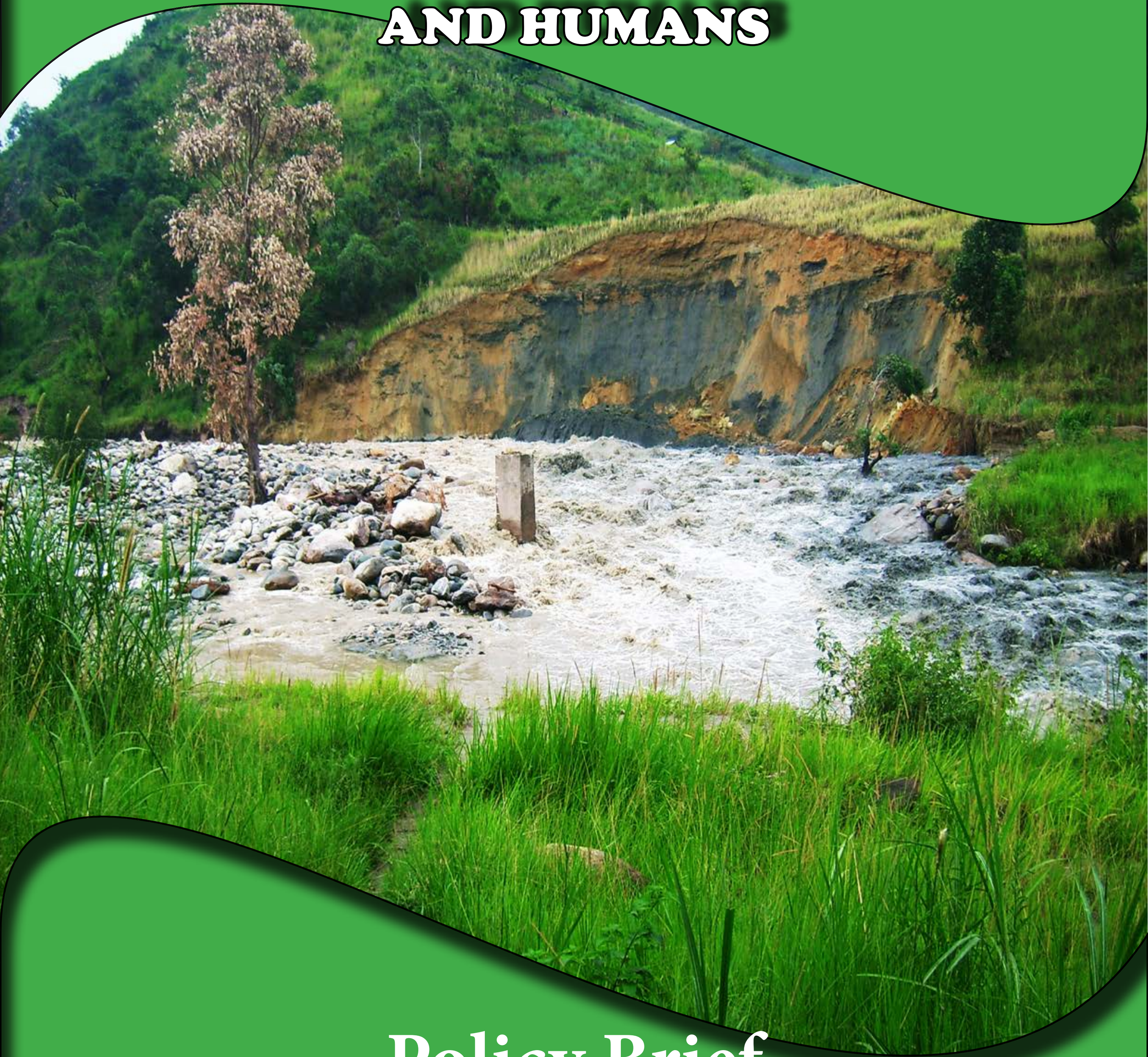
THE IMPACTS OF KILEMBE MINE AND TAILING SITES ON SOIL AND WATER QUALITY, FOODS, FORAGE AND HUMANS



Policy Brief

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Executive summary

The mining and processing of copper in Kilembe, Western Uganda, from 1956 to 1982 left over 15 Mt of tailings containing cupriferous and cobaltiferous pyrite dumped within a mountain river valley. In addition, underground Kilembe mine water is pumped to the land surface or allowed to flow by gravity into surrounding agricultural soils and water bodies. The study was conducted in Kilembe mine, Kasese district to assess the impact of Kilembe mine and the wastes (tailings) on soil quality, water quality, foods frown, forage and local people exposure. The samples collected included soil, water, foods, forage, sediments and toe nails from local volunteers. Sample analysis was conducted from the school of biosciences, Nottingham University, UK. The study found high levels of metal concentration especially copper, cobalt, nickel, zinc, arsenic and lead in agricultural soils, public water sources, house dusts and sediments in water. Aluminium and Iron metals were more abundant in public water sources. The metals were originating from mine tailings but also underground Kilembe mine water. The leachate water at Kilembe mine also contain large amounts of metals especially copper, iron and aluminium. The foods and forage grown contained significantly higher concentrations of copper, cobalt, zinc, possibly taken up during growth and accumulated in the foods which could lead to consumption of the same elements by local people. Indeed, tests on human toe nails from Kilembe area volunteers confirmed that local people were more exposed to the mine metals especially copper, cobalt and nickel. Children were more exposed than adults. It is on this note that the following policy recommendations are made;

1. There is need for enforcement of proper waste storage and disposal protocols
2. Local people living in contaminated environments should be sensitized on the dangers so that they make informed decisions
3. There is need for construction of a containment all around Kilembe tailing sites and landfilling with soil so as to prevent erosion of tailings into agricultural soils and water
4. There is urgent need to treat Kilembe mine underground water before it is discharged into River Nyamwamba
5. There is need to implement remediation activities for soils along River Nyamwamba and below tailings

1. Introduction

The mining, milling and metallurgical processes for the production of copper generates large hills of sulphide bearing waste rocks (also known as red mud) with significant concentrations of heavy metals. Copper is usually associated with sulphides of zinc and lead. The presence of metal sulphide deposits within an ecosystem can have significant impacts on the quality of water and sediment and on the health of humans and other biota that come in contact with the metals released in these systems. The consumption of food con¬taminated with metals can cause cancer, gastro-intestinal complications, a decrease of immunologi¬cal defenses, physical and mental disabilities and retardation.

1.1 **Study methodology**

Samples of soil, water, sediments, foods, forage were collected from Kilembe along the mine area and downstream to assess concentrations of the mine metals. Control samples were also sampled upstream and from nearby areas where mine contamination is not known to occur. Toe nails were collected from volunteers within Kilembe mine area while control toe nails were collected from Kampala residents. All samples were acid digested and diluted with deionized water before being tested using Induced Coupled Plasma-Mass Spectrometer. Local people (64) were interviewed on farming practices, areas cropped, food sources, water sources, access to tailing sites and mine water. The results from the study were statistically analysed using a 2 sample T-test to assess if there were significant differences.

2. Key findings

2.1 Metals in tailings

Table 1. Metals in Kilembe tailings

	Al	Cr	Mn	Fe
Tailing sites1	33354	152	876	54043
2	37397	121	945	52209
3	37779	136	1428	42094
4	28044	113	809	49797
5	29953	97.4	727	52088
6	32277	107	800	58019
World average crust [i]		100	350-2000	

Bold figures indicate where concentrations of elements were much higher than world averages

Location of tailings along River Nyamwamba leads to tailing erosion by the river

2.2 Metals in mine water

The mean concentration (μg L $^{-1}$) of Cu was 9500, Co was 3430, Ni was 600, Fe was 1350, Al was 4700 while Mn was 5800 in the mine water and leachate compared with elemental concentrations in the un contaminated waters (μg L $^{-1}$) which were 1.5, 0.21, 0.67, 185, 204 and 23.1 for Cu, Co, Ni, Fe, Al and Mn respectively.

Co	**Ni**	**Cu**	Zn	As	Ag	Pb
79.7	**101**	**2267**	29.6	11.7	0.35	6.33
101	**164**	**165**	52.6	6.30	0.23	13.3
148	**156**	**1100**	68.3	2.90	0.16	7.01
152	**125**	**10217**	36.2	5.01	0.79	4.80
78.2	**119**	**691**	50.9	13.6	0.63	21.8
110	**118**	**5472**	41.1	11.9	0.88	16.2
1-15	**20**	**20-75**	70	1.8	0.06	15

i. Kabata-Pendias (2011)

2.3 Natural metal inputs into water

Although there were no mining activities upstream of River Nyamwamba, 50% of the water samples collected (n=4) exhibited Al concentrations measuring 216 μg L-1 and 214 μg L-1, exceeding UK drinking water thresholds of 200 μg L-1 while the Al concentration in the remaining 50% of water measured 190 μg L-1and 197 μg L-1, close to the UK drinking water threshold. Iron (Fe) concentrations in the upstream water ranged between 179-192 μg L -1, close to the UK drinking water threshold for Fe which is 200 μg L -1. Water in tributaries flowing into River Nyamwamba, located outside the mine and tailing zone (n=8) also contained elevated concentrations of heavy metals, exceeding recommended drinking water thresholds for Fe (38%), Ni and Mn (13%). Heavy metals and trace elements found upstream of River Nyamwamba (before the mining and tailing zone) and in the tributaries possibly originated from geological weathering, attributed to area mineralogy and geology.

Underground mine water contributes acidity and metals into Kilembe soils and water

2.4 Metals in agricultural soils

Element	Range	Mean	Background mean	World average	Agricultural thresholds
Co	**4.9-110**	25	9.7	10	22 [ii]
Ni	**5.3-180**	41	18	13-37	35 [ii]
Cu	**3.5-975**	115	19	14-109	100 [ii]
Zn	20-189	61	62	60-89	350 [ii]
As	0.5-9.6	2.4	1.3	6.8	31 [iii]
Ag	0.03-0.31	0.08	0.09	-	-
Pb	4.1-48.6	14.4	14	27	80 [ii]

ii. Riccardo and Gabriella (2008), iii. Nova Scotia Environment (2014)

Metals whose levels exceed agricultural thresholds are indicated in bold

The concentrations of trace elements in 51% of the soil samples collected from crop fields exceeded the recommended agricultural soils thresholds. The main sources of heavy metals were tailings but also the underground mine water also released heavy metals and trace elements into the mine area.

2.5 Heavy metal accumulation in foods

Table 3. Metals in locally grown Foods

Food crop		Co	Ni	Cu	Zn	Pb
Maize	Range	0.01-0.47	0.12-3.11	1.48-16.2	16.3-40	0.00-0.07
Cassava	Range	0.15-1.41	1.56-2.98	2.99-20.47	15.4-36.2	0.06-0.1
Banana	Range	0.01-0.5	0-1.1	2.03-5.06	6.7-19.3	0.01-0.37
Mangoes	Range	0.26-0.41	4.4-5.3	5.58-7.1	7.14-7.5	0.19-0.24
Amaranthus	Range	0.01-81	0.33-9.1	**1.95-35.4**	**25-846**	0.08-2.7
Cassava and Banana guidelines		-	67.9	73.3	99.1	0.3
Guideline for vegetables		50i	66.9i	20ii	99.4i	0.3 i

Foods which exceed thresholds for consumption are indicated in bold
iWHO /FAO (2011); iiEC standards (2006), n.d. = not detectable n.a = not applicable

Beans, yams, cassava, sweet potatoes, maize, ground nuts, bananas and Amaranthus vegetables appeared to be accumulating Co, Cu, Ni and Zn. However onions did not show any accumulation of the heavy metals found in Kilembe soils. Over 26% of the vegetable samples exceeded Cu thresholds of 20 mg /kg recommended by European Community (2006) for human consumable vegetables. Zn concentrations exceeded WHO/FAO thresholds of 99.4 mg kg-1 in 36% of Amaranthus vegetables.

2.6 Dust in buildings

The dust collected from the interiors of private homes and public buildings had concentrations of Cu, Co, Zn and As that were significantly higher than elemental concentrations in control house dusts. Cobalt exceeded the recommended limits of 22 mg kg -1 in 75% of the dust samples collected from private residences and 86 % of public buildings. Some of the metals in house dust existed around tailing sites while houses in the Nyamwamba valley often flooded with river water which contained eroded tailings. Many homes were also constructed using sand from River Nyamwamba which contained eroded tailings.

2.7 Water quality

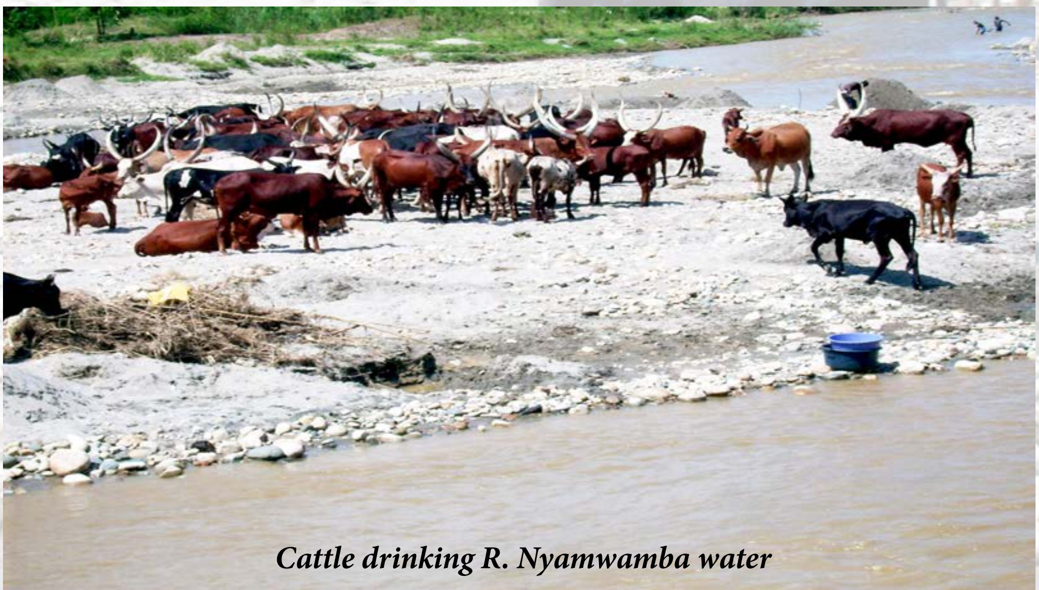
A social survey conducted established that more than half the households in Kilembe (51%) depended on tap water for their water sources; 38% depended on the River Nyamwamba while 11% collected water from community water sources such as streams, water wells and gravity water systems. River Nyamwamba was the only reliable source of water at all times because tap water supply systems faced frequent breakdowns.
Concentration of heavy metals and trace elements in River Nyamwamba water and its tributaries, (units= μg L -1)

Table 4. Metal levels along River Nyamwamba and tributataries

Element	Upstream Mean	Mining and tailing zone (Mean)	Downstream Mean	Tributaries Mean	Drinking water thresholds
Al	204	100	98.5	73	200 iii
Mn	23.1	63.2	100	37	400 i
Fe	186	185	265	188	200 iii
Co	0.21	35.6	55	0.53	40 ii
Ni	0.67	8.8	12	0.98	70 i
Cu	1.9	59	61	2.1	2000 i
Zn	4.1	10	14	6.2	3000 i
As	0.12	1.5	0.15	0.13	10 i
Pb	0.35	0.3	0.4	0.27	10 i

i.WHO (2008), ii.Wisconsin Department of Natural Resources (2011),iiiEU (2014).

Upstream of River Nyamwamba water contained elevated concentrations of Iron and Aluminium while along the mine area and downstream, only cobalt exceeded recommended thresholds although the levels of copper and nickel were quite high.



Cattle drinking R. Nyamwamba water

Table 5. Metal levels in domestic water and public water sources

Sources	**Tap water**	**Water well**	**Gravity flow water**		**Domestic water**		**Drinking water Thresholds (µg L-1)**
Element	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	
Al	0.12-51.3	24.8±20	21.9	14.7±1	**2.4-4835**	699±1419	200 [iii]
Mn	0.3-3.4	1.64±1.1	**649**	3.75±1.2	0.57-254	61.1±76.3	400 [i]
Fe	0.9-121	62.8±61	**2612**	20.6±4	**4.5-7179**	885±2063	200 [iii]
Co	0.02-1.21	0.34±0.44	2.43	1.3±1.5	**0.03-66.1**	20.4±23.4	40 [iv]
Ni	0.02-1.1	0.48±0.37	1.21	0.8±0.3	0.6-16	5.6±5.73	70 [i]
Cu	0.3-6.5	3.1±2.54	2.37	2.9±0.5	2.9-119	36.1±47	2000 [i]
Zn	0.0-82.2	30±32	5.88	27.4-174	101±104	4.8-104	3000 [i]
As	0.0-0.2	0.08±0.04	0.91	0.05-0.06	0.05±0.01	0.06-0.82	10 [i]
Pb	0.0-0.57	0.25±0.19	0.22	0.29-0.58	0.44±0.21	0.19-3.2	10 [i]

i. WHO (2008), iii. Drinking water inspectorate (UK), iv. Wisconsin department of natural resources (2011)

Leaking steel pipes cannot guarantee clean water supplies

Over 25 % of domestic water samples collected and 40% of River Nyamwamba waters along the mine area and downstream exhibited Co concentrations exceeding the Wisconsin (USA) drinking water thresholds of 40 µgL-1. Almost all water samples upstream of River Nyamwamba exceeded UK recommended Fe and Al concentrations in drinking water. Most domestic water samples (67%) exceeded recommended drinking water thresholds for Aluminium, iron and Cobalt

2.8 Forage

Elevated concentrations of Fe, Co, Cu, Zn and Pb were found in Imperata cylindrica forage grasses. Guinea grass (Pannicum maximum) collected along the mine area and downstream contained elevated concentrations of Fe, Co, Ni, Cu, Zn and Pb. Coach grasses sampled from the mine area and downstream exhibited elevated concentrations of heavy metals with Fe, Co, Ni, Zn and Pb being multiples of the levels found in control forages. Elephant grasses contained elevated concentrations of Co, Ni Zn and Cu in all samples. Zinc in 14% of guinea grasses, 33% of couch grasses and 20% of elephant grasses exceeded grazing thresholds of 100-150 mg kg -1 while Cu in 14% of guinea grasses and 20% of elephant grasses exceeded recommended grazing thresholds of 20 mg kg -1. The high levels of metal in forage could affect the health of animals and will also be reflected in the milk and beef produced in Kilembe area exposing consumers to metals.

Goats grazing around Kilembe mine industrial complex

2.9 Human exposure

Trace elements concentrations (mg kg-1 dw) in toe nails of 15 adults and 12 children from the Kilembe copper mining district in Western Uganda. Control samples were from 5 children aged 9-14 years and 5 adults aged 20-60years

Table 6. Metals in toe nails of Kilembe volunteers

Trace element	Age Group	Range	Control range
Co*	Children	0.57-5.39	0.19-1.03
	Adults	0.04-1.44	0.11-1.2
Ni* æ	Children	2.1-6.7	0.65-2.57
	Adults	0.92-40	0.45-3.1
Cu* æ	Children	**5.3-37.6**	2.20-5.53
	Adults	**0.93-35.4**	1.84-5.5
As*	Children	**0.11-2.52**	0-0.08
	Adults	0.05-5.22	0-0.07
Zn	Children	75-144	69.5-129
	Adults	85-602	45-135
Pb	Children	0.25-2	0.4-1.1
	Adults	0.4-8.76	0-0.21
Cd	Children	0.01-0.07	0.1-0.21
	Adults	0.02-0.024	0.4-1

The toe nails clearly confirmed exposure of the local people with children being more exposed and affected than adults.

3. Conclusion

Kilembe mine continues to contaminate Kilembe soils and water bodies largely due to the large quantities of metals found in mine tailings and mine water. The soils also contain large quantities of the mine metals especially copper, cobalt and nickel and some of the soils exceed recommended thresholds for agricultural soils. The large amounts of soil metals could affect soil productivity through reduced fertility levels. The foods and forages grown in Kilembe valley contain high quantities of copper, cobalt, zinc and nickel. Foods especially Amaranthus species exceed the recommended thresholds for human consumption. Drinking water was contaminated especially with cobalt, iron, aluminium and manganese. The contaminated water could expose consumers to metal poisoning. The dust in peoples' homes and public buildings especially along River Nyamwamba valley and downhill of tailing sites also contain large amounts of metals which could be inhaled or accidentally ingested. Children exposed to contaminated environments are more likely to accidentally ingest or inhale the mine metals

The forages also contain large amounts of copper and zinc and these elements could affect animal health but also affect the quality of milk and beef produced in the Kilembe area. The consumers of such milk and beef will be exposed to large quantities of mine metals. Indeed, local people were confirmed to be exposed to large quantities of copper, cobalt and nickel. Children were more exposed than adults perhaps due to their small body weights but also their playing and feeding habits which exposed them to contaminated environments, foods and water.

4. Recommendations

- There is need for awareness creation in Kilembe mine area for the largely ignorant households who depend on contaminated land for farming and residence. The awareness should also raise awareness about clean domestic water sources and the status of Kilembe catchment waters.
- There is urgent need for the environment stakeholders in Uganda especially The Ministry of Environment, National Environment Management Authority, Environmental NGOs and Kasese district Local government in particular to plan and implement contaminated land mitigation programs through containment of tailing erosion, treatment of mine water before discharge and remediation of mine metals presently in the soil
- There is need for implementation of rules and regulations which govern industrial and mine / hazardous waste disposal waste to prevent future occurrence of such incidences in all mining areas in Uganda
- An option of resettling people living in contaminated areas could be explored to minimize contact of local people with mine waste

Further reading

- Mwesigye AR and Tumwebaze SB. Water contamination with heavy metals and trace elements from Kilembe copper mine and tailing sites in Western Uganda; implications for domestic water quality. Chemosphere 169 (2017) 281-287
- Mwesigye AR., Young AD., Bailey EH., Tumwebaze SB. Population exposure to trace elements in the Kilembe copper mine area. Western Uganda: A pilot study. Science of the Total Environment 573 (2016) 366–375
- Mwesigye AR. Soil contamination from heavy metals in Kilembe mine catchment, Western Uganda (un published)
- Mwesigye AR. Forage uptake and accumulation of heavy metals in Kilembe mine catchment (un published)

Whereas River Nyamwanba is well known for the destruction of property and loss of life whenever it over flows, the environmental effects are less known and could be more lethal

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