Effect of Mining to Water Quality in Chua and Revué Rivers, Mozambique

Clemêncio Nhantumbo[1], Estêvão Pondja[1], Dinis Juízo[1], António Cumbane[1], Nelson Matsinhe[1], Bruno Paqueleque[1], Miguel Uamusse[1], Gretchen Gettel[2], Mário J. Franca[2,3], Paolo Paron[2]

[1]*Eduardo Mondlane University, Faculty of Engineering, Av. de Moçambique km 1.5, C. Postal 257, Maputo, Mozambique, Clemencio.nhantumbo@uem.mz*

[2]*IHE-Delft Institute for Water Education, 2611 AX Delft, Delft, The Netherlands, m.franca@un-ihe.org*

[3]*Delft University of Technology, Department of Hydraulic Engineering, Stevinweg 1, 2628 CN Delft, The Netherlands, M.J.Franca@tudelft.nl*

Abstract

Anthropogenic activities, particularly artisanal and industrial gold mining, have been affecting water resources in Manica Province, in Mozambique. Evaluation of water pollution in Révue and Chua rivers due to gold mining was done through field observations and laboratory analysis. This investigation revealed that water quality is being affected by activities developed in the river basin. Turbidity (200-5600 NTU) and concentration of sulfate (25-56 mg/L) are the most affected parameters. pH values measured were below 6.5 in two monitoring points. Although, agriculture is also present in the studied area, gold mining is likely to be the main source of water pollution.

Keywords: goal mining, river, water quality, environmental impact

Introduction

Water is an important resource, since it is widely used for Human consumption, agricultural activities, recreational and industrial purposes. Currently, anthropogenic activities have been affecting seriously the water quality. Organic, inorganic and biological pollutants, as well as extremely toxic metals are usually released to the water resources (Asare Donkor et al. 2018). Toxic metals in water represents a serious threat to the health of animals, particularly Humans and aquatic animals, due to their persistence and bioaccumulation in the food chain (Asare Donkor et al. 2018). In Southeast Asia including Bangladesh, India and the Bengal region, were recorded cases of skin, kidney, bladder and lung cancer associated with the consumption of arsenic-loaded water in rice food crops (Keita et al. 2018).

Mining activity is developing fast in most developing countries and when regulated, it brings revenue to government. However, mining is also linked to severe impacts to the environment and water resources on a global scale (Nhantumbo et al. 2015). Mining is linked to the increase of turbidity, acid mine drainage, sediment transport and is the main source of toxic metals released to water (Ochieng et al. 2010). Mining is contributing to the degradation of the environment with negative environmental impacts that outweigh socioeconomic benefits, such as, the pollution of air, water and soil degradation (Ncube-Phiri et al. 2018).

In most cases, artisanal and industrial gold mining is carried out in developing countries where the regulation is limited and it is not well implemented, thus, with higher potential impact on the environment. The release of pollutants to the environment affects the entire ecosystem and biodiversity, and it contributes to deforestation (Keita et al. 2018; Mamodu et al. 2018).

In Mozambique, the artisanal and industrial gold mining occurs mostly in Manica province. There were about 13,000 workers working in six legal mines until 2009 and it is known that more illegal mines are operating in private properties, rivers, or remote, uninhabited land (Drace et al. 2012). These mines are operated preferable near the rivers, because the water of the rivers is used for washing the gold, and there are several reports of water quality being affected by gold mining in Manica (Drace et al. 2012; Muacanhia et al. 2012). However, limited data on water quality in the rivers affected by gold mining is available, thus limiting selection of measures to prevent and mitigate the negative effects to water resources. This paper intends to evaluate the level of pollution of the Révue and Chua rivers due to gold mining in Manica district, through field observations and laboratory analysis.

Description of study area

Manica district is located in Manica province in the central part of Mozambique, Figure 2. Manica district is bordered in north by the Barué district through the Pungue River, in south by the district of Sussundenga through the Zónue and Révue Rivers, in east by the Vandúzi district and in west by Zimbabwe (Castigo et al. 2017). The district has about 4400 km2 and the population density is approximately 59 habitants/Km^2 (MAE 2014). The present study will be restricted to Révue and Chua Sub Basins.

Gold deposits are common in Manica District, and they can be classified as primary deposits or alluvial. Primary deposits are in ferrous quartzite. The gold is associated with sulfides, pyrite (FeS_2) pyrrhotite (FeS), aresnopyrite (FeAsS), chalcopyrite ($CuFeS_2$) which is about (10-35%) of the ferrous quartzite (Maculuve, 2001). The alluvial gold can be found in the river banks and it is distributed irregularly (Maculuve 2001; Marrumbe 2012).

Due to high concentration of deposits, gold mining is common in the Manica District and it can be classified as industrial and artisanal. Artisanal mining is more common than industrial mining. There are 23 mining areas identified in the Révue River and its tributaries, in which, 8 are industrial and the remaining 15 are artisanal, Figure 2 (Marrumbe 2012). Artisanal gold mining is done using instruments such as shovels, picks, baskets and industrial mining is done using open pits or galleries (Manhique 2011).

Artisanal mining in Manica District is not organized due to limited legislation and its weak implementation. The rivers are highly affected due to inappropriate techniques during extraction and processing of gold. Gold is processed and washed in the rivers and it leads to high turbidity, and concentration of solids and metals, Figure 1. Additionally, mercury is used for artisanal gold processing in artisanal gold mining and it also contaminates the water of the rivers. Some industrial gold mining companies are mobile and do not have environmental management plans that makes environmental monitoring and protection inefficient (Castigo & Fopenze 2017).

***Figure 1** Revué River (right) Chua River (left) (image: Bruno Paqueleque).*

Table 1 Location of Monitoring points.

Monitoring Points	Location	Latitude	Longitude	Altitude
1	Révue River	78o99'04.4"	13o41'04"	793
2	Messambúzi River	78o95'71.6"	14o59'53"	706
3	Révue River	79o00'29.6"	14o56'73"	744
4	Confluence of Chua and Révue River	79 o00'56.9"	14o71'33"	727
5	Upstream Révue River	79o03'43.2"	15o80'51"	716
6	Chua River	79o02'75.9"	15o16'89"	724
7	Upstream Chua River	78o98'39.0"	15o41'30"	713

Methods

Seven monitoring points were chosen along the rivers, Figure 2. The points were selected in order to get information on water quality upstream and downstream the mining area. The samples were collected using 500 ml polyethylene containers previously washed and identified. Sampling was carried out using a rope in the opposite direction of the stream flow, and at the depth of approximately 10 centimetres. Analysis of the following physical parameters, pH, conductivity and TDS were done using the HQ40D Multi-Meter Portable. Turbidity was measured using the 2100Q Portable Turbidimeter using the USEPA 180 method. Determination of the alkalinity was done using the volumetric method with potentiometric detection and the titration was done until the set pH of 4.8. pH, electric conductivity, TDS and turbidity were measured in the field while other parameters were measured in the laboratory.

Analysis of the chemical parameters, sulfate, sulfite and metals (arsenic, copper, iron, manganese, chromium and zinc) were made using the DR 1900-Portable Spectrophotometer. The samples were diluted before the measurement and the determination of the initial concentration was done by the USEPA Bicinchoninate-Powder Pillows method. The concentration of iron, manganese, zinc, sulfate (SO_4^{2-}), (S^{2-}) and arsenic were determined FerroZine-Reactant Solution Pillows Method; USEPA Periodate Oxidation-Powder Method Pillows, USEPA Zincon-Powder Pillows, USEPA SulfaVer 4, and USEPA Methylene Blue and Arsenic Test, respectively.

Results and Discussion

Results of chemical analysis in Figure 3 and Table 2, show that the water quality of Chua and Revué Rivers is affected by mining. Considering the monitored parameters, before the mining area the water quality is good, monitoring points, P7 and P5. Most analysed parameters were affected negatively when the rivers streams passed through the mining area, turbidity, (200-5600 NTU), concentration of arsenic (0.01-15 mg/L), copper (1.6 mg/l), iron (0.73-6 mg/L), manganese (8-165mg/L), chromium (0.11-4.95 mg/L), zinc (4.8-24.2 mg/L), sulfate (25-56 mg/L) and and pH (values below 6.5). Worst water quality results were obtained from analysis of water in the monitoring points P6, P4 and P3. P6 is a monitoring point along Chua River within the mining area, P4 is the monitoring point at the confluence of Chua and Révue River, and P3, is immediately downstream the confluence of Chua and Révue River. Most mining sites are located upstream monitoring points P4 and P3, Figure 2. As the water moves downstream the mining sites, the water quality recover its quality, Figure 3.

Water quality of the river was also compared to water quality standards obtained from Mozambican Legislation, "Diploma Ministerial no. 180/2004 de 15 de Setembro". It has been observed that, most of monitored parameters satisfy the water quality standards before the mining area, except concentration of copper (Cu) and chromium (Cr+6), monitoring points P7 and P5. However, once the river enters the mining area, the pH drops to values below the standard value, (pH=6.5) in monitoring points P6 and P3, and the turbidity, concentration of arsenic, iron, manganese, zinc and sulfate, become higher that the standards, Table 2.

Beside of mining, agriculture is also common in the studied area (MAE 2014). Relative contribution of agriculture and mining to changes of water quality of the

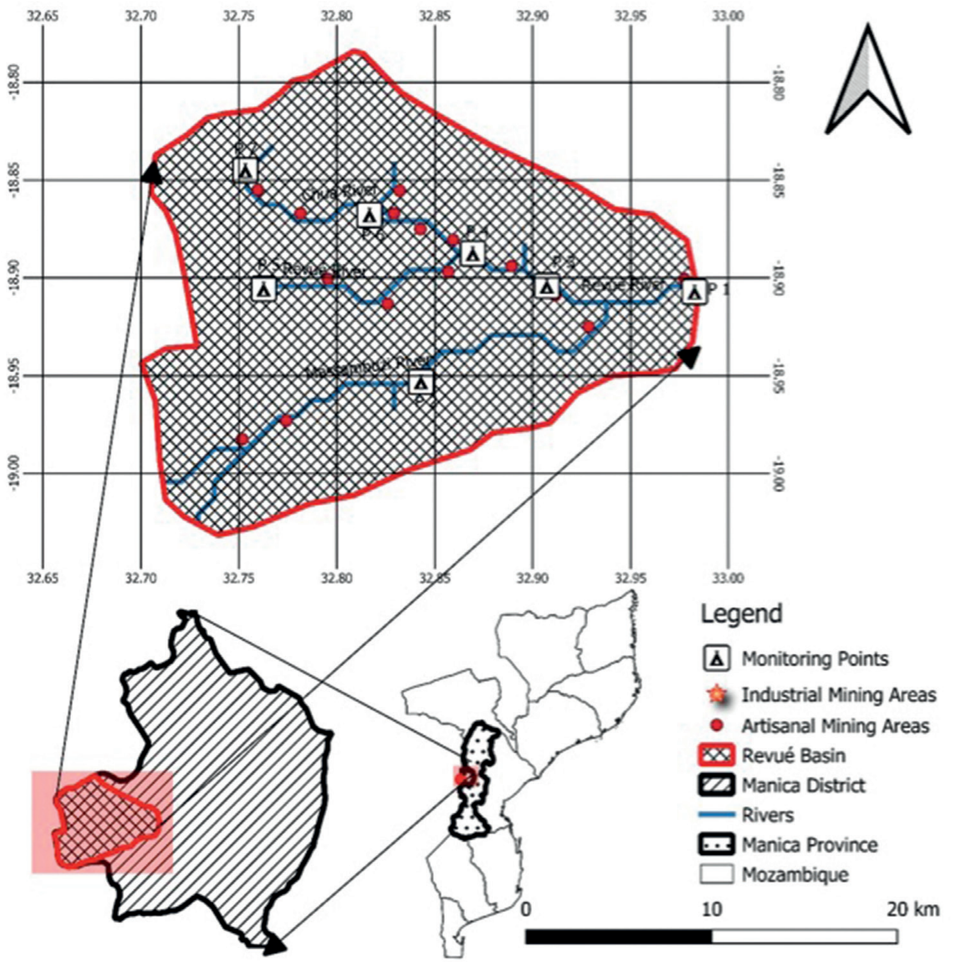

Figure 2 *Mining areas and monitoring points in the Chua and Révue River Basin.*

rivers is not known. It was also observed that mercury is used for artisanal gold processing. No measurement of mercury concentration in the water of the rivers and its bioaccumulation to the food chain was done, while mercury is known on its negative impact to environment and Human health. Results of this study showing that the Chua and Revué River water quality is being affected, opens an opportunity for further investigation on the relationship between sources of pollution and water quality of rivers, on human health and biodiversity, and using statistical tools and mapped using drone with multispectral camera.

Conclusions

Twenty-three mining sites where identified in the studied area, among them, fifteen are artisanal and eight are industrial. Water quality of Chua River and Revué River is being affected by activities developed in the river basin. Most analysed parameters were affected negatively when the rivers streams passed through the mining area, for example turbidity, (200-5600 NTU), concentration of arsenic (0.01-15 mg/L), chromium (0.11-4.95 mg/L), sulfate (25-56 mg/L) and pH (<6.5). Monitored parameters, exhibit recover after the mining area. Although, agriculture is notable in the studied area, mining is likely to be explaining the water quality changes.

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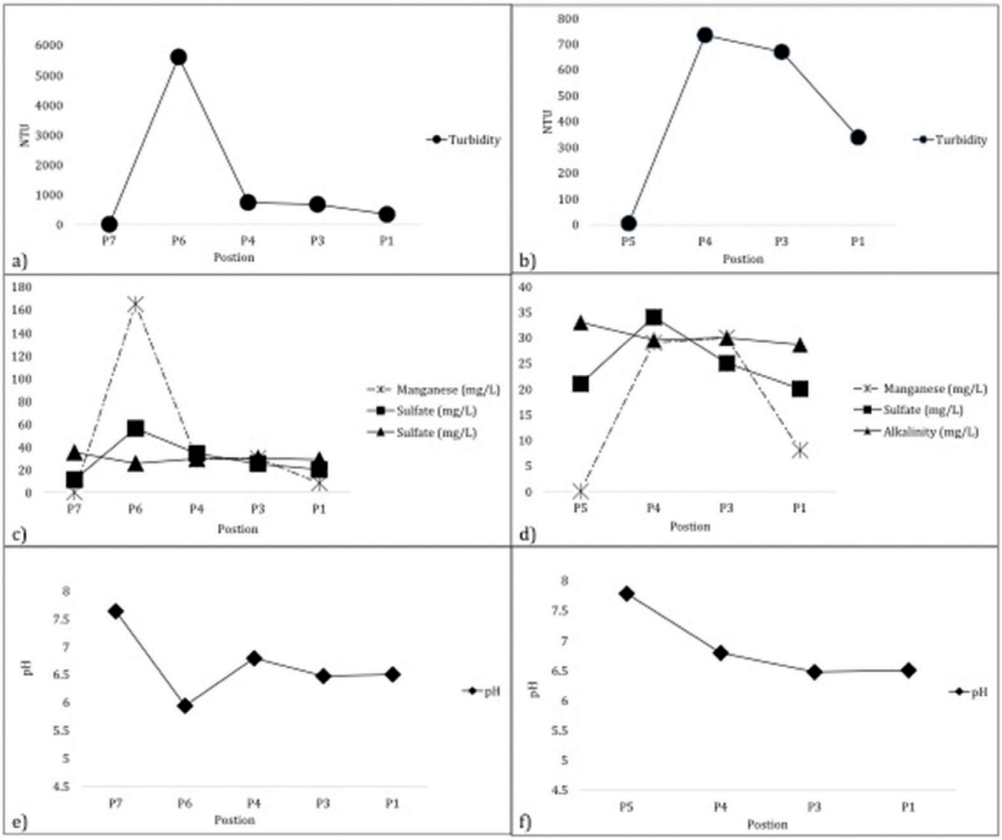

Figure 3 *Change of turbidity, alkalinity, pH and concentration of manganese and sulfate along Chua River [a), c) and e)] and Revué River [b), d) and f)]. P1, P3, P4, P5, P6 and P7 are the monitoring points indicated in Figure 2.*

Table 2 *Results of chemical analysis in Chua and Revué rivers, and standard values. P1, P2, P3, P4, P5, P6 and P7 are monitoring points indicated in Figure 2.*

		Monitoring points							
Parameter	Units	P7	P6	P5	P4	P3	P2	P1	Standard*
pH	-	7.63	5.94	7.78	6.79	6.47	6.91	6.50	6.5 - 8.5
EC	µ.S/cm	896	659.3	941	760.3	749	148.6	837	50 – 2000
TDS	mg/L	423	378	545	362	358	705	407	1000
Alkalinity	mg/L	35	25.4	33	29.51	29.96	-	28.63	-
Turbidity	NTU	6	5600	5.27	734	669	197	338	5
As	mg/L	0	15	0	1.5	0.5	0	0.01	0.01
Cu	mg/L	0.001	1.6	0.006	0.9	0.3	0	0.27	1.0
Fe	mg/L	1.46	6	1.52	3.68	1.28	2.23	0.73	0.3
Mn	mg/L	0.003	165	0.03	29	30	18	8	0.1
Cr^{6+}	mg/L	0.15	4.95	0.11	1.27	0.96	0.69	0.83	0.05
Zn	mg/L	2.9	24.2	4.8	10.6	8	7.2	4.9	3.0
SO_4^{2-}	mg/L	11.0	56.0	21.0	34.0	25.0	22.0	20.0	25.0
S^{2-}	mg/L	0.21	4.18	0.11	1.50	1.16		0.73	-

Values that exceed the standard

Values that do not exceed the standards

* Mozambican Legislation, extracted from "Diploma Ministerial no. 180/2004 de 15 de Setembro"

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