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CONGENITAL ANOMALIES OBSERVED IN XIKRIN INDIANS IN THE AREA NEAR THE PUMA MINE IN THE STATE OF PARÁ: EVALUATION OF HEAVY METAL TERATOGENICITY

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ABSTRACT
As a result of the results obtained from the sampling campaigns and chemical analyses of the monitoring points of the rivers that cross the Xikrin indigenous lands in the region of Carajás, southeast of the state of Pará, chemical and mineralogical analyses of the waters of the Cateté River, which pass through the installation point of the Mineração Onça Puma – MOP, that they are contaminated and, after comparative observations between pathological reports and bibliographies of research and scientific works on symptoms and diseases caused by human, plant and animal contact with heavy metals, the Group for the Treatment of Ore, Energy and Environment - GTEMA/CNPq/UFPA awoke to a marked concern with the health of the Cateté River and the Xikrin indigenous people. Realizing this need, the Cateté River Monitoring and Recovery Project was created, which was filed with the Dean of Extension of the Federal University of Pará. In this project, semiannual visits are made to the river with the intention of verifying the degree of its environmental degradation in the vicinity of the villages and the mineral enterprise.

Keywords: Results. Enterprise. Symptoms. Diseases.

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INTRODUCTION

Mining activity often causes serious environmental impact. A consequence of this activity is the removal of the capping and geological basement of a certain region, in order to force the adjacent communities to live with the noise of the machines and the dust particles raised by the movement of vehicles. With the installation of the plants, the irregular disposal of tailings causes the contamination of soils and rivers and damages the health of the populations in their surroundings. One of the main causes for this is the dumping of ore processing waste, called tailings, because depending on the content of metals present and the toxic effect of this metal, it will bring damage to health such as the collapse of the nervous system, carcinomas, congenital anomalies, mortality of fetuses, even the mortality of adult individuals. Indigenous health agencies are also aware of the presence of these pathologies in communities near power plants and mines in the Amazon.

The study area is located in Parauapebas, in the region of Carajás, between the Itacaiúnas and Cateté Rivers, the latter being the one that supplies the villages of Cateté and Djudjekô, the latter being the main one affected by the discharge of mining effluents. The Xikrins Indigenous Lands (TI) are formed by the Djudjekô, Cateté and O-ôdjã villages. The region was once rich in hardwood such as mahogany and chestnut trees, also having a large concentration of babassu and buriti. It is characterized as a submontane hillside forest and its vegetation is composed of species typical of humid forests such as palm trees, gueiroba, babassu, urucuri, inajá, among others. The Xikrins Indians have the characteristics of building their houses close to the rivers, with care for personal hygiene and main sources of food such as fish, game, etc. The Research Group on Mineral Treatment, Energy and Environment (GTEMA) of the Federal University of Pará (UFPA) was motivated to make a monitoring and recovery plan due to the advance of environmental degradation of the Cateté River.

The present project began in November 2017, but due to the bureaucracy of contracts, the purchase of equipment and utensils necessary to carry out the activities and also the logistical difficulties, due to the distances and roads of difficult access, the sampling campaigns suffered unexpected and unplanned delays that culminated in a request for another eight months of work demanded from the indigenous associations. But even with all the various difficulties, the project has been complying with the monitoring, studying the location of drains and effluents coming from the mining area of the Onça Puma mining enterprise. Thus, the points of the Cateté River, also inspected by satellite,

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such as drain dump points, were visited in loco in order to collect samples. The reports show us the partial results of the work, carried out in the Cateté River basin and its effluents: Seco River and Bekwara River, Itacaiúnas River where part of the Ôodjan Village is inserted; and the Cateté River, with the Djeduko and Cateté Indigenous Villages.

Taking into account the 25 points visited and monitored and the results of the chemical analysis of the water, there is no doubt that the problem with heavy metal contaminants above the limits required by Brazilian legislation in CONAMA 357 continues to be the most disturbing occurrence among the indigenous people. Resolution No. 357, of March 17, 2005, of the National Council for the Environment (CONAMA), published in the Federal Official Gazette No. 053, of 03/18/2005, pp. 58-63, amended by Resolution No. 410/2009 and No. 430/2011, provides for the classification of 2nd class water bodies and environmental guidelines for their classification, as well as establishes the conditions and standards for the discharge of effluents and other measures that must be taken for better clarification.

According to Paraense (2018), the geomorphological domain of the region covered by the study is inserted in the Southern Amazon Residual Plateau, which is a relief unit that presents imposing mountain alignments, with a mountainous aspect, a group of hills and low mountains and a set of isolated plateaus arranged in distinct lithostructural arrangements immersed in the midst of the vast flattened surfaces of the Southern Amazon. At the tops of the plateaus there may be the occurrence of laterites.

The same author explains that the slopes of this domain are steep and remnants of old erosion surfaces, generally the existing lands in the Southern Amazon Residual Plateau are within the preserved forest, many generally inserted in areas of indigenous lands.

Paraense (2018) states that the flattened surfaces of the southern Amazon constitute an extensive geomorphological domain that covers vast areas of the center-south of the state of Pará (Trairão, Novo Progresso, Novo Repartimento, Pacajás, Anapu, Xinguara, Ourilândia do Norte, Tucumã, São Félix do Xingu, Rio Maria, Pau d'Arco and Redenção). The landforms of the region are predominantly shaped in granitoid rocks: granites and gneisses of the Xingu Complex, and subordinately in Precambrian metavolcanic and metasedimentary rocks. Therefore, this geomorphological domain presents a notorious predominance of flattened surfaces.

Ruggiro (2013) points out that Onça-Puma is a nickel deposit of hydrothermal alteration, generated by supergenic processes, where laterization acted intensely on basic and ultrabasic rocks, resulting in the formation of a thick ferruginous saprolytic horizon.

Oliveira (1990) explains that they are configured as mafic-ultramafic complexes (serpentinized dunites and peridotite, pyroxenites and gabbros), elongated in shape and with an approximately east-west direction, which stand out in the landscape as tabular-topped mountain ranges, with unevenness of up to 200 meters.

The author reports that the Serra do Puma, with an extension of 23km x 3km, is composed of serpentinized peridotites, in its ultramafic portion. On these rocks, a lateritic capping was developed with silicate saprolite at the base (serpentine, chlorite and smectite) and ferruginous material at the top (goethite, hematite and quartz). The alteration profile is better developed in the areas with a lower slope and, at the tabular top of the mountain, it is always covered by a thick level of silcrete. Oliveira (1990) also says that in the lower levels of the alteration profile, the saprolite is cut by veins of quartz and garnierite. According to the expert, the average Ni, Fe and Cobalt (Co) contents of the ore are, respectively, 2.0%, 26.4% and 0.084%, indicating that it is an ore with a strong oxidized component.

Oliveira (1990) details that in the Serra da Onça (22km x 3km), the ultramafic rocks are represented by serpentinized dunites and pyroxenites. The alteration profile is similar to that of Puma, and also in Onça appears the level of silcrete capping the tops of the mountain range and veins filled with quartz and garnierite at the base of the profile. The average contents of Ni, Fe and Co are, respectively, 2.14%, 15.9% and 0.067%, characterizing, therefore, a less oxidized ore than that of Puma. The Onça-Puma deposit has high nickel grades (average grade above 2% Ni for a *cut-off* of 1.5% in i), and tonnages above 40 million.

The Serra Arqueada is located between the Serra da Onça in the southern part and Puma in the north, approximately 51 km long, aligned east-west. According to Paraense (2018), this mountain relief can present a sharp and elongated top, steep slopes and with strong structural control.

It is geologically formed by foliated and mylonitized acidic volcanic rocks, schists and iron formations, probably part of a sedimentary volcano sequence that forms the set of supracrustal rocks attributed to the Sapucaia Group. Valetim and Olivito (2011) say that iron formations outcrop at the top, along with ferruginous breastplates (cangas).

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The main types of soil in the study area are: the Lithophic Neosol, shallow, located in steeper reliefs and composed of bases and aluminum; the deep, well-drained Eutrophic Red Nitosol, with little differentiation between the horizons, developed from the weathering of basic and ultrabasic rocks, with little notable horizon differentiation; the deep Dystrophic Red-Yellow Argisol, with a marked increase in clay content from the superficial horizon "A" to the subsurface horizon "B", evidencing the textural diagnostic horizon B, which may or may not present waxiness. According to Embrapa (2018), the red color is due to higher levels and the nature of iron oxides present in the original material, in well-drained environments. It has very variable natural fertility due to the diversity of source materials.

Located SW of the Xikrin do Cateté Indigenous Land, in the southeast region of Pará, municipality of Ourilândia do Norte, there has been a large nickel extraction project since 2011, licensed by the Pará State Department of the Environment (SEMAS-PA). The region arouses the interest of companies in this segment because it is rich in garnierite, a magnesium and nickel silicate of variable composition.

INDIGENOUS PEOPLE AFFECTED BY MINING ACTIVITY

Indigenous villages have a very strong relationship with rivers, using them for ritual activities, consumption, bathing, fishing and transportation, being fundamental for their maintenance, but it is the main contaminated means, due to the intense exploratory economic activities close to the area where they live. Two important rivers can be highlighted, the Cateté River, where the main villages and plantations are located, and the Itacaiúnas River.

According to the Environmental Impact Study, carried out within the scope of the licensing of the Pantera project, the area of the mining enterprise is located in the Xingu-Araguaia-Tocantins interfluves, in the basins of the Itacaiúnas, Parauapebas and Xingu rivers, located on the border of two hydrographic basins of the Rio Branco and Cateté. The drainages that cut through the area required for mining are small, drying up in the dry season. In most cases, these are springs and headwaters of first to third order gullies in the constitution of the hydrographic basins of the Branco River, a tributary of the Fresco River, a tributary of the right bank of the Xingu River and the Cateté River basin, a tributary of the Itacaiúnas River. Figure 1 below shows the map of the hydrography of the area.

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Figure 1 - Record of the Cateté River basin

Source: authorship

Typical activities of mining enterprises are quite impactful, and in the case of the Pantera project, its activities of suppression of vegetation, soil disturbance, earthmoving, excavation in the areas of the pit and waste piles, transportation of ore from the mine and tailings are no exception to this rule. In the midst of these activities, the soil is exposed, especially in the rainy season. All of them favor the transport of sediments and can cause the silting of local watercourses, especially in the rainy season in the region.

Historically, indigenous villages are settled close to rivers and streams due to fishing and water supply conditions. In this sense, the important Catete River stands out, which cuts the Xikrin Indigenous Land in half and where the main villages and plantations are located. The role played by this river is essential for the maintenance of these traditional peoples, however, it is the main contaminated environment, in addition to the accelerated process of silting of watercourses, due to the intense economic activities near the area.

It is possible to see the current difference between the preserved Xikrin Indigenous Land in contrast to the area surrounding it with intense vegetation suppression activity and highlighting the capillarity of the local hydrography. It is noted that the area around the TI is quite deforested due to the development of agribusiness and mining activities.

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In the case of the analysis of the potential of this environmental impact, it is observed that in the current situation of the Cateté River, which currently visibly suffers from the silting of its potential impact channel , it is extremely negative and without attentive mitigation measures. The impact is classified as very high and of great relevance.

RESULTS AND DISCUSSION

Among the most important impacts evidenced in the monitoring reports are changes in water quality, changes in chemical composition and in the original and natural properties of the water in the region and the Cateté River. Emphasis on pH, conductivity, turbidity, dissolved oxygen and temperature.

The environmental characteristics of a river can be altered from contamination by effluents and waste generated in mining activities and operations, whether they are mainly rainwater effluents, sanitary or industrial effluents, and waste of industrialized materials left in unprotected places that can be carried to the watercourse by rainwater.

Groundwater can be contaminated from possible contamination through the soil, mainly by percolation of spilled chemical compounds, residues or weather-reactive components deposited or left directly in the soil without the necessary control. Insequence, they can contaminate the surface waters of rivers through their springs.

In the case of the Cateté River, it already has a contaminated water body to the point of harming the lives of the Xikrin people, who before the arrival of the mining companies, lived in full enjoyment of the river's waters , which was clean and had an abundant ichthyofauna , capable of sustaining the entire communities of fish protein.

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Table 1 - Points at which samples were collected

POINT	COORDINATES	DESCRIPTION OF THE POINT
PT01	06° 15' 24.92" S 50° 47' 49.07" W	"Port of the Indigenous Village Cateté": Cateté River, where the indigenous people carry out moments of work, fishing, preparation of tubers (potatoes and cassava), washing clothes, baths and leisure.
PT02	06° 28' 08.80" S 51° 02' 04.19" Or	"Channel 02" for transporting effluent, downstream of the MOP area, which also receives the drain coming from the burnt bridge.
PT03	06° 33' 08.27" S 51° 02' 56.65" W	Located in the MOP area, between the Onça and Puma mines.
PT04	06° 39' 46.14" S 50° 59' 37.89" W	Located upstream of the MOP Development
PT05	06° 41' 55.99" S 50° 56' 28.59" W	In the area of influence of the water intake pipeline facilities for the Pantera Project
PT06	06° 45' 43.92" S 43° 92' 49.28" W	"Ourilândia Bridge": Source of the Cateté River. Place taken as a reference, as without anthropic activity.
PT07	06° 15' 24.84" S 50° 52' 16.90" W	"Port of the Djudjekô Indian Village" of the Cateté River. Where the indigenous people develop work. It is the Indigenous Community closest to the mining project.

Table 2 below presents the results of the physicochemical analyses of two sampling campaigns carried out at strategic points chosen along the stretch of the Cateté River in August 2023, the dry river period, and January 2024, the full river period. The parameters in red indicate that the result is outside the standards established by CONAMA Resolution 357/05.

Table 3 shows the results of the physicochemical analyses of a sampling campaign of sediments from the water channel, carried out at strategic points chosen along the stretch of the Cateté River in August 2023, the dry river period. The parameters in red indicate that the result is outside the standards established by CONAMA Resolution 454/12.

Table 4 shows the results of the biochemical analyses of a sampling campaign of the local ichthyofauna, carried out in the ports of the Cateté and Djudjekô indigenous villages, along the stretch of the Cateté River in August 2023, the dry river period. The parameters in red indicate that the result is outside the standards established by RDC ANVISA 487/2021, IN 88/2021.

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Table 2 - Results of the physicochemical analysis of the Main Parameters of the surface water of the Cateté River in the dry and full period.

	Unid	Refe-rência	PT01 - Aldeia Xikrin Cateté (seco)	PT01 - Aldeia Xikrin Cateté (Cheio)	PT02 - Localizado a jusante do Empreendimento Puma	PT02 - À jusante do Empreendimento Puma (Cheio)	PT03 - Entre a Mina Onça e a Mina Puma	PT04 - À montante do Empreendimento MOP	PT05 - Localizado na Adutora	PT05 - Localizado na Adutora (Cheio)	PT06 - Ponte de Ourilândia (A montante da adutora)	PT07 - Aldeia Djudjekô	PT07 - Aldeia Djudjekô (Cheio)
Coordenadas Geográficas	Graus DMS		6° 15' 24.92" S 50° 47' 49.07" O Elev. 212m	6° 15' 24.92" S 50° 47' 49.07" O Elev. 212m	6° 28' 08.80" S 51° 02' 04.19" O Elev. 253m	6° 28' 08.80" S 51° 02' 04.19" O Elev. 253m	6° 33' 08.27" S 51° 02' 56.65" O Elev. 262m	6° 39' 46.14" S 50° 59' 37.89" O Elev. 266m	6° 41' 55.99" S 50° 56' 28.59" O Elev. 282m	6° 41' 55.99" S 50° 56' 28.59" O Elev. 282m	6° 45' 43.92" S 50° 52' 16.90" O Elev. 291m	6° 15' 24.84" S 50° 47' 49.28" O Elev. 222m	6° 15' 24.84" S 50° 47' 49.28" O Elev. 222m
Data da Coleta			23/08/2023	24/01/2024	23/08/2023	23/01/2024	21/08/2023	21/08/2023	21/08/2023	23/01/2024	21/08/2023	22/08/2023	23/01/2024
Data de envio			01/09/2023	20/02/2024	06/09/2023	25/02/2024	01/09/2023	31/08/2023	01/09/2023	05/02/2024	31/08/2023	31/08/2023	05/02/2024
Laudo Nº			OS5951/2023AM27275		OS5952/2023AM27276		OS5951/2023AM27271	OS5950/2023AM27269	OS5951/2023AM27270		OS5950/2023AM27268	OS5950/2023AM27266	
Alumínio Dissolvido	mg/L	0,1	<0,01	0,293	<0,01	0,402	2,085	<0,01	<0,01	0,155	<0,01	<0,01	0,169
Cádmio Total	mg/L	0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001
Chumbo	mg/L	0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Cloretos	mg/L	250	1,641	2,763	2,062	1,561	1,415	1,845	1,600		1,857	2,105	1,798
Cobre Dissolvido	mg/L	0,009	<0,005	<0,005	<0,005	<0,005	0,020	<0,005	<0,005	<0,005	<0,005	<0,005	<0,005
Cromo	mg/L	0,05	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
DBO5 20°C	mg/L	5,0	<2	3,0	<2	<2	<2	<2	<2	<2	3,0	<2	<2
Ferro Dissolvido	mg/L	0,3	0,283	1,681	<0,01	1,226	0,484	0,474	0,814	1,333	0,540	0,335	0,793
Fluoreto	mg/L	1,4	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	<1	<0,2	<0,2	<0,2	<0,2
Manganês	mg/L	0,1	0,024	<0,01	0,017	<0,01	0,017	0,015	0,048	0,026	<0,01	0,017	0,058
Mercúrio	mg/L	0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002	<0,0002
Níquel	mg/L	0,025	<0,01	<0,01	0,056	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
pH		6-9	8,19	7,38	8,34	6,98	8,51	8,39	8,46	7,05	10,14	8,58	7,39
Resíduos Sólidos Objetáveis		VA	Ausente	Ausente	Ausente	Ausente	Ausente	Ausente	Ausente	Ausente	Ausente	Ausente	Ausente
Sólidos Dissolvidos Totais	mg/L	500	40	37	28	38	29	30	28	31	26	38	52
Turbidez	NTU	100	2,31	1,11	5,23	54,60	6,00	10,40	5,13	32,20	3,72	2,86	10,00
Zinco	mg/L	0,18	<0,009	0,412	0,021	<0,009	<0,009	<0,009	<0,009	<0,009	0,014	0,066	<0,009
Coliformes Termotolerantes	ml	1000/100	<1,1/100	<1,1/100	200/100	<1,1/100	<1,1/100	45/100	20/100	<1,1/100	78/100	<18/100	<1,1/100
Cianobactérias	Cél/ml	NFR	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

Source: authorship

Table 3 - Results of the physicochemical analysis of the Main Parameters of the sediments of the Cateté River in the dry season, August 2023.

	Unid	Refe-rência	PT01 - Aldeia Xikrin Cateté	PT02 - Localizado a jusante do Empreendimento Puma	PT03 - Entre a Mina da Onça e Mina da Puma	PT04 - À montante do Empreendimento MOP	PT05 - Localizado na Adutora	PT07 - Aldeia Djudjekô
Coordenadas Geográficas	Graus DMS		06° 15' 24.92" S 50° 47' 49.07" O Elev. 212m	06° 28' 08.80" S 51° 02' 04.19" O Elev. 253m	06° 33' 08.27" S 51° 02' 56.65" O Elev. 262m	06° 39' 46.14" S 50° 59' 37.89" O Elev. 266m	06° 41' 55.99" S 50° 56' 28.59" O Elev. 282m	06° 15' 24.84" S 50° 47' 49.28" O Elev. 222m
Data da Coleta			23/08/2023	23/08/2023	21/08/2023	21/08/2023	21/08/2023	22/08/2023
Data de envio			30/08/2023	30/08/2023	30/08/2023	30/08/2023	30/08/2023	30/08/2023
Laudo Nº			OS5952/2023AM27279	OS5952/2023AM27280	OS5951/2023AM27274	OS5951/2023AM27272	OS5951/2023AM27273	OS5950/2023AM27267
Cromo	mg/kg	37,3	9,56	14,64	25,81	2,58	32,78	31,22
Níquel	mg/kg	18	6,37	6,52	22,29	3,24	9,21	24,62
Zinco	mg/kg	123	15,06	23,04	19,92	17,72	29,57	37,11
Cádmio	mg/kg	0,6	< 0,62	< 0,69	< 0,64	< 0,60	< 0,75	< 0,82
Chumbo	mg/kg	35	4,94	10,06	1,67	3,66	11,30	5,05
Cobre	mg/kg	35,7	6,31	5,62	6,28	30,10	7,93	21,28
Ferro	mg/kg	-	2685,35	1811,22	5593,73	905,89	11742,47	20530,11
Alumínio	mg/kg	-	1589,87	1409,19	2911,84	904,45	11782,29	25700,24
Manganês	mg/kg	-	35,74	47,67	175,12	91,32	440,71	176,02

Source: authorship

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Table 4 - Results of the physicochemical analysis of the Main Fish Parameters of the Cateté River in the dry season, August 2023.

	Unid	Refe-rência	PT01 - Aldeia Xikrin Cateté
Data da Coleta			23/08/2023
Data de envio			01/09/2023
Laudo Nº			OS5952/2023AM27277
Alumínio	mg/kg	-	28,712
Bário	mg/kg	-	6,130
Cálcio	mg/kg	-	5871,962
Magnésio	mg/kg	-	356,830
Cádmio	mg/kg	0,05	< 0,006
Cromo	mg/kg	0,1	0,204
Ferro	mg/kg	-	17,886
Chumbo	mg/kg	0,3	0,012
Mercúrio	mg/kg	0,5	0,048
Níquel	mg/kg	5	0,138
Zinco	mg/kg	50	8,003

Source: authorship

Observing the result of the metallic contents in the sediments, it is verified that the river has contaminated sedimentary material. The findings of the chemical characterization were compared with the national guiding values established for soils by CONAMA Resolution No. 454/2012 or current state standard, classified into two levels: a) Level 1 - threshold below which there is a lower probability of adverse effects to the biota and b) Level 2 - threshold above which there is a greater probability of adverse effects to the biota.

CONAMA Resolution 357/05 establishes a maximum value of 0.009 mg/L of dissolved copper for liquid effluents transported to Water Bodies considered as Class 2 waters.

Chromium can be present in natural waters in different oxidation states, the most common being trivalent and hexavalent. In the trivalent form, chromium is essential to human metabolism and its deficiency can lead to diseases, but in excess it causes skin rashes. As Bergamasco et al (2011) allege, in the hexavalent form it is toxic and carcinogenic, causing corrosive effects on the digestive system and nephritis.

CONAMA Resolution 357/05 proposes a limit of 0.05 mg/L of total chromium. Bergamasco et al. (2011) confirm that the consumption of water containing hexavalent chromium can result in allergic reactions, ulcers, reduced immune system responses, cancer, and other changes in genetic material.

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Iron is one of the most abundant elements and is therefore commonly found in natural waters. In adequate quantities, this metal is essential to the biochemical system of water. However, Silva (2018) states that, in large quantities, it becomes harmful, giving an unpleasant taste and color to the water, in addition to increasing the hardness, making it unsuitable for domestic and industrial use.

CONAMA Resolution 357/2005 defines the maximum limit of dissolved iron as 0.30 mg/L for class 2 waters.

Aluminum is also one of the richest metals in nature. In fact, it is the third most abundant metal in the Earth's crust.

Barreto and Araújo (2008) inform us that aluminum, when in excess, causes a series of toxic effects in human beings. Aluminum can be responsible for triggering mental problems of dementia, Alzheimer's, among others, and even autism in babies still in the mother's womb. In addition, it can cause chronic fatigue, difficulty concentrating, depression, anxiety, insomnia and excessive coughing.

CONAMA Resolution 357/2005 establishes the maximum limit of dissolved aluminum of 0.10 mg/L for Class 2 waters.

It is noted that in just one battery of analyses, the return of the result already shows the negative impact of mining in the area, contributing to the contamination of the Cateté River. This can be observed by the indication that the metals susceptible to being oxidized, iron, aluminum, manganese, lead, nickel and chromium, appear in a higher degree of concentration at point PT 05, with a value of 11,782.29 mg/l of aluminum in the sediments, where the pipeline of the Pantera Project is intended to be installed.

Manganese is the third most available metal in nature, right after aluminum and iron, and usually arises in the presence of the latter. The presence of manganese and iron, depending on the concentrations, can provide a yellowish and cloudy color to the water, also causing a bitter and astringent taste.

CONAMA Resolution 357/05 states as a maximum value 0.1 mg/L of manganese for class 2 waters.In the monitoring carried out, none of the sampling stations presented results above the limit proposed by the legislation for manganese.

Even though it is the 24th most abundant chemical element on Earth, and can be found in plants, animals and even in the soil, nickel is included in the rule that says that excess is harmful.

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Contact with nickel makes us more sensitive to it, which can cause dermatitis and malformation of fetuses, such as anencephaly, in cases of high exposure. The main anthropogenic sources of nickel are the burning of fossil fuels, metal mining and smelting processes, alloy melting and shaping, and electroplating industries.

CONAMA Resolution 357/05 presents a total limit of 0.025 mg/L of nickel in Class 2 waters.

Lead has a cumulative effect, causing a chronic poisoning called saturnism, which consists of an effect on the central nervous system, with serious consequences. As Silva (2018) says, in aquatic environments, it is toxic to fish, mollusks, and crustaceans in concentrations between 0.1 mg/L and 0.4 mg/L.

Lead can cause several undesirable effects, such as: disturbance of hemoglobin biosynthesis and anemia; increased blood pressure; kidney damage; Abortions; changes in the nervous system; damage to the brain; decreased fertility of men through damage to sperm; decreased learning in children; changes in children's behavior, such as aggression, impulsivity, and hypersensitivity.

According to Boniolo (2010), lead can reach the fetus through the mother's placenta, and can cause serious damage to the child's nervous system and brain. CONAMA Resolution 357/05 declares the maximum value of 0.01 mg/l allowed in class 2 waters.The results for all sampling stations were below the laboratory quantification limit (0.01 mg/L).

Cadmium is present in natural waters mainly due to the discharges of industrial effluents, fertilizers, insecticides and leaching in mining areas, occurring in its inorganic form, as its organic compounds are unstable. It has an acute effect, and a single dose of 9.0 grams can lead to death, and also with a chronic effect, as it is concentrated in the kidneys, liver, pancreas and thyroid. Silva (2018) describes that in fish it has effects similar to zinc and is also bioaccumulated. CONAMA Resolution 357/05 confirms that the maximum value for cadmium is 0.001 mg/l in class 2 waters.

From the results obtained, in all the sampled stations they were below the limit for the concentration in surface waters and above the limit for amounts of cadmium in values of the threshold parameter, in which there is less probability of occurrence of adverse effects to the biota.

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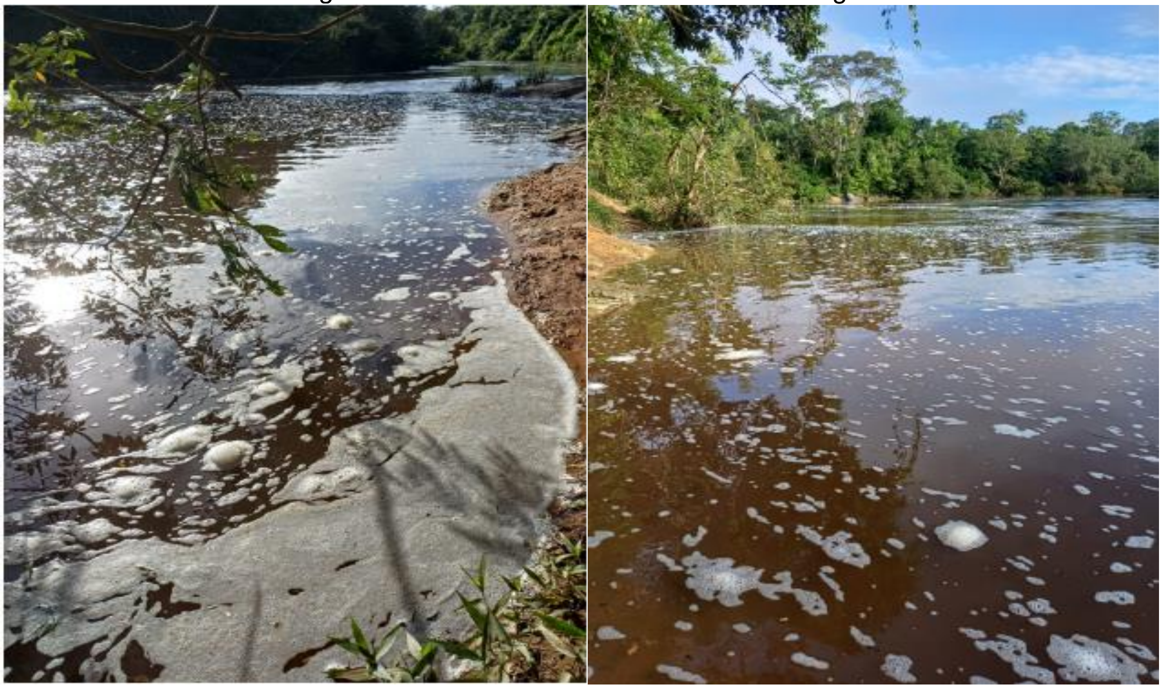
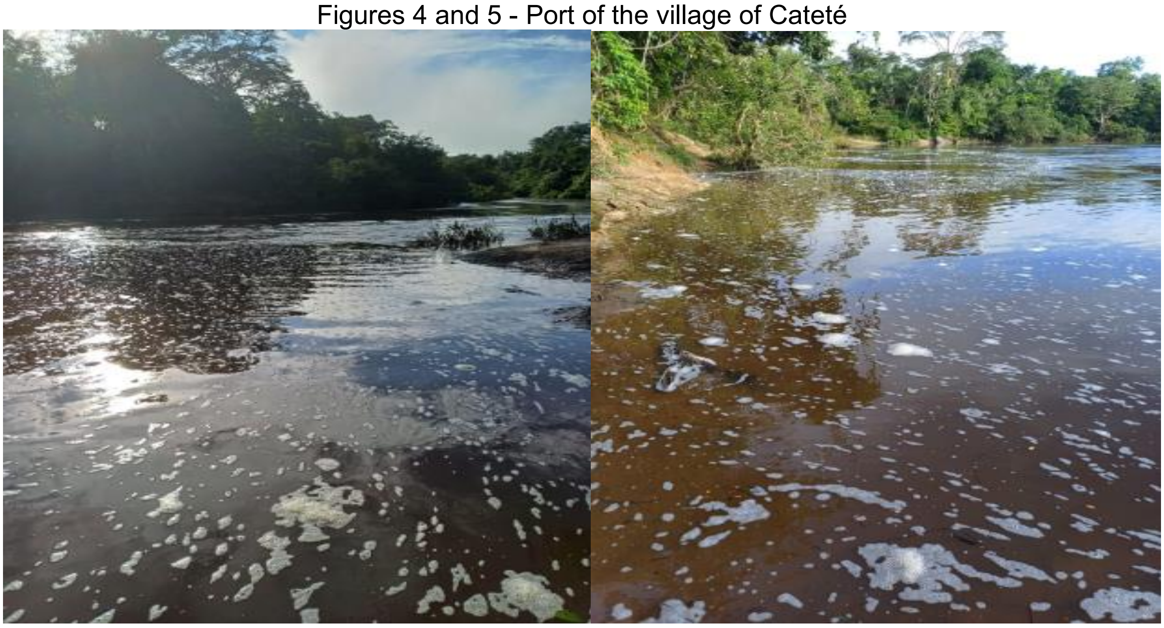
Figure 2 and 3 - Port of the Xikrin Cateté Village



Source: authorship

Figures 4 and 5 - Port of the village of Cateté



Source: authorship

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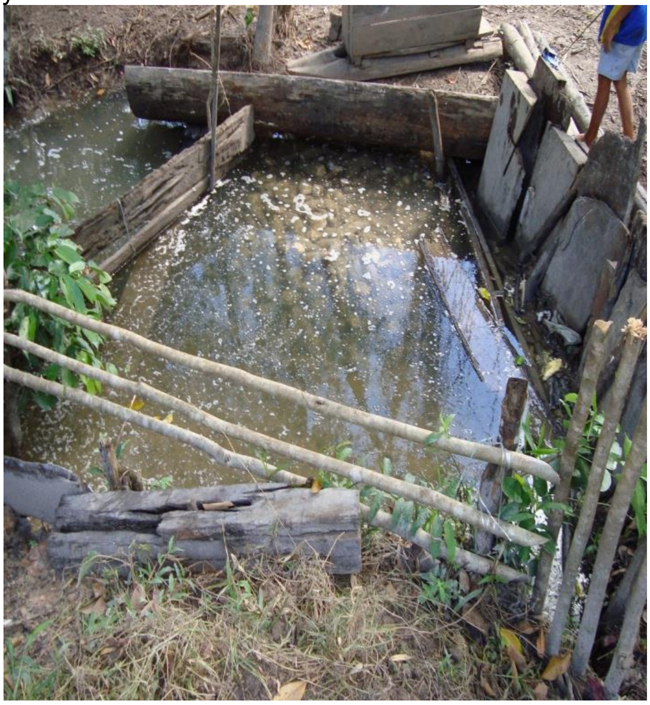
Figure 6 - Tubers such as cassava, potatoes and manioc soften in the river within 20 days. The bark of tubers, fibers or even vegetable roots has excellent ability to adsorb (ability to extract from the medium for itself) various types of heavy metals



Source: authorship

Due to environmental persistence, cumulative effect and high toxicity, it is suggested that the bioindicators of the ichthyofauna (fish) are contaminated by metals.

The relationship between recent symptoms found in medical reports and those reported in the literature references was compared and similarities were found. It should be noted that copper, found in dangerous proportions of 2.7 times more than the maximum allowed by law, after a period of 12 – 15 years of bioaccumulation can cause Wilson's disease, a commonly degenerative and hereditary disease that attacks the nerves and brain, leading the patient to physical and cerebral paralysis.

According to the Ministry of Health (2023), Wilson's disease is caused by mutations in a gene on chromosome 13 that encodes the ATP7B protein, an ATPase-like enzyme that has the function of secreting copper in bile. It is responsible for transporting this metal, leading to its accumulation, initially in the liver and later in various organs and tissues, particularly in the brain.

Excess chromium in the body causes diseases in the liver, brain, hepatitis and neurological and psychiatric symptoms such as: homicidal behaviors, depression and aggressiveness. In women, they can also cause irregularities in menstruation, infertility or multiple abortions and fetuses with congenital malformations.

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According to Figure 7, it is already possible to confirm the harmful impacts of mining on the health of the Xikrin people since 2015, especially in the pregnancy of indigenous women.

Figure 7 - Extract of the report attached in case 1001616-03.2015.4.01.0000, of the Federal Regional Court of the 1st Region, proving the effects of mineral contamination on the Xikrin people

Histórico

Em novembro de 2015, recebemos cópia de laudos de malformações detectadas a partir de ultrassonografias pré-natais em gestantes da tribo Xikrin com as seguintes descrições:

1. **Nhokrute Xikrin**, aldeia Cateté, gestante de 16 anos, gestação de 40 semanas, US realizado em 10/2/2015. Laudo descreve cavidade ventricular única, indicando **provável holoprosencefalia**.
2. **Bekuoi Ruti-Xikrin**, aldeia Djudjekô, gestante de 18 anos, gestação de 29 semanas e 06 dias, US realizado em 24/12/2014. Laudo descreve perda de formação do telencéfalo, com cavidade ventricular única com mesencéfalo rudimentar, indicando diagnóstico diferencial de **holoprosencefalia alobar**.
3. **Panh-O Xikrin**, aldeia Djudjekô, gestante de 15 anos, gestação de 31 semanas e 05 dias, US realizado em 26/07/2014. Descrição de ectasia das câmaras direitas do coração. Acompanha ainda um laudo de US obstétrico com doppler de 05/09/2014 que refere fluxo placentário e fetal normais, artéria cerebral com fluxo normal sem efeito de centralização
4. **Nhak Nhoti Xikrin**, aldeia Óodjã, com 02 anos, com diagnóstico de encefalocele na face por defeito ósseo fronto-nasal. Laudo feito por neurocirurgiã do Hospital Belém datado de 06/10/2014
5. **RN de Paruti Xikrin**, aldeia Djudjekô. Não foi anexado laudo, apenas copia de prontuário com algumas informações contraditórias. Em 12/12/2013 foi "solicitado vôo para retirada do RN de Paruti, com hematoma craniano e cianose de extremidades". RN nascido de parto vaginal na madrugada daquele mesmo dia com "macrocrania" e paciente se recusava a seguir pré-natal. No dia 17/12 foi transferido para Belém para acompanhamento médico por diagnostico de "anencefalia"

- **Observação nossa**: o diagnóstico de anencefalia é discutível pela história. A anencefalia é incompatível com a vida pós-natal e portanto o RN não poderia ter sido transferido com 05 dias de vida para Belém onde foi internado.

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6. Ireki Xikrin, aldeia Cateté. Gestante de 17 anos, gestação de 33 semanas, US realizado em 30/04/2012. Laudo descreve hidrocefalia com atrofia cerebral. Cerebelo e corpo caloso não foram observados. Indagada cardiopatia.

7. Kokonoite Xikrin, aldeia Djudjekô. Gestante de 14 anos, 35 semanas de gestação. Não está disponibilizado o laudo ultrassonográfico. Há uma informação escrita do médico do Hospital Santa Terezinha de Marabá, PA, no dia 06/09/2012 que relata "alteração acentuada morfo-estrutural dos hemisférios cerebrais".

SERVIÇO DE GENÉTICA MÉDICA
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FINAL CONSIDERATIONS

What can be seen, at this crucial moment, when there is a collective mobilization to carry out the work of recovery and revitalization of the Cateté River, is that even with the environmental programs proposed by the developer, or even those indicated by the environmental agencies, it is not a good occasion to use the water supply of the Cateté River and suppress areas with riparian vegetation, until the procedures to restore the river are carried out.

The moment is to request, mobilize forces to recover the riparian forest that acts in the function, among many others, of protecting the river, because as verified in the recent analyzes focused on this research, its sediments are deposited in its channel, compromising water transport. This means that only by dredging part of these sediments containing metals harmful to human health and biota can one have a visualization that the actions of mitigation and protection of the river by the responsible companies will be

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effectively efficient and sufficient to authorize the continuity of the operation of the mining activity in the vicinity of the Xikrin Indigenous Land.

Another problem identified is the issue of the extraction pit being planned for a depth of 80 meters, with the center of this being located 9.5 km from TI villages, and the water table in the area starts at a depth of about 15 meters. It was not clear what measures will be adopted, knowing that at this depth the first water table will be reached and, consequently, will be lowered. It was found that in the villages, water for consumption by the indigenous people is obtained through semi-artesian wells about 20 meters deep. The lowering of the water table will harm the water collection of indigenous people who live in nearby villages, as they will lose all the investments allocated to produce the well.

It is important to note that this analysis found that for the Xikrins indigenous people, the effects of the identified impacts are all negative, of high significance and cumulative, even considering the environmental control measures and social programs proposed as conditions. Since 2015, genetic problems have already been found in the population, as it was possible to see in the report contained in the process of the Federal Court of the 1st Region. The report confirmed the occurrence of fetal malformation in several pregnant women that year. As for negative natural impacts, these in mining projects are common, since natural environments are greatly altered. When it comes to a river for human use for various activities, with the quality already outside the normal standards for use, the intensification by accumulation of effects will tend to accelerate the process of death of the Cateté River, which may occur when it is no longer able to fulfill its ecological role or sustain any forms of life.

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