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Natural radionuclides and heavy metals in fish from the Tracunhaém river in Nazaré da Mata-PE

The Tracunhaém river that crosses the city of Nazaré da Mata is being the target of permanent and diverse environmental aggressions. The problem would be mainly caused by the discharge of domestic sewage without any treatment. In this context, the objective of this work was to use samples of traíra (Hoplias malabaricus) and curimatã (Prochilodus lineatus) fish as bioindicators of the levels of environmental pollution of the Tracunhaém river, in Nazaré da Mata city, in relation the presence of heavy metals (lead-Pb and cadmium-Cd) and natural radioactive elements (uranium-238U and thorium -232Th). For this purpose, the ICP-MS technique was used. The results showed that there is accumulation of Pb, Cd, 238U and 232Th in the trophic chain of the Tracunhaém river in the municipality of Nazaré da Mata. It is recommended that the traíra (Hoplias malabaricus) and curimatã (Prochilodus lineatus) fish of the Tracunhaém river, in the Nazaré da Mata city, are not consumed by humans due to the health risk. It is necessary to carry out an environmental education program with the purpose of raising the awareness of the local population about the damage caused to the Tracunhaém River, as well as the need from public authorities to implement sewage treatment units in the city of Nazaré da Mata.

Keywords: Water Pollution; Sanitary sewage; Sustainability; Bioindicators.

Radionuclídeos naturais e metais pesados em peixes do rio Tracunhaém em Nazaré da Mata-PE

O rio Tracunhaém que corta a cidade de Nazaré da Mata está sendo alvo de permanentes e diversas agressões ambientais. O problema seria causado principalmente pelo lançamento de esgoto doméstico sem nenhum tratamento. Nesse contexto, o objetivo deste trabalho foi utilizar amostras de peixes traíra (Hoplias malabaricus) e curimatã (Prochilodus lineatus) como bioindicadores dos níveis de poluição ambiental do rio Tracunhaém, na cidade de Nazaré da Mata, em relação à presença de metais pesados (chumbo-Pb e cádmio-Cd) e elementos radioativos naturais (urânio-238U e tório -232Th). Para tanto, foi utilizada a técnica ICP-MS. Os resultados mostraram que há acúmulo de Pb, Cd, 238U e 232Th na cadeia trófica do rio Tracunhaém no município de Nazaré da Mata. Recomenda-se que os peixes traíra (Hoplias malabaricus) e curimatã (Prochilodus lineatus) do rio Tracunhaém, na cidade de Nazaré da Mata, não sejam consumidos pelo homem devido ao risco à saúde. É necessária a realização de um programa de educação ambiental com o objetivo de conscientizar a população local sobre os danos causados ao Rio Tracunhaém, bem como a necessidade do poder público em implantar unidades de tratamento de esgoto no município de Nazaré da Mata.

Palavras-chave: Poluição da Água; Esgoto sanitário; Sustentabilidade; Bioindicadores.

Topic: **Desenvolvimento, Sustentabilidade e Meio Ambiente**

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INTRODUCTION

Brazil has a large reserve of fresh water, however, due to disordered population growth, many of these water resources are contaminated by organic and inorganic elements. In general, the Brazilian population is not aware of the need to protect the country's natural resources, nor is it educated to understand the relationship that exists between preserving the environment and the health of the population. Water is a vital substance for the survival of any nation. Thus, each water resource should be primarily preserved. Despite having many water resources, Brazil does not have a uniform distribution of water, there are regions with great abundance of this substance, while others have severe shortages, such as the Northeast.

The state of Pernambuco, located in the Northeast region, has in its geological configuration, hydrographic basins formed by perennial and temporary rivers. Due to the natural scarcity of rainfall, the state has the worst water availability in Brazil. In addition, a large part of Pernambuco's water resources is polluted. Water quality indexes in the state are negative, and some stretches of water analyzed in rivers are unsuitable for use, navigation or public supply. The water quality of Pernambuco's rivers is at the limit of the standards established by legislation. The water used for consumption in many Counties in Pernambuco reflects the precarious environmental condition of the river basins. Solid residues and waste discharged into rivers are the main factors that contribute significantly to water pollution in the state of Pernambuco. So, educating society is the guarantee of improving water quality. Therefore, it is necessary to elaborate educational measures within an environmental education planning jointly with the population of each county in Pernambuco. By recognizing rivers as mirrors of the environmental quality of cities, hydrographic regions and countries, we will be able to quickly identify the values of their community, the health condition in the basin and development.

The Tracunhaém River is a very important watercourse for the state of Pernambuco, as it bathes most of counties in the North Forest, including Nazaré da Mata. In this municipality, in some stretches of the river, artisanal fishing activities are still practiced, with their products consumed by the local population. Considering the fact that the ecologically balanced environment is well used by the people, it is necessary that measures are taken to avoid environmental degradation of the Tracunhaém River. Considering the fact that the ecologically balanced environment is well used by the people, it is necessary to take actions to avoid environmental degradation of the Tracunhaém River. However, in County of Nazaré da Mata, the Tracunhaém river has been highly degraded. Such degradations are being caused by constructions and occupations on the banks of the river (preventing the natural regeneration of the riparian forest), discharge of domestic sewage effluents without any treatment and solid waste. The local population itself plays an important role in the degradation of the Tracunhaém River. Thus, it is necessary to develop environmental education programs in the local communities, aiming to make the inhabitants aware of the need to preserve the river.

Polluted rivers have high amounts of heavy metals and natural radionuclides. Heavy metals are dangerous because they tend to bioaccumulate. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the concentration of the chemical in the environment. Compounds accumulate in living beings whenever they are taken and stored more quickly than they are decomposed (metabolized) or excreted. Heavy metals can enter the water supply through industrial and consumer waste, or even through acid rain that wash the soil and release heavy metals into streams, lakes, rivers and groundwater (HUTTON, 1997). Heavy metal toxicity can result in damage or reduction in mental and central nervous system function, lower energy levels and damage to the composition of the blood, lungs, kidneys, liver and other vital organs. Long-term exposure can result in muscle weakness and neurological degenerative processes such as Alzheimer's disease, Parkinson's disease, muscular dystrophy and multiple sclerosis. Allergies are not uncommon and repeated long-term contact with some metals or their compounds can even cause cancer (VERMA et al., 2013). The heavy metals lead (Pb) and cadmium (Cd) are extremely toxic to living beings, even in small amounts. Pollution by heavy metals in surface and groundwater is due to contamination of the soil or materials discharged directly into water courses. In this case, specific to agricultural activities, heavy metals are leached (washed) from the soil and enter surface water courses. Marine lives that reproduce in polluted waters with heavy metals also accumulate these elements in their tissues, as is the case with fish (TRUEBY, 2003). The biotoxic effects of heavy metals are related when the concentrations of these elements exceed the maximum intake limits recommended by the health surveillance agencies. Although each metal is specific in relation to its chemical toxicity, some symptoms have been observed in the human body associated with the ingestion of cadmium and lead: gastrointestinal disorders, diarrhea, stomatitis, tremor, hemoglobinuria causing a rust-red color in the stools, ataxia, paralysis, vomiting and seizures, depression and pneumonia when vapors are inhaled. The nature of the effects can be toxic (acute, chronic or sub-chronic), neurotoxic, carcinogenic, mutagenic or teratogenic (MCCLUGGAGE, 1991).

Cadmium is toxic at extremely low levels. In humans, long-term exposure results in renal dysfunction, characterized by proteinuria. High exposure can lead to obstructive pulmonary disease, cadmium pneumonitis, resulting from the inhalation of dust and fumes. This is characterized by chest pain, cough with foamy sputum and blood, and death of the lining of the lung tissues due to excess accumulation of aqueous fluids. Cadmium is also associated with bone diseases such as osteomalacia, osteoporosis and spontaneous fractures, and also with increased blood pressure and myocardial dysfunction (MCCLUGGAGE, 1991).

Lead poisoning is the most significant of heavy metals, where inorganic forms of this element are absorbed through food, water and inhalation of vapors and dust. A particularly serious effect of lead toxicity is its teratogenic effect. Lead poisoning also causes inhibition of hemoglobin synthesis, kidney and joint disorders, neurological and cardiological diseases (MCCLUGGAGE, 1991).

The radioactivity present in continental surface waters is mainly due to the presence of radioactive elements in the earth's crust. Other artificial radionuclides have emerged due to human activities such as nuclear power plants, nuclear weapons testing and the manufacture and use of radioactive sources. There are two sources of radioactive contamination in drinking water (BONAVIGO et al., 2009). The first is natural radionuclides that are contained in the soil that the water goes through. Some areas are susceptible to contamination of phosphate-rich soils and rocks. The second source of radioactive contamination comes from man-made sources. The radionuclides found in drinking water are members of three radioactive series, Uranium-238 (^{238}U), Thorium-232 (^{232}Th) and Uranium-235 (^{235}U), and include naturally occurring elements, radio, polonium and radon which is a noble radioactive gas. These radioisotopes can cause different types of biological damage. Radium is concentrated in bones and can cause cancer. Uranium is a radiotoxic element, mainly for the kidneys (BONAVIGO et al., 2009). The radionuclides produced by the decay of Uranium-238 and Thorium-232 are widely distributed throughout the earth's crust. Most of them are alpha emitters and include isotopes of polonium, radon and radium.

Uranium is a naturally occurring radionuclide in granite and other mineral deposits. It enters the local supply of water, air and food by varying concentrations through leaching of natural deposits, its release in plant waste, emissions from the nuclear industry, dissolution in phosphate fertilizers and combustion of coal and other fuels. The average daily total uranium intake for an adult of 70 kg in Canada is estimated at 2.6 µg, with food accounting for 77% (2.0 µg) and water for the rest natural uranium consists almost entirely of the isotope of Uranium-238 (^{238}U) in its hexavalent state, which is commonly associated with oxygen such as the uranyl ion (UO_2^{2+}) (WEIR, 2004). Uranium-238 (^{238}U) decays by alpha emission (ie, nucleus of a helium atom) and gamma (ie, high-energy photons). In relation to other radionuclides, natural uranium has a low level of radioactivity due to its extremely long half-life (4.5 billion years). Although there is a risk of radiological toxicity of ingested natural uranium, the main health effects are chemical toxicity. Uranyl compounds have a high affinity for phosphate, carboxyl and hydroxyl groups, and readily combine with proteins and nucleotides to form stable complexes. The skeleton and kidney are the main sites of uranium accumulation; little is found in the liver (WEIR, 2004).

On average, 1% to 2% of the ingested uranium is absorbed in the gastrointestinal tract in adults. The absorbed uranium quickly enters the bloodstream and forms a diffusible ionic uranyl hydrogen carbonate complex ($UO_2HCO_3^+$) in equilibrium with a non-malleable uranyl albumin complex. In the skeleton, uranyl ion replaces calcium in the bone crystal hydroxyapatite complex. Once equilibrium is reached in the skeleton, uranium is excreted in the urine and faeces. Under alkaline conditions, the uranyl hydrogen carbonate complex is stable and is excreted. When the pH drops, the complex dissociates and binds to cell proteins in the tubular wall. The uranium half-life in the rat kidney is about 15 days and considerably longer (300 to 5000 days) in the skeleton (WEIR, 2004). Nephritis is the main chemically induced effect due to uranium intake. There are discussions about whether the segment of the nephron with the highest risk of injury is the proximal tubule or the glomerulus. Evidence from animal studies does not show carcinogenic effects of ingesting uranium compounds. Signs of acute uranium toxicity include piloerection, significant weight loss and bleeding in the eyes, legs and nose. There is little information on the health effects of chronic exposure to natural uranium. Human studies comparing communities with different levels of uranium in their drinking water supply showed a tendency for high levels of alkaline phosphatase and an increase in urinary β2 microglobulin excretion in people with increased exposure to uranium (ZAMORA et al., 1998).

Uranium exposure is not high on most lists of causes of kidney disease, but should be considered by doctors who serve communities with relatively high levels of natural uranium. By routinely taking a complete environmental history, including information about the patient's source of water supply and proximity to the local industry, a doctor will be in a position to suspect environmental exposure as a possible cause. The local public health unit or municipality should also have information on sources of potential local exposures (MARSHALL et al., 2002).

Thorium is a naturally occurring radioactive metal found in different concentrations in soil, rocks, water, plants and animals. The presence of thorium in surface waters is due to the leaching of rocks and soils that contain this element. However, mining activities can contaminate watercourses with natural thorium. Almost all natural thorium exist as the radioactive isotope of Thorium-232 (^{232}Th), Thorium--230 (^{230}Th) and Thorium-228 (^{228}Th). There are more than 10 other Thorium isotopes that can be produced artificially. Smaller amounts of these isotopes are generally produced as decay products of other radionuclides and as unwanted products of nuclear reactions. Thorium is used to make ceramics, flashlights, cloaks, welding rods, cameras, telescopes, lenses and metals used in the aerospace industry. Thorium-232 decays, releasing radiation, and forming radioactive elements like Radium-228 (^{228}Ra) and Thorium -228 (^{228}Th). The radioactive decay process will continue until a stable final product (non-radioactive) (LEITERER et al., 2010).

The rate of decay of Thorium-232 (^{232}Th) is extremely slow, hence the total amount of this element remains relatively constant on earth, but it can be transferred from one place to another by natural processes and human activities. As thorium is present in very low levels in the environment, all living beings are exposed to thorium, due to food consumption and water intake. Normally, the concentration of thorium is low in water and fish from lakes, rivers and oceans. Exposure to higher levels of thorium can occur if a person lives near an industrial mine, mill or thorium product factory. When Thorium is ingested by humans through the consumption of water or food, most of it will be eliminated in the faeces. The rest of the thorium enters the bloodstream and then settles on the bones, where it can remain for many years. Studies of workers have shown that inhaling thorium-containing dust will cause an increased risk of lung disease, including lung cancer, or pancreatic cancer. Liver disease and some cancers have been found in people who received injections of thorium-based compound used in contrast to x-ray examinations. Bone cancer is also a potential risk to human health due to the incorporation of thorium in the skeletal structure (LEITERER et al., 2010).

The phosphogypsum ($CaSO_4.2H_2O$) it is a product of waste generated by the phosphate industry. The global production of this waste is over 200 million tons per year (SAADAOUI et al., 2017). Phosphogypsum discharged into the sea, into watercourses or in natural reserves, contains toxic elements harmful to ecosystems and human health, including heavy metals and natural radionuclides, and there is, therefore, a concern with environmental impacts. The concentrations of these elements vary between the regions and the processes used, which require particular and specific monitoring after the release of phosphogypsum and during its use. Phosphogypsum is used in agriculture as a soil corrector or fertilizer, as well as in the brick and cement industry and in road construction (SAADAOUI et al., 2017).

The region where the city of Nazaré da Mata is located has intense sugarcane monoculture activity. This type of agricultural activity uses large amounts of phosphogypsum. Thus, due to the leaching of the soil by rainwater, significant amounts of heavy metals and natural radionuclides present in phosphogypsum can be transferred into the interior of the Tracunhaém River, being incorporated into the aquatic environment. Solid waste discharged into water courses can contain significant amounts of natural radionuclides (IFE-ADEDIRAN et al., 2018), and to cause contamination of the aquatic biota, and possible transfer to man, due to the ingestion of fish, thus increasing the dose of radiation that can induce different types of diseases, where the most lethal is cancer.

Thus, and within this context, the objective of the present work was to use samples of traíra fish (*Hoplias malabaricus*) and curimatã (*Prochilodus lineatus*) as bioindicators of the environmental pollution levels of the Tracunhaém river, in the stretch of the city of Nazaré da Mata, in the presence of heavy metals (lead-Pb and cadmium-Cd) and natural radioactive elements (^{238}U and ^{232}Th).

MATERIALS AND METHODS

Sample selection criteria

The research work was carried out on the Tracunhaém river in Nazaré da Mata. The Figure 1 (CARVALHO et al., 2017) shows the sample collection location. Figure 2 shows the Tracunhaém River in relation to the city of Nazaré da Mata.

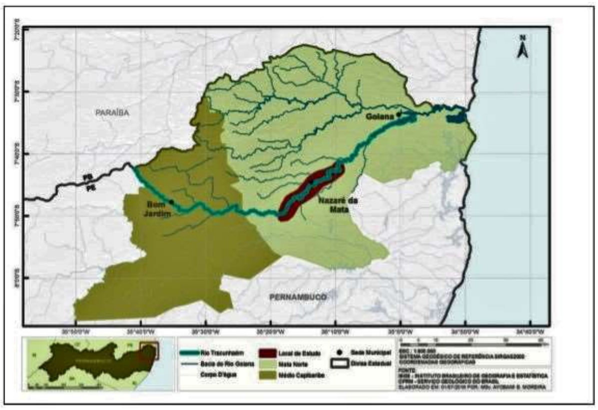

Figure 1: Collection Spot (Sampling location). **Fonte:** Carvalho et al. (2017).

Figure 2: Tracunhaém River from Nazaré da Mata City (Sampling location).

All sample collection and chemical analysis procedures were based on the methodology of the *Environmental Protection Agency*-EPA-3052 (EPA, 1996). Contact with fishermen in the city of Nazaré da Mata was the first methodological criterion for carrying out the work, as the fish samples were not chosen at random, but aimed at their importance within the food chain of the Tracunhaém River, as well as their period of greater abundance. Based on the objectives of the work and the information provided by the fishermen, samples of traíra fish (*Hoplias malabaricus*) and curimatã (*Prochilodus lineatus*) were collected in February 2019, the period of greatest abundance of these species. Despite several contacts with fishermen, only three (03) samples of traíra fish (*Hoplias malabaricus*) and three (03) samples of curimatã fish

(*Prochilodus lineatus*) were collected. This happened due to the low demand for these species in the Tracunhaém River, despite being considered the month where they should be in greater quantity. This scarcity of fish, certainly, was due to the high pollution level of the river.

Sample preparation

After collection, the samples were washed with ultrapure water (18,5 MΩ.cm to 25ºC) and then immediately frozen at a temperature of 3ºC. After refrigeration, the fish were covered with a polypropylene knife and the meat and skin were removed. The meat, skin and offal were lyophilized in a Savante® equipment, MicroModulyo model,

The meat, skin and offal were lyophilized in a Savante® equipment., and then ground into particles smaller than 80 µm in a branded equipment Retsch® PM 200 model. The samples after being ground were homogenized and placed in polyethylene containers. 0.5 g aliquots were taken from each sample and transferred to polytetrafluoroethylene tubes (Teflon®), and then 9.0 ml of suprapure nitric acid from MERCK® and then taken to the microwave assisted digester of CEM® MarsXpress model. The temperature was raised to 180º C, keeping it that way for 9.5 minutes. The sample was cooled down to room temperature. Then, the sample solutions were filtered in a polyethylene container, diluted to 30 ml with 2% pure nitric acid aqueous solution and the concentrations of ^{238}U, ^{232}Th, Pb and Cd were performed in ICP-MS PerkinElmer® NexION 300D® model.

Evaluation of the quality of the analytical procedure

To demonstrate the analytical quality of the method used, the parameter called normalized error was calculated (E_n) (Equation 1), obtained through certified reference material IAEA-140/TM – *Trace Elements and Methylmercury in Seaweed (Fucus sp.).* When the value of the E_n is less than or equal to 1, it is concluded, then, that the methodology used was adequate for the determination of the analytes. In this case, the values obtained for ^{238}U, ^{232}Th, Pb and Cd are shown in Table 1.

$$E_n = \frac{V_{det} - V_{ref}}{\sqrt{(U_{det})^2 + (U_{ref})^2}} \quad (1)$$

Where: V_{det} = Determined value, V_{ref} = Reference material value, U_{det} = Determined uncertainty and U_{ref} = Reference material uncertainty. The value of the $E_n \leq 1$ indicates that there is no significant difference between the determined value and the reference, and the methodology used is adequate for the proposed chemical analysis.

Table 1: Quality parameters of the analytical procedure for the ^{238}U, ^{232}Th, Pb and Cd.

Parâmetro	^{238}U	^{232}Th	Pb	Cd
V_{det} (mg kg^{-1})	0.68 ± 0,09	0.25 ± 0,04	2.2 ± 0.2	0.5 ± 0.1
V_{ref} (mg kg^{-1})	0.730 ± 0.083	0.299 ± 0.062	2.19 ± 0.28	0.537 ± 0.037
En	-0.4996	-0.0830	0.0171	-0.2796

RESULTS AND DISCUSSION

Pollution on the Tracunhaém River

The county of Nazaré da Mata is inserted in the domains of the hydrographic basin of the river

Goiana. Its main tributaries are rivers Tracunhaém, Ribeiro, Paraná, Pagé, das Bestas e Itapinassu, beyond the streams: Ventura, Morojó, Japaranduba and Bonito. There are no dams with accumulation capacity equal to or greater than 100.000 m^3. The main water courses in the municipality have a permanent drainage system and the drainage pattern is dendritic (BRASIL, 2005). The stretch of the Tracunhaém river that crosses the city of Nazaré da Mata is being subjected to permanent and diverse environmental aggressions. The problem is being caused mainly due to the discharge of domestic sewage effluents without any treatment. Another factor that contributes to the degradation is the creation of beef animals and the unrestrained construction of multiple buildings, residential and commercial, on the banks of the river. Industrial sewage has also contributed to the degradation of the Tracunhaém river in the stretch of the city of Nazaré da Mata (CARVALHO et al., 2017). The Figure 3 shows solid waste in the waters of the Tracunhaém river in the city of Nazaré da Mata.

Figure 3: Solid waste on the Tracunhaém River in Nazaré da Mata.

Discarded electronic devices or electronic waste is one of the fastest growing waste streams in the industrialized world, due to increasing sales and the rapid obsolescence of these products. Electronic waste encompasses a wide and growing range of electronic devices, such as televisions, computers, refrigerators, air conditioners and cell phones, etc., which contain various types of toxic materials that pose risks to occupational and environmental health, in addition to severely polluting the adjacent environment (MUNDADA et al., 2004). The dumping of electronic waste has further aggravated the problem associated with waste management and, therefore, waste management is one of the main focuses in studies of environmental education. The environmental and occupational risks associated with the processing of electronic waste are outlined considering hazardous materials and their composition, handling and processing methods. The predominant flow of waste management systems is analyzed to develop an appropriate strategy for improvement. So, there is a need to improve the management of electronic waste, including technological improvements, institutional arrangements, operational plans, etc. (MUNDADA et al., 2004). Various waste of electronic devices was observed in the waters of the Tracunhaém river in the stretch of the city of Nazaré da Mata. Solid residues provide variable concentrations of heavy metals (ABDULI et al., 2003) and natural radionuclides for the environment (SILVA et al., 2018).

Concentration of ^{238}U, ^{232}Th, Pb and Cd in fish samples from the Tracunhaém river

Comprehensive knowledge of fish taxonomy, habitat requirements and physiology is a fundamental prerequisite for using fish as indicators. No other aquatic organism is suitable for the application of so many different methods that allow assessing the severity of toxic impacts, determining the accumulation of toxic substances in the tissues, using histological and hematological approaches or detecting morphological anomalies (CHOVANEC et al., 2003). Due to its complex habitat requirements, ichthyofauna is a crucial indicator of the ecological integrity of aquatic systems at different scales, from micro-habitat to capture. The fitness of fish species, both at the individual level (eg growth performance) and at the population level (eg population structure) is determined by the connectivity of different habitat elements in a broad space-time context. Thus, bioindication using fish represents a good monitoring tool, especially with regard to both pollution aspects and river engineering, for example, river restoration and management (CHOVANEC et al., 2003). Fish are excellent bioindicators for heavy metals (LEGORBURU et al., 1989) and natural radionuclides (GIRI et al., 2010) in river water. The Traíra (*Hoplias malabaricus*) and curimatã (*Prochilodus lineatus*) fish are abundant in the Tracunhaém river, in the stretch of the city of Nazaré da Mata, being possible to use them as bioindicators of the levels of environmental pollution. However, due to the high pollution of the river, these types of fish are increasingly scarce. However, there is still artisanal fishing carried out exclusively for personal consumption.

The concentration values of ^{238}U, ^{232}Th, Pb and Cd in fish samples from the Tracunhaém river are shown in Table 2. In the calculation of the standard deviation of the concentrations, a 95% significance level adopted in the chemical analysis of the samples was considered, according to the methodology of the *Environmental Protection Agency*-EPA (EPA, 1996). Lead (Pb) concentrations in traíra (*Hoplias malabaricus*) and curimatã (*Prochilodus lineatus*) samples ranged from 46.0 to 130.0 µg kg^{-1} in the wet matter; and from 23.0 to 670 µg kg^{-1} in the wet matter, respectively (Table 2).

In the case of cadmium (Cd), concentrations varied from less than the limit of quantification (<LQ) to 9,0 µg kg^{-1} in wet matter, and less than the limit of quantification (<LQ) to 140,0 µg kg^{-1} in wet matter, respectively, for fish samples (*Hoplias malabaricus*) and curimatã (*Prochilodus lineatus*) (Table 2).

For Uranium-238 (^{238}U), the concentrations in the samples of Traíra (*Hoplias malabaricus*) and Curimatã (*Prochilodus lineatus*) samples varied, respectively, from 2.0 to 10 µg kg^{-1} in the wet matter; and from 2.0 to 98.0 µg kg^{-1} in the wet matter (Table 2). For Thorium-232 (^{232}Th), the Traíra (*Hoplias malabaricus*) and Curimatã (*Prochilodus lineatus*) samples showed concentrations ranging from less than the detection limit (<DL) to 7.0 µg kg^{-1} in the matter wet; and less than the detection limit (<DL) at 310.0 µg kg^{-1} in wet matter, respectively (Table 2).

Table 2: Wet mass concentration of ^{238}U, ^{232}Th, Pb and Cd in fish samples.

Amostra	**Wet mass concentration (µg kg^{-1})**			
	^{238}U	**^{232}Th**	**Pb**	**Cd**
Curimatã 1 (flesh and skin)	14.0 ± 2.0	9.0 ± 1.0	76.0 ± 6.0	8.0 ± 2.0
Curimatã 1 (guts)	98.0 ± 13.0	310.0 ± 50.0	670.0 ± 50.0	140.0 ± 40.0
Curimatã 2 (flesh and skin)	6.0 ± 1.0	<DL*	63.0 ± 5.0	2.0 ± 0.5
Curimatã 2 (guts)	33.0 ± 4,0	47.0 ± 8.0	190.0 ± 10,0	130.0 ± 40.0

Curimatã 3 (flesh and skin)	2.0 ± 0.2	<DL*	23.0 ± 2,0	<QL**
Curimatã 3 (guts)	72.0 ± 9.0	240.0 ± 40.0	370.0 ± 30,0	33.0 ± 9.0
Traíra 1 (flesh and skin)	4.0 ± 0.5	4.0 ± 0.6	46.0 ± 3.0	4.0 ± 1.0
Traíra 1 (guts)	10.0 ± 1.0	<DL*	98 ± 7.0	3.0 ± 0.7
Traíra 2 (flesh and skin)	2.0 ± 0.3	7.0 ± 1.0	47,0 ± 4.0	2.0 ± 0.5
Traíra 2 (guts)	3.0 ± 0.4	<DL*	130.0 ± 10.0	30.0 ± 8.0
Traíra 3 (flesh and skin)	5.0 ± 0.6	2.0 ± 0.3	63.0 ± 5.0	<QL**
Traíra 3 (guts)	2.0 ± 0.3	<DL*	91.0 ± 7.0	9.0 ± 2.0

*DL (Detection limit) = 0.15 µg kg^{-1}; **LQ (Quantification limit) = 0.09 µg kg^{-1}. Estimates of uncertainties calculated at a 95% confidence level.

Table 2 shows great variability in the concentration values of ^{238}U, ^{232}Th, Pb and Cd. This indicates that the incorporation of these chemical elements varies in different species of fish, and also in the same species. This suggests that, in general, the distribution of ^{238}U, ^{232}Th, Pb and Cd in the Tracunhaém River food chain is not uniform. Certainly, the variability of the values shown in Table 2 depended on the eating habits of each species of fish. The Curimatã fish (*Prochilodus lineatus*) is distributed throughout the Northeast region of Brazil, inhabiting both the bottom of lakes and the banks of rivers. Curimatã is a detritivorous fish (it feeds on organic remains), consuming the vasa from the bottom of rivers, as organic and vegetable sediments (ROTTA, 2003).

The traíra fish (*Hoplias malabaricus*) is popularly known as Lobó and Tararira, it is distributed throughout Brazilian territory, inhabiting still waters of lakes, dams, swamps, backwaters and rivers, with a preference for ravines with vegetation, where they lurk and ambush their prey. The Traíra fish is carnivorous, feeding on small fish, frogs and insects. It waits for the immobile prey, next to the mud bottom or in rocky places, launching a fast and fatal boat. The Traíra fish has scales, and has a cylindrical body, large mouth, large eyes and rounded fins, except the dorsal. Its coloring is brown or black stained with gray. It has powerful and very sharp teeth. His tongue is rough to the touch. It is a fish used in dams and water reservoir as a controller of overly prolific populations, such as Tilapia and Piabas. It has high resistance to places with little oxygen. Despite the excess of pimples, in some regions it is quite appreciated as food. It can reach 60 cm in length and 4 kg of mass (ROTTA, 2003).

However, most fish are not specialized in their eating habits, that is, they are generalists, a necessary condition for ingesting, digesting and absorbing different types of food, exploring a wide variety of available food items, natural or industrialized. Even when they eat a single type of food, fish can replace it with a totally different one when the first becomes unavailable, or they can change their eating habits throughout life, this adaptation being more efficient in omnivorous fish than in carnivores. During the larval development of fish, both in herbivorous and carnivorous species, they undergo a change in eating habits, which is initially planktonic, feeding first on phytoplankton, then zooplankton and later, specializing in the ingestion of animal organisms or vegetables (ROTTA, 2003).

As the fish species shown in Table 2 have diverse eating habits, the concentrations of ^{238}U, ^{232}Th, Pb and Cd certainly varied in each species. The diversity of eating habits makes it difficult to find the main cause of the incorporation of ^{238}U, ^{232}Th, Pb and Cd in the fish species studied in the present work. However, despite having food diversification, in general, the highest concentrations of ^{238}U, ^{232}Th, Pb and Cd shown in Table 2 were determined in Curimatã fish (*Prochilodus lineatus*). This may possibly be related to the fish's own physiology, as it has a suction cup-shaped mouth, with fleshy lips, which keep atrophied teeth in rows. That is, a device suitable for scraping and sucking mud on the riverbed (ROTTA, 2003). Thus, in a polluted river, such as the Tracunhaém River, contaminants in sediments are easily transferred to the curimatã (*Prochilodus lineatus*), entering the human food chain, due to the consumption of the meat of this fish.

The guts of the traíra fish (*Hoplias malabaricus*), except for ^{232}Th, showed higher concentrations than in meat and skin, for the elements ^{238}U, Pb and Cd (Table 2). In the case of curimatã fish (*Prochilodus lineatus*), the concentrations of ^{238}U, ^{232}Th, Pb and Cd were higher in the viscera than in meat and skin (Table 2). Brazilian law establishes the maximum allowed limit of 300 µg kg^{-1} of wet matter for lead (Pb) and 50 µg kg^{-1} of wet matter for cadmium (Cd), in case of fish intake (BRASIL, 2013). The samples of curimatã 1 (viscera) and curimatã 3 (viscera) (Table 2) presented concentrations of lead (Pb) higher than the maximum limit allowed by Brazilian legislation (BRASIL, 2013). However, even though the guts are not used as food, the high concentrations of Lead (Pb) found in them indicate the degree of contamination of the Tracunhaém River in Nazaré da Mata, in relation to this element. In the case of cadmium, the samples of Curimatã 1 (Guts) and Curimatã 2 (Guts) presented concentrations higher than the maximum limit allowed by Brazilian legislation (BRASIL, 2013), indicating points of contamination in the Tracunhaém River, with this element.

Although the concentrations of Lead and Cadmium are high in the guts of fish Traíra (*Hoplias malabaricus*) and Curimatã (*Prochilodus lineatus*), the transfer of these elements to meat and skin did not result in high concentrations. Thus, all concentrations of Lead and Cadmium in the flesh and skin of Traíra (*Hoplias malabaricus*) and Curimatã (*Prochilodus lineatus*) fish showed values of an order of magnitude lower than the maximum limit allowed by Brazilian legislation (BRASIL, 2013). However, the systematic consumption of Traíra fish (*Hoplias malabaricus*) and Curimatã (*Prochilodus lineatus*) by the population, can lead to accumulation of Lead and Cadmium in the body. Once incorporated into the human body, these metals are responsible for the appearance of many diseases, including cancer (HUTTON, 1997).

Regarding radioactive elements, ^{238}U and ^{232}Th, Brazilian legislation does not have maximum limits allowed for fish consumption. However, as it refers to radioactive elements, small amounts can cause harmful effects to human health. In addition, even if ingested in small amounts, and in a systematic way, ^{238}U and ^{232}Th can accumulate in the human body in different compartments causing different effects (WRENN et al., 1989; LEITERER et al., 2010).

The specialized literature is very scarce of studies on the presence of natural radionuclides and heavy metals in Traíra (*Hoplias malabaricus)* and Curimatã (*Prochilodus lineatus*) fish. The only study found was carried out by Lima et al. (2015), where they determined average concentrations of Lead and Cadmium in fish traíra from the Cassiporé river, in Amapá, of 141 µg kg^{-1} and 33 µg kg^{-1}, respectively. These values are in the same range as those shown in Table 2.

CONCLUSIONS

Samples of Traíra (*Hoplias malabaricus*) and Curimatã (*Prochilodus lineatus*) fish collected from the Tracunhaém river in Nazaré da Mata showed that this ecosystem has been systematically contaminated with ^{238}U, ^{232}Th, Pb and Cd. It is recommended that the fish traíra (*Hoplias malabaricus*) and curimatã (*Prochilodus lineatus*) from the Tracunhaém river, in Nazaré da Mata, does not be consumed by humans, due to the risk to health, due to the accumulation of ^{238}U, ^{232}Th, Pb and Cd in the food chain.

In the case of the degradation of the Tracunhaém river in Nazaré da Mata, it is necessary to involve the population, public agencies and the private sector in the formation of discussion forums on the issue of environmental education in schools, universities and neighborhood associations.

The first initiative is to create mobilization instruments in order to provide an overview of the action that will be developed in the hydrographic basin and in the source of the Tracunhaém river. Then, it is necessary to develop a project to recover native vegetation around the source and to recover marginal areas of the river.

The Companhia Pernambucana de Saneamento (COMPESA) plays a major role in the recovery of the Tracunhaém River. In partnership with the prefecture of Nazaré da Mata and the private sector, COMPESA can develop recovery projects for the Tracunhaém River, creating sewage treatment plants for domestic and industrial effluents. Another parameter that should be encouraged is the selective garbage collection, through environmental awareness programs with the population.

REFERENCES

ABDULI, M. A.; SAFARI, E.. Preliminary analysis of heavy metals in the Kahrizak landfill leachate: a conceptual approach. **International Journal of Environmental Studies**, v.60, n.5, p.491-499, 2003. **DOI:** http://doi.org/10.1080/0020723032000050394

BONAVIGO, L.; ZUCCHETTI, M.; MANKOLLI, H.. Water radioactive pollution and related environmental aspects. **Journal of International Environmental Application & Science**, v.4, n.3, p.357-363, 2009.

BRASIL. Ministério das Minas e Energias. **Projeto cadastro de fontes de abastecimento por água subterrânea estado de Pernambuco-diagnóstico do município de Nazaré da Mata.** Brasília: MME, 2005.

BRASIL. Ministério da Saúde do Brasil. Agência Nacional de Vigilância Sanitária. **Resolução-RDC nº 42.** Dispõe sobre o Regulamento Técnico MERCOSUL sobre Limites Máximos de Contaminantes Inorgânicos em Alimentos. Publicada no Diário Oficial da União nº 168, seção 1, p. 33-35, em 30 de agosto de 2013. Brasília: DOU, 2013.

CARVALHO, J. A. R.; OLIVEIRA, M. G. A.; SILVA, H. P. B.. Identificação e avaliação de impactos ambientais em domínios urbanos e rurais do entorno do rio Tracunhaém, município de Nazaré da Mata-PE. **Caderno Prudentino de Geografia**, v.39, n.2, p.160-174, 2017.

CHOVANEC, A.; HOFER, R.; SCHIEMER, F.. Fish as bioindicators. In: MARKERT, B. A.; BREURE, A. M.; ZECHMEISTER, H. G.. **Bioindicators and biomonitors.** Elsevier Science Ltd., 2003.

EPA. US Environmental Pollution Agency. Method 3052. **Microwave assisted acid digestion of siliceous and organically based matrices**. EPA, 1996.

GIRI, S.; SINGH, G.; JHA, V. N.; TRIPATHI, R. M.. Natural radionuclides in fish species from surface water of Bagjata and Banduhurang uranium mining areas, East Singhbhum, Jharkhand, India. **International Journal of Radiation Biology**, v.86, n.11, p.946-956, 2010. **DOI**: http://doi.org/10.3109/09553002.2010.492490

HUTTON, M.. Human health concerns of lead, mercury, cadmium and arsenic. In: HUTCHINSON, T. C.; MEEMA, K. M.. **Lead, mercury, cadmium and arsenic in the environment**. John Wiley & Sons Ltd., 1987.

IFE-ADEDIRAN, O.; ISABOTA, O.. Gamma dose profile and risk to scavengers and occupants near waste dumpsites in coastal Nigeria. **International Journal of Environmental Studies**, v.75, n.5, p.708-718, 2018. **DOI:** http://doi.org/10.1080/00207233.2018.1430663

LEGORBURU, I.; CANTON, L.. Heavy metal analysis in fish-kill cases in rivers in Guipuzcoa (Spain). **Toxicological & Environmental Chemistry**, v.23, n.1-4, p.161-167, 1989. **DOI:** http://doi.org/10.1080/02772248909357462

LEITERER, A.; BERARD, P.; MENETRIER, F.. **Thorium and health: state of the art**. CEA Fontenay aux Roses Direction des Sciences du Vivant Unité Prositon. Rapport CEA-R-6251, 2010.

LIMA, D. P.; SANTOS, C.; SILVA, R. S.; YOSHIOKA, E. T. O.; BEZERRA, R. M.. Contaminação por metais pesados em peixes e água da bacia do rio Cassiporé, Estado do Amapá, Brasil. **Acta Amazonica**, v.45, n.4, p.405-414, 2015. **DOI**: http://doi.org/10.1590/1809-4392201403995

MARSHALL, L.; WEIR, E.; ABELSOHN, A.; SANBORN, M.. Identifying and managing adverse environmental health effects: 1. Taking an exposure history. **Canadian Medical Association Journal**, v.166, n.8, p.1049-55, 2002.

MCCLUGGAGE, D.. **Heavy metal poisoning**. NCS Magazine, Published by The Bird Hospital, 1991.

MUNDADA, M. N.; KUMAR, S.; SHEKDAR, A. V.. E-waste: a new challenge for waste management in India. **International Journal of Environmental Studies**, v.61, n.3, p.265-279, 2004. **DOI:** http://doi.org/10.1080/0020723042000176060

ROTTA, M. A.. **Aspectos gerais da fisiologia e estrutura do sistema digestivo dos peixes relacionados à piscicultura**. Documentos 53. Embrapa, 2003.

SAADAOUI, E.; GHAZEL, N.; ROMDHANE, C. B.; MASSOUDI, N.. Phosphogypsum: potential uses and problems-a review. **International Journal of Environmental Studies**, v.74, n.4, p.558-567, 2017. **DOI**: http://doi.org/10.1080/00207233.2017.1330582

SILVA, A. N. C.; SANTOS JÚNIOR, J. A.; AMARAL, R. S.; VIEIRA, J. W.; BARRETO, C. A. A.. Natural radionuclides in electronic waste: an initial approach. **Environmental Technology**, v.39, n.16, p.2051-2055, 2018. **DOI**: http://doi.org/10.1080/09593330.2017.1349187

TRUEBY, P.. Impact of heavy metals on forest trees from mining areas. In: INTERNATIONAL CONFERENCE ON MINING AND THE ENVIRONMENT, 3. **Annals.** Sudbury, 2003.

VERMA, R.; DWIVEDI, P.. Heavy metal water pollution- A case study. **Recent Research in Science and Technology**, v.5, n.5, p.98-99, 2013.

WEIR, E.. Uranium in drinking water, naturally. **Canadian Medical Association Journal**, v.170, n.6, p.951-952, 2004. **DOI:** http://doi.org/10.1503/cmaj.1040214

WRENN, M. E.; LIPSZTEIN, J.; BERTELLI, L.. Pharmokinetic models relevant to toxicity and metabolism for uranium in humans and animals. **Radiation Protection Dosimetry**, v.26, n.1-4, p.243-248, 1989.

ZAMORA, M. L.; TRACY, B. L.; ZIELINSKI, J. M.; MEYERHOF, D. P.; MOSS, M. A.. Chronic ingestion of uranium in drinking water: a study of kidney bioeffects in humans. **Toxicological Sciences**, v.43, n.1, p.68-77, 1998.
DOI: http://doi.org/10.1006/toxs.1998.2426

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