Analysis of Environmental Impacts Caused by the Construction of Power Transmission Lines in Brazil

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Abstract

A country's energy production, transmission and distribution systems are directly linked to its technological advances and economic growth. In Brazil, the creation and expansion of several transmission lines are planned. Such ventures often come up against environmental aspects, as they advance over forest and conservation areas. In this context, the objective of this research was to study the main environmental impacts caused by the implementation of transmission lines in forest areas in order to have a better understanding of the subject, thus being able to minimize or extinguish them. After gathering information, it was found that most of the environmental impacts are due to the deforested area around the transmission lines, called the right of way, which creates a corridor that alters the vegetation. Other serious impacts are related to the type of foundation most used: the micropile, which uses a toxic stabilizing mud in its drilling. The results of this research can be used as a basis to minimize such impacts that can cause damage to the environment and delays in the construction of the lines.

Keywords: Transmission Lines; Environmental Impacts; Right of Way; Drilling Mud.

1. Introduction

The electrical power system consists of three parts: the production, transmission and distribution of energy. After energy production, it is transported through transmission lines, where these are a fundamental component of a country's energy infrastructure, especially in Brazil, where most of the power generation plants are hydroelectric, generally away from the largest consumer centers (Murta, 2015).

The transmission lines are basically composed of two parts: the active part (cables-phase) and the passive part (insulators, hardware and the structure). The structures that exist along the aerial transmission lines with the support function are called towers. They are responsible for maintaining the proper spacing between the cables, transmitting the efforts that arise in the lines and in the towers themselves to the foundations, who have the function of transmitting the loads from the superstructure to the ground, avoiding overloads that would damage the system. Foundations can be divided into direct (or shallow) and deep.

Among the types of direct foundations, the Spread Footing foundations are the most used in energy transmission towers, however, this type of foundation, despite being the most economical and simple to implement, has technical limitations as to its more widespread use, therefore, very often so-called deep foundations are employed.

The various types of deep foundations used have advantages and disadvantages both for the economic aspect, as well as for safety and environmental impact. Therefore, the search for types of foundations that present mainly economic advantages in relation to those traditionally employed, reducing environmental damage, is of great interest to the energy sector in Brazil, since it has the need for a greater expansion of its network energy transmission, caused by the demand demanded for the growth expected in this country in the coming years.

In Figure 1, it is possible to observe the current size of the energy distribution network in Brazil. In addition, it can be observed that there is a forecast of a great expansion of this network for the next ones, as indicated by the dashed lines. Highlight for the planned expansion between Manaus and Boa Vista, which should pass through areas of native forests in the region.

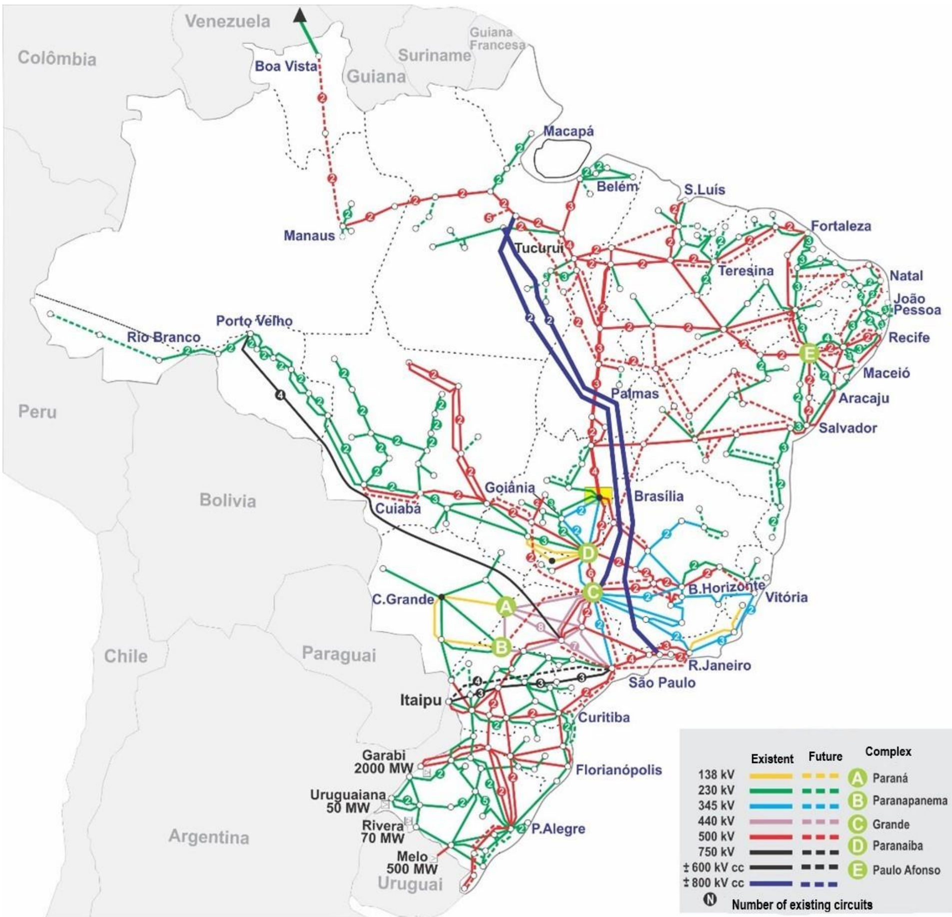

Figure 1 – Brazilian power transmission system (Source: Adapted from ONS, 2019)

Thus, one must look for constructive technologies for the execution of this line that minimize the environmental impacts to the forest, where it should pass. In this context, a study was carried out of the environmental impacts that may be caused by the implementation of transmission lines in forest areas, mainly in relation to the use of the main technology currently used in tower foundations of transmission lines to places of difficult access, seeking alternatives to minimize them.

2. Theoretical Reference

2.1 Transmission towers foundations

Foundations are structures responsible for transmitting loads from the superstructure to the ground in such a way that excessive overload does not occur. A possible overload would result in excessive deformation of the soil (settlement) or shearing of the underlying soil. Foundations are divided into two groups: direct (also known as shallow or superficial) and deep foundations. According to NBR-6122: 2010, what differs one group from the other is the depth of settlement ratio with the smallest dimension of the foundation base, if it is greater than twice or more, it is considered deep.

2.1.1 Micropiles

They are elements of deep foundation, can reach depth greater than 50 meters and have diameters between 80 to 500 mm, being able to be used both in soil and in rocks. They are piles “in loco”, that is, built on the construction site according to the foundation project. They are characterized by the use of rotary or rotosurgical drilling, using the aid of stabilizing fluid (bentonite mud or synthetic polymer) or not, they are the main substitutes for compressed air tubes. In its execution, metallic lining tubes are used throughout the soil section after excavation to avoid the risk of landslides. The mortar used is densified with the aid of the pressure normally given by a compressed air system (Pereira, 2018).

According to Nogueira (2004), they are widely used in the construction of transmission lines and in foundations that are in difficult access areas, allowing a quick and economical displacement of the equipment used between the different towers (it is not necessary to use pile drivers) traditional). Matias (2018) highlights the great versatility of this type of foundation in his work, which contributes to being one of the most used in transmission lines, which often cross forest sites and rocky terrains.

The main advantages of the root stake are:

- Elimination of vibration and decompression of the terrain, which can be used close to neighboring buildings;
- Execution in limited spaces because the equipment used is small and medium-sized;
- Use in terrains with the presence of boulders (rock mass protruding from slopes), concrete and other rigid materials;
- Possibility to combat flexion efforts;
- Execution on slopes from 0 to 90^o;
- Low noise pollution.

As a disadvantage, we can mention:

- Relatively high cost;

- High cement consumption;
- High hardware consumption for the reinforcement;
- Great environmental impact (mainly related to bentonite mud);
- Large water consumption.

Figure 2 shows the schematic execution of the foundation in micropile.

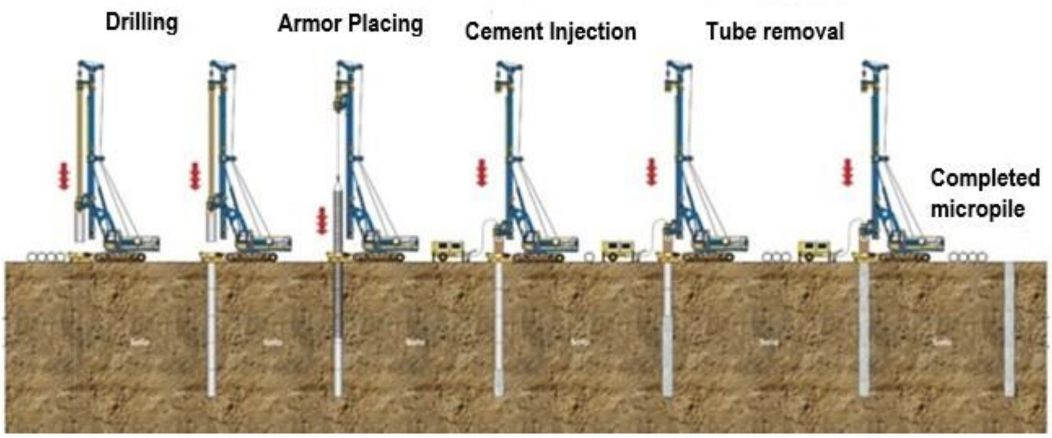

Figure 2 – Execution of micropile foundation (Source:Pereira, 2018).

2.2 Environmental Impact

With the constant growth of the energy sector, there is an increasing demand for changes in landscapes, caused by the installation of new power transmission lines. According to the International Energy Outlook (2019), in the next 26 years, there is an estimated growth of 48% in world energy consumption, consequently, there will be a major expansion of the transmission system. The transmission lines have large extensions and are generally located in remote and less altered environments, often passing through nature conservation sites. (Araneo et al. 2014).

In addition to the presence of cables and power transport towers, the transmission lines interact with the environment through the right of way (open area required for the installation of these structures) that varies in width according to the voltage used, reaching up to 100 meters, where vegetation is suppressed and managed to promote less interference and risk to the lines. Although the width of the right of way is somewhat narrow, the large extension of the transmission lines causes a major transformation in the environment in which they are located, as illustrated by the following figure. The corridor formed, maintenance and the presence of the line itself are the main factors responsible for environmental impacts (Biasotto, 2017).

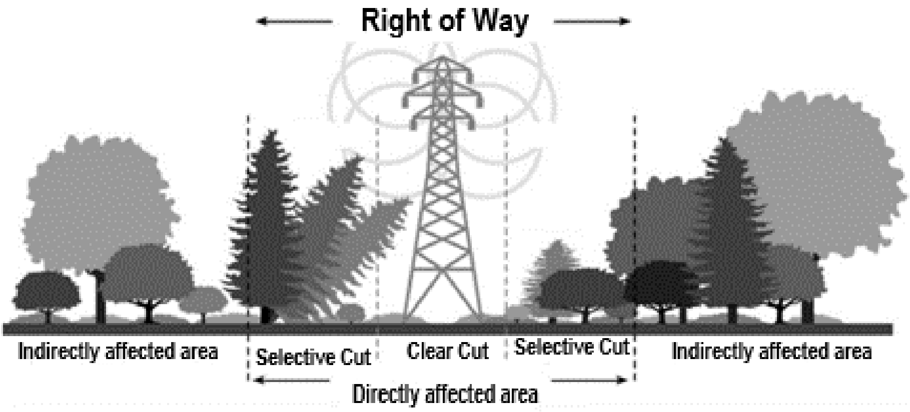

Figure 3 - Right of way and areas directly and indirectly affected by the transmission lines (Source: Biasotto, 2017).

According to Bagli et al. (2011), transmission lines can cause significant environmental impacts both in their installation phase and in their operation phase, thus emphasizing the need for such procedures to undergo a careful analysis in their licensing. Although the Environmental Impact Assessment (EIA) is of great importance for minimizing environmental impacts, there are authors who argue that it is necessary to adopt preliminary assessments for the licensing of individual projects, such as a Strategic Environmental Assessment (Biasotto, 2017).

According to CONAMA Resolution 001/1986, environmental impact can be considered "any change in the physical, chemical and biological properties of the environment, caused by any form of matter or energy resulting from human activities that, directly or indirectly, affect (. ..) the health, safety and well-being of the population; social and economic activities; the biota; the aesthetic and sanitary conditions of the environment and the quality of environmental resources ".

3. Methodology

In this research, the topic addressed was: Analysis of Environmental Impacts Caused by the Construction of Power Transmission Lines in Brazil, whose objective will be to analyze the environmental impacts most commonly caused by these enterprises, which can often lead to greater costs and delays.

In this study the deductive method will be used. According to Marconi and Lakatos (2009), two basic characteristics of the deductive method are: if all the premises are true, then the conclusion must be true and, all factual information of the conclusion was already, at least implicitly, in the premises. Deductive reasoning aims to explain the content of the premises, reaching a conclusion.

Thus, in order to understand the main environmental impacts caused by power transmission towers, it is necessary initially to raise the main environmental impacts resulting from this type of activity and its main causes, thus, from the deductive reasoning method it is possible work on minimizing the causes and consequently mitigating such impacts.

This work is classified as an applied research, as it aims to generate knowledge for future practical applications, directed to the resolution of problems of great relevance. This type of research is based on theoretical knowledge applied to problem solving (Gil, 2010).

According to Salomon (2010), this type of research aims to solve a practical or concrete problem, through the application of theories already elaborated. According to Fleury and Werlang (2017), this type of research seeks to recognize and answer problems questioned by organizations, institutions, society, social groups, communities etc., endeavoring to build diagnoses, with the purpose of finding solutions.

As for its approach, this research is qualitative. The intention of choosing this type of research is to guarantee the accuracy of the results, avoiding possible distortions and greater security to the hypotheses. A qualitative research is appropriate for formative evaluation, seeking better the functioning of a program, plan, or even proposing new actions and plans, in addition to allowing the researcher to study cases or events in depth and in detail (Richardson, 1999). In this case, this type of approach is ideal, as it seeks to study the environmental impacts of the construction of energy transmission towers.

A bibliographic survey was carried out, through books and scientific articles, in addition to Environmental Impact Studies and Environmental Impact Reports. Recent materials were prioritized, preferably from 2015 to 2021, mostly in English, where the database used was CAPES journals and Google Scholar. The keywords used in the research were: Transmission Lines, Power Transmission Towers, Transmission Towers Foundations, Environmental Impacts on Power Transmission Lines and Drilling Mud. Some materials outside these parameters were used, mainly to support the theoretical concepts.

After the bibliographic survey, based on the materials found, the main environmental impacts caused by the construction of transmission lines will be defined.

4. Analysis and Results

4.1 Environmental impacts related to transmission lines

After a bibliographic search using scientific articles, master's dissertations and some Environmental Impact Studies - EIA’s, some environmental impacts related to the construction of power transmission lines were raised, which are described below.

4.2 Barrier Effect

According to Colman et al. (2012), the presence of a new structure in a landscape, such as a transmission line, represents a physical obstacle for some individuals, which may cause, for example, bird collisions with the power lines. Several authors address this impact by relating to the population decline of several species, including endangered species. Tere and Parasharya (2011), highlight that the effects of transmission lines accumulated with other sources of mortality can manifest themselves only decades later, thus hindering a possible reversal.

Some individuals can respond to the presence of the barrier by changing their behavior, avoiding crossing it. According to Santiago-Quesada et al. (2014), transmission lines can influence the choice of breeding and resting place for migratory birds. Some authors, such as Bartzke et al. (2014) suggest that the easement range can alter the population density of some mammals, considering that it makes the habitat more exposed, facilitating their predation. Another problem often mentioned in the EIA's is the trampling of fauna on the access roads during the implementation of the transmission lines, caused by the flow of machinery and automobiles.

4.3 Border Effect

Its cause is the vegetation suppression for the creation and maintenance of the right of way, occurring both in the operation phase and in the implantation of the transmission lines. According to studies by Pohlman et al. (2009), the clearings opened for the construction of transmission line infrastructures can reduce the availability of habitat in the forests. The studies by Berg et al. (2011) observed that the effects of edges can also cause positive impacts, such as the increase in the population of certain species of butterflies, considering that the forest edges are the ideal habitat for them.

4.4 Eletromagnetic Field Effects

Although the impacts of electromagnetic waves on organisms still remain uncertain, some authors suggest that continuous exposure to the electromagnetic field may generate some behavioral changes that result in a decrease in reproductive success in addition to causing changes in biochemical processes (Fernie and Reynolds, 2005). They were also observed by Mahmood et al. (2013) impacts of the electromagnetic field on plant physiology, with changes in enzymatic activities and increased genetic mutations.

4.5 Fire Hazards

According to Cho et al. (2015), the insertion of the transmission line in an environment can, in addition to making it more vulnerable to human actions, facilitate the spread of fire. The likelihood of fires may increase as a consequence of the transmission of electrical energy, for example, by the death of electrocuted animals or electrical discharges. The study by Rodrigues et al. (2014) noted that the presence of transmission lines as one of the risk factors for forest fire in Spain.

4.6 Sound Effect

The action of the wind for causing noise due to vibrations in the cables, resulting in crackles or pulses. The impacts caused by these noises can result in chasing away the fauna. (Straumann, 2011). As stated in several EIA's, during the construction phase of the transmission lines, the noise from machinery and vehicles can also result in the evasion of fauna, causing a reduction in the use of the area by some species of animals (Colman et al., 2015) .

4.7 Air Pollution

Air pollution, which appears in most EIA’s, is mainly associated with the installation phase of the transmission lines, where dust and atmospheric emissions can be suspended by mobile sources on access roads or construction sites. This effect is mostly temporary and local. (Biasotto, 2017).

4.8 Soil Interference

The main impacts caused on the ground by the implantation of the transmission line are related to interventions such as improvement, opening and use of accesses, implantation and cleaning of the right of way, assembly of towers and equipment and others. Such interventions cause soil movement, excavation of the soil, reduction of vegetation cover and intensification in the use of space, leading to the emergence or acceleration of erosive processes. The incidence of erosion processes varies over the area of implementation, being more intense in more rugged terrain. (Pereira, 2015).

During the assembly of the power transmission lines, the towers' foundations are executed, which, as already mentioned, present a range of options that can be used. However, one of the most used techniques is the micropile foundations, due to the economic question and its versatile use for different types of terrain.

When using micropiles, there is also a risk of soil contamination through bentonite mud, used in drilling the soil. Bentonite mud is basically made up of water and bentonite, the last being a volcanic rock, where the predominant mineral is montimorilonite. There are different types of bentonite, varying in color and composition. The most widely used in drilling is mud-green bentonite, found in deposits in northeastern Brazil (Baltar and Luz, 2012).

Bentonite mud is responsible for, during drilling, creating a column that puts pressure on the ditch wall, preventing collapse by forming an impermeable film, called a "cake". However, it ends up depositing in the soil, contaminating it with its polluting metals. Contamination can occur in both the drilling and storage phases. (Ghazi et al, 2011).

Metals found in the composition of bentonite mud in large quantities can be toxic. Many authors suggest that the contamination of heavy metals and metalloids in the soil (and subsequent human contamination) can cause different types of health problems in newborns, such as underweight and impaired growth. The most harmful of these metals is manganese, which has an important role in the functioning of the nervous system and immune system, however, in large quantities is neurotoxic (Mihaileanu et al., 2019).

According to Augustsson et al. (2015), studies conducted close to old industrial areas concluded that the high concentration of metals in the soil continues even after years of the end of industrial activities, resulting in vegetables and fruits with a high metal content, causing health risks.

4.9 Contamination of Water Bodies and Alteration of Water Quality

It can occur for several reasons, among them the dragging of the soil through interventions followed by intense rains, handling of fuels and oils in the use of machines and vehicles, spill of coolant from transformers, use of contaminating substances with risk of occasional leakage . Contamination occurs mainly in construction sites and in the installation of substations. (Biasotto, 2017).

Another pollutant harmful to water bodies, as already mentioned, is bentonite mud. During the drilling for the installation of the foundation piles of the transmission line towers it comes into contact with the soil, later it can be carried by rain to rivers and lakes (where it is deposited in its beds), or even to contact the water table. The accumulation of metals from bentonite mud in water bodies compromises the its quality, which can make it unfit for consumption. In addition to the high concentration of metals, bentonite sludge sometimes also contains petroleum hydrocarbons that are highly toxic (Agwa et al., 2013). The next figure describres how this contamination may occur.

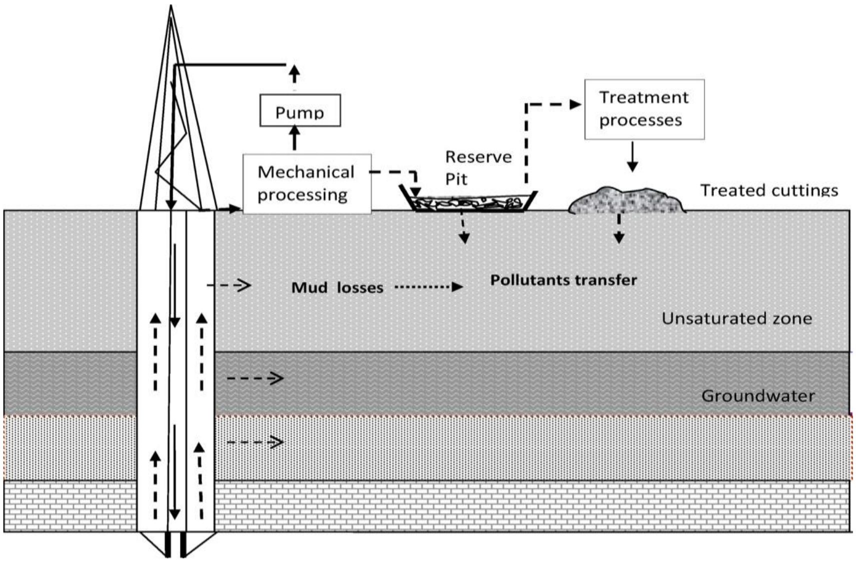

Figure 4 – Diagram of pollutants transfer from drlling well and reserve pit on the site (Ghazi et. Al., 2011).

According to Meyer et al. (2017), very high concentrations of metals in water are extremely harmful to life. Chronic exposure to high doses of Manganese turns out to be neurotoxic, especially in children and that Aluminum, although not considered to be very toxic, can cause neurological disorders and even Alzheimer's. Agwa (2013), on the other hand, suggests that in the case of bentonite sludge, one should not only take into account the toxicity of the metals individually, but rather go deeper into the interaction of the different metals in their composition with each other, which can cause impacts even further. larger ones not studied. According to Ghazi et al. (2013), in addition to the toxicity of the metals present, bentonite mud can also be harmful to aquatic life by settling on the bottom of rivers, lakes and oceans, where many animals essential for the ecological balance of the ecosystem feed.

4.10 Alternatives for using micropiles

A series of current researches have been found that aim to create less aggressive alternatives when it comes to the drilling muds used. The main studies suggest the use of biodiesel-based sludge or the use of water-based sludge with the addition of additives.

4.10.1 Biodiesel mud

With the growth and restriction of environmental laws, there is a growing need to create an oil-based mud that is more benign for the environment. The alternative suggested by Oseh et. Al. (2019) was the use of oil extracted from the seed of an inedible almond as the continuous phase for the manufacture of a drilling mud based on biodiesel. Different properties (including economic aspects) were evaluated and compared with diesel-based mud to determine the applicability and toxicity of the new type suggested. The results indicated that the properties of biodiesel are compatible, and that some properties are even superior, as is the case of the highest flashpoint, thus having greater security in contact with fire. Regarding the environmental impact, biodiesel has been shown to biodegrade three times faster in testing with *Penicillium*. Economically speaking, it was shown to be of low manufacturing cost and easy to dispose of the waste.

Another alternative found was the research by Kumar et. Al. (2019) which deals with a drilling fluid created with a methyl ester extracted from mango seed oil from India. The physical, chemical, rheological and filtration properties were shown to be superior compared to diesel, in addition to having lower environmental impacts (they were analyzed using the acute lethal concentration test). The mud proved to be thermally stable and presented a strong pseudoplastic behavior, which is an attractive when it comes to drilling muds.

4.10.2 Use of water based mud with additives

Oil-based muds are the best drilling fluids but their use is not recommended due to their high environmental impact. Some authors suggest the use of water-based sludge with additives that improve their properties, making them equal or superior in quality to those based on oil (Kusrini et. Al., 2018).

In the study by Ekeinde et. Al. (2018) evaluated the use of environmentally friendly materials in water-based drilling fluid systems. Four systems were analyzed at different temperatures in order to observe their properties. It was concluded that the materials worked effectively increasing the viscosity of the mud, but the best green material was *Averrhoa carambola*.

One of the additives used in drilling fluids are the so-called lost circulation materials (LCM), which are responsible for minimizing or preventing the loss of fluid in the formation. The study by Idress and Hasan (2019) developed a new LCM made from agro-waste such as orange peel and sunflower seed. The performance of the drilling fluid with the new additives has been tested in terms of rheology and filtration properties, proving to be effective compared to those used in the industry today.

The study by Kusrini et. Al (2018) analyzes the use of nanomaterials as additives: graphene as a “cake” formator and filtration barrier along with magnesium oxide to increase viscosity. After analyzing the rheological properties using Bingham's plastic method, it is concluded that only graphene can be used for high pressure drilling wells.

5. Final Considerations

With the expected growth for transmission lines in Brazil and the constant increase in demand for the electrical system is inevitable. Such expansion will be made mostly in areas of forest and forest conservation, impacting directly and indirectly on the present ecosystems. Despite the environmental impacts caused, it is important to note that these ventures are essential for the technological development of the country, so less aggressive alternatives should be sought.

The main impacts raised by this work are mainly related to the right of way that accompanies the extension of the transmission lines and, depending on the height and tension transported by the towers, causes a greater or lesser deforested area around it. Such impacts are more difficult to avoid, having as an alternative only the alteration of the route through in-depth studies, opting for a path that avoids the largest amount of conservation areas possible.

Other impacts are related to the construction of transmission towers, more specifically their foundations, due to the large use of root piles in the construction of transmission lines. In their installation they use the bentonite mud, used to create a layer during the drilling of the soil that prevents landslides, but in its composition heavy and potentially harmful metals that end up being dispersed in the soil and can be taken to water bodies. Such impacts, on the other hand, because they are linked to the type of foundation of the transmission lines can be avoided or reduced. One of the alternatives would be the use of other types of less aggressive foundations, such as the spread footing, but they do not have the same resistance capacity to the efforts of the micropiles, being able to be applied only to some types of smaller towers.

Another alternative proposed by more recent research that also presents a viable solution is the use of biodiesel-based mud, which is less toxic. Some authors suggest the use of water-based mud with the addition of additives that would improve its physical and chemical properties.

Currently, it is very important to advance in studies of alternatives that reduce the environmental impact and that are economically viable, thus enabling an economic and technological advance in the country without the degradation of environmental resources occurring.

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