

Construction of the Estreito Hydroelectrical Dam in the state of Maranhão, northeast Brazil and the origin of a water-born disease in the Babaçulândia municipality, state of Tocantins

ABSTRACT

Within the national development framework and following the growth projections of the different sectors demanding energy, the government of Brazil has prioritized the construction of several river dams, considering the availability of natural resources in each region. The main objective was to infer the effects of the flooding of areas due to the construction of the Estreito Hydroelectrical Dam, located in the state of Maranhão, on the health of the inhabitants of the Babaçulândia municipality in the neighboring State of Tocantins. The study is based on diarrhea notifications generated by the Basic Health Unit of the municipality. The data obtained directly from the department of the Brazilian Unified Health System (DATA/SUS), for the period 2007–2016, were analyzed by an ANOVA test. Results showed a significant increase in the number of diarrhea cases in 2012, year in which the hydroelectrical plant started its operations. The study highlights the necessity of further studies in the same population to unravel possible connections between the effects of the dam and climate characteristics in this region.

KEY WORDS: Dam, disease, metadata, public health.

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1 INTRODUCTION

Construction of hydroelectrical dams in Brazil and the world is the subject of analysis from different perspectives, encompassing those related to the environment and possible economic, social and cultural impacts on human populations. In year 2006, technical studies on the energy resources of Brazil considered the growth projections of the population and the energy demands of the commercial, industrial, residential and agricultural sectors (EPE, 2007). The country underwent an initial progressive substitution of less efficient sources of energy with others that were considered more efficient and independent of the international market fluctuations. Currently, the energy efficiency in Brazil is expressed in a wide sense, trying to fulfill the demand with an economically viable socio-environmental cost (EPE, 2014).

Even when the Government currently has a technical projection in search of a more sustainable development, it is important to analyze the latter from a more regional standpoint. For the northern region of Brazil, the Environmental Ministry has considered the watersheds of the rivers Tocantins and Araguaia (Tocantins-Araguaia Hydrological Region) as centers for exploration projects ever since the 1970's (MMA, 2012). Recently, such projects are the core of the development plans for the region.

An article published in *Le Monde Diplomatique Brasil*, reveals the pressure exerted on the Cerrado Ecoregion (where the Tocantins and Araguaia basins are located) and its hydrological resources by projects related to electricity generation, mentioning among several of such projects the Estreito Hydroelectrical Dam (EHD, VEIGA; BONFIM, 2018). These adverse effects were also denounced by Sieben and Junior (2016), who stated that the construction of large dams and transmission lines are often presented as a necessity in the electricity industry expansion of Brazil, indicating that there are 23 projects for transmission lines (21% of the total for the entire country) concentrated on this northern Amazonian region. Plans were drawn for the construction of 25 hydroelectrical dams between 2011 and 2021, with 10 of them already constructed until 2015 (ANDERSON et al., 2018).

Specifically along the Tocantins River, which runs through the Pará, Tocantins and Goiás states, there are seven functioning hydroelectrical dams: Tucuruí, Estreito, Lageado, Peixe Angical, São Salvador, Cana Brava and Serra da Mesa, with a generation potential of 11.500 MW (ANA, 2020). Following the report from the National Water Agency of Brazil (ANA by its abbreviation in Portuguese), the area in the Tocantins-Araguaia Hydrographic Region occupied by the superficial waters, including those of rivers and their dammed reservoirs is equal to 16.454 km² (ANEL, 2019), and this region is counted among those with higher capability of reservoir water storage in the country.

Environmental impact studies in the Tocantins-Araguaia Hydrographic Region show that 56.4% of its area is used for agriculture, demanding a considerable volume of water for rice and soy fields, which accelerate the erosion of soils and contribute to the contamination of rivers by agrochemicals (GOMES et al., 2018). The same authors state that another impact comes from the livestock industry which affects the carrying capacity of ecosystems altering the riparian forest through degradation of soils and vegetation. The water quality in rivers of the region is also compromised, with substantial microbial contamination of

consumption waters in a region that already has problems with potable water distribution for the population (SNIS, 2018).

The Tocantins-Araguaia basin sits on areas of extreme biological importance (VEIGA; BONFIM, 2018) and any exploration or hydroelectrical project is a threat to its ecological integrity. For this reason, the basin constitutes a priority for the Water National Agency within the “Plan of Basin” which still is under elaboration. The latter not only considers the biological aspects, but also the human social diversity, including traditional and indigenous populations. The Plan recognizes the implications of anthropic pressures resulting from the exploration of natural resources of the region on the customs and way of life, suggesting an overview on integration between water resources and territorial management (MMA, 2006; ANA, 2019).

The construction of the EHD in the northern state of Maranhão began in 2006 and ended in 2012 (TRACTEBEL ENERGIA, 2012). The EHD reaches 12 cities, including the municipality of Babaçulândia in the neighboring state of Tocantins, approximately 130 km to the southwest of the city of Estreito, Maranhão, where the hydroelectrical plant is located (SIEBEN; JUNIOR, 2012). Following information from the Estreito Energy Consortium, the EHD has the capacity to produce 1.087 MV, which would be sufficient to satisfy the energy demands of 4 million people (MASSOLI; BORGES, 2014).

Despite the mitigation measures of the impacts of the EHD plant, which were described in the environmental license, the construction of the plant has meant a series of adverse compromises in their economic activities below and upstream of the reservoir, and the compulsory relocation of the population residing in flooded areas. Other impacts are still expected, such as those that occurred to populations adjacent to the hydroelectrical plant of Tucuruí in the nearby state of Pará. In this latter plant, the water quality decreased notoriously and there was an increase in waterborne diseases and a suppression of the multiple uses given to the flooded territory prior to the dam construction (PINTO, 2012).

Tavares et al. (2017) described the conditions in which the inhabitants of the districts around EHD lived before the construction of the dam. The project ended up affecting 12 municipalities, 10 of them belonging to the State of Tocantins and 2 to the State of Maranhão. One of the municipalities in Tocantins is Babaçulândia, in which the building company participated in the construction of two “Vilas de Assentados” (Settler Villages), Novo Milênio I and II with the compromise to attend the basic sanitation and housing needs of the people (SIEBEN; JUNIOR, 2012). Tavares et al. (2017), write that in 2010, the year in which the relocation began there were already structural problems with the newly constructed houses, probably related to the disruptions of the water table in the sites of construction.

Following Rocha (2016), a flooding, probably caused by the presence of the dams (EHD and two other along the Tocantins River) took place in early 2011, which had evident negative effects on the surrounding population. The author refers to the inundation of the sewage system in municipalities such as Babaçulândia, affecting common drinking water artisan wells, open landfills, cemeteries, and probably even the water of the reservoir itself.

The present study focuses on discussing unforeseen consequences of the EHD construction on the health of the population living in the area of influence. The specific objective of this study is to analyze the prevalence of waterborne diseases

between years 2007–2016, focusing on diarrhea outbreaks, occurring in the Babaçulândia municipality in the state of Tocantins.

2 MATERIALS AND METHODS

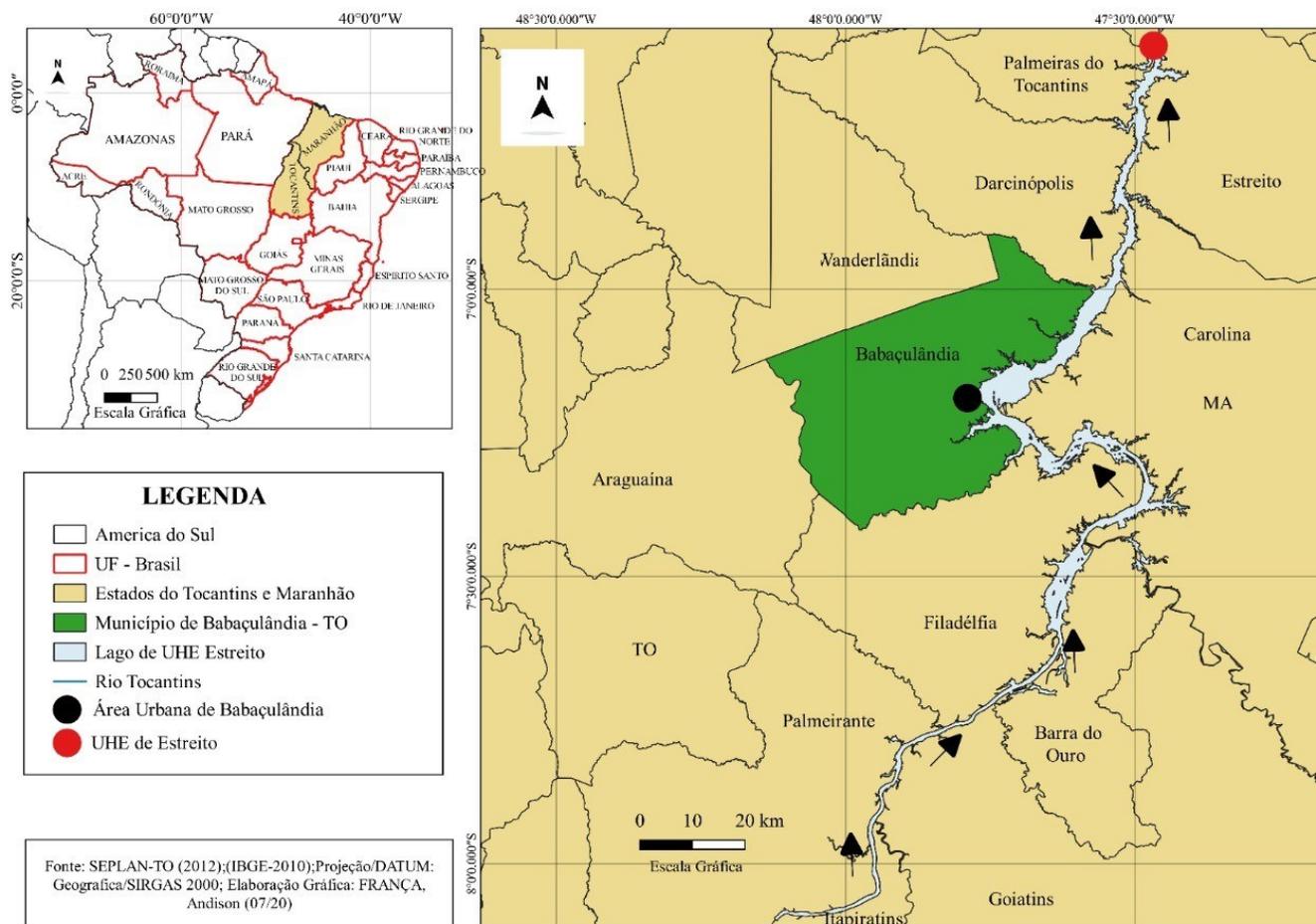
2.1 Study area

The Babaçulândia municipality is located on the margin of the Tocantins River (figure 1). It was founded in June, 1926 by the merchant Henrique Brito, who arrived in the area looking for the babassu palm (*Attalea speciosa*). He initially called the founding place “Nova Aurora do Coco”, but it was changed to its current name in 1938, after a prior political reorganization, at the same time that it was given the rank of municipality (SIEBEN; JUNIOR, 2012).

Following Barbosa et al. (2019) Tocantins has nine “economic poles”, being Palmas, the state capital, and Araguaína the first two largest poles. The municipality of Babaçulândia is under the economic influence and control of Araguaína, with the largest potential of growth within the State. The municipality borders with the municipalities of Darcinópolis and Wanderlandia to the north, Filadélfia to the south, the state of Maranhão to the east, and the municipality of Araguaína to the west.

Following the Brazilian Institute of Geography and Statistics (IBGE, 2017), Babaçulândia has 10.424 inhabitants and 78.9% of the houses do not have or have an inadequate sewage system. The main income came from tourism in the river and neighboring areas, which stopped completely after the construction of the EDH. Health related data show that the average infant mortality rate is 18.18 per 1.000 newborn children, while the hospital admissions due to cases of diarrhea are 0.1 per 1.000 inhabitants. Compared to the other municipalities in Tocantins, Babaçulândia ranks 35th among a total of 139 municipalities (TOCANTINS, 2017).

Figure 1 - Map showing the location of the Babaçulândia municipality in the state of Tocantins, Brazil. Organized by the authors



2.2 Data collection and statistical analyses

The present study is based on documentation, bibliography and it is of a descriptive type. Secondary data of reported cases of diarrhea to Babaçulândia municipality, from the 2007–2016, were obtained from the DATA/SUS Oficial Website (2017). The registry of notifications was tabulated for each year following the epidemiological weeks, for a total of 52 weeks in each year. This calendar of weeks is official for the country and standardizes the temporal survey of epidemiological data on notifications of complaint (SINAN), which is an operational system performed by the Brazilian Ministry of Health. Sorted data were statistically analyzed and compared using an ANOVA (Analysis of Variance) test in order to verify if there were significant differences between the sorted groups (Paese et al., 2001). This was followed by a Tukey test to determine which years presented the most significantly different number of diarrhea cases along the 53 analyzed weeks for the period 2007–2016. The latter was then used for comparisons between two means of treatments (Oliveira, 2008).

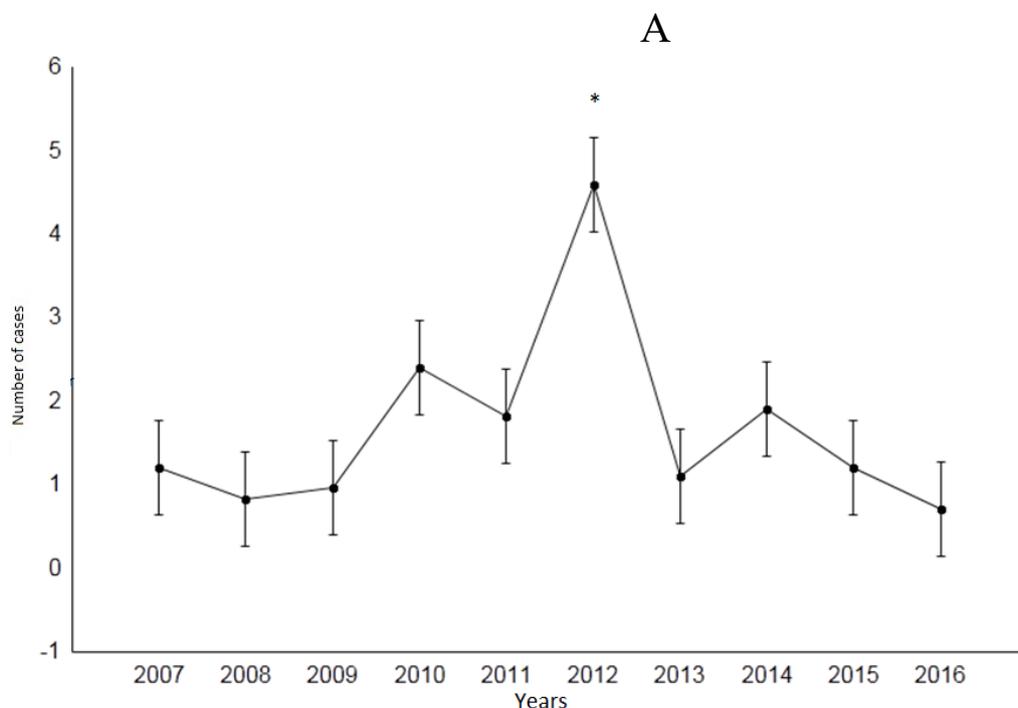
3 RESULTS AND DISCUSSION

The construction of the hydroelectrical plants, which still continue to be built in the country, generates environmental and social impacts in time, including violence against riparian human populations, who experience great changes when they are forced to move from their original sites. The transition implies damages against their life style, work and consequences on the physical health of the people (GIONGO et al., 2017). Some of these damages have already been reported for the municipalities affected by the EHD since its inauguration in 2010, mainly those related to territorial loss and psycho-social issues (SIEBEN; JÚNIOR 2012, 2016; SILVA, 2014, SILVA; SIEBEN, 2019; CARVALHO; SIEBEN, 2019). Very few studies focus on aspects of such impacts on healthiness and population well-being in those localities (ROCHA, 2016; TAVARES et al. 2017).

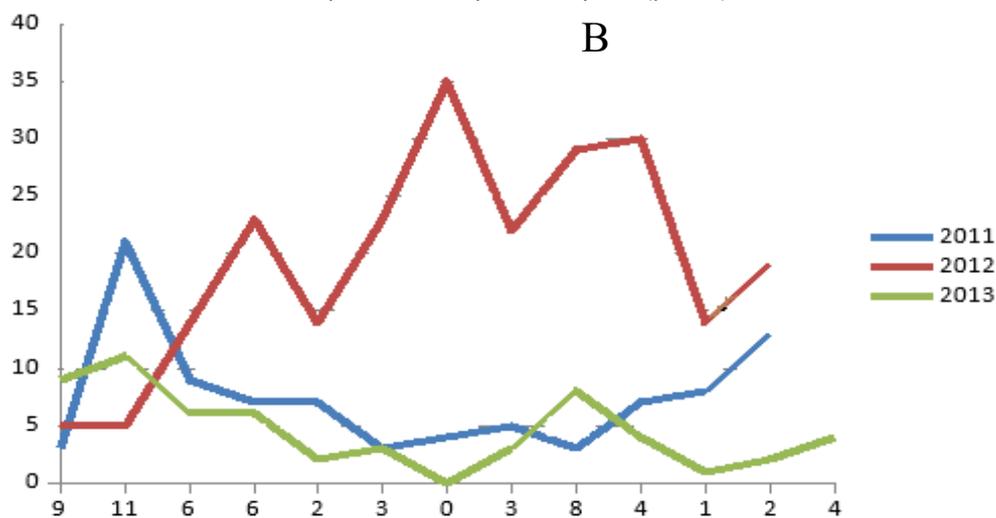
Considering aspects of sanitation and water consumption, part of the population in Babaçulândia still gets water from wells, but the majority is provided by an outsource company, the BRK Ambiental, which is responsible for the potable water and sewer services in the entire state of Tocantins. It is worth noticing that the water collected and treated by this company originates in EHD reservoir.

The data from the DATA/SUS source for the municipality show that the cases of diarrhea in 2012 were significantly higher when they were compared to other years (figure 2A). We analyzed the years prior and posterior to 2012, year in which the reservoir was filled, noticing that there was a significative increase in the diarrhea cases by 151.5% from 2011 to 2012, followed by a decrease in 313.5% from 2012 to 2013. When the epidemic weeks of diarrhea cases were compared in the narrower period 2011–2013, the weeks with higher number of cases were those belonging to the months of June and September (Figure 2B). We suggest that the diarrhea outbreak was the result of an accumulation of various factors such as the consumption of untreated water from wells, the effect of increased tourism, with increased swimming and other activities in the river throughout the year (SIEBEN; SILVA JUNIOR, 2012). These activities associated to tourism were high during the dry months in which the diarrhea outbreaks occurred.

Figure 2 – Survey of diarrhea cases in the municipality of Babaçulândia, State of Tocantins. (A) Yearly progress of the diarrhea cases in the period 2007-2016. (B) Focus on data from epidemiological weeks in the period 2011-2013.



* The TUKEY test indicates the significant difference between 2012 compared with the previous and posterior years ($p < 0.5$).



* The ANOVA test indicated that the peak in 2012 was significantly different from the other years ($p < 0.5$).

The contamination of the water for consumption could have initiated with the beginning of the filling of the reservoir in 2011, which increased the level of the water table, as explained by Albuquerque Filho e Leite (2002), who considered the hidrogeology of the surface and underground water as a system of communicating vessels, so the hydric stress of one affected the other. The same authors explain

that the increase in the level of the water table is immediate after the river was dammed since a process of influx into the aquifer is initiated that floods latrines and trenches, contaminating the entire aquifer.

The region was affected by EHD, despite that CESTE, the enterprise in charge of its functioning, carries out monitoring of climate, bathing and hidrogeological conditions. These data were made available through their website only since 2016 (<http://www.uhe-estreiro.com.br/meio-ambiente/monitoramento-ambiental/>). For the municipality of Babaçulândia, the monitoring of the water table levels did not stop flooding and trespass of water into residences in several parts of the municipality. There was also a massive death of thousands of fish and other animals, besides the degradation of the vegetation present in flooded areas, which may have accounted for an increase of microorganisms in the water. Apart from posing a threat to human health, these microorganisms decompose organic matter producing carbon dioxide and methane, processes accelerated by the high temperatures of the region, thus increasing the adverse effects of these dams built in tropical areas (FARIA et al., 2015).

The data we analyzed here could even be underepresenting the actual number of cases since individual diarrhea cases are not always reported. This is why an “outbreak”, in the sense of a large number of cases that are epidemiologically related, could not be necessarily detected by the official alert systems, and thus, could not be identified in due time to assess real collective risk conditions. To this, it should be added the tourist affluence that the reservoir received between June and August, months that are traditionally used by tourists and bathers, raising the hypothesis that these tourists could have gotten the same symptoms as the locals, but tourists could have reported their illness in their own municipalities.

The history of hydrological resources, inadequate and deficient sanitation in the state of Tocantins help to understand the lack of information at the moment of the diarrhea outbreak in Babaçulândia, without the source of pathogenic microorganisms being revealed and the simultaneous change of the entire landscape due to the filling of the reservoir. Under these conditions there was a need for a close attention to the distribution of good quality water. In the absence of an appropriate control there are risks such as the high number of diarrhea cases in 2012 (RUFINO et al., 2016).

It is important to mention other diseases related to water and the lack of basic sanitation in the Babaçulândia municipality. The report from the municipality described by the Secretariat of Planning and Budget (SEPLAN, 2017) presents transversal and longitudinal data between the years 2011 to 2015. The 125% increase in the cases of dengue (from 4 to 9 confirmed cases) from 2011 to 2012 is noticeable. From 2012 to 2013 there was an increase to 22 confirmed cases of this disease, which represents an increase of 450% for the time the filling was complete and the hydroelectric power plant began its operations.

The results presented by Valadares et al. (2013) show that between the years 2000 to 2010 there was an increase in the incidence of dengue in the two larger municipalities in the State of Tocantins: Palmas and Araguaína. The authors did not find a correlation among the dengue cases, precipitation and atmospheric temperatures. However, they did find an increase in the incidence of dengue changing from medium (years 2002 and 2004) to high (years 2005 to 2010), representing an increase of 199% for both municipalities. The increase of 450% in

the city Babaçulândia, close to the city of Araguaína, indicates a direct effect of the new environmental conditions determined by the increase of water in the reservoir on dengue cases. This is, most likely, due to an increase in the availability of water for reproduction of the dengue vectors, the mosquitoes *Aedes aegypti* and *Aedes albopictus*. (Oficial Website DATA/SUS)

Findings in similar studies have shown damage to the health of populations affected by the construction of other plants, such as damage from water contamination by waste and also by metals such as mercury, in addition to other infectious and parasitic agents (PINTO, 2012).

A similar case to the effects caused by EHD is that of the Tucuruí Hydroelectrical Plant, a reservoir of 2.917 km² which started operations in 1975 with a generation capacity of 8.370 MW. One of the first impacts was on the health of nearby human populations, with the manifestation of acute respiratory syndromes, dermatological problems, and diarrhea associated to bathing and lack of basic sanitation in the affected localities (PINTO, 2012). Following the revision of Moran (2016), the construction of hydroelectrical plants had an initial objective of supplying energy to a nation that had an energy urgency. But the author emphasizes the social and environmental costs of these undertakings, which generates a global concern, resulting in a decrease in the release of resources to the country.

4 FINAL CONSIDERATIONS

Based on the analyses of the epidemiologic weeks in 2011–2013 and the historical data available, we showed that it is highly likely that consumption water in Babaçulândia was contaminated with the filling of the reservoir of the EHD, which caused a diarrhea outbreak.

It is possible that the outbreak was worse than shown by the data since mild diarrhea cases are easily treated in households and people do not go to health institutions. The great majority of these cases remain unregistered.

The construction of hydroelectrical plants has adverse impacts on environmental and social aspects, directly threatening the quality of life in the areas where they are developed. Thus, any study and project directed toward the minimization of such impacts are of great value for the populations that are directly affected, ultimately ensuring their survival and the quality of life that the state should provide.

The use of certain diseases as indicators of the impacts of hydroelectrical plants could result in a useful health monitoring tool. In the case of diarrheas, these are noticeable and easily recordable incidences of the causal effect of the impact of such plants.

In the light of alternative clean energy technologies being developed nowadays, the relevance of hydroelectrical plants in the economic development of Brazil is questionable. This is even more evident in the increasing light of the adverse effects of these constructions on fauna, flora, entire ecosystem structure and functioning, and the health and long term stability of native peoples and settlers living nearby. Though, construction projects are required to present environmental and social impact assessments, it is evident that the depth with

which these assessments are being done is not sufficient to avoid the potential and real risks that these structures have on the planet.

Construção da barragem Hidroelétrica Estreito no estado do Maranhão, nordeste do Brasil e a origem de doença hídrica no município de Babaçulândia, Tocantins

RESUMO

Dentro do quadro de desenvolvimento nacional e seguindo as projeções de crescimento dos diferentes setores demandantes de energia, o governo do Brasil tem priorizado a construção de diversas barragens fluviais, considerando a disponibilidade de recursos naturais em cada região. O objetivo principal foi inferir os efeitos das inundações de áreas decorrentes da construção da Usina Hidrelétrica Estreito, localizada no estado do Maranhão, sobre a saúde dos moradores do município de Babaçulândia, no vizinho Estado do Tocantins. O estudo baseia-se nas notificações de diarreia geradas pela Unidade Básica de Saúde do município. Os dados obtidos diretamente da Secretaria do Sistema Único de Saúde (DATA/SUS), para o período de 2007 a 2016, foram analisados pelo teste ANOVA. Os resultados mostraram um aumento significativo no número de casos de diarreia em 2012, ano em que a hidrelétrica iniciou suas operações. O estudo destaca a necessidade de mais estudos na mesma população para desvendar possíveis conexões entre os efeitos da barragem e as características climáticas desta região.

PALAVRAS-CHAVE: Barragem, doença, metadados, saúde pública.

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