56
E_3	9.3	4.6	1184.8	1.2	ND	3.14
E^4	0.2	2.9	1160.5	1.5	ND	3.16
E_5	2.0	1.2	495.1	1.7	ND	3.40
E_6	2.0	3.0	501.4	1.7	ND	5.21

Table 3 shows the comparison of the observed results with National and International allowable levels of heavy metals and Cyanide. The present result showed that concentration of all heavy metals investigated (Chromium, Cadmium, Nickel and Lead) were several times higher than WHO, Tanzania and Environmental Protection Agency (EPA allowable levels. However, Cyanide was not detected in water samples from some

sites but where detected was mainly within the levels accepted by WHO, Tanzania and US EPA. Table 4 compares levels of heavy metals in samples of water of river Tighite with WHO, Tanzania and USA EPA standards which showed that level of heavy metals in each liter of water sample was higher than WHO, Tanzania or US EPA allowable levels. However, the pH of water was within allowable standards. Table 5 presents levels of heavy metals and Cyanide in soil/sediment against standard levels. On contrary to levels of CN in water, soil/sediment materials registered higher CN concentrations ranging from 0.08- 0.84mg/kg. Of the heavy metals Lead and Chromium fell within the standard range of metals of Global soils but Nickel and Cadmium significantly higher than the used standards. The result also indicated varied pH range from acidic (2.14) to basic (8.27) and acidic 2.41 to basic 8.7 in soil/sediment and water respectively. Further more, the concentrations of heavy metals in this study were found to be higher than levels observed in 2002 in the same area (Table 6, Fig 1).

Table 3: Comparison of North Mara Gold Project tailing, waste rock drainage and standard water quality for heavy metals and cyanide (CN)

Parameter	**Unit**	**Observed range**	**Standards**		
			WHO	**Tanzanian**	**US EPA**
Chromium (Cr)	mg/L	0.2- 20.9	0.05	0.05	0.1
Cadmium (Cd)	mg/L	0.12- 4.9	0.003	0.01	0.005
Nickel (Ni)	mg/L	15.13- 1212.7	0.05	0.02	0.052
Lead (Pb)	mg/L	1.17- 124.8	0.01	0.05	0.015
Cyanide (CN)	mg/L	0.001- 0.076	-	0.1	0.0052
pH	N/A	2.41- 8.70	6.5- 8.5	6.5- 8.5	-

Table 4: Comparison of levels of heavy metals in water samples from Tighite River with WHO, Tanzania, and US EPA standards

Parameter	**Unit**	**Observed range**	**Standard**		
			WHO	**Tanzanian**	**US EPA**
Chromium (Cr)	mg/L	2.00 – 3.14	0.05	0.05	0.1
Cadmium (Cd)	Mg/L	0.12- 0.25	0.003	0.01	0.005
Nickel (Ni)	Mg/L	15.13- 26.14	0.05	0.02	0.052
Lead (Pb)	Mg/L	1.17 – 2.16	0.01	0.05	0.015
pH	N/A	7.11- 7.21	6.5- 8.5	6.5- 8.5	-

Table 5: Comparison of heavy metals and Cyanide levels in soil/sediments with standard ranges of metals of Global soils* (Fifield and Haines, 2000*)

Parameter	**Unit**	**Observed range**	**Standard range***
Chromium (Cr)	mg/kg	0.7 - 33.4	5 - 1100
Cadmium (Cd)	mg/kg	0.9 - 11.7	0.01 - 2.5
Nickel (Ni)	mg/kg	261.7 - 11200.0	1 - 120
Lead (Pb)	mg/kg	0.9 - 32.4	1.5 - 80
Cyanide (CN)	mg/kg	0.05 - 0.84	-

Figure 1: C River Tighite bet

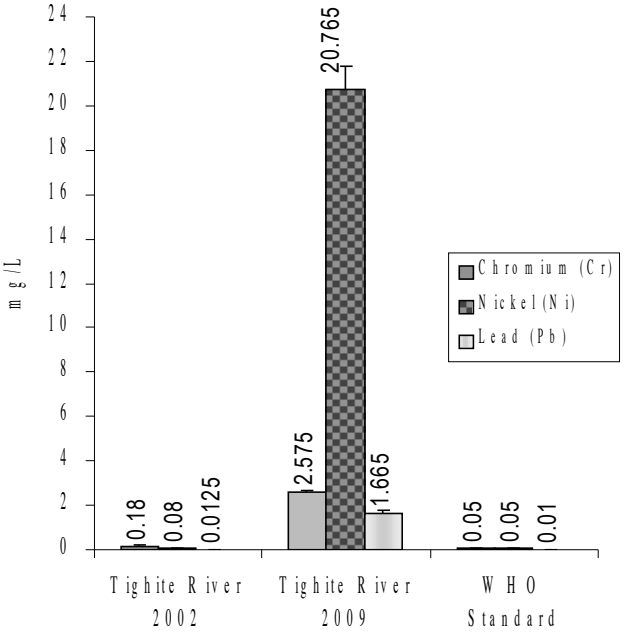

Figure 1 ar rded in river Tighi l WHO standards l ing the present stu and by then they v

Table 6: C o those observed in

Parameter	Tighite River 2002	Mean	Tighite River 2009	Mean	Mean number of times higher than 2002 levels
Chromium (Cr)	All 0.018	0.08	2.01- 3.14	2.575	14
Nickel (Ni)	0.004 - 0.012	0.08	15.13 - 26.4	20.765	260
Lead (Pb)	0.007 - 0.016	0.0125	1.17 – 2.16	1.665	168
Cadmium	-	-	0.12 – 0.25	0.135	-

Implication of the observed findings

Gold mining is known to be a source of pollutants that affects people's health and affects the sustainability of the ecosystem. In order to protect people and the environment from hazards resulting from mining activities National and International Institutions have set up levels of pollutant that can be accommodated in the environment and be considered safer. When such levels are exceeded the health of humans and the ecosystem in general therefore can be considered jeopardized or threatened.

On the other hand mining companies including Barrick Mining Company that owns NMMC have registered under the Cyanide code that require closer monitoring of the purchase, transport and safer use of Cyanide in mining. Furthermore in the year 2007 International Council on Mining and Metal (ICMM) published *Metals Environmental Risk Assessment Guidance (MERAG),* and *Health Risk Assessment Guidance for Metals (HERAG).* Having HERGA and MERAG it is clear evidence that ICMM acknowledges the fact that mining is environmentally and healthily unfriendly. On the same line ICMM has discussed with IUCN on Good Practice Guidance for Mining and Biodiversity that

stipulates the need of mining company to ensure that their activities remain sustainable. Barrick Gold that owns North Mara Gold Mine is one of the 17 corporate members of ICMM thus is aware of its responsibility for protecting the health of the people and the ecosystem where it operates.

In the current study we observed that all water samples had levels of heavy metals higher than WHO, Tanzania or US EPA recommended standards. This means effluents flowing from North Mara Mining project are highly polluted thus unfit for any use. Similar conclusion can also be made for water of river Tighite sample of which had heavy metals levels that were beyond the standards they were compared with. River Tighite has been a source of drinking water for people and live stock. The pH values obtained fall within the allowable ranges and compare with those obtained presented to Kewanja village Executive Officer from Barrick North Mara Mining Project on 22/05/2009. The mining company used these pH values solely to inform the village executive officer that the quality of Tighite river was of good (See appendix 1). Based on the present finding the information passed on by Barrick about water quality of river Tighite was misleading as pH alone can not tell the quality of water intended for use.

That Cyanide levels was below the set standards or was not detected in water samples from some sites including river Tighite was not surprising for two reasons. First, Cyanide is known to breakdown into various compounds in presence of sunlight and air (photodegradation). Second, Cyanide was only expected in sites closer to a tailing dam in this case at or closer to Kwinyunyi (site C). Note also that it is at this site where levels of Cyanide were highest i.e. 0.63 – 0.84mg/kg of soil/sediment. The first reason also explains why the level of Cyanide was higher in soil/sediment than in water samples. Cyanide will not breakdown when seep underground into sediments/soils, under cloudy or rainy condition or during winter in temperate countries (Gold Album). Presence of Cyanide in the environment as in the present case suggests that NMGM tailing dam is leaking/porous at several places. As it can be seen in the plate 5 the NMMC tailing is less protected and in some places the wall is simply clay. Under acidic condition CN changes to gaseous form which is rather more toxic (Gold Album) thus it is reasonable for a gold mining company to find ways of keeping Cyanide under alkaline condition. This probably explains why pH values where higher at Kwinyunyi, Kwimanga and between the two sites.

Although Cyanide that is found in sediments does not cause immediate danger, studies e.g. Robert Molarn cited in Gold Album, found that Cyanide was still detected in sediment samples 25 year after mine closure. The higher cyanide concentration in sediments therefore can be source of water pollution for a long period of time affecting the life of human and other living organisms in the environment. Cyanides are readily absorbed by inhalation, oral, and dermal routes of exposure. The primary target organ for cyanide toxicity is the central nervous system (CNS). Ingestion and inhalation of cyanide has been associated with neurotoxicity, Cardiac and respiratory effects. Short-term exposure to high concentrations may result to immediate collapse, respiratory arrest, and death (Hartung, 1982; EPA, 1985). In animal studies, cyanides have been linked with

fetotoxicity and teratogenic effects, including exencephaly, encephalocele, and rib abnormalities (Doherty et al., 1982; Willhite, 1982; Frakes et al., 1986).

In sediments and soil samples we observed levels of cadmium, and Nickel that were several times higher than the acceptable levels based on WHO, Tanzania and US EPA standards. This indicated that NMGM waste rocks were releasing Acid Mine Drainage (AMD). This was the reason for lower pH levels in water and sediment/soil at some sites e.g. Nyabigena, where water and sediment/soil pH ranged between 2.14 - 5.21 but mainly around 3 which is a real acidic condition. This range of pH falls outside the pH range of 6.5 – 8.5 acceptable by all standards compared with in the present study. It is also outside the agricultural optimum pH range of 6.5 - 6.9 (Thien and Graveed, 1997).

As said above, acidification of soil and water in this area suggests that Sulphuric acid was being formed from mined underground sulphide rocks (Acid forming waste rocks). This phenomenon occurs when water and oxygen come in contact with sulphide rocks generating what is referred to as Acid Mine Drainage (AMD) in Gold mine. Observations by Global Mining Campaign (2001) indicated that, the formation of AMD in areas where sulphide ores are mined, changes water color to red, orange or yellow easily recognizable to human eyes due to separation of iron from solution (See plates 1 and 2).

AMD harms the environment by lowering soil and water pH hence increased heavy metal drainage from rocks and soil colloidal materials into water bodies such as rivers and wells and the environment in general. At lower pH levels heavy metals release from soil colloids increase. Accumulation of heavy metals in soil and water leads to both increasing bio-concentration and bio-accumulation in plants, fish, livestock and humans through the process of eating and being eaten (food chain/web) (Cunningham and Saigo 2001). Bio-concentration and bio-magnification of heavy metals in plants, fish and livestock poses higher health risks to humans who are at end of the food chain (higher trophic level). Consumption of food and water polluted by heavy metals has been attributed to many health problems that endanger human life. The various health effects associated with heavy metals poisoning include a wide range of casinogenic effects such as skin, liver, kidney; teratogenic effects, mutagenic effects as well as brain damage. (Tu¨rkdogan et al. 2003; WHO, 1996; WHO, 2001; Global Mining Campaign; 2001; Nicholas, 2004; Weitzel, 2006). In addition, intoxication from higher concentration of metals such as cadmium and lead may lead to decreased body defence mechanism rendering the victim organism prone to disease attack (WHO, 1996; Iyengar and Nair, 2000).

Conclusion and recommendations

It is evident from the present study that NMGM pollutes environment in the villages and water bodies that surround their project. Levels of heavy metals and Cyanide in water and sediments of river Tighite are higher now than they were in 2002. For example the levels of Ni has risen 260 times, Pb was 168 times and Cr 14 times. These pollutants come from waste rocks of the project tailing dam. It has been documented that both heavy metals and

Cyanide pose both environmental and health problems to humans and their livestock. However based on this study it is not possible to say how wider the pollution has spread because if that happens will have not only a local dimension but will directly threaten the whole agroecosystem in the area and other surrounding ecosytems e.g. the Serengeti world heritage. Some people show some diseases symptom e.g. skin diseases (Plate 3) that can be linked to heavy metal pollution. However, a thorough study is required before this is confirmed. In fact, some conditions caused by these pollutants do not show immediate or observable symptoms. Lack of symptoms therefore does not mean absence of health problems.

We also recommend that since the level of heavy metals, CN and soil and water pH around the NMGM project are higher than permissible levels thus a threat to the survival of organisms (fauna and flora), intensive Environmental Audit involving a team of scientists from various organs, Governmental and Non Governmental, Local and International be formed to assess the impact of such pollution on the ecosystem in the area. This is necessary because it was observed during the Environmental management plan (2002), that the area supports some CITES Endangered Species such as orchid *Eulophia guineensis* (CITES appendix II) and IUCN red list specie pancake tortoise *Malacochersus tornieri* and possibly leopard *Panthera pardus,* another appendix I CITES specie. Other species are FAO identified rare specie of fish *Ctenopoma muriei* and *Haplochromines sp* possibly IUCN listed specie.

It is also recommended that further studies on effects of heavy metals and cyanide be conducted for human, plants and livestock in this area as it is most possible that higher effects may result due to bio-concentration in plants and bio magnification in livestock and humans with regard to their positions in the food web.

We feel strongly that if measures to serve people and the environment around North Mara are not taken, the government of Tanzania will be defeating its National Strategy for Growth and Reduction of Poverty (NSGRP) (URT, 2005). The NSGRP is conceived as a tool to the aspiration of Tanzania's Development Vision 2025 that intends to attain among others high and shared growth and high quality livelihood. This frame work is also committed to the Millennium Development Goals (MDGs), with its internationally agreed targets for reducing poverty, hunger, diseases and environmental degradation by 2015 among others.
For mining companies including NMGM project it is important for them to fulfill their responsibility of protecting people's health, the environment and conserve biodiversity as required by ICMM, Cyanidecode, and according to national and international standards. Barrick is an international company.

Plates

Plate 1: Acid Mine Drainage from Waste Rock piles at Nyabigena

Plate 2: Acid Mine Drainage on the Environment

Plate 3: Skin condition that people associate with use of water that has Acid Mine Drainage around North Mara Gold Mine project

Plate 4: Plant drying due to AMD at Nyabigena. The pH at this spot was below 3

Plate 5: Cattle grazing within the unfenced upstream side of the tailing dam at Matongo village. This is very dangerous as both animals and human may be at high risk from improper protected tailing material containing Cyanide and heavy metals

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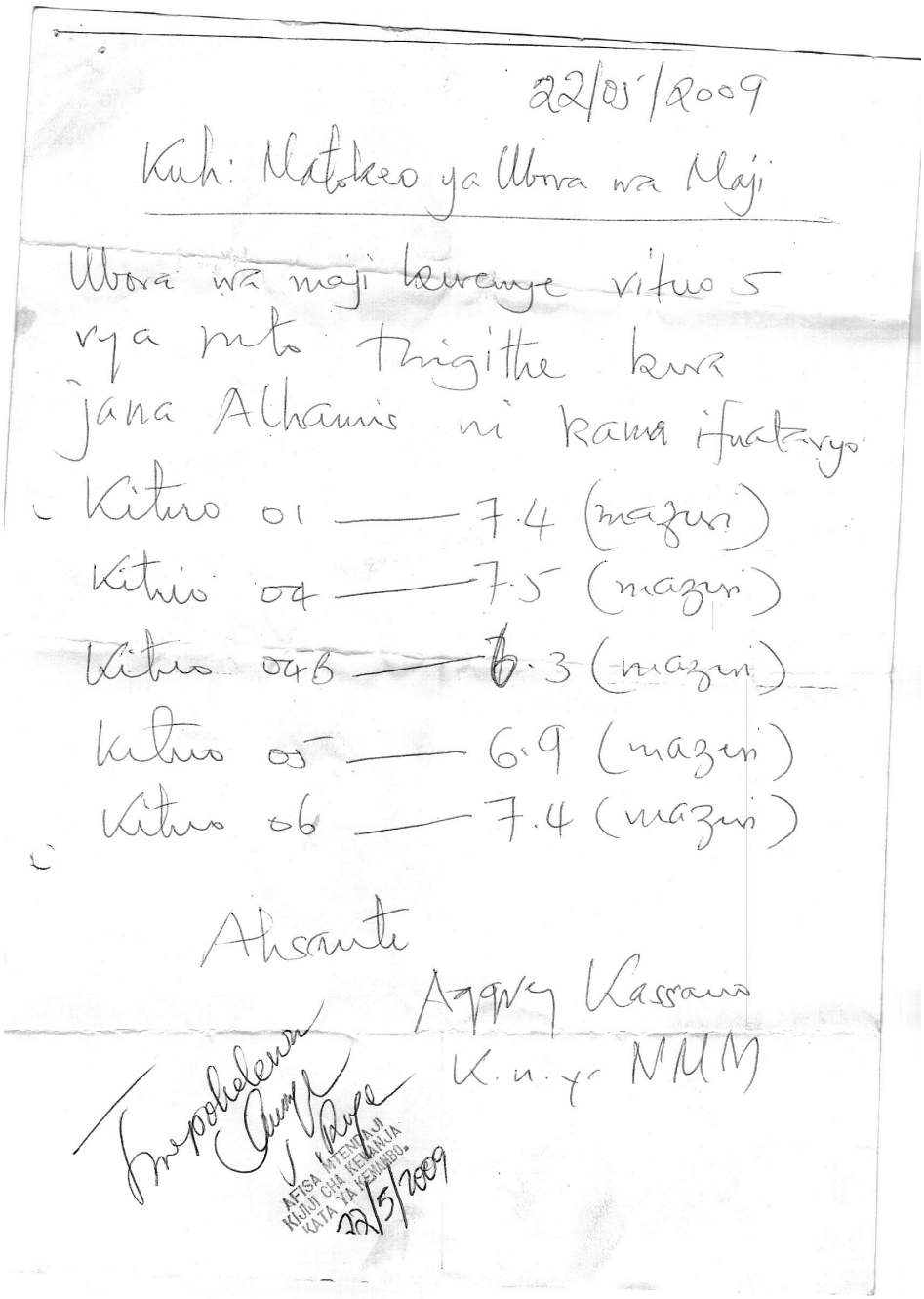
Appendix 1



22/05/2009

Kuh: Matokeo ya Ubora wa Maji

Ubora wa maji kwenye vitwo 5 vya mto Thigithe kwa jana Alhamis ni kama ifuatavyo.

Kitwo 01 —— 7.4 (mazuri)
Kitwo 04 —— 7.5 (mazuri)
Kitwo 04B —— 6.3 (mazuri)
Kitwo 05 —— 6.9 (mazuri)
Kitwo 06 —— 7.4 (mazuri)

Ahsante

Agnes Kassava
K.n.y NMM

Imepokelewa
[illegible]
AFISA MTENDAJI
KIJIJI CHA KEMANJA
KATA YA KEMAROBO.
22/5/2009