Colloids and their influence in the diagnosis of minewater quality

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Abstract

The Aroeira tailing dam of Nexa Resources SA is located at Vazante MG town in Brazil. This mine is the largest zinc producer in the country and has operating over 50 years. It has recently incorporated a new zinc deposit known as *"Extremo Norte"*, located couple kilometers northeast from Vazante Mine, and has featured a sporadically reddish color effluent. However, a numeric correlation of turbidity with the visual water color of the dam with a red color effluent was not verified. This water phenomena also had no correlation with the seasonality where rainiest period in tropical countries, like Brazil, typically increase parameters such as: turbidity, water color and total suspended solids.

The main goals of this study were to find out the causes for the change in water color and how to manage this issue. So, historical satellite image analysis of the dam, technical visits, and water sampling campaign at several points (in the effluent of the underground mine, inside the tailing reservoir and one in the receiving water) were performed. The parameters sampled were (trace and major metals, pH, temperature, electric conductivity, turbidity, color, total solids, total dissolved solids and suspended solids). The main cause of the reddish color is the addition of 30% of ore from the *"Extremo Norte"* , which has in average 10% of iron oxide in its chemical composition, according to results from ore chemical characterization.

Introduction

This zinc mine owned by Nexa Resources S.A is located at Vazante/MG in Brazil (Figure 1). This unit has recently incorporated a deposit known as *"Extremo Norte"* and has featured a sporadically reddish color effluent in its tailing dam effluent.

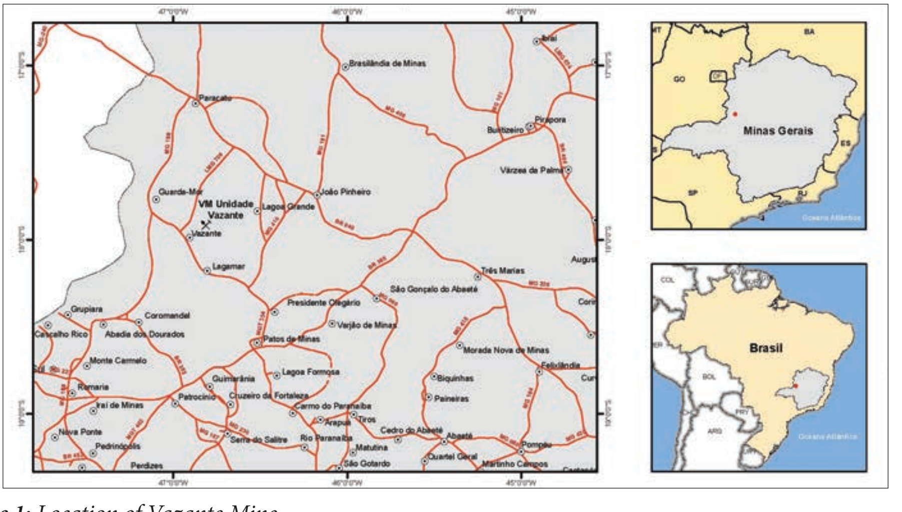

Figure 1: *Location of Vazante Mine.*

Technical Background

The cause of reddish water coloration in the dam water is associated with the processing of zinc ore from the *"Extremo Norte"* Mine that has a high content of hematite in its composition. Another possibility that was discarded, would be due to the change in atmospheric temperature that would "raise" the very fine particles from the bottom of the tailing dam.

The monitoring data of the dam and its effluent chemical parameters such as: color, dissolved iron and total iron, are not conclusive about the causes of the change in color in the water reservoir and what must be done to solve this phenomenon. Therefore, the objective of this study is to establish the causes of this phenomenon and to be able to present possible solutions. To achieve this, a water sampling campaign as well as analysis of historical images of this reservoir were performed.

The presence of colloids in solution: Colloids are particles of 1 µm (micrometer) to 1 nm (nanometer) in size and are composed of mineral or organic material. These can significantly influence the characteristics of the water (Vasconcelos et al. 2009).

Based on the history of occurrence of apparent color in the Aroeira dam and the inclusion of *"Extremo Norte"* ore in January 2015, it is very probable that the reddish color of the dam is associated with the presence of colloids generated by the ore processing of this new mine, in a proportion that is above 30%. Generally, the proportion is 80% of ore from the Vazante mine and 20% of the *"Extremo Norte"*. In the sample collected on 12/14/2016 the percentage of ore from the Far North was 51% and the percentage of iron in this waste was about 15%.

When analyzing water samples like those collected on 12/14/2016, due to the size of these suspended particles, it is not possible to characterize higher turbidity, color, or total iron. However, the presence of these colloidal particles in the water is remarkable and for sure they are able to change the apparent color of it. The best strategies to deal with

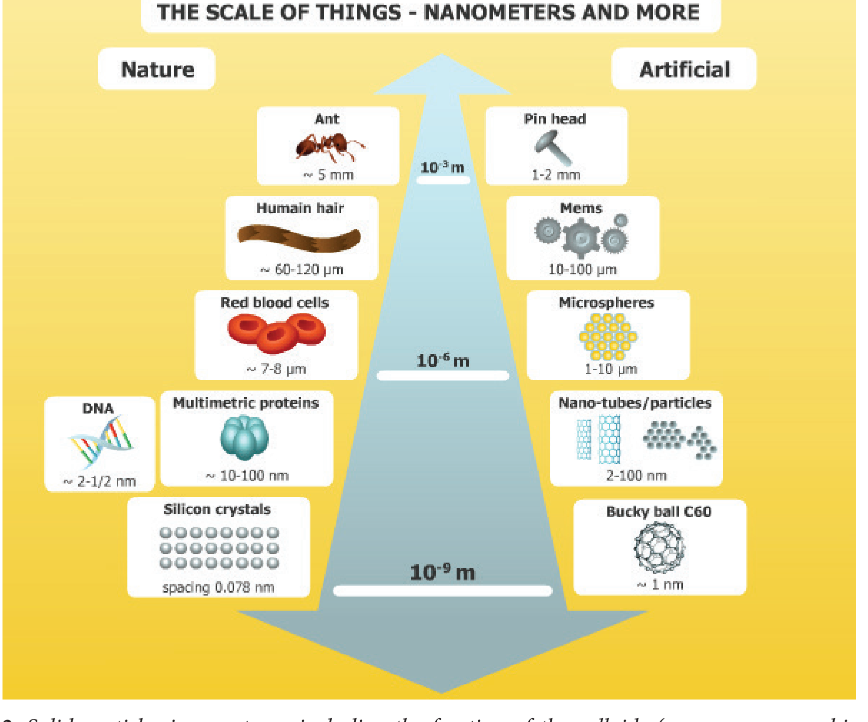

Figure 2: *Solid particle size spectrum including the fraction of the colloids (source: www.prochimia.com (2016).*

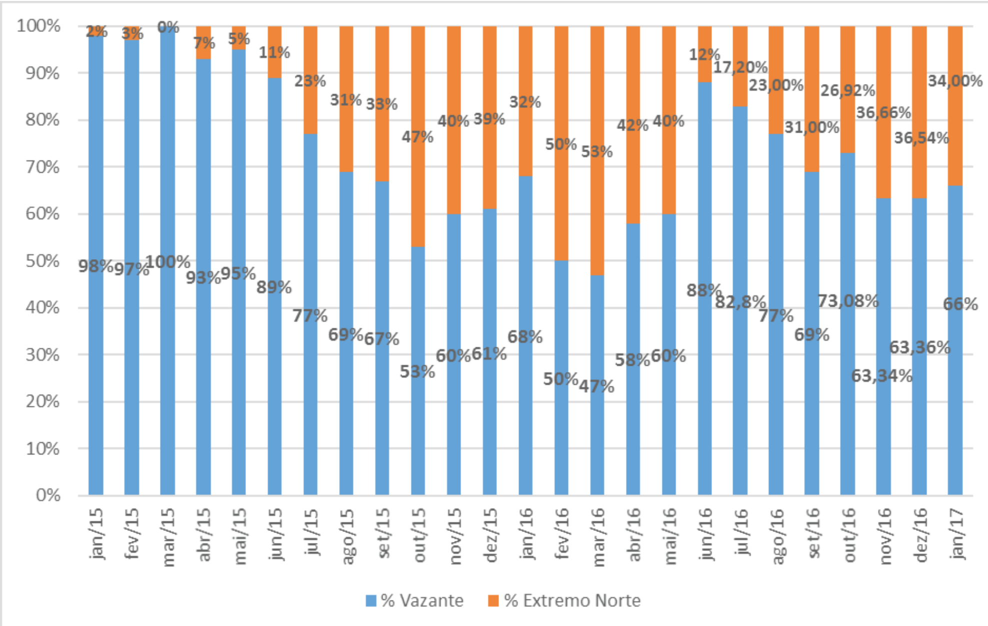

***Figure 3:** Contribution percentage of the northernmost ore in the USICON plant feed cell.*

this problem would be: 1- Controlling the percentage of ore from the *"Extremo Norte"*, or 2- by treating the mill plant effluent, using chemical reagents.
The percentage of ore from the Far North deposit has been reported from January 2015 to January 2017. These data are presented in the following figure(Figure 3).

For the validation of the causal nexus of the inclusion of the *Extremo Norte* ore in the USICON mill plant and the appearance of the red coloration in the dam, a historical survey was made via satellite images obtained via Google Earth. In this survey we searched for images available on the web in years before the plant received ore from the *"Extremo Norte"* Mine and in years after receiving this type of zinc ore. It is easy to observe the color change of the tailings located on the dam beach, as shown in the following image record. So, in the first two imagens there is no strong red color, but in the three imagens someone can notice the difference in red color. In addition, that the addition of zinc ore from *"Extremo Norte"* Mine, increased significantly after September 2015; therefore, the color in the tailing dam also changed.

***Picture 1:** Aroeira DAM in 11/06/2009.*

***Picture 2:** Aroeira DAM in 07/21/2013.*

Picture 3: *Aroeira DAM in 07/10/2015.*

Picture 4: *Aroeira DAM in 04/10/2016.*

Picture 3: *Aroeira DAM in 07/10/2015.*

Methodology

Sampling: Four water samples were collected, in December of 2016, and the percentage of *"Extremo Norte"* Mine ore in the whole process was 51%. The sampling points were the following: one of the effluent from the dam, the second from the underground mine, the third from the waste that was disposed in the dam and finally the waste from the underground mine. Sampling was carried out based on ABNT NBR 9897, and the methodologies of analysis of the water samples used are those recommended by the Standard Methods for the Examination of Water and Wastewater. Environmental Protection Agency (EPA) methodologies were also adopted. The samples were: sample 01 (tailing dam effluent, sample 02 (effluent from the underground mine), sample 03 (effluent from mill plant processing Vazante + Extremo Norte ore, sample 04 effluent from mill plant processing Vazante mine ore only).

Treatability Study: Treatability studies evaluating the possible chemical routes to reduce the presence of colloids in the USICON effluent were carried out by a specialized laboratory. Samples 2 and 3 presented in the previous item, were submitted to the treatability study.

The Physical Chemical treatment was divided into four (4) alternatives:

1. System 01: Treatment with aluminum sulfate: For this treatability test, the simulation of a Chemical Physical system under agitation with the addition of 700 ppm of 10% lime was used to raise the pH to 9.5. After this blending 2,000 ppm of 50% Aluminum Sulfate Coagulant and then 6 ppm of Anionic Polymer Flocculant was added.
2. System 02: PAC treatment: For this treatability test, the simulation of a Chemical Physical system under agitation with the addition of 700 ppm of 10% lime was used to raise the pH to 9.5. After this blend was added 900 ppm of PAC flocculant and then 6 ppm of Anionic Polymer.
3. System 03: Treatment with Tanac (Tanfloc SL 10% solution): For this treatability test, a physical Chemical system simulation

was used under agitation with addition of 100 ppm Tanfloc SL 10% and 0.6 ppm anionic polymer.

4. System 04: Treatment with Tanac (10% Tanfloc SG solution): For this treatability test, a physical chemical system was simulated under agitation with addition of 200 ppm Tanfloc SL 10% and 0.6 ppm anionic polymer.

Analysis and Interpretation of results

Table 1 presents the results of the chemical analysis of the four water samples collected.

Results of Water Analyses: It is observed that the first two samples have similar characteristics, whereas the third and fourth samples had more total suspend solids and similar pH values. Between the last two samples collected from the mill plan the third one, that has ore from the *"Extremo Norte"* had higher values of total suspended solids.

According to the chemical analyzes of the samples 2, 3, and 4, concentrations of the total suspended solids, cadmium, total iron, lead and zinc concentrations were found to be above the limits established in Brazilian regulation (CONAMA Resolution 430/11 and DN COPAM 01/08), which establish release parameters of effluents in the receiving body. Again, someone can notice that sample 3 has a very high concentration of iron and probably in the colloidal form.

Treatability Study: Four routes for treatment using basically three different reagents (Aluminum sulphate, aluminum policlorate – PAC, and Tanac) were tried in laboratory in sample 3 collected from the mill plant. From the analysis of the results it was concluded that the system 03 is the best treatment option for both the underground mine effluent (sample 02) and the mill plant processing Vazante. + *"Extremo Norte"* mines (sample 03).

Conclusions

According to the history of the appearance of the phenomenon of increasing the water color of the dam and the disposal of effluent from the USICON plant, it is very probable that the increase of the ore percentage of the *"Extremo Norte"* mine is the cause of the increase of the water color of the tailing dam Aroeira;

Table 1: *Results of chemical analyzes of water and effluent samples*

Parameters	DN COPAM 01/08	Sample 01	Sample 02	Sample 03	Sample 04
pH	6.0 – 9.0	6.1	6.3	8.8	8.6
Total Suspended Solids mg/L	100	8.0	**321**	**6,136**	**3,332**
Total Lead (mg/L)	0.1	<0.02	0.13	**2.75**	**1.05**
Total Coper (mg/L)	1.0	<0.02	<0.02	<0.02	<0.02
Total iron (mg/L)	15	0.09	7.2	**15**	3.3
Cadmium (mg/L)	0.1	<0.02	<0.02	0.06	**0.24**
Dissolved iron (mg/L)	15	0.09	5.8	7.9	2.5
Total Zinc (mg/L)	5.0	0.04	0.93	**26**	**10**

Table 2: *Results of treatability test of effluent samples*

Treatment system	DN COPAM 01/08	Sample 01	Sample 02	Sample 03	Sample 04
01	TSS = 100 (mg/L)	23	19	53	172
02	Fe diss. (mg/L)	0.21	0.22	1.3	1.0
03	Pb total (mg/L)	0.02	0.06	< 0.02	0.33
04	Zn total (mg/L)	0.21	0.35	0.19	3.0

The causes of this change in water color are most likely related to the presence of hematite mineral colloids that are present in the "*Extremo Norte*" ore tailings at a concentration above 10%;

The field results have shown that the change of color of the dam was associated with the use of more than 30% of a new zinc ore from the "*Extremo Norte*" mine that had a higher percentage of iron oxide in relation to the Vazante mine. After processing of these two types of ore in the mill a significant amount of Hematite mineral colloids were formed. These colloids particles were at the surface of the dam and change its color, however, this does not modify the monitoring parameters in the water dam (e.g., total suspended solids and color).

The extremely reduced size of the material causes an extremely slow sedimentation. Therefore, a strategy to increase the water residence time in the dam to allow sedimentation will not work. So, the best way to reduce its presence, is either by reducing the percentage of "*Extremo Norte*" ore in the beneficiation plant, or, by treating the effluent from the plant according to the results of this study.

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