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Elements of a New Rhetoric in Foucault's Work

Alex Pereira de Araújo

Doctor in Memory: Language and Society from the PPGMLS of UESB with doctoral internships at the Sorbonne Nouvelle (Paris 3 - France), Member of the Unified Black Movement in Itabuna-BA and the Research Group on Languages, Power and Contemporaneity – GELPOC (IFBA), Member of the Social Strategic Council at UFSB, Brazil.
Email: alex.scac@hotmail.com

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***Abstract*—*The principal objective of this study is to present and discuss the elements that emerge from Michel Foucault's archeological undertakings, which, in our view, configure the existence of a new rhetoric that deals with what the French philosopher called the rarefaction of the subject and rarefaction of discourse in his inaugural lecture at the Collège de France (Foucault, 1996). This new rhetoric would be in charge of reflecting and analyzing the phenomena that result from both the rarefaction of the subject and the rarefaction of discourse, that is, such rhetoric invests in what is responsible for imposing on the speaking subject what to say and how to say it. Therefore, it turns to certain mechanisms of control of discourses that Foucault presented in The Discourse on Language, a work that completes five decades of its publication. This Foucauldian rhetoric also has as its main function to deal with the history of the present, that is, to reflect on what we do and think at this exact moment, which, in turn, would be in charge of contributing to the history of how we became subjects in a culture like ours, at this stage of high modernity and the Information Age. From this perspective, she would be interested in the processes of identification and subjectivation that result from the ways in which we become subjects. In short, it is a study that seeks to present elements that demonstrate the emergence of a new rhetoric that emerges from the work of Michel Foucault, who, according to Deleuze (1992), increasingly invested in a generalized pragmatics.*

I. INTRODUCTION

The influence of Foucault's work in the field and studies of language is so remarkable that Deleuze even noted that the renowned professor at the Collège de France increasingly invested in a generalized pragmatics (cf. Deleuze, 1992, p.112), as His undertakings prove this and allow us to think about a pragmatic rhetoric that emerges from the theoretical machinery that reflects Foucauldian thought.

The discussion we present here is in charge of highlighting the elements that allow us to think and defend this point of view that gives rise to this pragmatic rhetoric, implicit in Foucault's undertakings and thought. To do so, we try to demonstrate these elements, and then discuss the contours of this rhetoric in relation to what we know as classical rhetoric and what has been called new rhetoric.

In these terms, the discussion plan was designed to bring to light such evidence that there is a latent pragmatic rhetoric in the endeavors carried out by Foucault. His book Archeology of Knowledge and his inaugural lecture at the Collège de France are the two most concrete examples of the existence of such pragmatic rhetoric; in other words, these two works manage to demonstrate that the thinking developed by Foucault was also capable of decoding a pragmatic rhetoric around the production of knowledge and power when he sought to make history of the way in

which we become subjects in a society like ours, and when he sought to write the history of systems of thought.

Therefore, the plan of this discussion is structured in three main moments in which we reflect on this field of knowledge called rhetoric that emerges in Hellenic culture with the aim of first persuading, a certain public linked sometimes to the political circle, sometimes linked to the legal circle, later, it ends up literally becoming a synonym for the art of speaking well. In the second moment of the discussion, we try to deal with this knowledge as a form of expression of Western thought; that is, as a way of ordering ideas in the West which, in turn, is in the order of discourses and in the emergence of human sciences and in the field of empirical knowledge.

Now, this mode is responsible for what Foucault called the rarefaction of the subject and the discourse and, consequently, for the discursive practices and discursive formations or even for the discussion he carries out on parrhesia in his latest studies. It is precisely from there that we discuss this pragmatic rhetoric that Foucault had to deal with to enter the order of systems of thought in the Western world and to be able to write the history of how we became subjects in this culture. Finally, we try to discuss the similarities between this pragmatic rhetoric that we find in Foucault and the main questions of the New Rhetoric presented by Perelman and Obrechts-Tyteca.

II. CLASSICAL RHETORIC: ARISTOTLE AND THE STUDIUM GENERALE IN THE MIDDLE AGES

The set of knowledge about metalanguage (discourses about discourse) that we know today as rhetoric, has its origins in the 5th century BC in the region of Magna Grecia, precisely in Sicily. Corax and his pupil Tisias are credited with his creation. The diffusion, in Athens, would occur soon after, thanks to the master Gorgias, considered a peripatetic, the way in which the sophists, who traveled from city to city, were known in that period. What is known about Corax's work is that it disappeared, but Cicero and Quintilian make some quotes from his work about his rhetoric. A century later, when rhetoric was already Athenian, Aristotle presents a treatise called *Τέχνη ρητορική* that brings the study of rhetoric closer to philosophical thought, defining it as "the art of extracting from any subject the degree of persuasion it entails" or as "the faculty of discovering speculatively what in each case may be capable of persuading." (cf. Barthes, 2001, p.15). It is in this way that rhetoric assumes the rhetorical perspective of proof, reasoning, and approximate syllogism (enthymeme). But extended to the literary field (which was not its original purpose), it develops as an aesthetic of the public, "more than an aesthetic of the work." (Barthes, 2001, p.16).

During the Middle Ages, this set of knowledge appeared institutionally as part of the *Studium Generale*, given the importance that the great thinkers of both Hellenic and Latin cultures gave it. Now, if rhetoric gained this dimension in classical culture, it is because, from an early age, it was associated with power in its relationship with knowledge, mainly through institutional support. In other words, those who wanted to stay in power, as well as those who desired it, had to have this knowledge that the sophists believed made men virtuous. Finally, by expanding his domains, Aristotle made it possible for rhetoric to reign for approximately twenty centuries, seeing "disappear, without being moved or altered: Athenian democracy, the Egyptian kingdoms, the Roman Republic, the Roman Empire, the great invasions, feudalism, the Renaissance, the monarchy, the French Revolution" (Barthes, 2001, p.7).

Without a shadow of a doubt, the theoretical aspects of this metalanguage called rhetoric contributed to giving a certain limit to the way we think in the West, that is, rhetoric helped to shape the way in which Western thought should be expressed both in public and in writing. Associated with power or the way of knowing to deal with power, rhetoric has become part of Western culture, penetrating its innards, nourishing the processes of subjectivation and identification, acting directly on the way in which the sciences were constituted and, on the form, how literature has developed in the last twenty centuries. The traces and traces of this rhetoric can be found in various discursive materialities. It is from them that Foucault develops means to analyze the pragmatics of the subject that results from this pragmatic rhetoric, as we discuss in the next lines.

III. PRAGMATIC RHETORIC: A REFLECTION ON THE RELATIONSHIP BETWEEN KNOWLEDGE AND POWER

Aiming, at the beginning, to create a theory that was focused on discourse itself, with the objective of dealing with Western thought, Foucault ended up coming across discursive practices that cannot be analyzed other than through the prism of the relationships between knowledge and power. However, to reflect on the discourses and such practices, he developed a series of expressions that take us back to this pragmatic rhetoric that resulted from this entire culture that developed around classical rhetoric, responsible for ordering and giving limits to Western thought. Political rationality, hermeneutics of the subject, rarefaction of the subject, authorship, will to truth, will to

know, parrhesia are some of these terms, as we mentioned before.

When we come across the study carried out in History of Madness in the Classical Age, his most controversial book, we realize how Foucault dedicated himself to the way in which arguments about madness enabled the exclusion of subjects considered crazy from social life (cf. Araújo; Milanez, 2018). In other words, we can say that in this work Foucault demonstrates the way in which rhetoric dominates our bodies under the pretext of reason in the face of unreason. It is interesting to note that Foucault did not just focus on speeches, including as part of his corpus, paintings and other pictographic elements as a rhetorical expression of thought in the Renaissance in transition with the Classical Age. In Order and Things: An Archeology of the Human Sciences, Foucault makes a point of dedicating the entire first chapter to the discussion of the way in which the painting, Las Meninas, by Diego Velázquez manages to express, with the internal logic of the painting, the era representations; in other words, we have an analysis in which we find not only the representation that could occur as pure representation, but the way in which we are placed in a kind of "large virtual cage" (Foucault, 1981, p.4).

Well, if in the History of madness in the Classical Age, Foucault works on the link between exclusion and truth in the midst of the way in which the "'scientific psychiatry' of the 19th century became possible" (Foucault, 1978, p.295), in Words and Things, he is committed to creating a history of épistémè, seeking to deal with the verisimilitude that united and ordered words and things. But are questions linked to verisimilitude and truth recurrent in several of Foucault's endeavors, an echo, perhaps, of Aristotle's rhetoric that has become part of the Western way of thinking?

By "truth", said Foucault, one must "understand a set of regulated procedures for the production, law, circulation and functioning of statements." (Foucault, 1979, p.14). In these terms, it "is circularly linked to systems of power, which produce and support it, and to effects of power that it induces and that reproduce it." (1979, p.14). This fact reminds us that rhetoric, as Aristotle thought, has no firm commitment to the truth, as the act of persuading is not directly linked to the truth.

In Discourse on Language, Foucault deals with the will to truth as something that appears when Hesiod and Plato decided to establish a certain division, "separating true discourse and false discourse". For Foucault, it was this division that undoubtedly gave "its general form to our will to know." (Foucault, 1996, pp.15-16). From then on, she didn't stop moving, because "Everything happens as if, from the great Platonic division, the will to truth had its own history, which is not that of the truths that constrain: history of the planes of objects to be known, history of the functions and positions of the knowing subject, history of material investments, instrumental knowledge technicians." (Foucault, 1996, p.17).

Perhaps, we could think of Aristotle as the first to seek to reduce the effects of this will to truth, responsible for our will to know, by bringing classical rhetoric closer to philosophy and dialectics. Placing it at the center of his concerns, Foucault seems to demonstrate, in his endeavors, the pitfalls of this will to truth by asking "what is at stake, if not desire and power?" (Foucault, 1996, p.20). Now, this will to truth has institutional support and distribution to exert "a kind of depression and a power of coercion" on other discourses (Foucault, 1996, p.18).

Discourse on Language is full of clues that could appear as elements of this pragmatic rhetoric that we are dealing with here (cf. Araújo, 2020). The rarefaction of the subject is another tangible example of this, as it is in charge of controlling both what is said and who speaks, because of this, "not all regions of discourse are equally open and penetrable, some are highly prohibited (differentiated and differentiating), while others seem almost open to all winds and placed, without prior restriction, at the disposal of each subject who speaks)." (Foucault, 1996, p.37).

Although the discussion about parrhesia (or parrhesia) is linked to the phase that corresponds to the last Foucault, it certainly cannot be thought of without contrast with the rarefaction of the subject, because they seem to be opposite sides of the same coin, both are forms of social control and we all know well that, in a society like ours, "one does not have the right to say everything, that one cannot speak about everything in any circumstance, that anyone, in short, cannot speak about anything." (Foucault, 1996, p.9). But what about parrhesia? Under what circumstances could one speak frankly to someone in a society like the one in which the Hellenic culture took place?

In The Government of Oneself and Others, a course that Foucault taught at the Collège de France between 1982 and 1983, parrhesia appears, initially, in the discussion about the constitution of the subject's ways of being based on the practices of the self that took place during the 1st century AD, still in Antiquity; therefore, Foucault encountered parrhesia at the moment he posed the question of the government of self and others. On that occasion, he stated that "I would like to try to see how truth-telling, the obligation and the possibility of telling the truth in government procedures can show how the individual constitutes himself as a subject in the relationship with

himself and in the relationship with the others." (Foucault, 2010, p. 42). The Greek word parrhesia is originally used in the sense of "'saying everything', but in fact it is translated, much more often, as free speech, freedom of speech, etc." (Foucault, 2010, p. 42). In this case, the word parrhesia means "a virtue, duty and technique that we must find in the one who directs the conscience of others and helps them to constitute their relationship with themselves." (Foucault, 2010, p.43).

In practice, this virtue was one of the three criteria, necessary and sufficient, to construct and characterize what Hellenic culture had as something that each man should observe in life in order to relate to himself and to others. So, it was necessary to respect: a man of age, a man of good reputation and a man of parrhesia, because those were the three criteria. Parrhesia, as Foucault demonstrates, had an important place in Hellenic culture in the first century AD, because it was associated with truth. It was, through parrhesia, that everything could be said, frankly, and old men, with a good reputation, also had to be men of parrhesia. Truth and parrhesia were part of the Greek world, of everyday life, as the government of oneself and others went through parrhesia. Finally, in this society, what today translates as speaking frankly, was, "in any case, saying all the necessary truth, and saying it in a certain way that is precisely parrhesia" (Foucault, 2010 p.43).

As can be seen so far, Foucault managed to find a series of reflections on the effects of classical rhetoric on Western culture, as we said before, that is, there are concrete examples that can help in new fronts of work that emerge in contemporary times, especially in what concerns refers to discursive materialities such as those of the pictographic world (paintings, graphics, moving images, etc.).In the New Rhetoric, as we will see later, there is an update of the theoretical discussions initiated by Aristotle and carried out by the Belgian school. This space is certainly not enough to point out all the possibilities within pragmatic rhetoric, but the discussion is provocative.

IV. THE THEORY OF ARGUMENTATION IN CONTEMPORARY TIMES: AN OPENING TO DIALOGUE

The considerations we have just made regarding the emergence of pragmatic rhetoric, which we find in Foucault, are in charge of contributing to the discussion that has been made by New Rhetoric, initially presented by Chaïm Perelman in collaboration with Lucie Olbretchts-Tyteca. This New Rhetoric, contemporary with Foucault, appears precisely in 1948 with Perelman's research undertaken with Olbretchts-Tyteca. In the following decade, the results of this research reached the world with the publication of Treatise on Argumentation: the new rhetoric, a work preceded by Rhetoric and Philosophy: for a theory of argumentation in philosophy. As the title of the founding work of this New Rhetoric makes evident, the research carried out by Perelman and Olbretchts-Tyteca focuses on questions linked to argumentation.

The rediscovery of classical rhetoric in our present, by these researchers, gave rise to new questions resulting from the careful reading carried out, above all, on the work of Aristotle, who is considered the father of the theory of argumentation. In other words, the reflections coined by Aristotle on argumentation are the main link between classical rhetoric and contemporary rhetoric that drastically opposes the Cartesian tradition, based on the formulation of logical reasoning and carried out by neopositivists.

The New Rhetoric conceives of argumentation, which is at the center of its interests, as something linked to the adherence (acceptance) of whoever occupies the role of interlocutor. Without this adherence there can be no argumentation, since it presupposes dialogue, its necessary condition of existence. For this reason, these authors dedicate themselves to the study of discursive techniques that allow the provocation or invitation of minds to adhere to the theses that are presented for their assent. It is from these studies that the notion of audience appears as a key concept to express this adherence on the part of those who appear as possible interlocutors, which configures the need for an audience so that arguments can be made. Contrary to such adherence, violence appears as the term that expresses this opposition to adherence through consensus and understanding, that is, this violence occurs because the necessary audience for argumentation cannot be obtained. These two concepts synthesize, in a way, this theory of argumentation spread by this New Rhetoric which, alongside this pragmatic rhetoric that we find in Foucault, can appear as another means of reflecting on who we are who use language that expresses what we do, do we think?

V. CONCLUSION

Throughout this discussion, we sought to find, in Foucault's work, some elements that demonstrate the emergence of a pragmatic rhetoric, with which we can verify the effects of classical rhetoric on Western culture. In other words, this study compactly presents an initial discussion that aims to contribute to the new discussions that the New Rhetoric brings from the second half of the 20th century. Therefore, this pragmatic rhetoric that emerges from the undertakings carried out by Foucault invites us to perceive the rarefaction of the subject and

discourse, that is, with it we can reflect on the way in which institutions act on us, controlling discursive practices and who puts them into practice. In practice. The issue of parrhesia is also part of this pragmatic rhetoric, although many consider parrhesia to be an anti-rhetorical expression. In short, here we sought to present only a part of this perspective on the emergence of such pragmatic rhetoric; it is a demonstration of the flavor it can provide to those who dare to taste it and follow the opening that this discussion has raised. The work from now on is to organize all this information around this emerging pragmatic rhetoric to give it the contours of this project that we present in this discussion in this draft phase so that it meets this demand that intends to answer a series of new questions that may arise. of work.

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Food Supplementation for Beef Cattle Raised on Pasture in the North of Minas Gerais

Gilmar Antunes Saude Neto, Iara Alves de Sousa, Jackeline Freitas da Silva, Letícia Campos Santos, Daniel Rodrigues Silva, Maria Eduarda Lima da Silva, Tauan Bremer Ramalho, Vania Graça Santos, Vinícius Nascimento Santos, Wagner Mendes Rodrigues

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***Abstract*—** *Brazil stands out for having the second largest cattle herd in the world, close to 208 million heads. Supplementation of pastured animals is an area of great interest in veterinary training. This is because food is one of the main factors that influence the productivity and health of animals, and nutritional supplementation is an important strategy to ensure the supply of adequate and sufficient nutrients to meet the animals' needs. If supplementation is not carried out properly, there may be an imbalance in the animals' diet, leading to health problems and reduced performance. Therefore, this work presents the problem question: What is the best food supplement for beef cattle? This work aims to describe the effects of supplementation on beef cattle in the pasture system. Analyze what the national beef cattle industry is like. Address the effect of supplementation on the performance of beef cattle in a pasture system. Identify supplementation during the rainy season, as well as its causes and effects. Explain pasture supplementation strategies for beef cattle. This is a methodology carried out through a bibliographic review of qualitative literature research. With a questionnaire applied to producers who visit the 26th Expoagro de Nanuque in September 2023.*

I. INTRODUCTION

Brazil stands out for having the second largest cattle herd in the world, close to 208 million heads, occupying a pasture area of 169 million hectares with a stocking rate of 1.23 heads and an annual slaughter of 43.3 million. of heads, of which 90.7% are on pasture and 9.3% in confinement, obtaining an annual production of 10.2 million tons of meat equivalent to the carcass, with 80.9% of production destined for the domestic market and 19 .6% to exports (ABIEC, 2013).

This work is justified in showing that the supplementation of animals on pasture is an area of great interest in the training of veterinarians. This is because food is one of the main factors that influence the productivity and health of animals, and nutritional supplementation is an important strategy to ensure the supply of adequate and sufficient nutrients to meet the animals' needs.

Supplementation of pasture animals aims to correct pasture nutritional deficiencies, increase pasture support capacity, increase body weight, reduce slaughter age, assist in pasture management and provide additives or growth promoters (REIS; MELO; BERTIPAGLIA, 2005).

If supplementation is not carried out properly, there may be an imbalance in the animals' diet, leading to health problems and reduced performance. The production of concentrated foods for food supplementation can generate environmental impacts, such as deforestation, intensive use of natural resources and gases. Therefore, it is essential to carry out a careful analysis of the benefits and risks before deciding on dietary supplementation for grass-

fed beef cattle, and seek guidance from a professional specialized in the area. Therefore, this work presents the problem question: What is the best food supplement for beef cattle?

Therefore, the main function of the digestive system is to digest and absorb food and excrete products that are not used by the body. The gastrointestinal tract consists of the mouth, pharynx, esophagus, stomach, small intestine (duodenum, jejunum and ileum), large intestine (cecum, colon and rectum) and anus, as well as accessory glands (saliva, pancreas and liver) (SILVA; LEÃO , 1979).

The digestive tract of ruminants has undergone some changes due to evolution, and this change is mainly due to the type of diet these animals eat, which is based on foods with a high fiber content. Changes in the gastrointestinal tract of ruminants begin in the mouth, as these animals do not have upper incisors, and the cow's tongue acts as a plunger, grabbing the food and transporting it into the mouth (KÖNIG; LIEBICH, 2016).

The motor function of the gastrointestinal tract is an important process related to digestion and absorption of nutrients. The walls at all levels of the gastrointestinal tract are muscular and capable of movement. The movement is called agency. The time it takes for a substance to pass from one part of the gastrointestinal tract to another is called transit time. These movements have multiple functions: moving food from one portion to the next; retain ingested matter in certain segments for digestion and absorption; physically breaking down food raw materials; mix the material with digestive secretions and facilitate the circulation of the substance ingestion so that all parts are in contact with the absorbent surface (CUNNINGHAN; KLEIN, 2008). Because this must promote continuous growth of grazing animals, there is a need for strategic supplements during the different seasons of the year, which provide limiting nutrients and increase the efficiency of pasture use (VALENTE, 2012).

Pasture supplementation strategies for beef cattle may vary according to local conditions, time of year and the stage of development of the animals. It is essential that supplementation is carried out appropriately, taking into account the quality of the supplements used and the way they are provided to the animals.

This work aims to describe the effects of supplementation on beef cattle in the pasture system. Analyze what the national beef cattle industry is like. Address the effect of supplementation on the performance of beef cattle in a pasture system. Identify supplementation during the rainy season, as well as its causes and effects. Explain pasture supplementation strategies for beef cattle.

This is a methodology carried out through a bibliographical review of qualitative literature research that allows the synthesis of various available research on dietary supplementation and directs practice based on scientific recognition.With the application of a questionnaire (Annex 1) to producers who visit the 26th Expoagro de Nanuque in September 2023.

II. BEEF LIVESTOCK

Beef livestock farming is a very important economic activity in Brazil, as it is one of the main sectors of the Brazilian agroindustry. Beef is one of the most consumed foods in the country and also an export product.

Brazil is one of the largest producers and exporters of beef in the world with an estimated herd of more than 220 million cattle. Beef production in Brazil is mainly based on pastures, which reduces animal profits due to livestock limitations. Therefore, the use of supplements is an alternative that allows zootechnical gains, generating greater profitability for the system (SENAR, 2018).

The Brazilian beef cattle production system consists of the breeding, reproduction and finishing phases. Mating can be defined as the final phase of weaning until the moment when, normally, females are used for reproduction (breeders) and males for production (fattening). One of the important characteristics of this phase is the animal's ability to gain efficiently, as it has a smaller allocation of energy consumed for maintenance, thus being able to allocate a greater amount to muscle and bone growth (MEDEIROS; ALMEIDA; LANNA, 2010).

More than 80% of the 220 million head of cattle are grazed. This increases the demand for more productive and resistant plants in the system, especially if more sustainable production is needed. Around 70% of Brazil's pastures are currently in decline, leading many to believe that the majority are not reaching their current production potential (MORCELLI, 2020).

III. PHYSIOLOGY

The movements of the digestive tract act on ingested food to perform the following functions: propel food along the digestive tract, hold food in place for digestion, absorption, or storage, facilitate the physical breakdown of food, and mix food with secretions digestive (OLIVEIRA, 2016).

Peristalsis of the gastrointestinal tract consists of the relaxation and contraction of the sphincter wall corresponding to the motility of the gastrointestinal tract, and the function of peristalsis is to crush, mix and break

down ingested food. The activity of smooth muscles in the digestive tract is initiated by intrinsic mechanisms located there. This mechanism determines the rhythm of contractions, with the exception of the anterior chamber of the stomach in ruminants, which is stimulated by nerves (RODRIGUES, 2018).

The digestive tract also has an endocrine regulatory system, and the gastrointestinal tract is the largest endocrine organ in the body. Endocrine cells are found in all tissues of the stomach, intestine and pancreas, and these cells synthesize and secrete hormones in response to stimuli (RODRIGUES; FONSECA; DAS NEVES, 2008).

IV. FOOD

Ruminants can use many types of foods in their diet. The fibrous carbohydrates stand out, making the animal easily identifiable. Microbes in the rumen are used to break down fiber. These fibers are important The importance of maintaining and continuing to maintain the health conditions of ruminants.

However, most go through a stage of low nutritional quality that does not meet the minimum requirements for animal production. Animals in the rearing phase are generally exposed to poorer quality pastures, especially during the dry season of the year, resulting in productivity below the national average per hectare per year. Supplementation should be considered as an alternative to supplementation to increase yield in farmed animals. on pasture (ABIEC, 2016).

4.1 PASTURE

Thus, seasonal changes in pasture characteristics strongly affect Brazilian beef cattle farming, especially pasture animals. During the dry season, forage production is significantly reduced, the aging of leaves and tillers is accelerated and tropical pastures, especially those kept under grazing, generally introduce low availability of good quality forage (EUCLIDES, 2000).

Around 80% of our fields today are made up of brachiaria, the majority being Brachiaria brizantha, cultivar (cv.) Marandu (Braquiarão). Brachiaria decumbens cv. Basilisks were introduced to Brazil in the early 1960s.

> It is a good option for sandy soils with low fertility, and can tolerate moderate acidity but is not particularly resistant to leaf attack. We have the genus Brachiaria humudícola cv. BRS Tupi is an alternative for humid areas with low to medium fertility. It is a high yield and fertility forage, has early flowering, dense clusters, long and narrow leaves and is well distributed throughout the year, guaranteeing an average performance superior to the regular variety (Quicuio) (MORCELLI, 2020, p.2).

The genus Panicum is increasingly used in this country. In general, productivity is high in DM/ha/year and the nutritional value is higher than that of Brachiaria. However, this makes soil fertility more demanding and makes it more difficult for farms to accommodate fluctuations in animal stock throughout the year, making the difference in productivity between the rainy and dry seasons even greater. The wing growth form (vertical septosis) promotes less soil coverage than other growth forms, such as brachial (squatting) and is not recommended for very steep areas (MORCELLI, 2020).

Colonião grass is the most famous variety of the Panicum genus, and one of the oldest, but still dominant in some areas. In the mid-1990s, Embrapa launched the Mombaça variety, which became very popular among breeders due to its higher leaf/stem ratio, high yield (up to 33 tons/ha) and low aging in the dry season (MORCELLI, 2020).

The use of forages under grazing is a very common alternative in the meat production scenario in Brazil, with grazing being the main source of raw material for the production of ruminants in tropical conditions (RESENDE; SIQUEIRA; OLIVEIRA, 2018).

In situations where grazing is ineffective in providing a certain level of production, complementary feeding is an opportunity for the producer to improve animal nutrition. Additives are used to promote lactation in young animals, improve reproduction and growth rate.

> Supplementing pastures with easily digestible forage can improve cattle performance by improving nitrogen absorption from forage in the rumen, increasing microbial protein production, increasing the production of digestible non-food protein in the rumen, and increasing propionate and propionate production. total. volatile fatty acids (HOOVER, 1986, p.2749).

The digestive system is the site of many problems in ruminants, especially those related to pre-gastric diseases and nausea. However, small intestinal obstructive disease occurs frequently and care must be taken to include it in the differential diagnosis of gastrointestinal

disorders that cause abdominal distension in cattle (REBHUN, 2000).

4.2 SUPPLEMENTATION

According to Pigurina (1993), there are specific benefits associated with dietary supplements: the ability to quickly take advantage of price conjunctions; short-term return on investment; almost immediate implementation; low relative costs; successful security.

The basic objective of concentrated feed supplements for grazing animals is to replenish the nutritional value of the pasture, thus increasing the efficiency of pasture use. Therefore, using dietary supplements, such as concentrates, during two seasons can correct specific nutritional deficiencies.

Supplementation is generally given at low levels to increase the availability of nutrients for ruminant microorganisms, improving the use of structural carbohydrates obtained from pasture resulting in better animal performance (CARDOSO; MACHADO; SCHUMACHER; FERNANDES; ANTUNES; SCHENKEL; RODRIGUES; BRONDANI, 2020). The use of supplements is a tool that improves the productive performance of cattle on pasture by providing nutrients not provided by pasture and is fundamental for the efficient conversion of forage into meat, being one of the main strategies to meet the demands of the animal protein market for ensure food security for the population.

Dietary supplementation in beef cattle in cattle feeding systems Pasture can be an important strategy to improve animal performance and increase meat production. Supplementation aims to provide additional nutrients that may be lacking in pasture, especially during periods of forage scarcity.

For Euclides (2005), in the case of pasture supplementation, it is important to meet the needs of the animals and complement the nutrients available in the pasture. Therefore, the nutritional value of the available forage must be supplemented to achieve the desired performance. However, for this to be adequate and effective, a good estimate of forage consumption and quality is necessary.

> In terms of food management, the pasture must have flat land, good water distribution, avoid an increase in maintenance energy and facilitate the acquisition and distribution of feed. To avoid competition between animals for supplements, provide troughs that allow simultaneous use, 40 to 50 cm/animal is recommended when concentrated feed is provided and 20 to 25 cm/animal is recommended for multimineral mixtures (EUCLIDES, 2005, p. 42).

Supplementing pastures with specific nutrients has been used as a way to improve animal performance, however, depending on the level of concentrate supply used, changes in consumption, nutrient digestibility and performance parameters (MATEUS; DA SILVA; ÍTAVO; PIRES ; SIVAR; SCHIO, 2011). Food supplementation for beef cattle during the dry season is an important strategy to maintain animal performance and avoid weight and productivity losses. During a dry season, forage availability can be reduced due to lack of rain and the resulting water stress on plants. Furthermore, the nutritional quality of the forage may be impaired, with low protein and energy levels.

4.2.1 PROTEINATE

A lack of adequate nutrients in the diet can lead to a series of health problems in animals, such as low immunity, reproductive problems and less weight gain. Food supplementation during the dry season aims to provide additional nutrients that may be lacking in the animals' diet, helping to maintain the animals' performance and productivity (MALAFAIA; PEIXOTO; GONÇALVES; MOREIRA; COSTA; CORREA, 2004).

According to Malafaia et al. (2004), there are three main types of supplements:

> 1.Protein Supplement: A mixture of urea and/or dietary protein plus sodium chloride (NaCl) and mineral salts. 2. Energy supplement: refers to the mixture of NaCl plus mineral salt and energy food. 3. Mixed or Multiple Multiple Supplement: Refers to the mixture of urea plus NaCl, mineral salts, energy food and protein food. In other words, 5 protein supplements + energy supplement. It is also a concentrated food with voluntary consumption regulators (MALAFAIA; PEIXOTO; GONÇALVES; MOREIRA; COSTA; CORREIA, 2004, p.160).

Providing protein supplements as a source of nitrogen during the dry water period leads to the proliferation of fiber-decomposing bacteria that use fibrous carbohydrates as substrates and ensures improved digestibility, voluntary consumption rate, rate of microbial protein synthesis and improved rate of microbial protein synthesis, thus improving the energy use of fibrous carbohydrates in feed (COSTA; MONTEIRO; SILVA, 2015).

For Quadros et al., (2016) protein supplementation alone is not enough to improve the animal's weight gain in this critical period of the year, as it only meets the animal's needs. Maintenance or at most small gains of less than 50 g/animal/day of daily gain when evaluating Nellore steers supplemented with protein salts in the dry period.

Therefore, it is interesting to use different mixtures as supplements during droughts, as such supplements can increase the consumption and digestibility of low-quality forage and the average daily gain exceeds 0.73 kg/animal/day. According to García et al. (2014) observed an increase in body weight of more than 0.700 kg when they provided protein-energy supplementation (0.8% of body weight) to crossbred bulls in a grazing system.

4.2.2 MINERAL

Mineral supplementation can represent 20% to 30% of the total production costs of grazing cattle. This highlights the economic importance of mineral supplementation and the adequate assessment of the herd's needs and requirements can help reduce feed costs (PEIXOTO; MALAFAIA; BARBOSA; TOKARNIA, 2005).

According to Teixeira et al., (2011) in cattle nutrition, minerals play an important role in the good development of the animal. These functions are essential for the perfect functioning of the body. Phosphorus performs many functions in the body. As Brazilian pastures, especially those in Central Brazil, are known to be deficient in this mineral, phosphate supplementation of pasture-raised cattle is essential for good agricultural performance.

Another important factor when talking about mineral supplementation is the antagonism between certain minerals. Depending on the amount and type of minerals contained in the mixture, it may inhibit the effects of another element or elements. An example of this antagonism is the use of iron sulfate in mineral mixtures. Iron sulfate reduces the absorption of phosphorus and copper in animals (PEIXOTO; MALAFAIA; BARBOSA; TOKARNIA, 2005).

Some minerals have shown surprising performance in supplementation, such as chromium chelate added to mineral supplements for Nelore cattle, resulting in greater weight gain and increased hot carcass yield (MOREIRA; LOURENÇO; POLIZEL NETO; HEINRICH; BERBER, 2012).

4.2.3 RATION

Feed balancing consists of providing sufficiently nutritious food that meets the animal's protein, energy, vitamin and mineral needs. Therefore, we face a number of challenges, including the importance of balance. If your diet is unbalanced, you have an excess and/or deficiency of certain nutrients.

> Some imbalances have serious consequences and, if left untreated, can even lead to the death of the animal (for example, a calcium imbalance at birth can cause milk fever and death of the animal if not treated immediately). Various Symptoms Are Observed In animals, it can help identify symptoms related to imbalances, especially vitamin and mineral deficiencies. However, other imbalances are difficult to identify as they result from some degree of performance loss. Cattle do not perform as well as their genetic potential would allow when there is an imbalance in the ration (SILVA, 2021, p. 7).

A balanced ration is the amount of food that provides the animal with a variety of nutrients in proportions corresponding to a specific daily production. Feed formulation therefore involves the integration of knowledge related to the animal's needs (for a specific production level), the nutritional properties of the feed and the expected costs/benefits (EMBRAPA, 1979).

Before proceeding with ration balancing, you need to have a clear idea of the type of animal you are feeding and the desired production level. Within the limits of this publication, abstinent beef cattle have only two functions in terms of nutritional requirements: maintenance of live weight and weight gain (EMBRAPA, 1979).

V. RESULTS AND DISCUSSIONS

The results obtained with the application of the online questionnaire my.survio.com, through a direct link, QR code or even WhatsApp, are sent to producers who visited the 26th Expoagro de Nanuque in September 2023. From producers who visited the expoagro and 55 people entered the online questionnaire, but in fact, 27 producers completed it and completed it until the end, with an average of 49.1% and the counterpart to 28 producers who did not complete the questionnaire.

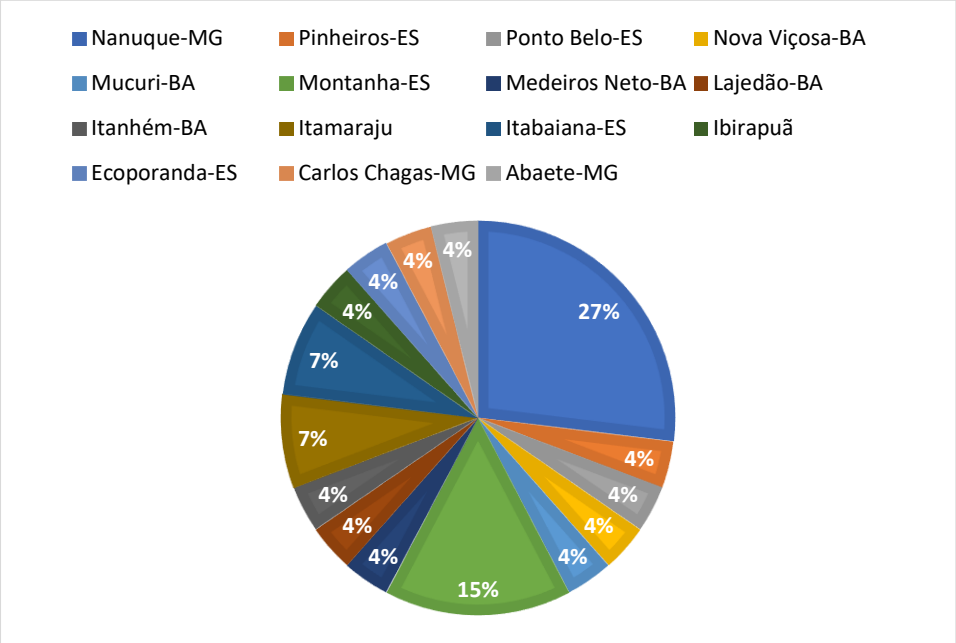
Planning and controlling feeding in grazing systems is an important issue to achieve efficiency, increase performance and reduce risks. To this end, pasture management practices and additives for livestock feed are sources that can be used as tools for such planning (PEREIRA; REIS; BERCHIELLI; BERTIPAGLIAS; MELO, 2008).

Food supplements have an impact on the sustainability of beef cattle production systems, especially in central Brazil. This is due to the strong seasonality of livestock farming in the region, with plant growth greatly reduced during the dry season. Water is obviously the most limiting growth factor, but shorter photoperiods and cooler temperatures also limit forage availability (GOMES; NUÑEZ; MARINO; MEDEIROS, 2015).

Adding drive wheels during the rainy season can help with pasture management, resulting in better nutrient utilization, more efficient use of feed and improved animal performance. Concentrated supplements generally reduce feed intake, especially if they have similar nutritional properties to pastures. Under conditions of high substitution effect, overcrowding occurs, therefore the number of animals needs to be adjusted according to the available stock, which can be done using management criteria based on height (REIS; BARBERO; KOSCHECK, 2014).

Several producers visited the 26th Expoagro de Nanuque in September 2023, which is an agricultural exhibition, bringing together producers, exhibitors and the entire region. the objective of promoting agriculture, livestock, agroindustry and rural development. This event includes animal exhibitions, competitions, auctions, agricultural company stands, shows, lectures and other activities related to the agricultural sector. Many producers participated, where 27% of participants are from the municipality of Nanuque-MG, 15% are from the municipality of Montanha-ES, Itamaraju-BA and Medeiros Neto-BA with the participation of 14% of producers, other municipalities that participated in expoagro boa part came from Bahia and Espírito Santo as we will see in graph 1.

Graphic 1-Municipality and State of the property.



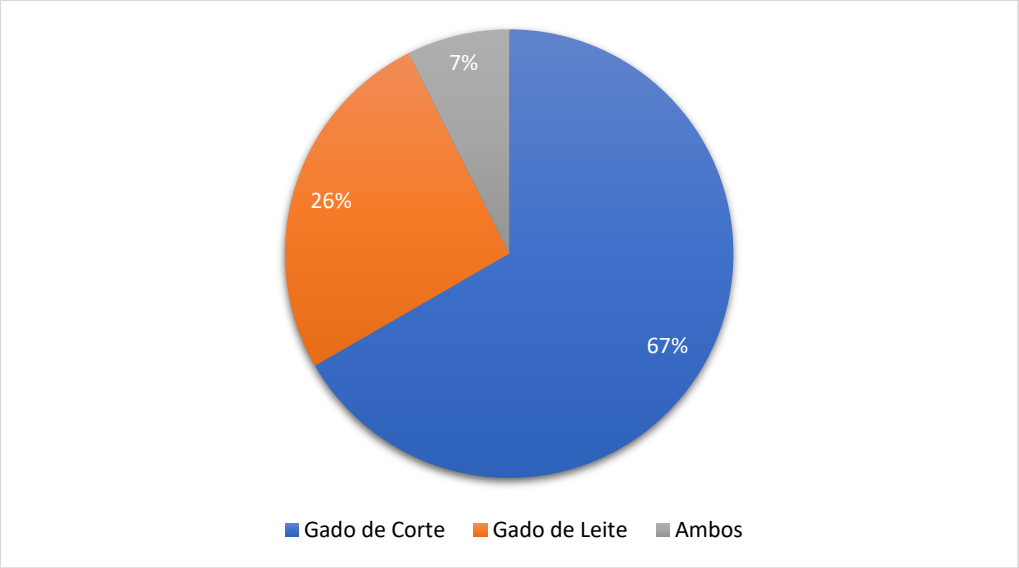
Source: Prepared by the author.

According to Marion (2007), livestock farming consists of the "art of raising and caring for livestock", and among some agricultural activities, livestock farming or livestock farming is one of the main aspects of Brazilian agricultural businesses and is commonly practiced. It is used for milk (dairy) or meat (livestock) purposes.

There are two main categories of livestock production: beef cattle and dairy cattle. Each of these categories involves different breeding systems and production objectives.

Beef cattle production is vital for Brazil, which has the largest commercial cattle herd in the world. According to the Brazilian Institute of Geography and Statistics (IBGE), there are approximately 209 million cattle, a result of poor nutrition, sanitation problems, inefficient management and low genetic potential of the animals (PORTAL BRASIL, 2015).

Graph 2- What type of production?



Source: Prepared by the author.

The expoagro producers, when asked about the production of their farms, are 67% have beef cattle, 28% of the producers have dairy cattle and 7% of them have beef and milk as we saw in graph 2. According to Lazzarini Neto (2000), " There is no other activity in this area, which has potential for growth, income generation and foreign exchange, like beef production". For Euclides Filho (2008), beef cattle production encompasses a set of technical and management practices, types of animals, breeding purpose, race or ethnicity and ecological region in which the activity takes place.

Table 1-Use of mineral salt.

Mineral Salt	Whole year	Dry	Water	Do not use
Whole herd	22	two	1	1
Matrices	11	3	0	1
Rebreeding of Males	14	0	1	1
Rearing of Females	13	two	0	1
Male termination	12	0	0	3
Termination of females	8	two	0	4

Source: Prepared by the author.

In table 1 we see that 22 producers add mineral salt supplements to their herd throughout the year. Because complementation is a practice that can be integrated systematically or structurally into the management of a business, or can be seen as a situational solution for certain situations. From a safety perspective, replenishment can continue production in the case of "abnormal" deficits, the frequency of which is unpredictable. In emergencies, replenish preservation or maintenance. To increase yields, supplements are used during "normal" times when forage is scarce, which is repeated seasonally every year. In production systems that operate at very high capacities, shortages are exacerbated during normal and abnormal periods (ROCHA, 2020).

Supplementation has indirect side effects: better management of pastures grazed by supplementary animals; possibility of using more appropriate capacity for other categories; maximum relative load that the pot can support and replenishment, possibility of timely purchase and appreciation of acquired kilograms (LANGE, 1980).

Therefore, mineral salt containing urea is an additional and low-investment alternative in dry conditions. The objective is to maintain the animal's body weight during this period. Food availability must be good, even if

it is of poor quality. The recommended application rate is approximately 100 g/PV, with approximately 30% of this amount being urea. A linear trough of at least 6 cm per animal is recommended (GOMES; NUÑEZ; MARINO; MEDEIROS, 2015).

Table 2-Use of white salt.

White Salt	Whole year	Dry	Water	Do not use
Whole herd	12	1	0	11
Matrices	6	two	0	5
Rebreeding of Males	8	1	0	5
Rearing of Females	6	two	0	5
Male termination	6	1	1	5
Termination of females	3	two	0	7

Source: Prepared by the author.

According to table 2, many producers use white salt throughout the year in their herd.In this scenario, the use of supplements concentrated in both drought and water can correct specific nutritional deficiencies in the feed to maximize utilization by rumen microorganisms and increase weight gain (REIS; RUGGIERI; OLIVEIRA; AZENHA; CASAGRANDE, 2012).

Table 3-Use of protein.

Protein	Whole year	Dry	Water	Do not use
Whole herd	8	12	0	5
Matrices	9	1	0	4
Rebreeding of Males	7	3	0	4
Rearing of Females	7	two	0	5
Male termination	11	two	0	1
Termination of females	7	two	0	4

Source: Prepared by the author.

Protein is more expensive than salt containing urea, but it is more economically practical because it is supplied in small quantities (1 to 2 g/kg) per animal. The recommended linear trough for protein delivery is 12 to 15 cm per animal. Filling the trough with proteins should be done as frequently as possible within the limits of each organ.

The ideal frequency will depend on local conditions, including labor costs, availability, distance from pastures, and animal utilization patterns. However, it is not recommended to leave more than a week between filling the water tank. In fact, one of the biggest challenges when using protein products is keeping your intake restricted. flat. Sometimes identical protein products come from the same farm, the same pasture and the same batch, resulting in differences in consumption. Therefore, it is recommended to determine the frequency of filling the trough and monitor consumption to achieve the planned consumption and know exactly the financial cost of the additives (GOMES; NUÑEZ; MARINO; MEDEIROS, 2015, p.67).

Table 4-Use of 18% CP feed.

Protein	Whole year	Dry	Water	Do not use
Whole herd	11	1	0	10
Matrices	4	two	0	8
Rebreeding of Males	4	4	0	7

Rearing of Females	5	1	0	8
Male termination	7	1	0	4
Termination of females	6	1	0	6

Source: Prepared by the author.

The total amount of food an animal consumes in a 24-hour period. For the purpose of product registration under the terms of Normative Ordinance 13/2004 of the Ministry of Agriculture; Livestock and Feed – MAPA, Feed is a mixture of ingredients and additives intended for livestock feed and represents the final product. be available and able to meet the nutritional needs of the target animal; It is a brittle and homogeneous food mixture with a moisture content of less than 13%. Its composition must include 18-20% crude protein (CP) and approximately 70% total digestible nutrients (TDN) (BRASIL, 2004).

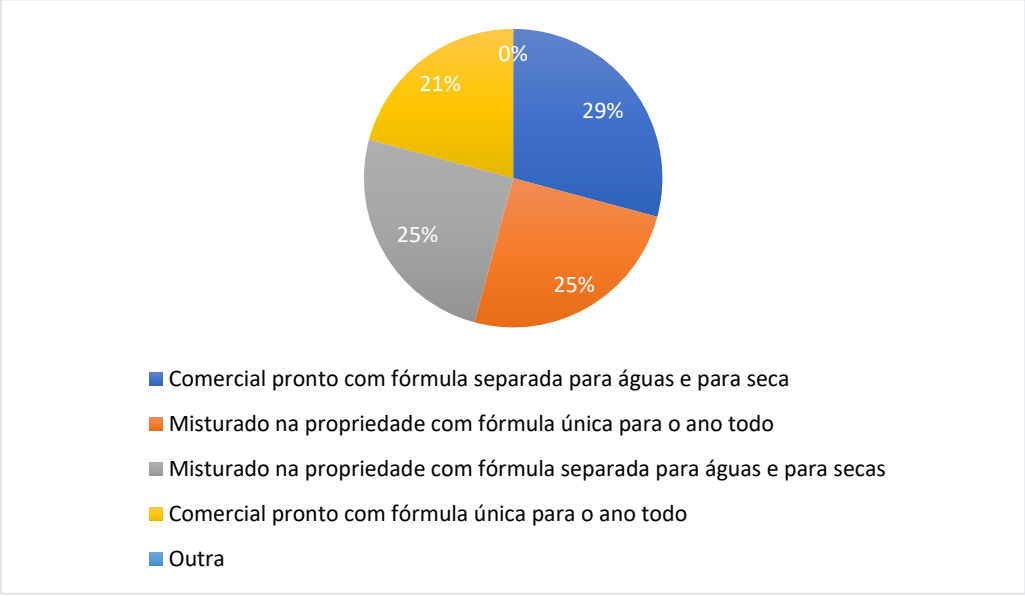
Table 5-Use of 20% CP feed.

Protein	Whole year	Dry	Water	Do not use
Whole herd	6	3	0	14
Matrices	1	3	0	9
Rebreeding of Males	1	two	0	9
Rearing of Females	3	two	0	8
Male termination	4	3	0	7
Termination of females	3	4	0	6

Source: Prepared by the author.

The total amount of food that an animal must consume in a 24-hour period to cover its nutritional needs. In fact, it is the amount of feed calculated to cover the nutrients needed for maintenance and production. H. Depending on the category of animals, they are at different stages of life. A balanced diet contains all the nutrients an animal needs to satisfy its specific physiological needs and must cover its nutritional needs from a quantitative and qualitative perspective. A balanced diet is usually prepared for a group of animals with similar needs (SALMAN, 2011).

Graph 3- Mineral salt. What is the source of the supplement?



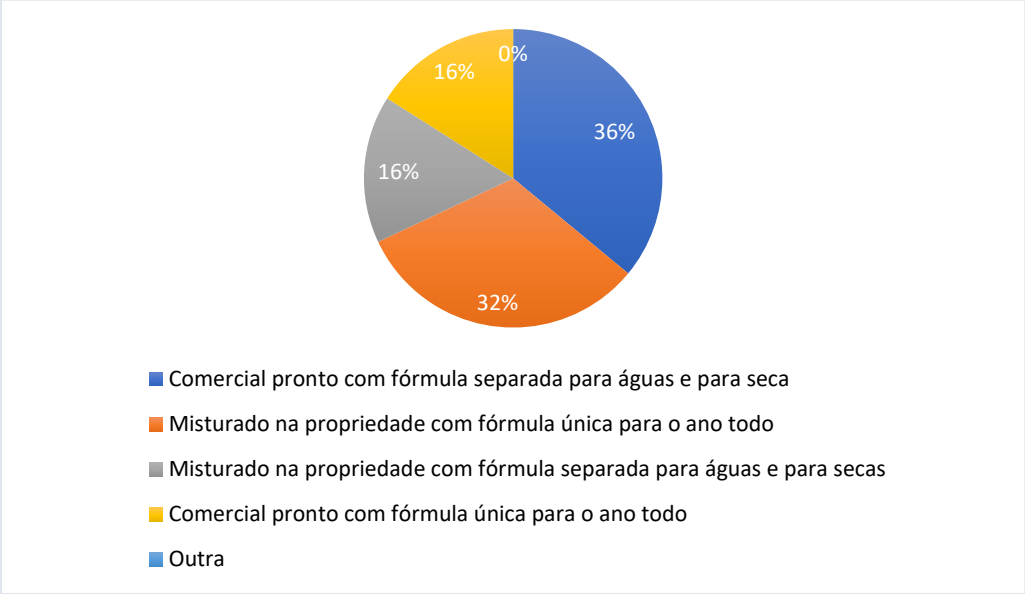
Source: Prepared by the author.

Mineral supplementation in cattle herds is known worldwide for its importance and is considered a fundamental aspect for the development of livestock farming, but it is also a necessary and viable practice from a productive and practical point of view.

> Despite being recognized as such, it has almost always been left in the background. It looks economical too. Therefore, efficient pasture-based livestock production can only be achieved with the help of nutritional strategies and high-quality products to reduce the negative effects of annual climate change (SEVERINO, 2018, p.12).

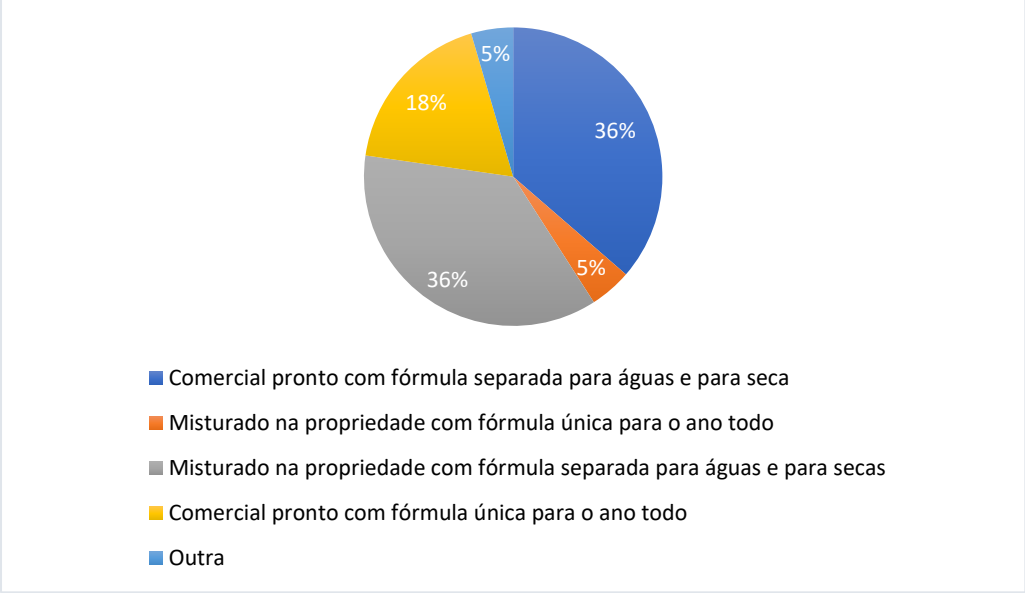
One of the most important points is the absorption of mineral salts by animals. This must be done in accordance with the manufacturer's recommendations. Recommendations vary depending on the type of food, soil fertility and fertilization, season, amount of salt in the water and reception conditions. Supplementary Content and Access/Location (AGROQUIMA, 2023).

Graph 4-Protein. What is the source of the supplement?



Source: Prepared by the author.

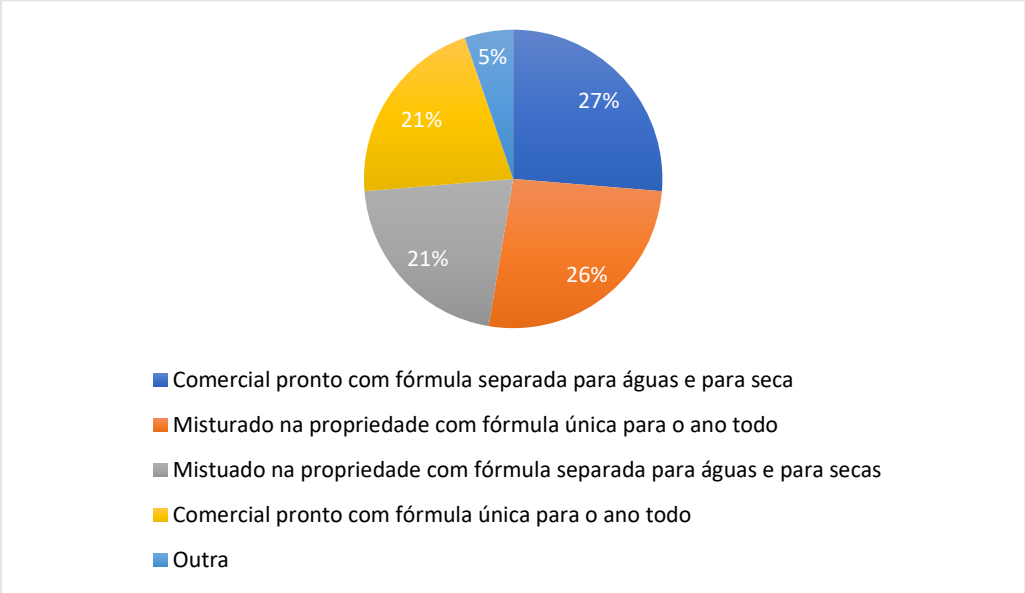
Graph 5-Feed 18% CP. What is the source of the supplement?



Source: Prepared by the author.

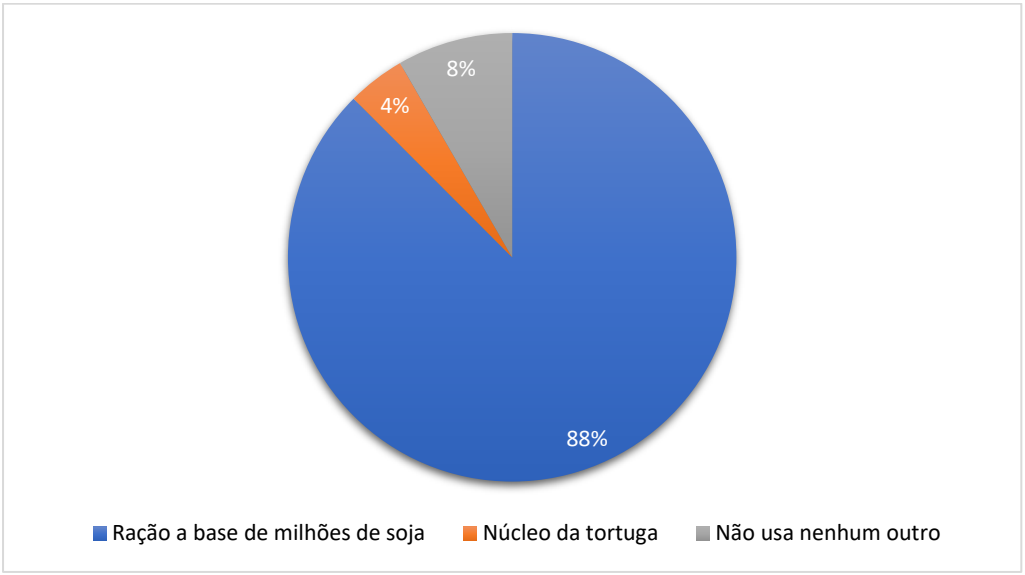
Feeds must be balanced using the cheapest ingredients possible to avoid a significant impact on the final cost. To compare available foods and use more, cheaper foods, it is necessary to know the relationship between the nutritional value or kg of nutrients and the price of the available foods. The food contained in the feed must be in good sanitary condition. It must not be subjected to undesirable fermentations or other changes that put the animal's health at risk. Furthermore, weevils, moths and other insects, not to mention rat urine, cannot attack stored grain. Contains leptospirosis, which transmits leptospirosis to animals and humans (SALMAN, 2011).

Graph 6-20% CP feed. What is the source of the supplement?



Source: Prepared by the author.

Graph 7- Another supplement?



Source: Prepared by the author.

According to graph 7, 88% of producers use the breed based on millions of soybeans, 8% use the tortuga nucleus, 4% do not use any other type of supplement.

Food should be as homogeneous as possible to prevent animals from selecting and consuming the most tolerated components. The food must be prepared properly so that the animal can eat and enjoy it easily. To avoid fermentation and the associated gastrointestinal discomfort

in the animal, it is necessary to remove the waste left by the animal in the manger overnight (SALMAN, 2011).

VI. CONCLUSIONS

The types of supplements used during the dry season may vary, depending on the nutritional needs of the animals and the forage characteristics available. Protein, energy and mineral supplements can be used, as well as concentrated foods such as corn, soy and cottonseed meal.

The effects of supplementation during the dry season include increasing weight gain, maintaining productivity and meat quality, and reducing costs with medicines and veterinary treatments. However, it is important to remember that supplementation must be carried out appropriately, taking into account the nutritional needs of the animals and the quality of the supplements used.

Furthermore, it is essential that supplementation is combined with other management practices, such as pasture rotation, pest and disease control and adequate herd management. Only in this way will it be possible to guarantee good animal performance and quality meat production during the dry season.

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ANNEXURE 1

Questionnaire applied to rural property owners. The data will be used to prepare a Scientific Article required to obtain a Bachelor's degree in Veterinary Medicine, at the UNEC Campus in Nanuque/MG.

County:_____

State:_____

Production: ☐Dairy cattle☐Beef cattle☐Both☐Others:_____

Type of Supplement	Whole herd	Only Matrices	Only Recreating Males	Only female breeding	Only male termination	Only Termination of Females
Mineral	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use

Protei-nado	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use
Feed 18% CP	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use
20% CP feed	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use
Other:___ _____ _____	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use	☐Whole year ☐Dry ☐Water ☐Do not use

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Characterization of hydropluviometric variability in the lower valley of the Ouémé

Caractérisation de la variabilité hydropluviométrique dans la basse vallée de l'Ouémé

AZIAN Déhalé Donatien[1], KOUMASSI D. Hervé[1,2], VISSIN Expédit W[2]

[1]Laboratoire de géographie rurale et d'Expertises Agricole /Universite d'Abomey Calavi (LAGREA/UAC)
[2]Laboratoire Pierre PAGNEY : Climats, Eau, Ecosystèmes et Développement, Université d'Abomey-Calavi 03 BP 1122 Jéricho, Cotonou 03 (Rép. Du Bénin)

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***Abstract*—** *Over the past 30 years, West Africa has been hit by climate variability. This variability affects the activities of the poorest populations. This situation makes communities vulnerable to the effects of climate change. The aim of the present study is to characterize hydroclimatic variability in the lower Ouémé valley. To achieve this, rainfall and flow records from the Bonou station were collected over the period 1986-2016. These data, obtained from the national meteorological agency and the Direction Générale de l'Eau, were processed and filled in. Statistical protocols were used to determine the characteristic elements of hydro-climatic variability in the environment. The pettitt test was used to determine any breaks in rainfall and flow rates. Analysis of the results revealed an uneven distribution of rainfall. Three phases were identified in the evolution of rainfall. The first, 1987-1990, was marked by rainfall surpluses. The second is characterized by rainfall deficits between 1990 and 2006, and the last (2006-2016) by very unstable rainfall trends. Application of the Pettitt test to this time series revealed a break in stationarity at the 95% threshold, highlighting two sub-periods, 1987-2006 and 2007-2016. This drop in rainfall leads to a drop in surface runoff, with values ranging from 0.2% to 1% in the Ouémé valley.*

***Keywords*— Characterization, hydro-rainfall variability, lower valley, Ouémé**

***Résumé*—** *L'Afrique de l'ouest est frappée ces 30 dernières années par la variabilité climatique. Cette variabilité affecte les activités des populations sur les plus pauvres. Cette situation rend les communautés vulnérables aux effets des changements climatiques. L'objectif de la présente étude est de caractériser la variabilité hydroclimatiques dans la basse vallée de l'Ouémé. Pour y parvenir, les chroniques de pluie et de débits de la station de Bonou ont été collectées sur la période 1986-2016. Ces données obtenues à l'agence de météologie nationale et à la direction Générale de l'Eau, ont été traité et comblées. Les protocoles statistiques ont été utilisé pour déterminer les éléments caractéristiques de la*

variabilité hydro climatiques dans le milieu. Le test de pettitt a été utilisé pour déterminer les éventuelles ruptures dans les hauteurs de pluie et de débit. De l'analyse des résultats, il ressort qu'il a une inégale répartition des précipitations. Trois phases ont été identifiées dans l'évolution de la pluviométrie. La première 1987-1990 est marquée par des excédents pluviométriques. La seconde est caractérisée par des déficits pluviométriques entre la période 1990-2006 et la dernière (2006-2016) caractérisée par une très forte instabilité dans l'évolution de la pluviométrie. L'application du test de Pettitt à cette série chronologique a mis en évidence une rupture de stationnarité au seuil de 95 % mettant ainsi en exergue deux sous périodes, 1987- 2006 et 2007 -2016. Cette baisse pluviométrique induit une baisse de l'écoulement superficiel dont les valeurs oscillent entre 0,2 et 1 % dans la vallée de l'Ouémé.

***Motsclés*— Caractérisation, variabilité hydro pluviométrique, basse vallée, Ouémé**

I. INTRODUCTION

Depuis plus de 30 ans, l'Afrique de l'Ouest doit faire face à un phénomène de variabilité climatique sans précédent à l'échelle historique. Les problèmes liés aux changements climatiques occupent une importante place parmi les préoccupations majeures de notre siècle (Ouedraogo, M, 2001, p. 15). En effet, cette baisse pluviométrique amorcée dans les pays du golfe de Guinée dès la fin des années 1960 s'est intensifiée au cours des années 1980 et 1990, avant de connaître une certaine rémission durant les années 2000.

En Afrique subsaharienne, les dernières décennies de la fin du deuxième millénaire ont été marquées par une évolution rapide des climats (Nicholson et al., 1998, p. 15; Ogouwalé, 2006, p. 42). Les recherches effectuées par (Olivry . C, 1983, p. 28) et (Sircoulon, 1990, p. 16), indiquent une diminution des précipitations en Afrique. Cette tendance est qualifiée de ‘’nouvelle phase climatique’’ ou encore de ‘’rupture climatique’’ par (Carbonnel et Hubert, 1992, p. 16). La région ouest-africaine a connu une récession pluviométrique aux ampleurs parfois très accusées, doublée d'une augmentation significative du nombre d'années sèches (Sircoulon, 1990, p. 15).

Celle-ci se manifeste, en particulier, par une modification du régime des précipitations et par une diminution des hauteurs annuelles. Cette récession pluviométrique induit des variations des dates de début, de fin et de durée des saisons pluvieuses (Noufé D. et al., 2015, p. 1). Celle-ci a des conséquences importantes sur la vie des populations. La variabilité climatique étant une contrainte pour le développement agricole, les politiques publiques de lutte sont l'ensemble des moyens et stratégies mobilisés par les pouvoirs publics pour en limiter les effets à défaut de l'éliminer. Les effets de la variabilité du climat et du changement climatique sont potentiellement plus importants pour la population pauvre des pays en voie de développement que pour celle des pays nantis. La vulnérabilité aux impacts du changement climatique est une fonction de l'exposition aux variables climatiques, de la sensibilité à ces variables et de la capacité d'adaptation de la communauté touchée. Souvent, la subsistance de la population pauvre dépend des activités économiques qui sont sensibles au climat (Brou Y. et al., 2005, p. 12). La variabilité du climat peut entraîner des bouleversements brusques tels qu'une inondation, une sécheresse ou une tempête tropicale. Ces bouleversements peuvent faire beaucoup de dommages à l'économie d'un pays si une partie importante de l'activité économique est sensible aux conditions météorologiques et au climat (USAID, 2007, p. 7). Au Bénin, la production agricole, essentiellement pluviale, reste sensible et vulnérable à la variabilité des paramètres climatiques observée ces dernières décennies. Face à ce phénomène, des solutions et des mesures d'adaptation efficaces doivent être trouvées. La mise en place des stratégies d'adaptation efficaces nécessite la connaissance préalable des caractéristiques des phénomènes climatiques. Dans cette optique que la présente recherche vise à caractériser la variabilité hydro climatique dans la basse vallée de l'Ouémé.

II. MILIEU D'ETUDE

La basse vallée de l'ouéme est une vaste zone humide constituée des fleuve Ouémé et de la plaine d'inondation de la rivière Sô. Elle couvre une superficie estimée à plus de 974 km² et est située entre 6°25'06'' et 6°62'47'' de latitude nord et entre 1°60'37'' et 2°40'46'' de longitude est (figure 1).

Le paysage est façonné par l'alternance des hautes et basses eaux, les crues et décrues du fleuve Ouémé occupant la basse vallée du fleuve Ouémé (510 km) et le delta de la rivière Sô (84,4 km). Les sédiments charriés par les crues

de l'hivernage venues depuis le nord du pays, viennent enrichir le milieu et favorisent sa productivité biologique (Colombani J. et al., 1972, p. 125).

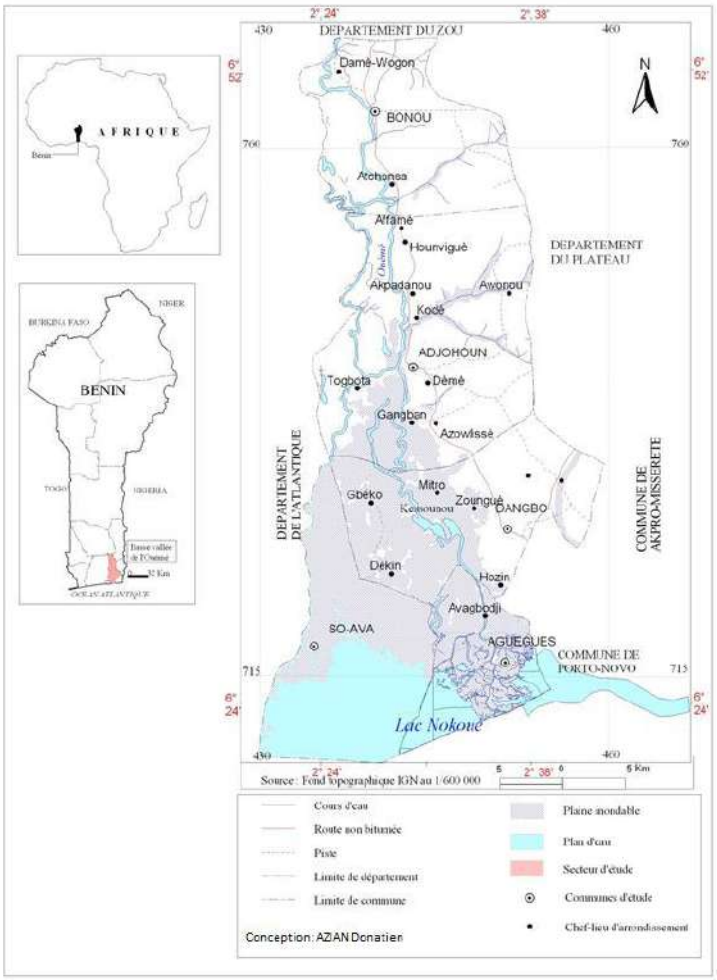

Fig.1:Situation administratif de la basse vallée de l'Ouémé

Sur le plan administratif, la basse vallée, du sud vers le nord est composée des communes de So-Ava, des Aguégués, de Dangbo, d'Adjohoun et de Bonou auxquelles il faut ajouter les rives orientales des agglomérations littorales de Zè, Zinvié et Abomey-Calavi qui totalisent une population de plus de 263 576 habitants (RGPH 3, 2002) avec des densités relativement élevées, entre 200 et 450 habitants au kilomètre carré (INSAE, 2004).

Sur le plan planimétrique, le milieu d'étude comprend une plaine alluviale large en moyenne de 20 km et étalée sur une soixantaine de kilomètres. Inscrite dans les plateaux du Sud Bénin, c'est une vaste dépression humide avec une superficie cultivable estimée à 74 930 ha (Adam, 1996) dans laquelle se sont installées de nombreuses populations.

La basse vallée de l'Ouémé est soumise à un climat de type subéquatoriale avec un régime à quatre saisons : une grande saison des pluies de mars à juin (4 mois), une petite saison sèche de juillet à août (2 mois), une petite saison des pluies commençant en septembre et s'achevant en octobre (2 mois) et une grande saison sèche du mois de novembre à février (4 mois). Il est caractérisé par des précipitations moyennes annuelles (1951-2000) variant entre 1200 mm et 1600 mm (Adam S. & Boko M., 1983, p. 13). La distribution spatiale des pluies mensuelles suit globalement un gradient décroissant Sud/ Nord d'octobre à juin. Au cours de cette période, les pluies les plus importantes sont enregistrées dans le sud de la basse vallée de l'Ouémé. À partir du mois de juillet, le gradient s'inverse (gradient croissant sud-est / nord-ouest). Les valeurs les plus fortes sont enregistrées en ce moment dans le Nord. L'analyse des valeurs moyennes fait apparaître une inégalité dans la distribution spatiale de la pluviométrie sur chacune des stations de Bonou et d'Adjohoun et entre les deux stations opérationnelles de la basse vallée de l'Ouémé.

Le système hydrographique de la basse vallée de l'Ouémé est constitué de :

- Fleuve ouémé est le principal cours d'eau du milieu d'étude ;
- la rivière Sô prend sa naissance dans la dépression de la Lama, draine la partie Sud du plateau d'Abomey ;
- la rivière Sissè d'une longueur de 7,5 Km environ, prend sa source à Sissè-Kpa, localité située à 1 Km environ du nord d'Azowlissè ;
- La rivière Tovè longue de 5 Km environ, elle prend sa source dans le village de Sôro au Nord-Est de Gouti ;
- Le lac Hounhoun est situé à 0,5 Km à l'ouest d'Adjohoun en bordure du plateau sur la rive droite de l'Ouémé. Sa superficie est de 20,5 ha environ en période de basses eaux ;
- Le lac Hondjè est situé près du village d'Aglangbin à 7 Km environ à l'ouest d'Affamè. Sa superficie est estimée à 20 ha ;
- Le Dazon est un étang localisé à l'ouest d'Azowlissé. Sa superficie est de 18 ha environ ;
- La lagune de Porto-Novo, d'une superficie de 50 Km², est située au sud du delta et constitue l'exutoire par lequel les eaux du fleuve Ouémé se jettent dans l'Océan par le chenal de Lagos.
- Cet ensemble de fleuve, lacs, lagunes et rivières lui confère cette appellation de zone humide et les terres sont inondées pendant une bonne période de l'année.

III. APPROCHE METHODOLOGIQUE

3.1 Données climatologiques

Les données climatologiques concernent les hauteurs de pluie, les températures minimales et maximales, l'humidité relative, l'insolation et la vitesse du vent. Ces données, fournies par la Direction de la Météorologie Nationale sont celles collectées au pas de temps mensuel sur la période 1986-2016.

Les données hydrologiques utilisées dans le cadre de cette recherche sont les débits mensuels au niveau de la station de Bonou. Elles ont permis de mettre en évidence le fonctionnement hydrologique du milieu d'étude.

Les chroniques hydrologiques de 1986 à 2016 ont été tirées de la base de données de la Direction Générale de l'Eau. Les stations qui ont des données très lacunaires (> 5 %) n'ont pas été prise en compte lors des traitements. Seules les stations, dont les données lacunaires sont < 5 %, ont été utilisées sans comblement. Cette même approche a été utilisée par Koudamiloro (2017).

3.2 Etude du bilan climatique

Le bilan climatique traduit le rythme des excédents ou des déficits en eau. Il exprime la différence entre la somme des abats pluviométriques et celle de l'évapotranspiration potentielle (ETP) et constitue, lorsqu'il est positif, le surplus disponible pour la recharge en eau du sol et pour l'écoulement (Sutcliffe et Piper, 1985 ; Vissin, 2007). Il permet également de mettre en évidence l'évolution du climat à travers les apports pluvieux et les pertes par évaporation et s'exprime par la formule suivante :

$Bc = P – ETP,$

Avec : Bc, bilan climatique en mm ; P, pluie totale annuelle en mm et ETP, évapotranspiration potentielle en mm.

L'ETP est définie comme la demande climatique en vapeur d'eau.

- Si P - ETP > 0, alors le bilan est excédentaire ;

- Si P - ETP < 0, alors le bilan est déficitaire ;

- Si P - ETP = 0, alors le bilan est équilibré.

Quand P<1/2ETP, il s'agit de la saison sèche, mais quand P>1/2ETP : c'est la saison pluvieuse.

Cette méthode a t été utilisé dans la réalisation de certaines études notamment au niveau régional sur les ressources hydroélectriques en l'Afrique de l'Ouest (Le Barbe *et al.,* 1993) ; en Guinée pour l'étude de la du bilan hydrologique, de même au Togo-Bénin (Sucliffe et Piper, 1985) et particulièrement au Bénin (Vissin, 2007 ; Koumassi, 2014).

3.3 Etude de la variabilité pluviométrique et hydrologique

3.3.1 Paramètre de tendance centrale, la moyenne arithmétique

La moyenne arithmétique est employée pour étudier les régimes pluviométrique et hydrologique aux différentes stations et dans les sous bassins hydrologiques. Elle est le paramètre fondamental de tendance centrale. Nous avons utilisé en « normale », la moyenne calculée sur une série de trente ans. Elle s'exprime de la façon suivante :

$$\overline{X} = \frac{1}{n}\sum_{i=1}^{n} xi$$

La moyenne $\overline{X}$ nous a permis de caractériser l'état hydro climatique moyen et de mettre au point quelques indices de dispersion.

3.3.2 Paramètres de dispersion

Ils sont calculés à partir de la moyenne.

Le calcul de **l'écart type** permet d'évaluer la dispersion des valeurs autour de la moyenne « normale ». Il se détermine par le calcul de la racine carré de la variance :

$\sigma(x) = \sqrt{V}$ où V est la variance

L'écart type est l'indicateur de la variabilité par excellence.

A partir du calcul de l'écart type, l'étude des **anomalies centrées réduites** pluviométriques et hydrométriques mensuelles et interannuelles a été entreprise en standardisant les données. Les anomalies sur chaque station et sur les différents bassins se calculent par la formule suivante : $X'_i = \frac{X - \overline{X}}{\sigma(x)}$ où : X'_i = anomalie centrée réduite pour l'année i

x_i = la valeur de la variable,

$\overline{X}$ = la moyenne de la série.

$\sigma(x)$ = l'écart type de la série

3.3.3 Coefficient de variation

Exprimé en pourcentage, **le coefficient de variation** permet d'apprécier le degré de variabilité de la pluviosité et de l'hydrométrie journalière, mensuelle et annuelle. Ce coefficient est le plus satisfaisant des mesures de dispersion dans l'étude comparée de la variabilité des précipitations et des lames écoulées journalières, saisonnières et annuelles entre les sous bassins. C'est le rapport de l'écart type à la moyenne qui s'écrit comme suit :

$Cv = \frac{\sigma(x)}{\overline{X}} \times 100$ ou : $\overline{X}$ = la moyenne de la série.

$\sigma(x)$ = l'écart type de la série

Toutefois, les paramètres de dispersion ne suffisent pas à eux seuls pour mesurer la variabilité proprement dite, car ils ne décrivent pas l'évolution temporelle des séries pluviométrique et hydrométrique.

Les précipitations constituent l'élément climatique le plus important dans la région sahélienne en ce qui concerne non seulement la survie des animaux et des végétaux, mais également celle des hommes

3.4 Moyennes mobiles et la régression

3.4.1 Moyennes mobiles

Quand une chronique est très complexe (« bruit » important, cycle irrégulier, plusieurs tendances successives), on peut la simplifier pour faire une représentation graphique des phénomènes essentiels qui la composent.

La technique des moyennes mobiles consiste à lisser les irrégularités en associant aux valeurs d'une chronique de nouvelles valeurs qui sont les moyennes arithmétiques d'une valeur originale et des valeurs qui l'encadrent. Les moyennes mobiles peuvent être calculées sur trois (3) ans ou cinq (5) ans.

Cette méthode a permis d'avoir des séries hydrométriques et pluviométriques lissées sur les différentes stations et les sous bassins hydrologiques au pas de temps journalier, mensuel et annuel.

3.4.2 Régression linéaire simple

Elle montre l'évolution linéaire sur le long terme. Elle permet de détecter les tendances dans les séries hydro-pluviométriques.

Une « rupture » de stationnarité est recherchée. Elle peut être définie par un changement dans la loi de probabilité d'une série chronologique à un instant donné (LUBES et *al.*, 1994).

IV. RESULTATS ET DISCUSSION

4.1 Variabilité interannuelle des précipitations dans la basse vallée

L'étude de la physionomie du climat dans la basse vallée a été effectuée en fonction des modifications notées sur la période considérée notamment celle qui couvre la période allant de 1987 à 2016 pour mieux mettre en évidence la variabilité climatique dans la vallée (Figure 2).

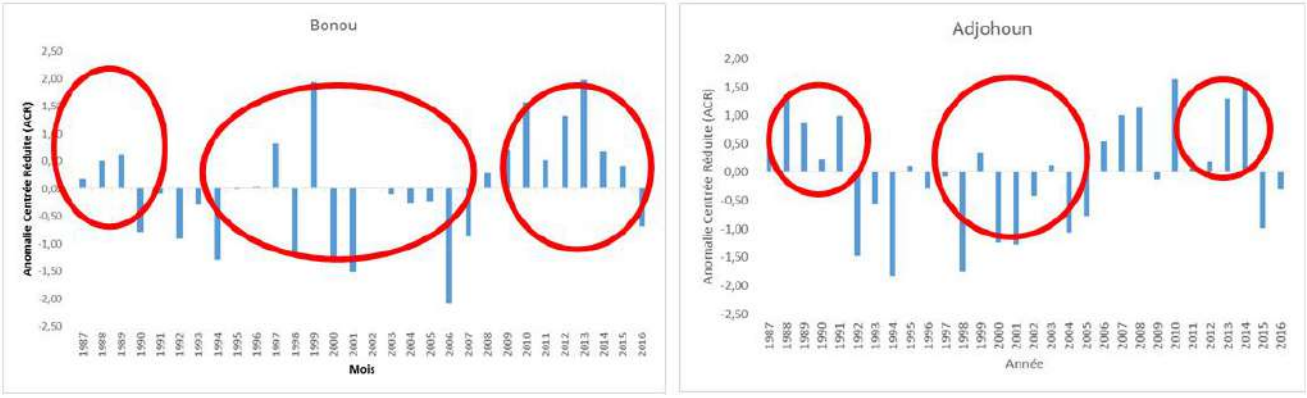

Fig.2: Variabilité interannuelle des pluies dans la basse vallée (1987 -2016)

L'analyse de cette figure 2 a permis d'identifier trois phases dans l'évolution de la pluviométrie dans la basse vallée de l'Ouémé. La première phase est marquée par des excédents pluviométriques, et concerne la période 1987-1990 ; la deuxième sous-série est caractérisée par des déficits pluviométriques entre la période 1990-2006. La troisième phase est caractérisée par une très forte instabilité dans l'évolution de la pluviométrie et concerne la période 2006-2016.

Dans la série chronologique des précipitations enregistrées à divers niveaux de la basse vallée, l'évolution des pluies n'est pas uniforme. Pour ressortir d'éventuelle rupture de stationnarité, le test de Pettitt a été appliqué. La figure 3 présente les résultats dudit test réalisés dans le milieu d'étude.

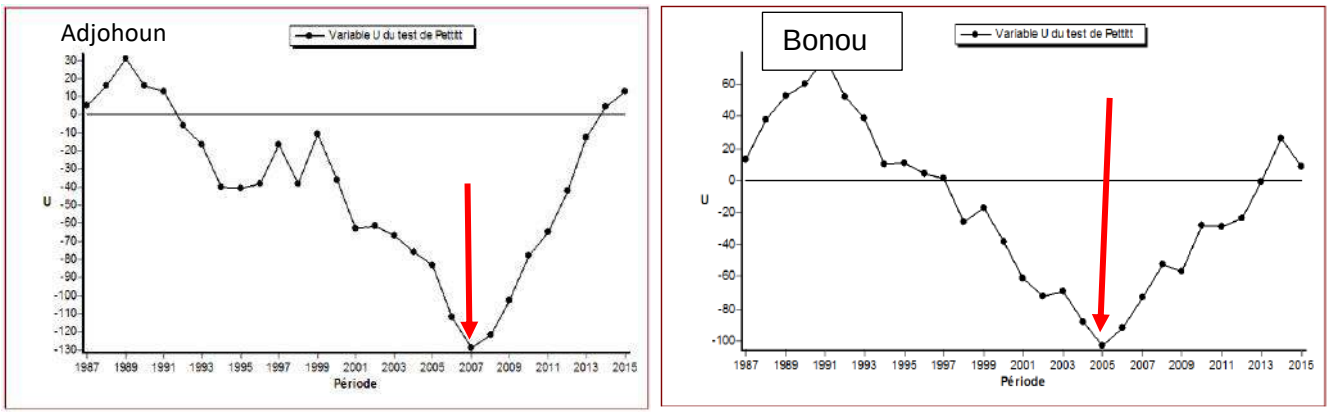

Fig3:Rupture de stationnarité dans l'évolution de la série pluviométrique dans la basse vallée de l'Ouémé

Il ressort qu'au seuil de significativité de 95 %, une rupture est observée pendant les années ''2000''. En 2007 pour la Station de Bonou et en 2005 pour la station de Adjohoun

En effet, à partir des 2005 jusqu'en 2016, une relative régularité est observée dans le sens d'évolution des valeurs pour l'ensemble des stations. De même avant 2005, on note une tendance dans l'évolution des données de la série.

La présence de rupture de stationnarité dans la série pluviométrique signifie qu'il y a variation du niveau des précipitations dans le temps dans le bassin et que cette variation est très significative au seuil de 95 %.

Par ailleurs, la tendance en hausse des hauteurs de pluie dans les stations de Bonou et de Adjohoun à partir de 2000 montre les dernières décennies dans la basse vallée de l'Ouémé est humide. Avant cette période, on remarque une baisse des précipitations depuis les années 1987.

4.2 Variabilité saisonnière comparée des précipitations par sous périodes

L'étude comparée des 2 sous-périodes identifiés à partir du test de Pettitt permet de mettre en évidence la baisse marquée des hauteurs de pluie saisonnières au niveau des sous-périodes (1987-2006 et 2007-2016). La seconde sous période a été relativement plus humide que la première période 1987-2006. La figure 4 en est une illustration.

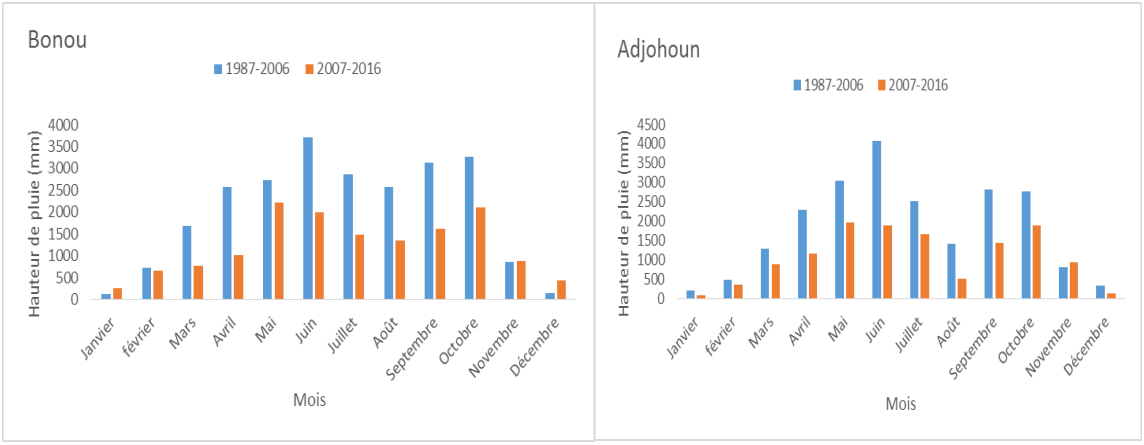

Fig.4: Régime pluviométrique des sous périodes 1987-2016 dans la basse vallée de l'Ouémé

Le cumul des précipitations reste plus important sur la période allant de 1987 à 2006 et celle allant de 2007 à 2016. La première période est donc plus arrosée que la seconde, même sur les stations de Bonou et Adjohoun ou la tendance des hauteurs de pluie sont à la hausse. Le mois le plus arrosé est le mois de juin. On remarque que la station de Bonou, les hauteurs de pluie des mois de janvier et décembre de la seconde période dépasse celle de la première période. Ceci est peut-être un signe du bouleversement de la variabilité pluviométrique dans la basse vallée de l'Ouémé.

La détermination du bilan climatique permet de déterminer les mois humides des mois secs dans la basse vallée de l'Ouémé. La figure 5 met en exergue les mois les plus humides de l'année.

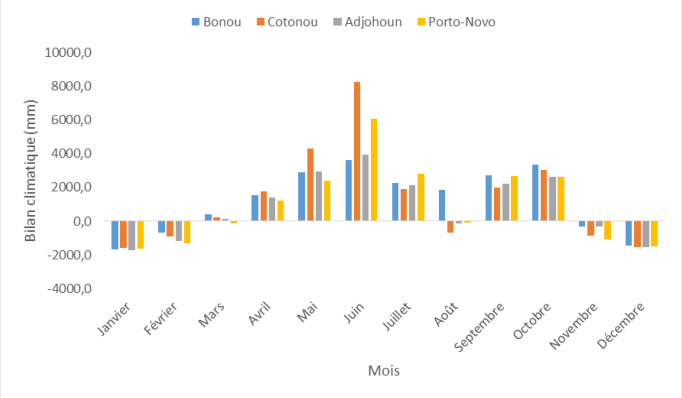

Fig.5: Bilan climatique mensuel dans la basse vallée de l'Ouémé

Le bilan climatique dans la basse vallée permet d'identifier deux périodes opposées :

- sept mois humides s'observent d'abord de mars à juillet et de septembre à octobre, avec un maximum en juin.

Les rivières pendant ces mois, sont alimentées en surplus d'eau et favorisent l'alimentation des réservoirs souterrains des sous bassins versants. Cette période est aussi favorable à l'inondation causée par les fortes pluies enregistrées en juin (Vissin, 2007 et Attigli *et al.*, 2017).

- entre octobre et février, ce sont les mois secs où la demande évaporatoire de l'atmosphère est très importante, avec un fort amenuisement et même l'assèchement des réserves d'eau du sol.

Le poids des hauteurs de pluie est de 85 % pour la première période et de 84 % pour la seconde période. La seconde période est donc relativement moins humide que la première. Cette situation pourrait s'expliquer d'un côté par le fait que la première période est plus longue que la deuxième, d'un autre côté par le fait que les décennies 1970 et 1980 ont été beaucoup plus déficitaires par rapport à celles de 1990 et 2000 marquées par une relative reprise pluviométrique. Néanmoins il faut remarquer que le déficit entre les deux sous-périodes n'est que de -1.25 %.

L'application du coefficient de variation aux deux séries (sous périodes) met en exergue l'hétérogénéité des données de la sous période 1987-2006 avec 70,69 % pour la première période et 73, 55 % pour la seconde période. Ces deux coefficients de variations étant supérieurs à 15 % on peut déduire que les données de cette série sont hétérogènes. Le tableau XIII montre l'écart et le déficit des mois les plus humides entre les sous-périodes.

Tableau I : Déficits entre les sous-périodes 1987-2006 et 2007-2016 des mois les plus humides dans la basse vallée de du fleuve Ouémé

	Ecart (1987-2006 et 2007-2016)				**Déficit % (1987-2006 et 2007-2016)**			
	Bonou	Cotonou	Adjohoun	Porto-Novo	Bonou	Cotonou	Adjohoun	Porto-Novo
M	-921,9	-646,3	-386,7	-678,35	-54,5	-44,3	-29,9	-51,9
A	-1556,05	-1711,5	-1130,5	-1110,25	-60,3	-61,7	-49,2	-50,7
M	-509,725	-1885,6	-1083	-1736,15	-18,7	-45,8	-35,5	-55,9
J	-1698,45	-2354,4	-2183,3		-45,9	-37,2	-53,5	
J	-1373,5	-1085,8	-859,5	-1050,3	-48,1	-42,9	-34,1	-35,4
A	-1224,9				-47,5			

S	-1517,2	-1506,6	-1374,5	-1800,25	-48,4	-54,4	-48,7	-55,1
O	-1154,7	-1496,1	-892,9	-695,95	-35,3	-45,5	-32,1	-25,8
	Total				**-44,62**			

Les sept mois les plus pluvieux jouent un rôle important dans la péjoration pluviométrique dans la basse vallée. Dans l'ensemble, le déficit des mois les plus humides varie de -44,62 %. Les déficits les plus important sont enregistrés pendant les mois d'avril à Bonou (-60,3 %) et à Cotonou (-61,7 %), et dans les mois de juin à Adjohoun (-53,5 %) et en mars à Porto-Novo (-55,9 %). La comparaison des moyennes par sous périodes des mois les plus humides révèle que la sous période 1987-2006 a été beaucoup plus humides (341,7 mm) que celle de 2007-2016 (337,5 mm) soit un écart de -4,3 mm. Les déficits pluviométriques observés entre 1987 et 2016, ne sont pas sans conséquences sur le fonctionnement hydrologique de la basse vallée du fleuve Ouémé.

4.3 Caractéristiques du bilan hydrique mensuel

L'analyse et la caractérisation des bilans hydriques montrent que le début et la fin des saisons humides. La figure 6 montre l'évolution du bilan hydrique potentiel, dans le milieu d'étude.

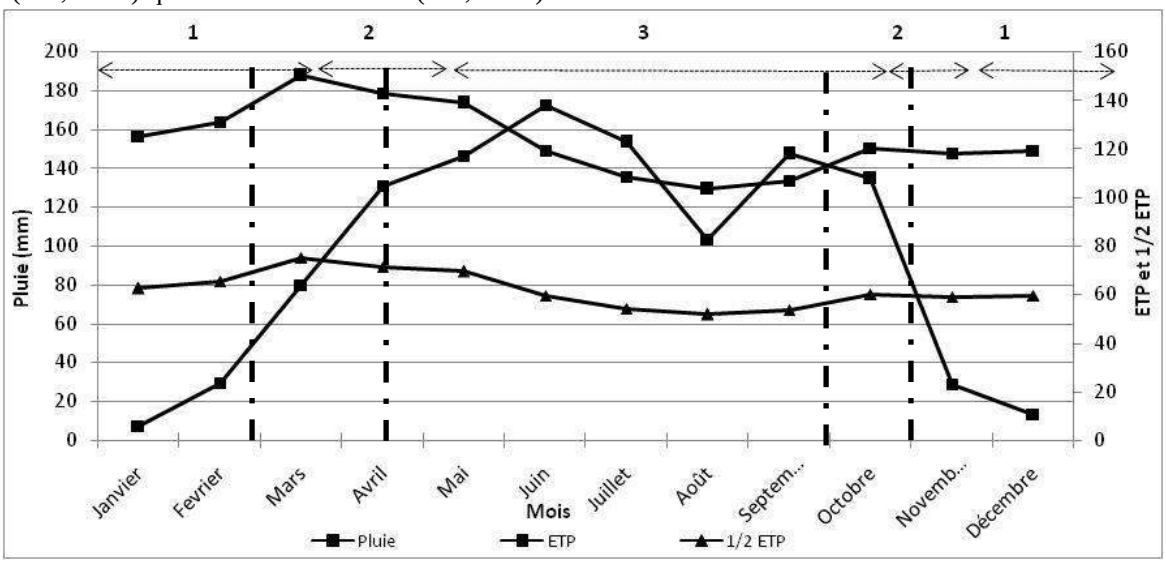

Fig.6: Diagramme climatique de Franquin (1969) à Cotonou (1987-2016)

***Source des données** : ASECNA (2018)*

Il ressort que 3 mois sont véritablement humides dans le milieu d'étude. Il s'agit des mois de juin, juillet et septembre. Il faut remarque que la période humide couvre les mois de mars à octobre. C'est la période de grande saison pluvieuse. Toutefois, le mois d'août marque une rupture relative, qui peut être considéré comme une petite saison sèche mais étant dans une zone de transition. A la petite saison sèche succède le second pic pluviométrique de l'année (petite saison), d'où le régime bimodal. On parle de petite saison de pluie qui va de septembre à octobre.

En revanche, de novembre à mars, il s'agit de la grande saison sèche. Toute la période se trouve alors sous l'influence du flux d'harmattan sec et chaud en phase diurne. L'approche du bilan hydrique montre l'existence d'une période de déficit hydrique. Le bilan hydrique potentiel est négatif en moyenne pendant la saison sèche.

4.4 Evolution des débits dans la basse vallée du fleuve Ouémé

L'analyse de la répartition mensuelle des débits enregistrés a permis de caractériser le régime hydrologique moyen (Figure 7).

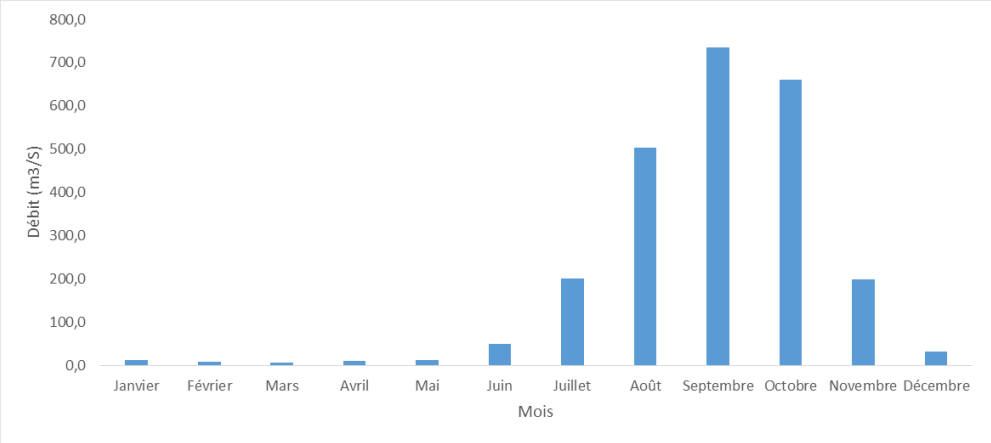

Fig.7: Evolution des débits annuels sur la période 1987-2016

De l'analyse de figure 18, il ressort que le débit du fleuve atteint son niveau maximal dans le mois de septembre. Ce sont les mois d'août, septembre et octobre qui enregistrent beaucoup plus d'écoulement. Les hautes eaux durent trois mois (août, septembre et octobre) qui, à eux seuls, représentent 80 à 90 % de l'écoulement annuel. Cette période est caractérisée par le débordement des cours d'eau qui inondent les champs et mêmes les habitations et perturbent les activités économiques des populations. La décrue est amorcée en novembre et atteint son niveau critique en janvier. Par ailleurs, les plus faibles débits sont enregistrés durant la période sèche de chaque année (décembre à avril, voire mai).

4.5 Variation interannuelle des débits dans la basse vallée de l'Ouémé

La figure 8 présente l'évolution interannuelle des débits moyens annuels dans la basse vallée sur la période 1987-2016.

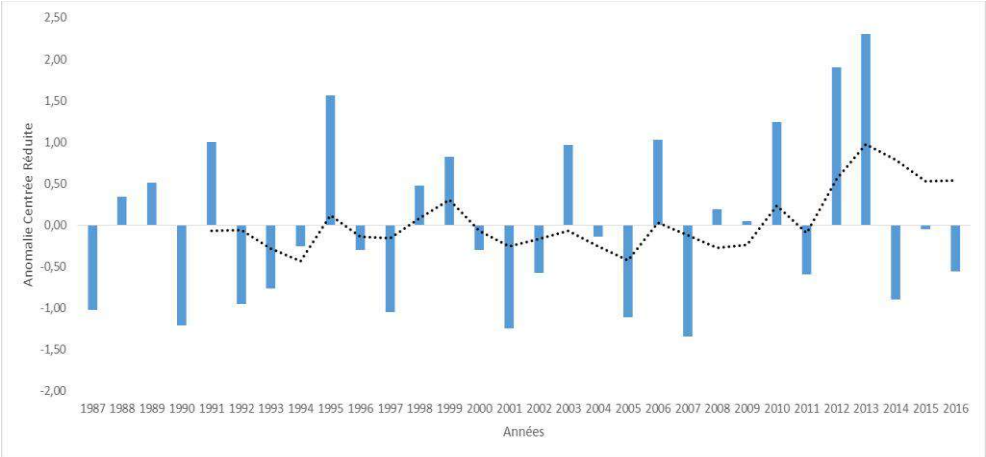

Fig.8: Variabilité interannuelle des débits annuels dans la basse vallée de l'Ouémé

L'analyse des indices hydrométriques annuels permet de dire que comme pour les séries pluviométriques annuelles, une variation importante des débits moyens annuels est observée à partir des années 2000. La variation dans les séries chronologiques des débits est généralement concomitante à celle de la pluviométrie.

Une comparaison des débits annuels et des précipitations annuelles confirme pleinement la règle qui stipule que la distribution des débits s'ordonne suivant les mêmes lois statistiques que les distributions des précipitations dans un bassin versant correspondant (Dekkiche, 1993, p. 25). Le phénomène est concomitant avec celui observé en pluviométrie. La baisse du débit est confirmée par le test de Pettitt qui détecte une rupture à une année près soit 2007 dans les séries chronologiques de débit.

Ainsi le test de Pettitt appliqué aux séries hydrométriques a permis de détecter des ruptures de stationnarité des débits au début de la décennie 2007 significatives à 95 % (figure 9).

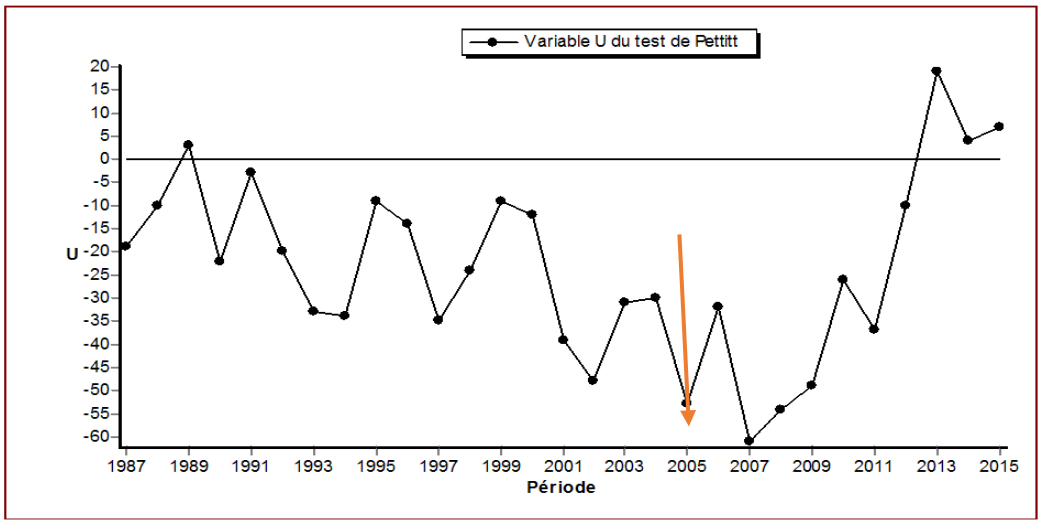

Fig.9: Rupture de stationnalité dans les débits annuels

Dans la même logique que sous période avec les hauteurs de pluie, l'=e débits dans la basse vallée est plus élevé dans la premier sous-période (1987-2007) que dans la deuxième sous-période (2008-2016). L'étude de la variabilité de l'écoulement dans la basse vallée permettrait de mieux déterminer la disponibilité de l'eau dans le milieu.

4.6 Evolution de l'écoulement de surface dans la basse vallée

La figure 10 présente l'évolution interannuelle des débits moyens annuels (valeurs centrées réduites) dans la basse vallée.

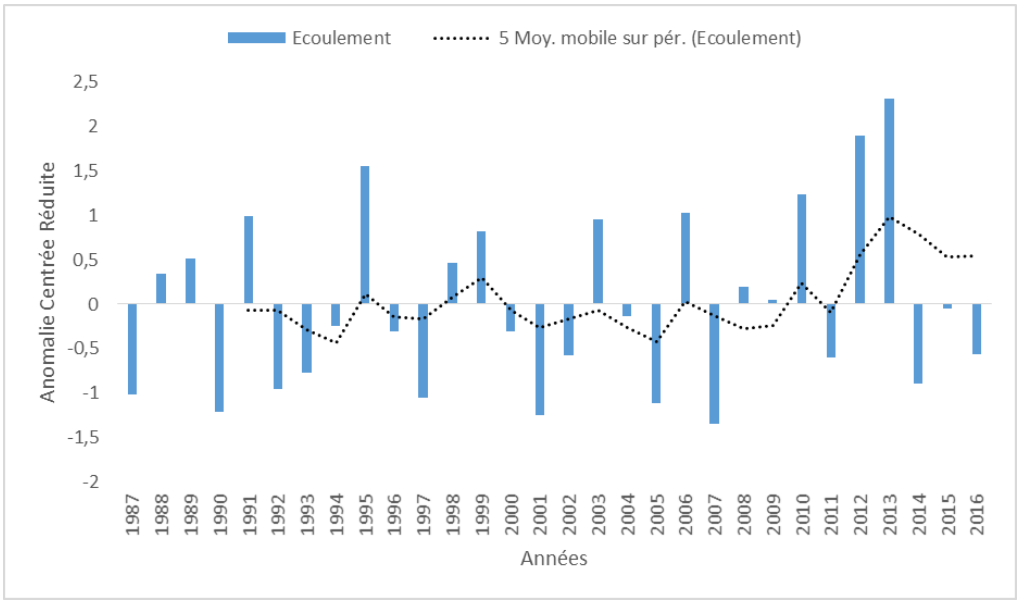

Fig.10:Variation interannuelle de l'écoulement dans la basse vallée de l'Ouémé

De l'analyse de la figure 10, il ressort que la période les écoulements les plus élevés ont été obtenus est de 2000 à 2016. Dans cette période, ce sont les années 2010, 2012 et 2013 qui ont les écoulements les plus élevé. Ces années correspondent aux années ayant enregistrés les plus fortes pluies. Des années de grands déficits d'écoulement enregistrés dans la basse vallée sont 1987, 1990, 1997, 2001, 2007. De façon global la période 2007-2016 est excédentaire et la période 1987-2006 est par contre déficitaire. La tendance à la hausse du coefficient d'écoulement dans le bassin amène à se demander si ce phénomène résulterait d'une augmentation des surfaces imperméables sous l'effet d'une pression anthropique élevée.

En effet, l'évolution des unités d'occupation du sol n'est pas sans conséquence sur la variation du coefficient

d'écoulement. Dans la basse vallée, il existe une mosaïque d'unité d'occupation du sol allant des savanes arbustives aux forêts galeries en passant par des plantations, des cultures, des jachères voire des agglomérations. Le tableau II, traduit l'écart entre les débits des deux sous périodes 1987-2006 et 2007-2016.

Tableau II: Déficit des débits écoulés entre les sous-périodes

	Débits (m3/S)	
Sous-période	**1987 - 2006**	**2007- 2016**
Moyenne	193,2	220,6
Ecart	24,7	

Dans l'ensemble, on observe un acrat conséquent des débuts entre la première période et à la deuxième. Cela se justifie d'un côté par la tendance à la hausse des hauteurs de pluie dans la basse vallée mais aussi en amont de la basse vallée. Partant de ces observations on pourrait conclure que les déficits pluviométriques observés au cours de la sous-période 1987-2006 ont impacté plus légèrement les écoulements dans la basse vallée.

Dans le but de connaître ce que deviennent l'eau précipitée et l'écoulement dans les sous-bassins, l'étude hydrologique a été faite.

4.7 Bilan hydrologique dans la basse vallée de l'Ouémé

La figure 11, présente la variabilité interannuelle des termes du bilan hydrologique dans la basse vallée du fleuve Ouémé.

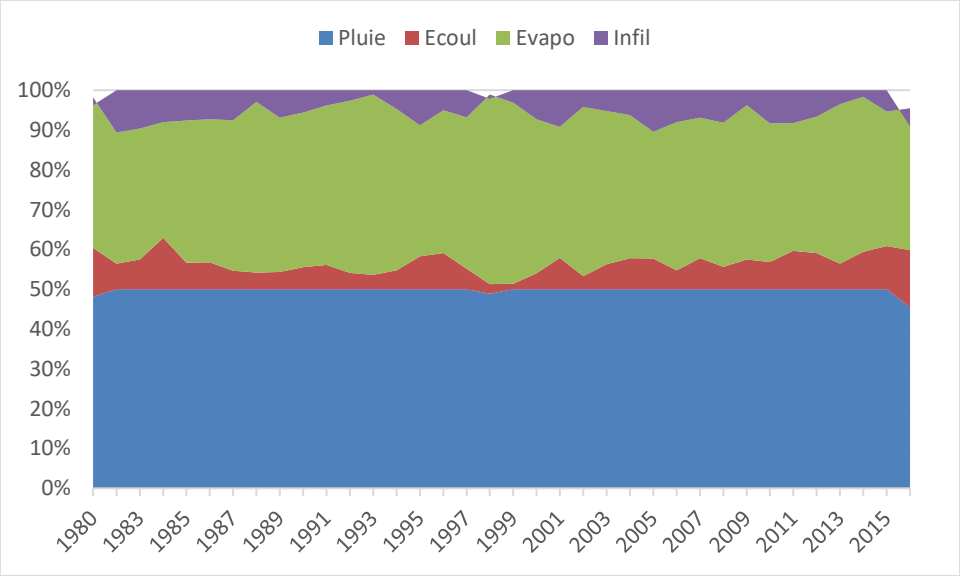

Fig.11 : Bilan hydrologique

Il ressort que les termes du bilan hydrologique représentés dans cette partie par les précipitations, l'écoulement et l'infiltration ont une évolution relativement identique. On note que pour une hauteur de pluie de 100 % reçue dans la basse vallée, on relève 10 % à 47 % pour l'évaporation, 20 % à 53 % pour la recharge et l'écoulement oscille entre 0,6 et 1 %.

Il y a donc d'énormes pertes par évaporation évaluées à presque 85 % des précipitations. Sur la période d'étude, l'écoulement a connu un faible écoulement. Cela est dû à la constitution pédologique de la basse vallée mais aussi à l'évapotranspiration qui est plus ou moins forte. Le tableau III montre l'évolution comparée des termes du bilan hydrologique en mm dans la basse vallée de l'Ouémé.

Tableau III: Evolution comparée des fluctuations pluviométriques et des autres termes du bilan hydrologique en mm dans la basse vallée de l'Ouémé

Périodes	**Pluie**
1987 - 2016	1171
1987 -2006	1106
2007 - 2016	1300
Ecart	194
Déficit	18
Périodes	**Evaporation**
1987 - 2016	1360,1
1987 -2006	929,0
2007 - 2016	431,1
Ecart	-929,0
Déficit	-100
Périodes	**Ecoulement**
1987 - 2016	17,9
1987 -2006	11,4
2007 - 2016	6,5
Ecart	-4,9
Déficit	-42,9
Périodes	**Recharge**
1987 - 2016	1549,7
1987 -2006	903,7
2007 - 2016	646,0
Ecart	-903,7
Déficit	-100

Source : traitement des données

Un déficit pluviométrique a été observé entre les deux sous période. Ce qui signifie que la deuxième période est plus arrosée que la première et par ricochet une tendance à la hausse des hauteurs de pluie dans la basse vallée de l'Ouémé.

Le déficit d'écoulement entre les deux périodes est relativement important -42 %. Malgré la hausse de la pluviométrie entre les deux périodes, la recharge du milieu montre un déficit de 88 % entre les deux périodes. De façon générale, cela suppose que le pouvoir évaporatoire du milieu est très élevé d'autant plus que l'écoulement est très faible à cause de la configuration du sol et de la géomorphologie du milieu.

V. DISCUSSION

L'étude des tendances pluviométriques a permis d'identifier trois phases dans l'évolution de la pluviométrie dans la basse vallée de l'Ouémé. La première phase est marquée par des excédents pluviométriques, et concerne la période 1987-1990 ; la deuxième sous-série est caractérisée par des déficits pluviométriques entre la période 1990-2006. La troisième phase est caractérisée par une très forte instabilité dans l'évolution de la pluviométrie et concerne la période 2006- 2016. Les résultats similaires avaient été déjà trouvés par Koumassi et al (2012) dans le bassin versant de Mono à l'exutoire de Athiemé où les auteurs ont estimé que trois phases ont été identifié dans l'évolution de la pluviométrie dans la basse vallée du Mono. La première phase concerne la période 1965-1970. Elle est marquée par des excédents

généralisés dans tout le Bénin. La deuxième période de 1971- 1990, est caractérisée par des déficits pluviométriques. La troisième phase de 1991- 2009 ; est caractérisée par une très forte instabilité dans l'évolution de la pluviométrie. De même dans la sous-région, cette variabilité a été observée dans la plupart des travaux sur le régime des précipitations de la sous-région de l'Afrique de l'Ouest (Mahé & Olivry J.C., 1995, p. 25, 1995; Olivry J.C, 1983, p. 12; Servat E.et al., 1999, p. 19) et particulièrement au Bénin (Houndénou, 1992, p. 40), (Vissin, E. 2007, p. 85),(Amoussou, 2010, p. 36),(Koumassi H., 2014, p. 33) et (Assaba M., 2014, p. 84).Quant au période de rupture trouvée en 2007, En effet, à partir des 2005 jusqu'en 2016, une relative régularité est observée dans le sens d'évolution des valeurs pour l'ensemble des stations. De même avant 2005, on note une tendance dans l'évolution des données de la série.

Cette tendance est similaire à celle observée par Amoussou E. (2010) dans le bassin-versant du Mono-Ahémé-Couffo au sud Bénin. A ce niveau, l'auteur a montré que la baisse des précipitations depuis les années 1970 s'est poursuivie en s'amplifiant au début de la décennie 1980, avec des sécheresses sensibles, surtout de 1982 à 1987. Cette fréquence des anomalies négatives entre 1987 et 2000 traduit un début de péjoration climatique.

Le cumul de pluie autour de la période de rupture montre que la première période est plus arrosée que la seconde. Le mois le plus arrosé est le mois de juin. On remarque que la station de Bonou, les hauteurs de pluie des mois de janvier et décembre de la seconde période dépasse celle de la première période. Ces résultats ont été obtenus par d'autres auteurs tel que KODJA J (2011) qui estime que la sous-période 1951-1970, il y a une diminution des pluies de tous les mois de la sous-période 1971-2003 à l'exception des mois de juillet et août. Cette baisse de la pluie mensuelle varie de septembre à juin avec les plus fortes baisses enregistrées en mars et juin. Ainsi, des deux sous-périodes, la baisse de la pluie est de 10,64%, ce qui témoigne que la sous-période 1951-1970 est plus humide que la sous-période 1971-2003. Les mois les plus secs sont décembre, janvier, février, mars.

On retient que la sous-période 1951 à 1970 est la période de la hausse pluviométrique avec un optimum de 192,72 mm en juin tandis que la sous-période 1971 à 2003 correspond à la récession pluviométrique avec comme maximum 160,3 mm en juillet.

Les variations hydrologiques se caractérisent par le débit dont le maxi est atteint dans le mois de septembre. Ce sont les mois d'août, septembre et octobre qui enregistrent beaucoup plus d'écoulement. Les hautes eaux durent trois mois (août, septembre et octobre) qui, à eux seuls, représentent 80 à 90 % de l'écoulement annuel. Une comparaison des débits annuels et des précipitations annuelles confirme pleinement la règle qui stipule que la distribution des débits s'ordonne suivant les mêmes lois statistiques que les distributions des précipitations dans un bassin versant correspondant. Ces résultats corroborent ceux obtenues par (Kodja,J. 2018, p. 137).

VI. CONCLUSION

La basse vallée de l'Ouémé à l'instar de toute sous-région ouest africaine est marquée depuis ces cinquante dernières années par une instabilité des paramètres climatiques sans précédente. Cette instabilité fut marquée par les épisodes de sécheresse qui a caractérisé les décennies 60 70. Les conséquences se sont répercutées sur les autres termes du bilan climatiques notamment une augmentation de l'évaporation et une diminution de la recharge. Cette situation est aggravée par les modes de mise en valeur des terres. De même, ces dernières décennies sont marquées par une récurrence des phénomènes extrêmes. Il est primordial pour mieux cerner les conséquences des changements climatiques, d'analyser l'occurrence des risques hydro climatiques dans la basse vallée.

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Adsorption of Ce^{3+} ions using a one-dimensional nanomaterial with natural halloysite-kaolinite dual components

Thao Le Thi Phuong[1,2,3,*], Thoa Nguyen Thi Kim[1,2,3], Duyen Le Thi[1,2,3]

[1] Chemistry Department, Faculty of Basic Science, Hanoi University of Mining and Geology, 18 Vien st., Hanoi, Vietnam
[2] Center for Excellence in Analysis and Experiment, Hanoi University of Mining and Geology, 18 Vien st., Hanoi, Vietnam
[3] BSASD research group, Faculty of Basic Science, Hanoi University of Mining and Geology, 18 Vien st., Hanoi, Vietnam
*Email: lethiphuongthao@humg.edu.vn

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***Keywords*— Adsorption, one-dimensional nanomaterial, halloysite, kaolinite, Ce^{3+} ions.**

***Abstract*—** *Rare earth elements are widely used in many technological domains, including reactants, alloying elements, catalysts, batteries, superconductors, etc., because of their unique electro-optical properties. Recovery and separation of rare earth elements are particularly crucial due to the steadily rising demand, as they can enhance scarce resources and reduce radiation-related waste disposal harm. Reports about the harmful effects of rare earth elements on microbes, plants, and animals have become increasingly common in recent years. More dangerously, residues from rare earth elements can build up in the human body through ingestion or digestion in the food chain. Finding a practical and affordable way to use rare earth elements or remove them from our surroundings is therefore essential. To extract these elements, halloysite is processed using a straightforward chemical procedure to produce rare earth metal ion adsorbent materials. The Halloysite that has been processed has a rod-shaped, one-dimensional nanomorphology. Halloysite-kaolinite is the two-phase version of the adsorbent material. The strong adsorption capacity of halloysite for Ce^{3+} is demonstrated by research findings. Halloysite adsorbs Ce^{3+} using the monolayer physical adsorption model and the pseudo-second-order adsorption kinetic equation.*

I. INTRODUCTION

Due to their unique electro-optical properties, rare earth elements are widely used in many technological fields, such as reactants, alloying elements, catalysts, batteries, superconductors, etc [1-5]. Continuously increasing demand makes rare earth element recovery and separation especially important, which can improve limited resources and minimize damage caused by waste disposal caused by radiation. In recent years, there have been more and more reports on the toxic effects of rare earth elements on bacteria, plants, and animals. More seriously, when rare earth elements are inhaled or digested in the food chain, residues can accumulate in the human body. Therefore, it is necessary to find an effective and economical method to exploit or remove rare earth elements from our living environment [5].

As an abundantly available and low-cost natural clay mineral, halloysite has the distinctive morphology of hollow one-dimensional nanotubes, whose walls consist of unit layers with one tetrahedral layer (SiO_4) and one octahedral layer (AlO_6). The outer diameter of halloysite nanotubes is about 50-150 nm, and their length is about 200-1000 nm. High specific surface area, adsorption capacity, physicochemical properties, availability, cost, and

environmental advantages make natural halloysites attractive for many applications [6-9]. Similarly, kaolinite is a bifacial alumino silicate layered clay of the kaolin group comprising octahedral $Al(OH)_3$ and tetrahedral SiO_4. Kaolinite usually has a multilayer array structure with two types of alternating surfaces: one side is SiO_6 macro ring, and the other side is $Al(OH)_3$. The negatively charged kaolinite surface is balanced by cations that can be easily exchanged with other cations [10].

In Vietnam, many areas have excellent mineral potential, including halloysite minerals. Tubular halloysite minerals commonly exist in weathered layers of pegmatite bodies of the Tan Phuong complex. Thach Khoan area, Phu Tho, is one of the areas where many pegmatite bodies are distributed in this complex. According to published research results on halloysite mineral characteristics in this area, halloysite exists in two forms with fundamentally different properties [11, 12]. Long halloysite has a more significant tube length (from 750 to 1,250 nm) and is mainly distributed in the lower weathering layer. Short halloysite has shorter tube lengths (from 250 to 750 nm) spread primarily in the upper weathered layer. The surface area of halloysites in the upper layer sample was determined to be 15.7434 $m^2.g^{-1}$; in the lower layer, it was 22.0211 $m^2.g^{-1}$. The inner diameter of halloysite tubes is mainly distributed at 4.3 nm, with smaller diameters of 9.2, 10.7, and 13.5 nm. In addition, the phase composition of the mineral sample shows the simultaneous existence of halloysite, kaolinite, and quartz phases. This study surveyed and evaluated the characteristic properties and ability to recover the rare earth element Ce^{3+} in the water environment of halloysite minerals in the Thach Khoan area, Phu Tho.

II. EXPERIMENTS

2.1. Materials and sample

The halloysite powder was taken after the screening process from Lang Dong Kaolin mine, Thach Khoan, Phu Tho. The samples were mixed well and separated using a wet sieve method with a mesh size of 32 µm. The sample under the sieve was filtered and dried at 60°C. After drying, the sample was tested and analyzed in the following steps.

2.2. Characterization

The material samples' infrared (IR) spectra were recorded using an FT-IR spectrometer (Brucker, Germany) in the 400-4000 cm^{-1} range. Scanning electron microscopy (SEM; Hitachi S-4600, Japan) was used to image the materials' surface and morphologies. Powder X-ray diffraction (XRD) patterns were measured using an X'Pert Pro diffractometer (Jeol, Japan) with CuK_α radiation (15 mA and 40 kV) at a scan rate of 2°.min^{-1} with a step size of 0.02°. The specific surface area values of the halloysite were calculated by the Brunauer Emmett Teller (BET) method and the Langmuir method using the nitrogen adsorption isotherm.

2.3. Adsorption experiments

A series of experiments were conducted at room temperature. The adsorption process was done by mixing an amount of halloysite with 50 mL of Ce^{3+} solution at self-generated pH (~ 6.5). At the reserved times, the remaining Ce^{3+} solution was analyzed, and its residual concentration at equilibration time t (min), (C_e, in $mg.L^{-1}$) was determined by Inductively Coupled Plasma Mass Spectrometry (ICP/MS).

C_o (initial concentration of Ce^{3+}) and C_e values were used to estimate the amount of Ce^{3+} adsorbed on the halloysite at each equilibrium, q_e ($mg.g^{-1}$), was determined as the following equation [13]:

$$q_e = \frac{C_0 - C_e}{m_{hal}} \times V_{Ce^{3+}} \quad (1)$$

where m_{hal} is the halloysite mass (g), and V_{Ce3+} is the volume of the Ce^{3+} solution (L).

Different equilibrium isotherms and adsorption kinetic models were used to study the adsorption process. Excel software employed the linear curve fitting method to fit kinetic and isotherm models to the experimental data. To assure the sureness of results, each investigation was performed three times and averaged.

The Langmuir, Freundlich and Temkin models were used in this study to describe the adsorption equilibrium:

Langmuir equation [13]: $\frac{C_e}{q_e} = \frac{1}{q_m} C_e + \frac{1}{K_L . q_m}$ (2)

Freundlich equation [13]: $lnq_e = lnK_F + \frac{1}{n} lnC_e$ (3)

Temkin equation [14]: $q_e = BlnA + BlnC_e$ (4)

where q_e is the adsorption capacity at equilibrium ($mg.g^{-1}$), q_m is the maximum adsorption capacity of the adsorbent ($mg.g^{-1}$), K_L is Langmuir constant; C_e is the adsorbate concentration at equilibrium (mg/m^3). K_F and n are model constants, K_F is related to the adsorption affinity of the adsorbent, and n indicates the adsorption process's support. B = RT/b, b ($J.mol^{-1}$) is the Temkin constant, related to the heat of adsorption, R (8.314 $J.mol^{-1}.K^{-1}$) is the gas constant, T (K) is the absolute temperature; A is the Temkin thermal constant ($L.g^{-1}$).

The adsorption kinetics of Ce^{3+} were explored based on two models: pseudo-first-order and pseudo-second-order. The kinetic rate constants were calculated, respectively [13].

- The pseudo-first-order equation can be expressed as follows:

$$\ln(q_m - q_t) = lnq_m - k_1 \times \frac{t}{2.303} \quad (5)$$

where q_t and q_m are the adsorbed amounts ($mg.g^{-1}$) at time t (min), and at equilibrium, k_1 (min^{-1}) is the corresponding adsorption rate constant.

- The pseudo-second-order model, as shown below, has been applied broadly for solute adsorption and catalysis reactions in liquid conditions:

$$\frac{t}{q_t} = \frac{1}{k_2 \times q_e^2} + \frac{t}{q_e} \quad (6)$$

where q_t and q_e are the adsorbed amounts ($mg.g^{-1}$) at time t (min), and at equilibrium, k_2 ($g.mg^{-1}.min^{-1}$) is the corresponding rate constant.

III. RESULT AND DISCUSSION

3.1. Characterization

XRD pattern of the halloysite sample in natural is presented in Fig. 1. The results indicated that minerals of the kaolin system coexisted in the material. The characteristic peaks of halloysite - 7 angstroms at the angular positions 19.9°, 24.8°, 35.0°, and 38.4° correspond to the triclinic structure $Al_2Si_2O_5(OH)_4$ (PDF No. 00-29- 1487). The peaks at the angular positions 26.6°, 54.8°, and 62.3° correspond to the hexagonal structure $Al_2Si_2O_5(OH)_4.2H_2O$ (PDF No. 00-29-1489) representing halloysite - 10 angstrom. In addition, the diffraction peaks at angles 12.3°, 22.8° and 45.5° are assigned to the monoclinic structure $Na_{0.3}Al_4Si_6O_{15}(OH)_6.4H_2O$ of kaolinite (PDF-00-029-1490).

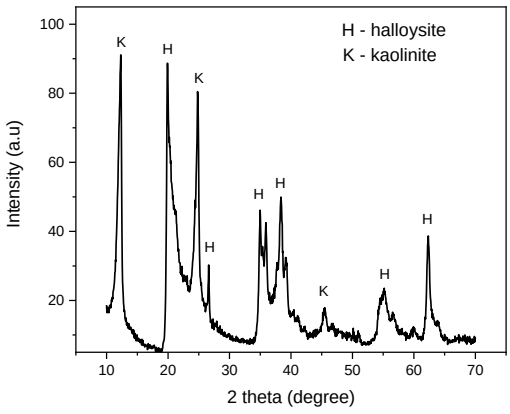


Fig. 1: The XRD patterns of the halloysite

Figure 2 shows the halloysite sample's FT-IR spectra and presents the kaolin minerals' existence. The absorption bands at 3695 and 3621 cm^{-1} in the FTIR spectra are assigned to the stretching vibration due to the inner surface of the O-H groups. The absorption at 1635 cm^{-1} is given to the interlayer water [15]. The Si-O stretching region comprises an absorption band at 1037 cm^{-1}. The band at 914 cm^{-1} is given to the bending vibration of Al-OH. The band observed at 752 cm^{-1} of the sample is set to the stretching mode of Al-O-OH. The low stretching band Si-O defined at 694 cm^{-1} confirms the halloysite in the sample. The band at 539 cm^{-1} is due to the vibration of Al-O-Si [16].

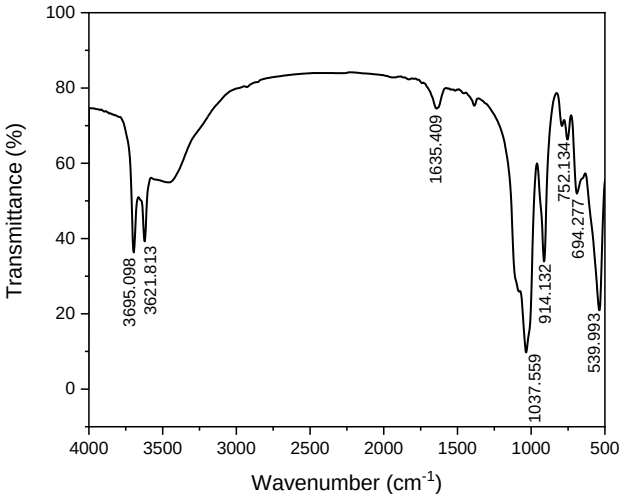
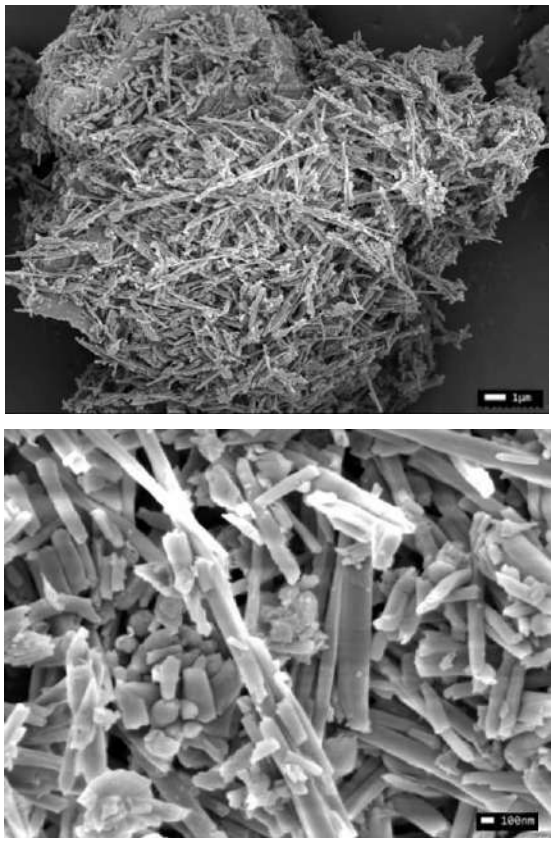


Fig. 2: The FTIR spectroscopy of the halloysite



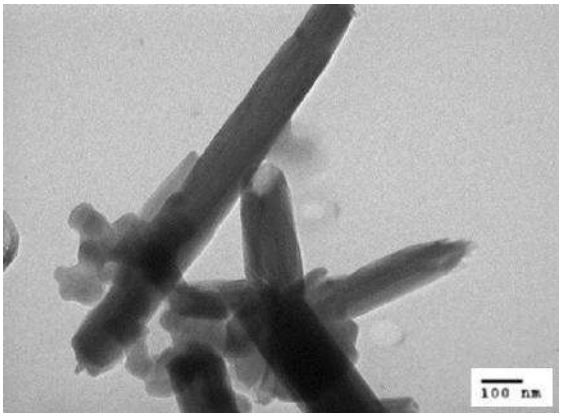
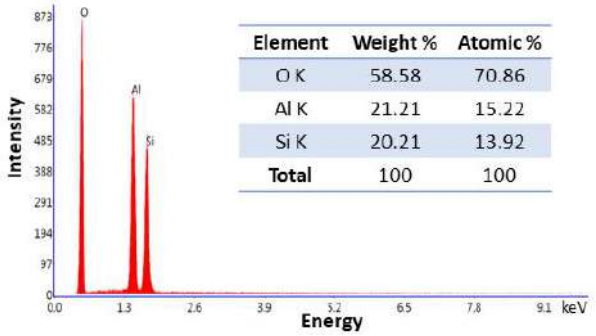


Fig. 3: The SEM (a, b) and TEM (c) images of the halloysite

The SEM images of the samples with the size fraction < 2 µm are shown in Fig. 3a,b. The rod-shaped minerals were interwoven and overlapped each other as matrices. From these images, it can be seen that there may be two types of halloysite available in the samples: short halloysites and long halloysites of the weathered pegmatite profile. The TEM in Fig. 3c also displays the 1D nano morphology of the material.



Element	Weight %	Atomic %
O K	58.58	70.86
Al K	21.21	15.22
Si K	20.21	13.92
Total	100	100

Fig. 4: The EDS spectroscopy of the halloysite

The EDS spectra (Fig. 4) shows the main elements of Al, Si, and O relative to the halloysite chemical formula ($Al_2Si_2O_5(OH)_4.2H_2O$).

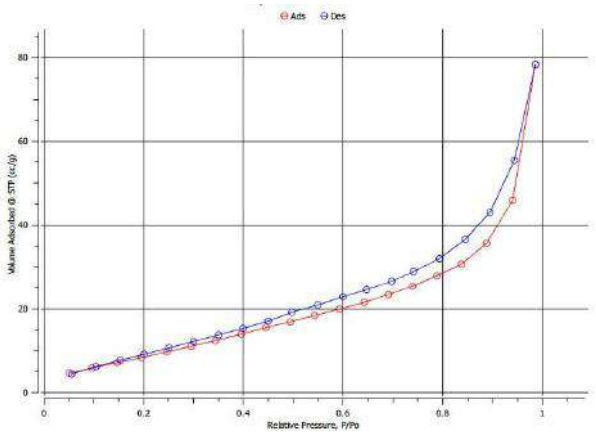


Fig. 5: The BET isotherm plot of the halloysite

The porous property of halloysite was identified by measurement of surface area (BET), which was investigated using N_2 adsorption-desorption isotherms. Nitrogen adsorption isotherms show type I curves, which reveal the microporous nature. The BET surface area of the halloysite in Fig. 5 was 30.93 $m^2.g^{-1}$. With this characteristic, halloysite can adsorb various objects, such as gases [17], toxic organic compounds [18], or heavy metal ions in water [19]. This study tested the halloysite for the adsorption of the ion Ce^{3+} in an aqueous medium.

3.2. Adsorption study

The ability to adsorb Ce^{3+} in halloysite was investigated under the following conditions: the mass of halloysite powder used was 0.5 g/50 mL of Ce^{3+} solution with a concentration of 40 $mg.L^{-1}$ and a pH of 6.5 (initial pH), 25°C. The survey results are shown in Fig. 6. The results show that halloysite has a good adsorption capacity for Ce^{3+}. The adsorption efficiency gradually increases and is almost stable after 60 minutes. After an adsorption time of 60 minutes, the adsorption capacity reaches 2.46 $mg.g^{-1}$ and remaines practically tough as the adsorption time continues to increase.

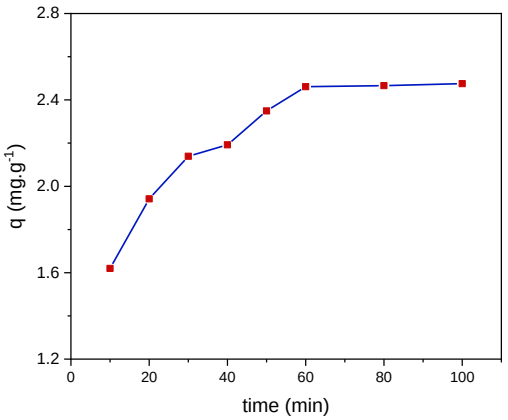


Fig. 6: The Ce^{3+} adsorption capacity of the halloysite

Based on the results of research on the effect of adsorption time on Ce^{3+} adsorption capacity, graphs of pseudo-first-order and pseudo-second-order adsorption kinetic equations can be built, the results are shown in Fig. 7. The results of calculating the value of the adsorption rate constant (k) and the adsorption capacity at equilibrium (q_e) based on the graph obtained in Figure 7 are introduced in Table 1. The pseudo-first-order adsorption kinetics (1.923 $mg.g^{-1}$) differs more from the q_e value determined from experiment (2.48 $mg.g^{-1}$) than the q_e value calculated by the second-order pseudo-adsorption kinetics equation (2.673 $mg.g^{-1}$), at the same time, the regression coefficient of the pseudo-second-order kinetic equation reaches $R^2 = 0.9985 \approx 1$ while the regression coefficient of the pseudo-first-order

kinetic equation (0.9359) is far from 1. This result proves that the adsorption process of Ce^{3+} by halloysite follows the pseudo-second-order adsorption kinetic equation. The determined adsorption rate constant is 0.0525 g.mg^{-1}.min.

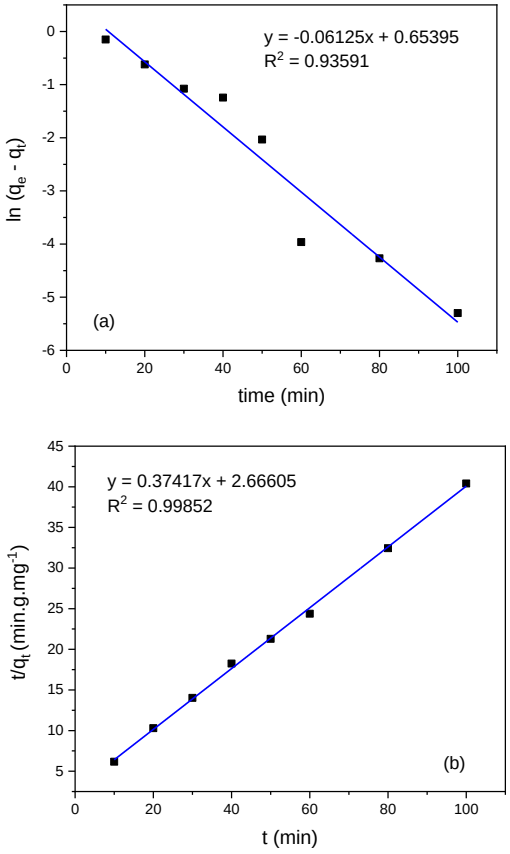


Fig. 7: The pseudo-first-order and pseudo-second-order kinetic curves for Ce^{3+}

Table.1: Isotherm constants and correlation coefficients for the adsorption of Ce^{3+} on halloysite

Pseudo-first-order			Pseudo-second-order			q_e exp (mg. g^{-1})
q_e (mg. g^{-1})	k_1 (min^{-1})	R^2	q_e (mg. g^{-1})	k_2 (g.mg^{-1}.min)	R^2	
1.923	0.06125	0.9359	2.673	0.0525	0.9985	2.48

The pH of the solution is an important factor that affects the adsorption of metal ions in aqueous media. pH not only affects the existence of ionic species in solution but also affects the surface state of the adsorbent [18]. The effect of pH on the Ce^{3+} adsorption capacity of halloysite was investigated in the range from 3.5 ÷ 7.2. The investigated pH range veries around the pH_{PZC} value (zero charge point) of halloysite (pH_{PZC} = 5.99) [19], while ensuring that there is no formation of hydroxide precipitate of Ce^{3+}, thus accurately determine the adsorption efficiency of halloysite to Ce(III) [20]. Investigation experiments were conducted with 0.5 g halloysite/50 mL of Ce^{3+} solution 40 mg.L^{-1}, 60 minute adsorption time. The results (Table 2) show that, in the investigated pH range, when pH increases, the adsorption efficiency and capacity increase. This result is explained by the fact that in an acidic environment, halloysite is protonated, then the surface of the particle will be positively charged, leading to a reduction in the number of adsorption centers of halloysite. In addition, the competitive adsorption between H^+ ions and Ce^{3+} ions will reduce the ability to adsorb Ce^{3+} ions [10]. As pH increases, the positive charge density of the surface gradually decreases, the Ce(III) adsorption capacity will gradually increase. pH > pH_{PZC} will be favorable for Ce(III) adsorption. Althought at pH = 6.5 (initial pH), the adsorption efficiency and capacity (61.53% and 2.46 mg/g, respectively) are lower than the values at pH 7.2, but to facilitate the treatment of large quantities without having to adjust pH, pH = 6.5 was chosen for the Ce^{3+} adsorption process in subsequent studies.

Table.2: The effect of pH on the Ce^{3+} adsorption capacity of halloysite

pH	C_{ion}, mg.L^{-1}	H, %	q, mg.g^{-1}
3.5	27.80	30.51	1.22
4.5	21.45	46.38	1.86
5.5	16.81	57.97	2.32
6.5	15.39	61.53	2.46
6.9	10.41	73.97	2.96
7.2	6.50	83.75	3.35

The effect of halloysite mass on the ability to adsorb Ce^{3+} was studied in the range of 0.3-1.2 g halloysite/50 mL of solution Ce^{3+} 40 mg.L^{-1} at pH 6.5, 25ºC. As the amount of solid adsorbent in the solution increases, the adsorption efficiency increases due to the increase of contact area between the adsorbent and the solution, so there are more active centers for adsorption [18]. According to the results in Table 3, the adsorption efficiency increases greatly from 45.4% to 71.3% as the halloysite mass increases from 0.3 g to 0.8 g, then increases slightly and stabilizes as the amount of adsorbent increases to 1.0 g. However, the adsorption efficiency remains almost unchanged while the adsorption capacity gradually decreases as the mass of the material keeps increasing, because the adsorption reaches an equilibrium state. The ratio of 0.8 g halloysite/50 mL of solution Ce^{3+} 40 mg.L^{-1} giving relatively high adsorption efficiency and capacity is suitable for further research.

Table.3: The effect of halloysite mass on the Ce^{3+} adsorption capacity

m_{hal}, g	C_{ion}, mg.L^{-1}	H, %	q, mg.g^{-1}
0.3	23.99	40.02	2.67
0.5	15.39	61.53	2.46
0.7	11.83	70.43	2.01
0.8	8.41	78.97	1.97
0.9	7.02	82.45	1.83
1.0	6.42	83.96	1.68
1.1	5.46	86.36	1.57
1.2	4.87	87.83	1.46

The initial Ce^{3+} ion concentration has a significant influence on the adsorption capacity and efficiency. In the initial Ce^{3+} concentration range investigated (10 mg.L^{-1}–80 mg.L^{-1}) under the conditions: halloysite mass 0.8 g/50 mL Ce^{3+} solution, pH = 6.5 and room temperature, as the Ce^{3+} concentration increases, the adsorption capacity gradually increases while the adsorption efficiency decreases (Fig. 8). When the initial Ce^{3+} ion concentration is low, the contact area between the Ce^{3+} solution and the halloysite solid phase is large, and the ability to adsorb Ce^{3+} ions onto the halloysite is favorable. However, when the solution concentration increases, the amount of Ce^{3+} ions increases, but the adsorption capacity of halloysite is saturated and does not increase anymore, so the adsorption efficiency will decrease [10]. At a Ce^{3+} concentration of 30 mg.L^{-1}, the adsorption capacity and efficiency reached 1.62 mg.g^{-1} and 86.64%, respectively. This result shows the high adsorption efficiency of halloysite to Ce^{3+} comparable to Cd(II) - 86.31% [19], As(III) - 82.4% [10].

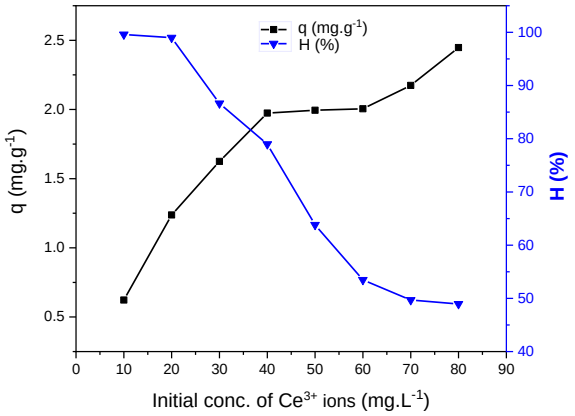


Fig. 8: The effect of initial Ce^{3+} ion concentration on the adsorption capacity

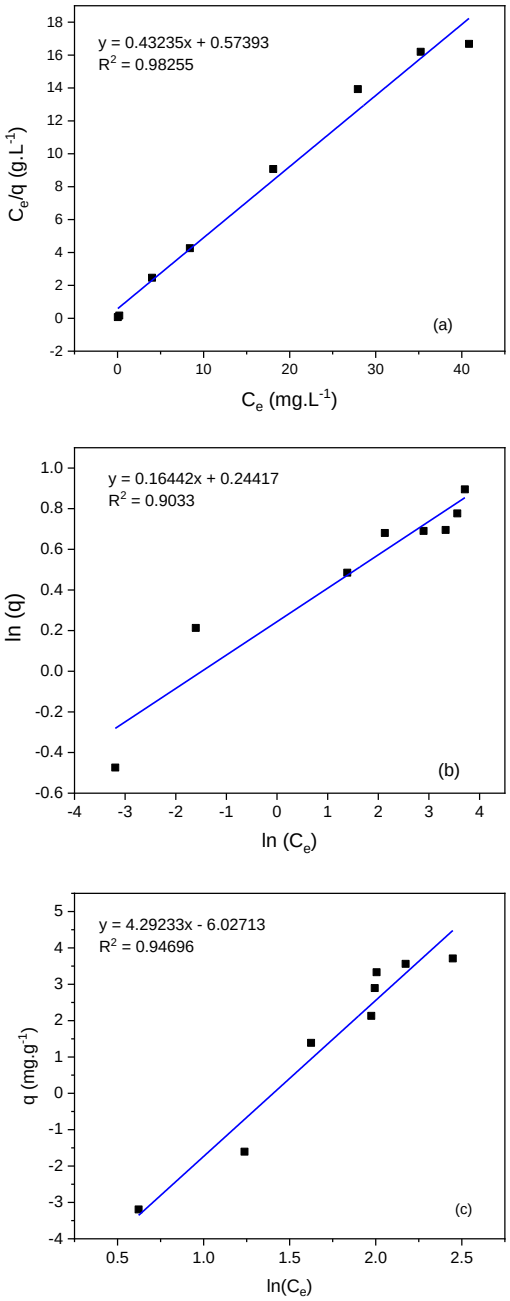


Fig. 9: The adsorption isotherms of Ce^{3+} on halloysite

Table.4: The adsorption isotherms parameters of Ce^{3+} on halloysite

Langmuir	q_m (mg.g^{-1})	2.313
	K_L (L.mg^{-1})	0.753
	R^2	0.98255
Freundlich	K_F (mg$^{1-1/n}$.g^{-1}.L$^{1/n}$)	1.276
	n	6.082
	R^2	0.90330
Temkin	A (L.g^{-1})	0.2456
	B	4.29233

	b ($J.mol^{-1}$)	577.209
	R^2	0.94696

Based on the experimental results of the effect of initial Ce^{3+} ion concentration on the halloysite's adsorption capacity of Ce^{3+}, the linear regression lines between C_e/q_e and C_e (Langmuir model, Fig. 9a), between lnC_e and lnq_e (Freundlich model, Fig. 9b) and between lnC_e and q_e (Temkin model, Fig. 9c) are build. The parameter values of the isothermal equations and other related parameters can be calculated from the slope and intercept values of the vertical axis according to equations (2)-(4), respectively. The results are presented in Table 4.

The results in Fig. 9 and Table 4 show that the Langmuir model is the most suitable among the three models when comparing the reliability coefficient R^2 (the reliability coefficient R^2 of the Langmuir isotherm model is 0.98255, the highest of the three models and close to unity) demonstrating the monolayer physical adsorption. This result is also consistent with studies on the adsorption of halloysite to some other metal ions [21].

IV. CONCLUSION

Halloysite is pretreated with a simple chemical process to create rare earth metal ion adsorbent materials, aiming to recover these elements. The morphology of the pretreated halloysite is rod-shaped and one-dimensional in nano dimensions. The adsorbent material exists in the two-phase form of halloysite-kaolinite. Research results show the high adsorption capacity of halloysite for Ce^{3+}. The Ce^{3+} adsorption process by halloysite follows the pseudo-second-order adsorption kinetic equation and the monolayer physical adsorption model.

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Why Businesses Evade Tax In Ghana

Massang Naa Norley[1], Wang Jianfeng[2], Adu Sarfo Philip[3], Massang Thomas[4]

[1,2]School of Business, Zhengzhou University, Zhengzhou, China
[3]School of Management, Zhengzhou University, Zhengzhou, China
[4]College of Arts and Social Sciences, Kwame Nkrumah University of Science and Technology, Ghana
corresponding author: adusarfophilip@yahoo.com

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***Keywords*— Tax evasion, Tax compliance, Ghana Revenue Authority.**

***Abstract*—** *The paper aims to assess why businesses evade tax in Ghana. This study uses a sample size of 100 respondents, consisting of 90 taxpayers 3 tax officials and, 7 personal interviews. Using descriptive statistics, the study's findings showed that the following are causes of tax evasion; a lack of tax education, high tax rates, a lack of enforcement of penalties, the perception that the government is misusing taxes, and unprofitable businesses. These are the main drivers of tax evasion in the country. The difficulties tax officials face in collecting taxes include their inability to contact all taxpayers and the lack of a taxpayer database. It was not surprising that less than 50% of the respondents responded to the fact that tax evasion may improve living conditions, given that the majority of the respondents did not obtain formal education. Furthermore, 32% of total respondents believe that tax evasion will end or reduce the social benefits enjoyed by citizens because the government will not have enough money to provide such amenities. This means that all respondents were aware of the negative effects of tax evasion on national development. Indeed, the administration must take every step plausible to incentivize tax payment. According to the research results, tax education was insufficient, as were improper sanctions implementation and tax collectors' inability to locate several liable taxpayers. The study concludes by proposing additional research focusing on raising tax adherence through tax education.*

I. INTRODUCTION

Each nation needs funds to start its socio-economic development. Policymakers are able to raise funds through taxation as a tool or vehicle. The revenue generated through taxes comes from the contributions that the state's citizens make as part of their share of the cost of advancing the nation's economy. When William Pitt was the Prime Minister in 1799, he enacted an income tax to help pay for the war against Napoleon Bonaparte of France (Middleton, 2015). In the Gold Coast, custom duty became the first form of taxation in 1850. It was administered by a principal collector stationed at Cape Coast Castle and levied a 2% Ad valorem tax on imported goods. In Cape Coast, a poll tax was instituted in 1852 after the system encountered some odd difficulties that made it ineffective. Due to the collective system's inherent weakness and the fact that the initial proceeds were primarily used to pay the salaries of British officials rather than for the provision of social amenities as intended, earlier attempts to introduce direct taxation were unsuccessful (Crook, 2017).

The PNDC government made a decision regarding the structural modifications to Ghana's organizational legislation and tax system in July 1968. This led to the passage of the Internal Revenue Service Law, 1968 (PNDC L143). Through this law, the previously existing central revenue department became a public service organization. The Revenue Agency Board Act of 1998 (Act 558), which established a central governing body in place of the current

government boards of the IRS, CEPS, and VAT, was passed as a result of additional restructuring. The majority of the population is quite cynical about paying taxes, so they refuse to pay them, or they evade them, despite the fact that the numbers of the year's taxation have remained, despite the numerous contributions of taxes in the generation of revenue for the nation.

Taxation is a significant revenue source for developing countries all over the world. A tax may be defined as a "property to assist the government, a disbursement exacted by legislative authority'. A tax "is not a voluntary payment or funding, but an imposed contribution exacted by legislative authority" (Nsor-Ambala, 2008). In Ghana, taxation is extremely important to the country's development. Ghana's government receives 75% of its cash flow from taxes to fund its numerous expenditures (Nsor-Ambala, 2008). The Customs Excise and Preventive Service Organization is in charge of collecting taxes on imports, exports, and locally manufactured goods. The Value Added Tax Service is in charge of collecting levies on goods and services. The Domestic Tax Revenue Division is in charge of collecting direct tax in Ghana, which is levied directly on the earnings of individuals and businesses.

Because of the matter of tax evasion, the various tax agents that oversee the tax system have been unable to meet their targets over the years. Tax evasion reduces the country's revenue, which in turn reduces infrastructure development and other social amenities (Afuberoh & Okoye, 2014; Al-Rahamneh et al., 2023). This explains why revenue collection agencies and divisions have been established in every city, town, and district in the country. In fact, each division has been assigned goals to achieve in a year. These agencies are primarily responsible for collecting revenue to fund government development machinery in order to improve people's living standards. Aside from this primary responsibility, they are also tasked with providing special allowance packages such as capital allowance to businesses and tax relief to individuals. These exemptions are intended to reduce the tax burden and encourage institutions and individuals to contribute to national development.

The illegal avoidance of taxes by people, businesses, and trusts is known as tax evasion (Alstadsæter et al., 2019). Tax evasion typically entails dishonest tax reporting, such as declaring less income, profit, or gain than what is typically earned, as well as the taxpayer willfully misrepresenting the true state of their financial affairs to the tax authorities to lower the tax liability. The informal economy is frequently linked to tax evasion. Tax evasion is a premeditated attempt to avoid paying taxes through deception. Tax avoidance is the legal use of the tax regime to one's own advantage in order to reduce the amount of tax payable through legal means. Tax evasion, on the other hand, refers to any attempt to avoid paying taxes through illegal means. People avoid paying taxes by under-invoicing and misrepresenting the quality and description of their products. Smuggling or exporting foreign products through unapproved routes is used to completely avoid paying levied customs duties, and importing contraband items is also a form of evasion.

Tax avoidance refers to the legal application of tax law to lower one's tax obligation (Huseynov & Klamm, 2012; Whait et al., 2018). However, since both tax evasion and tax avoidance aim to undermine the state tax system, they are both types of tax noncompliance. Without tax revenue, it is impossible for the government of a country to run efficiently. Prominently in Ghana, it has been discovered that the government, having allegedly admitted that now the income from taxes is very low in comparison to the anticipation of growth and development, has decided to introduce another type of tax, or shift focus to an already existing one by increasing such taxes. Despite this, collecting all of the taxes owed by the informal sector has been extremely difficult (SMEs).

Given this, the study aims to investigate tax evasion in Ghana and determine what can be done to stop the trend.

1.2. Problem of the study

The resource envelope made available to the government for development includes tax revenue as a significant component. Particularly in considering the recent decline in the Ghanaian economy, tax revenue as a percentage of GDP is a critical component of the nation's consumption basket.

The most important and trustworthy method of generating the necessary funds to support the numerous development projects undertaken by the Ghanaian government is through taxes. The Ghana Revenue Authority (GRA) has spent a lot of money on taxpayer education over the years to encourage people to fulfill their tax obligations. Tax evasion is still widespread in the Ghanaian economy, despite the crucial role that taxes play in the development of nations and the numerous campaigns that have been launched to educate the public about taxes. Therefore, the goal of this study is to gain a deeper understanding of the elements that contribute to tax evasion in among businesses in Ghana.

II. LITERATURE REVIEW

2.1. A brief history of taxation in Ghana

In Ghana, taxation was first enacted in 1943 (Randolph 2011). Despite this, the government had already attempted to introduce it prior to its introduction in 1943. For instance, the government introduced the poll tax ordinance in April 1852 as a means of raising money to pay for the rising costs of British administration (Kawor & Kportorgbi, 2014;

Tackie et al., 2022). The poll tax ordinance required men, women, and children living in a district under British protection to pay one shilling per head per year (Kawor & Kportorgbi, 2014). These efforts to introduce direct taxes failed due to flaws in the tax collection system and the fact that the initial revenue collected was not used for the intended purpose.

In Ghana, taxation was introduced in this manner, and since then, significant changes have been made to the tax laws over the years. According to Ali-Nakyea (2019), the first income tax law was an ordinance that was introduced in 1943. The ordinance was based on that Act because the United Kingdom did not already have an income tax law. The ordinance only taxed income that originated in Ghana, so income from outside Ghana was not subject to taxation absent remittance there. Act 68, which amended the consolidated edition after it, was amended in 1961. Acts 178, 197, and 312 came before them in 1963, 1965, and 1961, respectively. The second consolidated edition, Tax Decree 1966 (No. 78), was unveiled in September 1966. In order to manage the administration of Ghana's income tax, capital tax, and gift tax administration and improve Ghanaian administration overall, the then-current government passed new tax laws in the year 2000 (Opoku et al., 2014).

Internal Revenue Service (IRS), VAT Service, and Customs Excise and Preventive Service (CEPS recent)'s merger into one organization known as the Ghana Revenue Authority (GRA) was a significant reform intended to modernize tax revenue collection. and administration as well as enhance customer service (GRA Act 2009 Act 791). This significant reform also aims to align revenue mobilization efforts, minimize compliance costs, cut down on waste, and get rid of redundant tax laws. As a result, on December 31, 2009, the GRA Act 2009, Act 791, was approved by the president and signed into law. The Domestic Tax Division, Support Service Division, and any additional Divisions determined by parliament are to be established under the Act.

2.2. The Tax Evasion Concept

A blatant attempt to avoid paying taxes through deception. Tax avoidance is the legal use of the tax regime to one's own advantage in order to reduce the amount of tax payable through legal means. Tax evasion, on the other hand, refers to any attempt to avoid paying taxes through illegal means.The payment of taxes demonstrates every citizen's desire to see the country develop. Taxation is a civic responsibility that governments impose on their citizens in order to help the administration establish the country by providing infrastructure and utilities to the people. Revenue from tax payments accounts for a larger portion of government revenue. Despite this, many countries, including Ghana, are plagued by tax evasion. Tax evasion is the deliberate failure of taxpayers to meet their tax obligations. Tax evasion reduces national revenue, which has a negative impact on the public sector and economic development.

Tax evasion investigations can be traced back to the work of Cesare Beccaria, a pioneer of "law and economics" (1797) Cesare, (1797), Tax evasion has long been separated to stand alone in order to attract the attention of tax authorities and ensure that much effort is put into finding a solution. According to Rynoids (1963), because tax is a larger portion of government revenue, when taxpayers evade or otherwise avoid it, the tax system is not equitable. Tax evasion hinders the government's ability to collect the revenue owed to it, resulting in a disparity between the actual amount of taxes obtained and what should have been accumulated. Tax evasion differs from tax avoidance in that it is illegal and, as such, punishable if discovered. Avoidance is a legal right, whereas evasion is a crime. Tax evasion is the modification or arrangement of one's financial affairs in order to reduce tax liability in a legal manner. According to Aumeerun et al. (2016), despite government protests against tax evasion and avoidance, taxpayers use tax avoidance strategies or, at times, willfully use false strategies with assistance from tax officials to evade tax. Tax evasion is an outright dishonest action in which the taxpayer attempts to reduce his tax liability by using illegal means.

Tax evasion is accomplished through deliberate omission or commission, both of which are illegal under the laws that govern taxation. For example, a tax payer may choose not to declare his income to tax authorities, either intentionally or unintentionally, and even if the income is declared, certain items may be excluded in order to avoid revealing the true financial situation of such businesses. Furthermore, a taxpayer can choose to include a specific group of people in his family data in order to receive tax relief. In terms of taxation, all of these are criminal offenses. Thus, tax evasion is simply defined as a situation in which a taxpayer pays less levy than he is legally required to pay through illegal means. Abdallah and Ashraf (2018) describes tax evasion as the use of illegal strategies to reduce tax. Thus, tax evasion is a term that refers to attempts by some individuals, businesses, and other entities to avoid paying taxes through illegal means. It primarily applies to taxpayers who intentionally misrepresent or choose not to disclose the actual reality of their matters to tax office in order to reduce their own tax liabilities. Inflating expenses or stating less revenue and profits are two examples. Abdixhiku (2013) believed that tax evasion did deserve to be studied theoretically.

Slemrod (2019) discussed income tax evasion. The goal of that paper was to examine the factors that influence a taxpayer's decision to evade or not evade taxes, and then to figure out the degree to which taxation are evaded. Tax evasion has a negative impact on a country's revenue, and when it is discovered, criminal charges should be brought against the offending taxpayer. It should be noted that tax evasion is not a new phenomenon; it has existed for some time. Because of the nature of the issue, various authorities continue to find it difficult to address.

2.3. Direct taxation and indirect taxation are the two basic types of taxes.

Direct taxes are those that are gathered from of the person or organization on whom they appear to be imposed. Income taxes, for example, are levied on the individual who generates the income, or on the person who receives the gift tax. Direct tax is however described as a tax that is charged on businesses and organizations and is paid by them. Direct tax, according to the ICAG Income tax Study (Barannyk et al., 2021), includes capital gains tax, corporate tax, gift tax, and income tax. The Residential Tax Revenue Division in Ghana is in charge of administering this taxation. Direct taxation is critical because it is a type of progressive tax that takes more from the wealthy. This reduces the rich's utilization of luxury goods and facilitates the redirection of resources from luxury products production to capital construction. According to Havi and Enu (2015), direct tax helps ensure a degree of freedom in the tax system, enhancing the likelihood of tax revenues increasing as income increases. The direct tax's progressive ability is ideal for developing nations like Ghana. In developing countries, this promotes distributive justice. According to Sodokin et al. (2023) inequalities are common in low-income countries, and as economies develop, these disparities tend to widen. It is understandable that the growth of a country is dependent on its citizens and their own willingness to pay taxes. In direct tax, the prevalence rate and yield are easier to calculate than in indirect tax. Despite these benefits, Havi and Enu (2015) claims that there is a significant administrative cost.

2.3.1. Taxation by Indirect Means

Indirect taxes are the inverse of direct taxes. Indirect taxes collected from an individual other than the individual who is liable for the tax payments and are gathered by an intermediating body, such as a retail outlet, which collects state sales tax from the proceeds of the purchase.

After that, the intermediary body documents a tax form and transmits the tax proceeds to the government. Simply put, an indirect tax is a tax levied on spending. Essentially, this is a tax levied on one individual with the presumption that it will be transmitted to another. The effect and incidence in this case are on different people (Sodokin et al., 2023). Examples include excise duty, customs duty, and value added tax (VAT). According to Havi and Enu (2015) the authorities in charge of this levy are indeed the CEPS and VATS. The tax office does not deal directly with the consumer, as in tax collection, but rather with importers, manufacturers, or other intermediaries, resulting in it being called indirect tax. The transfer of this tax liability according to Barannyk et al. (2021), Taxation and Fiscal Policy, 2015, is accomplished by charging the tax component just on sale value of the commodity markets to the following individual in the advertising sequence until it is finally borne by the consumer.

According to Sodokin et al. (2023), the value of the product determines the amount of duty with indirect tax, which implies that attributes of the good or service determine the tax rate, that is also premised on a fixed amount. A bag of rice, for example, could be taxed at GH30.00 per kg, and drinks could be taxed predicated on their volume. The following are some of the benefits of indirect taxes. To begin with, enhanced tax revenue means allowing for labor market subsidies because the government can reduce the total tax imposed on earnings and capital. This is particularly so given that Ghana's income and corporate taxes have been reduced over the years. According to Barannyk et al. (2021), often these individuals chose indirect tax to direct tax because indirect tax allows employees to keep more of their earnings. This explains why when tax rates on income are reduced, the goes back on working hours extra rise. Nevertheless, in the case of the tax, people can earn a specific target post-tax income with fewer working hours than they did previously well before tax cut (Barannyk et al., 2021). If leisure is considered a normal good, employees will choose not to work in order to have more leisure time while earning the same income.

The next benefit of indirect taxes is that they only gathered from businesses, making them less expensive to administer than direct taxes. With indirect taxation, the government gains so much control over its fiscal policy. Furthermore, some indirect taxes can be changed among both budgets even without parliamentary approval. VAT and excise taxes are two examples, whereas direct taxes may only be shifted in the yearly budget. Despite these advantages, one could argue that an indirect tax is regressive. The reason for this is that with indirect taxation, each taxpayer pays the same rate of tax regardless of income level, which means that those with lower incomes pay more than those with higher incomes. In terms of direct taxation, those with higher incomes pay more tax than those with lower incomes. As previously stated, tax revenue are progressive.

2.3.2. Taxation's Role in the Country's Economy

According to Altus Directory (2006 - 2010), the following are the motives for taxation from the perspective of the authorities:

2.3.4. Revenue and Redistribution

Taxpayers' money is used by the government to fund social amenities such as hospitals and clinics, as well as infrastructure such as roads and education systems. This is a contentious but arguably significant purpose of taxation. Its goal is to properly distribute wealth between all sections of society, both wealthy and impoverished. It is a normal practice in any democratic country, but the manner and proportion vary from country to country.

2.3.5. Ghanaian Tax Evasion Prevention Measures

In light of the foregoing, the following basic suggestions are made on the surface: The government should use various forms of advertising to start educating the public about the importance of paying taxes (Essilfie-Afful, 2018). In the case of Ghana, because the government owns a television station, it should seize the opportunity to use that platform to educate the public, particularly on certain misconceptions about the use of taxpayers' money. Authorized people should be hired and trained on a regular basis so that they are up to date on changing dynamics. There should also be enough incentive to keep officials from conspiring with some taxpayers to evade or avoid paying their taxes. In order to encourage tax compliance, the evaluation and collection processes should be properly reviewed and evaluated. Tax officials typically send printed portions of tax laws to taxpayers, and the majority of these laws are authored in legal language, making them challenging for the taxpayer to comprehend. Improving the design of printouts can be a significant step toward bettering levies and collection processes. It is therefore the sole duty of the government to monitor the trend of inflation in order to ensure equality in paying taxes. Furthermore, the government should do everything possible to ensure that certain basic utilities and amenities are available to all people and citizens in the country.

Again, employment opportunities must be made available to all so that people understand the value they receive in exchange for paying taxes. The taxable citizenry should be ascertained on a regular basis, and relevant documents should be kept up to date in order to support all taxpayers and make tax data reliable. Tax evasion would be greatly reduced once most, if not all, taxpayers, including businesses, were captured in the data. The Ghana Revenue Authority must ensure that systems are in place to determine the needs of each employee and the efforts required to avoid regression. According to Alhempi et al. (2020), tax officials must follow these suggestions to increase tax efficiency. Simplification: Tax administration shouldn't be as difficult to evaluate and collect as necessary, resulting in lower costs to tax executives and taxpayers. Audits that are shorter: A tax audit should, as soon as possible after a return is filed, begin. This enables the taxpayer to respond quickly to information requests.

2.3.6. Reasons for Tax Evasion in Ghana

When an individual intends to comply with these laws, it means that he will properly expose his tax base as well as calculate his tax liability, file returns on time, and then pay the tax due. Many taxes evasion decisions stem from all these simple points. Those who evade tax may first determine not to accurately reveal their tax base, and thus will not provide an accurate determination of their tax liability. Most tax evaders choose not to file their correct returns and thus avoid paying taxes. To properly address the issue of tax evasion, it is necessary to identify some of the factors that influence people's decision not to pay taxes. To develop methods and tools to combat tax evasion, it is critical to first establish a broad knowledge of the various reasons why individuals evade taxes. Some causes of tax evasion are generally specific to certain countries; however, the possible factors of tax evasion are universal and can be applied to nearly all countries. (Feld & Schaltegger, 2010)conducted research to identify the determinants of tax evasion. In their study, those who used the appearance of grudge in absolute terms. Findings indicate that as sentiments of perceived injustice risen in real numbers, the level of fiscal evasion also increased and the level of tax moral belief decreased".

At the conclusion of his inquiry, it was discovered that just because people can easily move through one district to another and continue with their company, there was a possibility of rescuing that legal money. He also discovered that some operators do not keep adequate or proper records of their transactions and, as a result, do not report their interim income to tax authorities for tax purposes. It was once again disclosed that people who earn wages or salaries freely dislocate at specific times in order to keep tax authorities from locating them and collecting tax revenue. The following are some of the most common reasons why people avoid paying taxes. The Lack of a "Quid Pro Quo" Essentially, people dislike the idea of paying taxes.

This is primarily because people believe they receive nothing of value in exchange for the taxes they pay. Most people argue that they should not pay taxes because those taxes are not used to provide them with the necessities of life. They would rather use that money to provide themselves with those amenities.

2.3.7. Inequitable Amenity Distribution

It is common in most countries, including Ghana, for people to blame the government for being unfair in the distribution of social amenities. Most tax evaders believe that because one part of the country has more amenities, those who work there should be taxed. This is reasonable in the context that one pays taxes while still lacking the amenities that others enjoy in their part of the country.

2.3.8. Poor management of Tax Income by the Government

On radio and television, there has always been bribery and misuse of public funds. There are examples of people in government positions wasting public funds, mostly for their personal gain. The issue of personal judgement debt is common in Ghana. Several government-funded projects have reportedly failed, and these issues are frequently discussed in the media. Because of this perception, people either choose not to pay the tax at all or pay only a small portion of the true amount, believing that the mismanagement of state money will continue.

2.3.9. Taxpayers' estrangement from the government and Absence of Civic Responsibility Spirit

Most people believe that taxes are paid to provide for the well-being of government officials, who are paid more than tax payers. People in government, in most cases, become enemies of the average Ghanaian, due to their way of life, which is diametrically opposed to that of the average tax payer. Most tax payers are aware of the various tax breaks available to these wealthy individuals. The taxpayer lives far away from the government and thus sees no reason to pay taxes to government officials who live in big cities. A little education will most likely help taxpayers understand this issue very well.

As previously stated, a higher proportion of the adult population in Ghana is illiterate. As a result, most people are unaware that they are subject to obligations such as tax payment. Regardless, whenever the government attempts to educate the public on such poor attitudes, the same public suggests that the government instead print enough currency to alleviate the country's challenges. Higher tax evasion in Ghana is attributed to a lack of this type of patriotism. Other authors from other countries have also proposed several other causes of tax evasion. According to Orewa and Izekor (2012) in Nigeria, partial evasion may occur due to traders' improper bookkeeping and accounting records, as well as some illiterate taxpayers' belief that only workers who earn wages or salaries should be taxed. This perception, however, is incorrect. Abille et al. (2020) believes that many entrepreneurs and business owners do not understand the importance of paying taxes, even if they make a lot of money. This clearly demonstrates citizens' unpatriotic. Some people simply choose to keep their earnings to themselves for that reason. Alhempi et al. (2020) conducted a study to investigate both the attitudinal and behavioral aspects of tax ethics. According to their findings, while most people believe that tax laws should be followed, they do not consider violations to be serious crimes deserving of harsh punishment. According to Chandra and Sandilands (2021), there is a strong link between tax evasion and the awareness of inequality in tax payment. That is, the greater people's view of tax disparity, the more likely they are to engage in tax evasion.

Dularif and Rustiarini (2022) also stated in one of his dissertations titled "The Behavioral Modem of Income Evasion" that there is positive association between individuals who evade tax as well as the rate of tax evasion among such evaders' friends. Braithwaite (2017) conducted a survey on taxpayer attitudes. The majority of respondents (93%), believed that "income tax is (much/little) too high," while a sizable proportion (62%), believed that government agencies do not spend taxpayers' money wisely. With regard to the latter point, most people believe that government wastes taxpayers' money. The survey also revealed that many participants feel they have been paying far to much income tax in comparison to others, even when comparing those with similar incomes. Excerpts of the study also has shown that "two thirds of the respondents did think that all or most taxpayers would exploit an opportunity for small scale evasion if they thought they could get away with it. Similarly, nearly a quarter of respondents believed that if they thought it would go undetected, all or most taxpayers would attempt large-scale evasion. According to Beattie et al. (2023), people evade taxes in order to increase their earnings. This is because every businessman wants to maximize his net income after deducting all expenses, including taxes.

His ultimate goal is to reduce costs while increasing sales and thus increasing the cash position of the company or organization at the end of the fiscal year. Ordinarily, it is understandable that people evade taxes because governments do not offer sufficient tax incentives to taxpayers. As Kumi-Dumor (2022) puts it, "the state subsidies offered by government have neither hind to the expectation or stimulating investments into the country nor influencing the location of company or organization". Thus, if the government provides enough tax incentives, individuals will be more likely to pay taxes rather than evade them. Again, individuals who are relatively poor do their best to avoid paying taxes. This is due to their constant desire to amass sufficient funds to maintain their standard of living. The little money they make at the end of their sales is not so large that they would be willing to use some of it to pay taxes. Another reason people evade taxes is due to flaws in the implementation of tax laws. People are more

likely to take advantage where law enforcement is weak. Inadequate tax personnel can sometimes lead to tax officials omitting the names of 30 tax payers from the tax list. Some people, inexplicably, evade taxes without even realizing it.

2.4. Ghana's level of tax evasion

Only by estimating the extent of actual evasion can the value of developing a conceptual comprehension of tax evasion be determined (Egbunike et al., 2018)"Information attempting to reach Contemporary Ghana Headlines from either the corridors of authority implies that now the Special Subsidiary on Tax Evasion at the governorship has unearthed approximately two hundred eighty (280) private and public enterprises that had circumvented tax in the country," according to a February 18, 2015 article on the website of Today Ghana News. This does indeed highlight Ghana's troubling tax evasion problem.

The Ghana Revenue Authority has expressed concern about the issue of tax evasion and its negative impact on the nation on numerous occasions. GRA discussed evasion in a news. GRA reportedly urged the media to work with the tax authority to inform the public about the importance of paying taxes that are due to them in order to support nation building (Amoah et al., 2014). GRA disclosed that 80% of Ghanaians who work in the informal sector of the country's economy do not pay taxes, and claims that this is because there is no historical database to track them. GRA also gave advice on the need to create a computerized database to capture the informal sector as a developing country (Amoah et al., 2014).

2.4.1. Methods of tax evasion

In developing countries, customs duties are a significant source of revenue. The importers claim to be evading customs duty by a. under-invoicing and b. mis-declaring quality and product description. Smuggling or exporting imported imports through unauthorized routes is used to avoid paying livable customs duties, and importing contraband items is also a form of evasion.

2.4.2. Reasons for tax evasion in Ghana

There are some fundamental explanations for tax evasion.hen someone makes the decision to abide by the tax laws, it means they will accurately disclose their tax base, calculate their tax liability, file their returns by the deadline, and then pay the tax that is owed. These basic ideas serve as the foundation for many tax evasion decisions. Those who firstly evade taxes may choose not to accurately disclose their tax base and as a result, will not provide an accurate assessment of their tax liability. The majority of tax evaders also choose not to submit their accurate returns, which results in tax evasion.It is crucial to identify some reasons why people choose not to pay taxes in order to combat tax evasion effectively. The various causes of tax evasion are general and can be applied to almost all countries, although some causes are generally specific to some countries.

Kumi-Dumor et al. (2022) carried out research to identify the causes of tax evasion. In their research, they used the absolute presence of grievance. The findings showed that as the degree of tax evasion increased and the degree of tax moral belief decreased, respectively, in direct proportion to the degree of grievance. At the conclusion of his investigation, it was discovered that there was a possibility of saving that legal money because people can move from one district to another without difficulty and carry on with their business. They also discovered that some business owners do not maintain adequate and accurate records of their transactions, and as a result, do not report their interim income to the appropriate tax authority for tax purposes. Once more, it was discovered that those who earn wages and salaries freely relocate at particular times in order to avoid being discovered and subsequently taxed.

III. METHODOLOGY

The researcher used three different techniques for sampling. These include stratified sampling, random sampling, and judgment sampling. Purposive sampling was used because of the unusual nature of the paper. In some cases, a non-probability sampling method like judgment sampling was used to identify the root causes of tax evasion. In these situations, inclusion and exclusion of people were the main concerns.

The researcher carefully considered the research problem before employing various techniques to gather pertinent data. As usual, primary and secondary sources made up the bulk of the data collections. In addition to these, questionnaires through goggle forms were the main tools used to gather the survey's data. It allowed the researcher to get honest or accurate answers to delicate and significant questions because the respondents felt comfortable answering them. Additionally, interviews were used to gather the required data from key informants.

For one hundred respondents, one hundred sets of questionnaires were created. There was a total of 18 questions. Five questions made up section "A," which provided background data on respondents. The remaining questions were covered in section "B," which contained the details about the study's goal that the researcher needs to address the problem statement. Data analysis methods included both qualitative and quantitative approaches. For the qualitative data, the researcher used both narrative and descriptive analysis, and Microsoft was used for the quantitative data, which included tables and chats.

3.1. Ethics consideration

Concerning ethical considerations, respondents were guaranteed that any information they provided would be treated with the utmost confidentiality. In light of this, the researcher made sure that everything was done ethically by keeping their pledge to the respondents. Before collecting data and conducting interviews, a letter was submitted to the Accra main office of Ghana Revenue authority seeking approval.

IV. RESULTS

95 questionnaires were distributed to tax payers, five to GRA staff and 10 personal interviews conducted in conformity with the study topic and objectives. Ninety questionnaires, or 94% of the total, were retrieved from the table 4.1 illustration for taxpayers, three questionnaires for Ghana Revenue Authority (officials) were retrieved, accounting for 60% of the GRA sample size.

Table 1. Response rate

Respondents	Number Distributed	Number Retrieved
Taxpayers	95	90
GRA staff	5	3
Personal interviews	10	7
Total	110	100

Field survey, (2022)

4.1. Demographics

The results of the researcher's investigation into the respondents' age distribution are as follows. According to the study's data, seven respondents (8%) were between the ages of 18 and 20; 13 respondents (14%), between the ages of 21 and 30; and 32 respondents (36%), between the ages of 31 and 40. Additionally, 22 (24%) of the respondents were in the category of 41-50, while 16 (representing 18%) of the respondents fell within the 51+ age range. The table above shows how this is depicted.

Table 2. Demographics

Respondents	Frequencies	Percentages %
Age		
18-20	7	8
21-30	13	14
31-40	32	36
41-50	22	24
50+	16	18
Educational data		
Basic	41	46
SHS	24	26
Tertiary	25	28
Others	0	0

Field survey, (2022)

All studies, including this one, have educational implications. Since education is widely regarded as a necessary element of human development and the primary agent of empowerment, it actually has a greater impact on studies of tax evasion. The table above shows how the majority of individuals in in Ghana are distributed in terms of educational attainment. In comparison to the secondary and tertiary classes, which make up 26% and 28% of the 90 respondents overall, the basic category has the highest number of respondents (46%). Other than these three qualifications, none of the respondents provided a response. With the exception of what they may have heard in the news or from friends and coworkers, 46% of the respondents are therefore likely to have little to no knowledge of taxation and tax evasion. This has a stronger impact on the problem of tax evasion.

According to Table 3, the total questionnaires of 66% representing 59 respondents work in the informal sector, and 31% representing 34 respondents work in the formal sector. It accurately reflects the educational statistics stated, which indicated that the majority of respondents only had basic education certificates.

Table 3. Types of Businesses

Types of business	Frequencies	Percentages %
Formal	31	34
Informal	59	66

Field survey, (2022)

4.2. Degree of Tax evasion

The degree of tax evasion in Ghana was a question that the respondents were asked about. This is shown in table illustrated below.

Based on the study, 26 respondents representing 29% believed that tax evasion was ubiquitous in the municipality. 20 % of respondents thought that tax evasion in the municipality was extremely rare. If more than half of the respondents concurred that there is a high level of evasion in the Ghana, there is cause for concern. 13% of the

respondents, likely in line with the earlier response, indicated that they were unsure of whether their coworkers paid taxes or not and were unable to definitively determine whether they were tax evaders themselves.

Table 4. Degree of tax evasion

Degree of tax evasion	Frequencies	Percentages %
Very high	26	29
High	34	38
Low	18	20
Uncertain	12	13

Field survey, (2022)

4.5. Views of respondents regarding the causes of tax evasion

After obtaining the respondents' opinions regarding the scope of tax evasion, the researcher set out to identify any potential causes of tax evasion in Ghana.

Table 5. shows that 31 respondents, representing 34%, believe they unintentionally evade taxes because they are ignorant of their obligation to do so. This accurately reflects some of the respondents' earlier claims that they were unaware of their obligation to pay taxes. Additionally, 17 respondents representing 19% of the populace purposefully fail to pay their taxes. Once more, 12 respondents, representing 13% of all respondents, stated that they evade taxes because of the high tax rate in the nation. Additionally, 9% respondents of the sample population admitted to evading taxes, which could be a result of their businesses being unprofitable and them not seeing the need to pay taxes with their meager income. Even though the majority of respondents had earlier acknowledged that tax officials do not frequently visit neighborhoods to collect taxes, none of the respondents clung to this issue as a reason why they or other people might evade taxes. Finally, 22 respondents, representing 24% respondents, agreed that tax evasion occurs because the government spends tax payers' money inefficiently. They believed that tax money was used more for the personal gain of government officials and administrators than for the advancement of the economy of the nation. They also said that the widespread corruption of the government and its representatives did not encourage them to pay taxes.

Table 5. Causes of Tax evasion among taxpayers

Perspectives	Frequencies	Percentages %
Intentionally	31	34
Unawareness	17	19
Tax liability too huge	12	13
Unprofitable business	8	9
Unnecessary use of Tax revenue by government	22	24
Proximity to GRA office	-	-

Field survey, (2022)

According to table 6 respondent, representing 10% indicates that, if they fail to not pay their taxes, nothing will happen. Since the majority of respondents did not receive a formal education, it was not astounding that only 21% responded to the possibility that tax evasion could improve living conditions. Additionally, 32% of all respondents believe that tax evasion might very well end or lessen the social benefits that citizens currently receive because the government will not have the funds to pay for them. This indicates that every respondent was aware of the detrimental effects that tax evasion has on the growth of the country.

Table 6. Implications of tax evasion to the general public.

Perspectives	Frequencies	Percentages %
Reduction in Government revenue	33	37
Inability to provide social benefits	29	32
Increase in standard of living	19	21
No effect	9	10

Field survey, (2022)

4.6. Ghana Revenue Authority Responses on Tax compliance level

All three participants discussed the nation's mean compliance rate. Subsequently, the researcher inquired whether there were any tax evaders in their vicinity, and each of them confirmed the presence of tax evaders. Following their affirmative responses, the researcher proceeded to examine the scope of tax evasion in the

country. According to the respondents, they inferred that the country experiences a substantial degree of tax evasion from the available statistics. Hence, the taxpayers' feedback is adequately represented.

The researcher then asked respondents for their opinions on what they believe causes tax evasion and why they believe people do it. According to the information gathered from the respondents, some people purposefully evade taxes, while others do so due to a heavy responsibility load. Again, some of the survey participants said that others evade taxes because tax officials cannot get in touch with them because there are not many of them, which makes it difficult for them to contact everyone. Other responses mentioned how tax payers invariably claim they are caregivers rather than the owners of various businesses in order to shield themselves from being held accountable for tax evasion. Nevertheless, the respondents also admitted that they have seen instances where some merchants and operators lock their shops and vanish when tax officials are hinted at. Additionally, some offered the defense that their businesses were no longer profitable as a result of the current economic crisis and poor governance, making it almost impossible to allow them to keep paying taxes. The researcher wanted to know if self-employed people pay taxes easily, and all three of the officials who answered the question said "No." This demonstrates the fact that perhaps the organized sector pays more in taxes than the unofficial sector does.

Once asked what could be done, the officials unanimously stated that taxpayer education should be a priority in order to prevent tax evasion. As previously mentioned, they claimed that the majority of residents do not understand the significance of paying taxes and that education will help them to realize the advantages of doing so and their responsibility as citizens. According to one official, they are working to create a repository that will give them access to data on all businessmen and businesswomen and make their jobs easier. The difficulties that officials face in performing their duties were queried. They replied that the absence of a database makes it challenging for them to identify all taxpayers. On top of that, some places are inaccessible. Occasionally, some taxpayers argue against them as if they were obtaining the funds for their own use.

V. DISCUSSION

According to the study, tax evasion in the country is widespread. According to our field survey, which included responses from taxpayers and officials, tax evasion is prevalent, as indicated by 38% of taxpayers. The majority of taxpayers said they are knowledgeable of their obligation to pay tax but still evade because of the aforementioned reasons. However, 19% of them let the researcher know that they were unaware of this obligation. With the current tax rate for corporations of 25%, 20% is given to businesses, and individual traders receive pay as you earn taxation based on their monthly earnings. In order to reduce the amount of tax evasion, taxpayers believe it to be too significant and hope for a reduction.

The fact that the tax authorities do not have an accurate database of every taxpayer was one of the problems they revealed. Only the sellers and business owners that the tax collectors meet and observe in market areas are subject to tax collection. Because individuals are only motivated to pay when confronted by tax authorities, this significantly contributes to the tendency toward tax evasion. The absence of a database, according to the tax authorities, allows many people to evade paying taxes.

VI. CONCLUSION

It makes sense that taxes make up a larger portion of government revenue since they enable the government to provide services to the populace. The study found numerous issues with how individuals handle taxes, along with the fact that they have low levels of awareness. Most of them are recent graduates of elementary and secondary schools who lack adequate knowledge of taxes and their obligations. In addition, tax payers' complaints that tax money is spent on government employees rather than on projects that will benefit both them and the entire country.

In actuality, the government must take every possible step to promote tax payment. According to the findings, there are still unresolved issues with tax education, improper sanctions implementation, and tax collectors' inability to find some liable taxpayers. The researcher recommends additional research that focuses on boosting tax compliance via tax knowledge as they come to a close.

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From Denigrating Violence against African Beliefs to the Construction of Cultural Values: A Postcolonial Study of Religious Cults in the Bamiléké Country (West Region of Cameroon)

Beaudelaire Noël Kaze

University of Dschang, Cameroon
beaudelairekaze@yahoo.fr

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***Mots clés*— Religions marginalisées, violence dénigrante, culte religieux, pays Bamiléké, stéréotypes culturels, amémoire culturelle, postcoloniale.**

***Abstract*—** *In the context of globalisation, African religions are marginalised because they are poorly understood and have to compete with the so-called revealed religions of the West. As a result, certain African beliefs are subjected to denigrating violence. This is the case of the Bamiléké cults in West Cameroon, which are characterised by specific rites, ceremonies and places. Based on a corpus of cults observed in the Bamiléké country (2021/2022), this article aims to rehabilitate them in order to place them in the context of a poorly understood monotheistic religion, hence the following problem: how is religious worship characterised in the Bamiléké country in a context of globalisation where certain African cultural values are marginalised? To carry out this research, we will use social and cultural anthropology and discursive memory as two approaches to postcolonial theory. Our findings are as follows: first, the problem of naming African religions is characterised by stereotypes and cultural memory. Secondly, religious cults in Bamiléké country have cultural specificities that may either be authentic to the Bamiléké or resemble cults practised in so-called monotheistic religions. Finally, these undervalued religious cults have various symbolic stakes for the Bamiléké that deserve to be taken into account in a context of unidirectional globalisation.*

***Résumé*—** *En contexte de mondialisation, les religions marginalisées sont africaines car elles sont mal comprises et font face aux religions occidentales dites révélées. Il s'observe donc de la violence dénigrante contre certaines croyances africaines. C'est le cas des cultes bamiléké à l'Ouest du Cameroun caractérisés par des rites, des cérémonies et des lieux particuliers. Ainsi, en partant d'un corpus constitué d'un ensemble de cultes observés en pays Bamiléké (2021/2022), cet article se propose de les réhabiliter afin de les replacer dans le cadre d'une religion monothéiste mal comprise d'où la problématique suivante : comment se caractérise le culte religieux en pays Bamiléké dans un contexte de mondialisation où certaines valeurs culturelles africaines sont marginalisées ? Pour mener à bien cette recherche, nous allons nous appuyer sur l'anthropologie sociale et culturelle et la mémoire discursive*

comme deux approches construites de la théorie postcoloniale. De ce fait, nous allons aboutir aux résultats suivants : d'abord, la problématique de la dénomination des religions africaines se caractérise par des stéréotypes et l'amémoire culturelle. Ensuite, les cultes religieux en pays Bamiléké ont des spécificités culturelles qui peuvent, soit être authentiques aux Bamiléké, soit ressembler aux cultes pratiqués dans les religions dites monothéistes. Enfin, ces cultes religieux sous valorisés ont divers enjeux symboliques pour les Bamiléké qui méritent d'être pris en compte dans un contexte de mondialisation à sens unique.

I. INTRODUCTION

Worship refers to a collection of religious practices such as ceremonies, prayers, and rites carried out to pay respect to a sacred being or divinity. These customary practices, as typical forms of lived religion, vary across different societies and periods, defining the unique religious identity of most societies worldwide. The involuntary contact between Africa and the West during colonization resulted in the negation of African culture. As a consequence, Africans were compelled to renounce their own demonized cults in favor of those of the colonizers, as seen in the realm of religion. In practice, Western religions such as Christianity share certain similarities with African religions, which were hastily labelled as polytheistic or animistic by colonialists in an effort to desacralise them. Although these beliefs were rejected, some African communities are currently attempting to conserve their religious practices, which are often undervalued in a post-colonial context characterised by one-sided globalisation.

This instance pertains to the Bamiléké people residing in the West region of Cameroon who follow a faith that is inadequately labelled by external viewers. They partake in their own customs, traditions, and sacred spaces. Based on a corpus of observed cults in Bamiléké country, this article aims to rehabilitate them, placing them within the context of a poorly understood monotheistic religion. This leads to the question of how worship is characterized in Bamiléké country, given the context of globalization, where certain cultural values are marginalized. To conduct this study, we will considere social and cultural anthropology (S. C. Abéga: 2007) and discursive memory (M.-A. Paveau: 2006) as two approaches within postcolonial theory. The study is structured around three components. Firstly, we will examine the issue of naming African religions, which is often influenced by cultural memory and stereotypes. Secondly, we will present the Bamiléké as a people whose cults exhibit particular features that may bear similarities to those observed in other major religions, such as Islam and Christianity. Finally, we will identify the symbolic concerns inherent in these undervalued cults, which have cultural, linguistic and environmental dimensions.[1]

II. THE NAMING OF RELIGIONS IN BAMILÉKÉ COUNTRY: BETWEEN STEREOTYPES AND CULTURAL MEMORY

There are two rival hypotheses concerning the etymology of the term 'religion'. According to Cicero (106-43 BC) and others, it is derived from the Latin religere, meaning 'to reread attentively' or 'to review carefully'. On the other hand, Henry Duméry proposes that the term derives from another Latin verb, religare, meaning 'to connect' (H. Duméry, online). The initial hypothesis underscores the devoted, careful attention that religious devotees exhibit in their religious practices and communal rituals. The following hypothesis accentuates the purpose of religion. Broadly speaking, religion symbolises the collection of faiths, ceremonial practices, and creeds that regulate the connection between humanity and the divine (or divinities) (Ibid). Its diversity is marked by the fact that human convictions differ from society to society and from one group of individuals to another. In these conditions, the religions practised in Bamiléké land differ from those observed elsewhere. It is only since the European penetration of Africa, specifically Cameroon, that they have been stereotyped as part of a cultural memory project.

2.1. The origins of the pejorative name given to African religions

The origins of the pejorative name given to African religions stem from Europeans using the pretext of evangelising and civilising peoples as a means to justify colonial conquests for political and economic reasons. In this endeavour, the European positioned himself as the pinnacle of scientific, religious, and artistic knowledge,

[1] Notably the Dschang Council ; capital of Menoua division in the West region of Cameroon. And Bafoussam council ; capital of Mifi division in the West region of Cameroon.

dubbing himself a 'civilised man', while casting the African as savage or primitive. This conflicting view of the world extended to beliefs as well. Western religions were regarded as favourable and advanced due to their shared origins: Judaism, Christianity, and Islam (E. E. Evans-Pritchard 1950: 8). Conversely, African religions were classified as primitive. This denial of African beliefs lacks validity; it stems only from the Eurocentric perspectives of anthropologists who fabricated an exotic portrayal of African cultures. Evans-Pritchard espouses this view:

> Remarkably, none of the anthropologists, whose theories on primitive religion carry weight, has ever closely interacted with a primitive community. It is as if a chemist had never stepped inside a laboratory. The anthropologists had to rely solely on the information provided by explorers, missionaries, administrators, and traders. It should be noted that the reliability of the information they obtained is questionable. Although not entirely fictional, the accounts provided by renowned explorers such as Livingstone, Schweinfurth, and Palgrave were often careless and inattentive. These narratives were largely unreliable, superficial, and out of context, according to the standards of modern research. This sentiment also holds true, to some degree, for the pioneering anthropologists (Ibid., p.6).

It can be understood that the negative labelling of African religions stems from the colonial era, in which binary thinking was necessary for Europeans to justify their own religious practices. In addition to this overall categorization of African religions, there are also stigmatizing labels emerging.

2.2 – Animism, Polytheism and Atheism: Stereotyping.

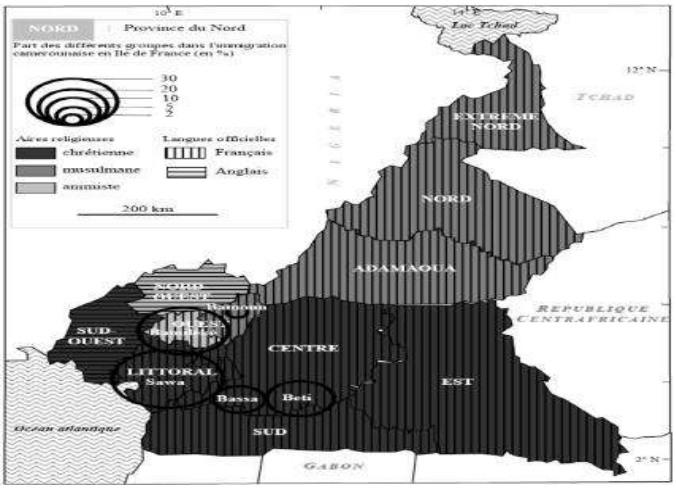
Since the earliest European exploration of Africa during colonialism, stereotypes have been a weapon that enables discursive editing in favour of denying otherness. African religions have been stereotyped as part of a process of desacralization. Several derogatory terms have been employed to classify religious practices in Africa. Of these, three are especially significant due to their frequent use in connection to worship in Bamiléké country.

Initially, these cults are accused of practising polytheism. Derived from the Greek polutheos (worshipping multiple gods), polytheism is a philosophical or religious notion that embraces the existence of a plurality of divine beings. In reality, the Bamiléké do not believe in the existence of multiple deities as some foreign sociologists and anthropologists suggest. Instead, they believe in a single supreme being, as revealed in religions. These cults are classified as atheism, as foreign anthropologists and sociologists are mistaken due to the stark contrast between their observed rituals and those practiced in revealed religions. In such circumstances, the Bamiléké people are occasionally viewed as atheists. Edmond Ortigues delineates the reasons for this phrase:

> It is noteworthy that this pejorative label, lacking any specific verb, has been employed in various manners over the course of history. In some contexts, various interpretations may be inferred. The preferred verb we are inclined to use is 'believe' (an atheist is someone who does not believe in the existence of God or gods). However, some instances call for the usage of 'deny,' especially when referring to an 'atheist doctrine' that negates the existence of God. Other times, an atheist is someone who declines to 'venerate' or 'worship' the gods (E. Ortigues, online).

Finally, religious practices in Bamiléké country are characterised as animist worship. Animism, derived from the Latin anima meaning soul, is a wide-ranging concept that assigns souls similar to those of humans to the universe's beings and objects. As such, it refers to faith in souls and spirits (M. Eliade & N. Sindzingre, en ligne). This title is the most commonly used by scholars and in social science education to describe the cults in Bamiléké country. However, the Bamiléké hold a belief in a supreme being, rather than in souls and spirits. Here is one of many maps displaying religious areas in Cameroon, sourced from the internet.

Image: Map of religious areas in Cameroon



Source: https://journals.openedition.org/cdlm/docannexe/image/4319/img-1.png

This map illustrates that three religions dominate in Cameroon – Christianity, Islam, and animism. Christianity holds a prominent position in five regions,

namely the South-West, the Littéral, the Centre, the South and the East. Islam has a strong presence in the Far North, North, Adamaoua and Bamoun country, which is part of the West region. Animism, meanwhile, is present in the North-West and Bamiléké country, the other half of the Western region. As the Bamiléké themselves, who practice these cults, did not construct these different denominations, it is safe to assume that they are the product of Western observers who are not familiar with the facts. Therefore, we can conclude that these denominations are stereotypes. According to Ruth Amossy, a stereotype is when one group applies a familiar schema to another, and it is the cultural equivalent of a standardized object. It is a preconceived notion that the community repeatedly exchanges in their thoughts and writings (Amossy, 1991:21). Similarly, Marie-Anne Paveau describes it as a manifestation that exists before discourse, passed down from one person and generation to the next, since it originates from shared, pre-existing frameworks (Paveau, 2006:56). Therefore, these labelled terms serve to perpetuate the remembrance of the existence of certain African communities, particularly the Bamiléké, who maintain primitive religious practices. This is because the catch-all category of African religion encompasses concepts such as magic, totemism, taboo, and even witchcraft – all of which can be attributed to the notion of 'primitive mentality' and appear irrational and superstitious to Europeans as noted by E. E. Evans-Pritchard 1965 :7. The transmission of so-called revealed religions to Africans was encouraged during colonisation, legitimising the practice and establishing these imported religions as universal models.

2.3 – An Attempt at Cultural Memory

We postulate the idea of cultural memory following the discursive memory formulated by Paveau in his work on discursive memory. In fact, discursive memory is 'a conscious or unconscious erasure of a past or discursive legacy, of "original formulations" that the speaker no longer wishes to have anything to say, but which are nevertheless said, through the unconscious and somatisation, in other ways, in the infinitely innovative languages of the symptom' (M.-A. Paveau 2006, p. 55).

From this perspective of discursive erasure, we see cultural memory as a process of (in) voluntary erasure of a people's cultural markers. This process of erasure can be facilitated by two types of agent: either one internal to the culture, or one external to it. In the case of African religions, the process of cultural erasure is carried out by external agents, i.e. Westerners, who since colonisation have taken it upon themselves to set African religions back in favour of Western ones. One of the resounding facts that explains this process of cultural amnesia on the part of Westerners is the speech made by Leopold II, King of the Belgians, in 1883 as a prelude to the colonial missions to Africa:

> Reverend Fathers and My Dear Compatriots.
>
> The task entrusted to you is a very delicate one and requires tact. Priests, you are certainly going to evangelise, but this evangelisation must be inspired above all by the interests of Belgium. The main aim of your mission in the Congo is therefore not to teach the Negroes to know God, because they already know him. They speak and submit to a MUNDI, a MUNGU, a DIAKOMBA and who knows what else; they know that killing, stealing, sleeping with someone else's wife, slandering and insulting is bad. So let's have the courage to admit it. (Leopold II, King of the Belgians, online).

This extract clearly shows that before the arrival of the Europeans, Africans had a religious organisation based on the worship of a supreme being, with names that varied from one people to another: UN MUNDI, UN MUNGU, UN DIAKOMBA, as indicated in Leopold II's speech. Throughout Bamiléké country, despite the linguistic diversity, two names refer to the supreme creator whom the whites of the Leopold II generation already recognised: 'NSé' and 'Nsí'. What's more, the Africans already had a respect for otherness and human nature, which is why in this extract we note this precision: 'They know that killing, stealing, sleeping with someone else's wife, slandering and insulting is bad'. So the main aim of Christian missionaries during colonisation was to make Africans doubt their religions and reject them in favour of selective Christianity. But the Bamiléké are one of the African peoples who have managed to retain an authentic cult despite the influence of globalisation.

III. WORSHIP PRACTICES IN BAMILÉKÉ COUNTRY

Worship in Bamiléké society is distinguished by specific characteristics, encompassing the venues, leading figures, and necessary prerequisites.

3.1. Places of Worship

One of these essential features is the diverse range of places of worship, despite the criticism and condemnation of Bamiléké religious practices. In essence, these are sites designated by deities established by ancestors within a lineage, a village, a community, etc., to function as a location for supplication and remembrance during times of necessity. In the Bamiléké worldview, multiple places of worship exist.

3.1.1. Sacred Forests

The sacred forests, which are typically exploited for their various resources. Amongst the Bamiléké, these spaces are also instrumental in asserting the veneration of divinities. Most of these holy sites are situated near traditional chiefdoms. The subsequent image serves as an illustration of a sacred site.

Image: Sacred Forest, Keleng Brewery Village (Dschang)

Photo Sotso, 2022

Sacred forests play a critical role in traditional chieftaincy in Bamiléké country, owing to their sacredness. These areas primarily serve as the initiation sites for the lineage chiefs. The existence of these hamlets can be attributed to 'La'akam,' as denoted by the linguistic register of Bamiléké country. Additionally, each chiefdom designates this area as its royal cemetery, as the 'Fam' hut, which houses the skulls of past rulers, is located in the sacred forest next to the royal land. The spiritual importance of the sacred forest is enhanced by the presence of animals that are not only totems for the chief but also for other important members of the chiefdom. The forest houses various secret societies that provide stability to the chiefdom and the village. Notable ones include Koungang and the council of nine or seven. It should be noted that the sacred power is not only limited to the chiefdom's sacred forest. In the Bamiléké community, certain village officials operate in the different neighbourhoods of the village instead of at the palace. They act as custodians of the little sacred woodlands in their localities, where they oversee the management of these territories. The same goes for familial lineages, where comparable areas are reserved for traditional practices, overseen by the head of the lineage or family. Such places, akin to the royal forest, are venues for diverse ceremonies, rituals, incantations and supplications addressed to relevant ancestors and deities. In brief, the sacred forest within Bamiléké territory holds equal importance to the sacred tree as a crucial element of worship.

2.1.2 The Sacred Tree

Additionally, the Bamiléké people erect trees as sacred sites as per the observations made during the field study conducted for this research. The following images serve as examples of this phenomenon.

Image: Image: The sacred tree at the entrance Foréké Chiefdom (Dschang)

Photo Kaze, 2021

Image: The Sacred Tree at Bamougoum Bus Station (Bafoussam)

Photo Sotso, 2022

Image: The sacred tree at Paid-ground (Dschang)

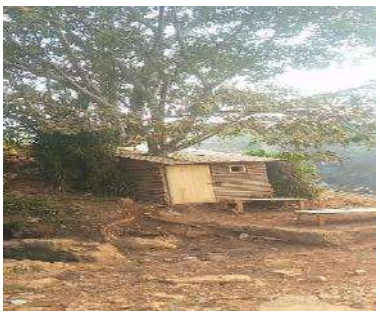


Photo Kaze, 2022

In numerous families, lineages, and even royal courts, a tree is identified as a site of worship for those involved. These sanctified trees are celebrated for their long lifespan and resilience. Practically, participants of the

cult convene at the base of the tree to recite incantations, express gratitude, and other rituals, under the leadership of a cult leader who facilitates the proceedings. Assembling in these locales necessitates gathering all the requisite elements for the worship ceremony. Places of worship are prevalent in Baméléké territory, and their use is dependent on circumstances. They can be affiliated with a lineage, family, or group, much like sacred forests.

3.1.3. The Houses of Skulls

The widespread and well-known symbol of worship in the area is the houses of skulls. The relics of ancestors materialised here are a crucial point of contact between the living and the Almighty God. Every precaution is taken, from extraction to housing in the skull hut, where various cult ceremonies are performed either in part or in full. These houses, built in very small spaces, are usually found surrounding each large concession. An example of this can be seen in the following image:

Image: House of Skulls, Keleng Brasseries Village (Dschang)

Photo Sotso, 2022

There are typically three stages involved in the skull ritual. Firstly, construction of the skull house involves building a small structure where all the removed skulls can be kept. Secondly, exhumation of the skull requires removal of the skull from the grave. Lastly, the skull (belonging to the ancestor) is brought into the skull house, where it is deposited in the previously constructed house. After reaching this final stage, the departed individual transforms into a genuine ancestor capable of appealing to God and other ancestors on behalf of the living.

This practice has existed since ancient times. A synthesis of the interviews conducted before this contemplation reveals a unanimous consensus regarding the age-old roots of these worship elements. The Baméléké have long held a desire to secure, protect, and communicate with their loved ones in the afterlife. Additionally, there is a passion to remain emotionally close to their physically absent loved ones. The prevalence of these places of worship among the Baméléké is evidence of individual freedoms to conceive a communication pathway to God. Modern religious people sometimes refer to these pathways as ‘hotels’. Furthermore, in accordance with Baméléké customs, the family’s guarantor is permitted to worship in these locations. This also applies to the skull houses affiliated with the community, town, district, and lineage. There is nothing unusual about these skull houses, which hold significant value to the Baméléké community. In fact, they create a link with revealed religions, only they are frowned upon by their followers. Piko Assongni has this to say:

> Western religions need funds and land to build churches. They need the human resources for their relationship with the metropolis, the quests to honour Leopold II’s speech from Belgium in 1883… In this context, it is a crime to allow black people to become rich or to perpetuate a cultural practice that could hinder the ‘evangelisation of pagan peoples’, the ‘Saracens’. From then on, gris-gris, skulls, the God tree, the subsoil, anything that might have a vision contrary to the aims of the Western churches becomes a nuisance. How can we understand that priests who carry around the cross of Jesus, who guard the relics in the pulpit, who permanently guard the fingernail, the finger, the habit, the glasses. In short, the objectives or organs that belonged to a dear relative, reject in the African, the audacity to carefully guard an object, in this case the skull of his parents? A pebble, a tree planted as a symbol are signified referents, like a grave in a cemetery that recalls the passing of someone dear to us. It is this practice that is wrongly called ‘pagan worship’ (P. Assongni 2018:11).

Worship is performed according to the rules of the art, in the presence of the officiants and the imperatives.

3.2 – Officials and Imperatives

The cosmogony of the Baméléké ethnic group acknowledges and establishes certain actors and elements as unyielding for veneration. These actors are divided into different categories and serve as religious leaders as required. On the family level, there are individuals who are responsible for the skull and are appointed by the head of the family. The latter is accountable for addressing grievances within the family unit. However, in exceptional circumstances, there may not be anyone within the family able to lead any form of religious service. As a result, another individual may be summoned, as ‘there must always be a messenger in any situation, and if there is no adult within the family, we can seek the elders residing within the family circle to fulfil this customary obligation to God and our ancestors’ (Assogni, 2022: interview).

The Nsi and Nkamsi likewise form part of this crucial chain of participants. The Nsi and Nkamsi possess the ability to predict destinies, prophesy, anticipate, protect, and communicate with the supernatural realm, similar to the roles of priests, pastors, and imams in revealed religions. The Nsi and Nkamsi possess the ability to predict destinies, prophesy, anticipate, protect, and communicate with the supernatural realm, similar to the roles of priests, pastors, and imams in revealed religions. Families can request intervention from them, whether in a place of worship or not, to safeguard and even heal heirs from any potential misfortunes or calamities stemming from their ancestors. The Nkamsi instruct beneficiaries on measures to ward off ancestral curses. It should be noted that the traditional chief, as well as select notables and dignitaries, also officiate depending on their area of jurisdiction. In addition, success of these events hinges on constituents that provide necessary consumable elements. From the numerous aspects of worship in Bamiléké society, a select few are deemed vital. The ensuing depictions serve as illustrations:

Image: Peace Tree in a Funerary Context (Fotetsa/Dschang)

Photo Kaze, 2021

Image: Image: Salt Cult at the Entrance to the Foréké Chiefdom (Dchang)

Photo Kaze, 2021

Generally speaking, water, red oil, salt, jujube and the peace tree are used.

Water is the primary element utilized in Bamiléké places of worship. It is brought based on the principle that the ancestors, who are deemed not truly deceased, are intercessors between the descendants and the powerful God. The water is essential for the ancestors to consume in order to maintain themselves, much like the living. Muslims use water to purify themselves before prayer, whereas Christians use it to bless, baptise, and protect their followers.

This valuable liquid holds a significant place in religious practices. Additionally, red oil is a prevalent element used in religious ceremonies, particularly with ancestors' involvement. It is served with other meal components or separately, according to reports from the field. The significance of red oil in Bamiléké cultural ceremonies is crucial to the success of the process.

Salt plays a vital role in several cult ceremonies among the Bamiléké community. While it is added for flavour to the related mixtures, it also serves as a purifying agent and promotes peace in these settings, fostering reconciliation and preventing potential sources of social instability.

Jujube (Ziziphus jujuba) is a spice extensively employed in Cameroonian religious practices, specifically in the Bamiléké locality. Its mystical power is highly esteemed, serving as a symbol of peace and prosperity, which the Bamiléké use during times of both peace and conflict. In religious ceremonies, jujube seeds, extracted from the pods, are chewed and dispersed on both sides to seek ancestral divine favour.

The Costus afer or Dracoena desteliana tree, also known as the tree of peace, holds great significance within Bamiléké cults due to its rich symbolic nature. This green plant is a staple of almost all Bamiléké worship ceremonies, representing unity within these societies. It is also commonly used in religious ceremonies which mark significant events such as the birth of twins, the union of two families, the farewell of a deceased person or the distinction of a customary position. The tree is especially popular in Bamiléké culture due to its versatile nature; it is used both as a stem and as single leaf. Catholics showcase the plant as a torch on festive occasions to demonstrate the faithful's commitment to the peace the plant represents. The significance and symbolism of the peace tree are essential and universal in various religions. The tree of peace holds an integral part in all Bamiléké ceremonies as it signifies peace and unity. There is nothing unusual or superstitious about these imperatives, as they are analogous to those found in other religious groups, such as the Catholic Church, as noted by Séverin Cécile Abega:

> Within the Catholic Church, for example, there are certain charismatic groups and African exorcist priests, who gather around them a large number of faithful and attract a diverse clientele to whom they sell or offer exorcism rites and promises of social

> success in the form of long prayers, masses and other rituals, and through a fetishisation of Christian symbols: oil, holy water, crucifix, rosary, hosts, etc. (C. S. Abega 2007:72).

These under-valued cults have various symbolic stakes for the Bamiléké people that deserve to be taken into account in a context of one-way globalisation.

IV. THE CHALLENGES OF BAMILÉKÉ CULTS IN THE CONTEXT OF GLOBALISATION

Cults in present-day Bamiléké face challenges due to rapidly increasing globalisation. These cults are often undervalued in comparison to imported cults, despite their significant symbolic value for the Bamiléké community. This creates a context of one-way globalisation, which must be taken into consideration.

4.1 Examines Religious Cults in Bamiléké as a Cultural Incubator

Religious cults in Bamiléké territory, like various other local customs, serve as crucial mechanisms for asserting Bamiléké culture specifically, as well as Cameroonian culture more generally. Simultaneously, they illustrate the perpetuation of an ancient civilization in a globalized context dominated by Western cultures. These traditions are not merely crude collective worship sessions, but instead facilitate the promotion of Cameroonian culture.

The aforementioned imperatives, such as jujube, tree of peace, red oil, and salt, serve as distinctive markers of this specific population and overall identity of Cameroon. We can agree with Séverin Cécile Abega that religion has an identification function:

> It has an identifying function, [because] it is part of cultural identity. In this sense, it reduces alienation from foreign values or the depersonalisation of the modern world. Africans have often had to fight against both Islam and Christianity to avoid being dispossessed of what they consider to be essential to their relationship with the divinity, and which was also important to their lives (C. S. Abega 2007:75).

The satisfaction of the faithful of these Bamiléké cults lies partly in the mobilisation of these intransigent elements, who in fact converge towards the success of the event and guarantee any spin-offs. This is what Séverin Cécile Abega calls 'the euphoric function of worship, which can be explained by the reward expected at the end of the event' (Idem). In addition, these easily obtained and less costly imperatives strengthen the attachment of the faithful to these cults, which they willingly pass on to their descendants to prevent their disappearance. In this way, these cults have a residual function, as they make it possible to preserve 'old practices and old knowledge, making things incomprehensible that otherwise would not be' (Idem).

4.2. The Promotion of Local Languages

Language is an essential component for promoting and preserving culture, as the Bamiléké people understand well, perhaps even unconsciously. The Bamiléké, much like certain modern religious beliefs, place great emphasis on the role of language in their fundamental beliefs. Nevertheless, many beliefs still maintain their own particularities. In the context of evangelism, accommodating the language of one's interlocutors is undoubtedly a crucial aspect to consider. Muslims pray in Arabic, while Christians utilise Latin and other spiritual languages. On the other hand, the Bamiléké accord precedence to their local mother tongues in their places of worship, as a means of sustaining accord with their ancestors who function as intermediaries for such events. In reality, the Bamiléké are promoting and preserving their mother tongues in the face of globalisation, which tends to trivialise all local cultural practices labelled primitive. This is a legitimate struggle to assert their local linguistic heritage, as promoters of various modern religions assert their hegemony through language and other means. In such settings, the use of local language is prevalent for exhortations, incantations, and other rituals. These actions are particularly beneficial as 'numerous mother tongues are at risk of disappearing as a result of lack of speakers"[2] (E. Nforbi 2012:97).

It is undeniable that religious worship, as observed in Bamiléké society, is a catalyst for vitality and overall progress. Furthermore, it can be asserted that mother tongues play a crucial role not only in Bamiléké religious practices but also in social affirmation and development. Nforbi highlighted that 'National languages are essential for a country's development and productivity. The national literacy programme must incorporate these languages in their strategies. It is only through these languages that functionality can be attained.' (Idem)[3]. In this manner, the practice of Bamiléké religious worship aids in preserving the regional linguistic heritage.

4.3. The Environmental Protection

Delves into how these cults, unlike others, contribute to environmental protection at a time when ecological concerns mount. Séverin Cécile Abega

[2] Our own translation.
[3] Our own translation.

concisely phrases it thus: 'Beliefs and practices provide insight into how individuals perceive economic, political, and social relationships, as well as the natural environment' (Abega, 2007:72). As previously mentioned, places of worship are essential to every religion as they facilitate the gathering of devotees to give praise to a higher power. Synagogues, mosques, and churches are commonly-associated places of worship for Jews, Muslims and Christians respectively. In contrast, the Bamiléké community refer to sacred forests, trees, and houses of skulls as their own form of places of worship.

For the first three entities discussed, establishing a place of worship entails harming the environment, owing to the diverse consequences that a construction site brings about, including landscape disruption, noise pollution, dust emissions, and adverse impacts on soil and water, alongside waste production, consumption of natural resources, and energy usage, as detailed on the website https://www.hagerservices.fr.. On the contrary, the Bamiléké people view the creation of a place of worship as a means of preserving nature, since it serves as the ultimate venue for praying and meditating, away from the disturbance of human commotion and conducive to effective communication with the spiritual realm.

Furthermore, the verbs employed to describe the construction of such sacred spaces offer illuminating insights into each instance. For Jews, Christians, and Muslims, the verb used is 'to build' or its synonym 'bâtir'. Derived from the Latin construere, which implies the act of stacking in layers, 'to build' means to construct or have constructed a house, a monument, or a structure. The use of this verb conveys a certain degree of aggression towards nature, as construction entails the destruction of it. The extent of harm inflicted on the environment may differ among Christians due to the variety of religious sites available, such as monasteries, chapels, cathedrals, primatials, parishes, decanals, basilicas, oratories, each of which varies in size. To illustrate this point, consider the potential ecological impact of constructing St Joseph's Cathedral in Sangmélima, the largest Christian edifice in Cameroon located on a 7-hectare plot in the south of the country. The cathedral can host over 5,000 devotees indoors and an additional 11,000 in its 6,000-metre forecourt.

Conversely, in Bamiléké culture, the concept of 'progress' pertains to the establishment of a site for communal worship. French language dictionaries define the term 'aménagement' as it pertains to the preservation of nature. According to Larousse, 'aménagement' refers to the act of arranging a location or property for installation or any other purpose, and by extension, it encompasses a set of guidelines for the growth and effective administration of a forest (Larousse, online). Therefore, the practice of constructing a place of worship by the Bamiléké people is environmentally non-destructive. Therefore, considering its minimal impact on both the environment and the economy, the practice of worshipping in Bamiléké country is worthy of celebration.

V. NOT TO CONCLUDE

The beliefs of the Bamiléké indicate that they have a well-structured and organised religious cult dedicated to a single God, similar to other monotheistic religions. Nonetheless, this cult has faced the challenge of being discredited due to stereotypes fabricated by colonialists during the colonial era. Like other imported religions, the Bamiléké's cult involves reaching out to God through diverse channels and frameworks. Although one-way globalisation presents a significant challenge to its expansion, the Bamiléké religious cult persists in asserting its unique identity, promoting Cameroonian culture and languages, and protecting nature. Alors, il participe à la promotion de la culture et des langues camerounaises d'une part, la protection de la nature d'autre part.

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Evaluation with different Amounts of Moisture and Temperature in the Substrate on the Vigor and Germination of Soybean Seeds

Guilherme Saraiva dos Santos, Angelo Ricardo Balduino

Department of Agronomy, Tocantinense Institute President Antonio Carlos, Brazil

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***Keywords*— Germination, humidity, temperature, vigor.**

***Abstract*—** *Seeds are considered to have high vigor as long as they are handled in the right way, always taking as fundamentals, in the pillars of their quality, which are: physical, physiological, genetic and sanitary. A total of 200 seeds were used for 8 treatments of the same variety conducted in the seed laboratory of the INSTITUTO TOCANTINENSE PRESIDENTE ANTÔNIO CARLOS (ITPAC-PORTO), which were subjected to conditions of two temperatures: 10°C and 25°C, under 4 situations of osmotic potentials On substrates: 1.5, 2.0, 2.5 and 3.0 ml. An evaluation was carried out at 5, 8 and 20 days after assembly, using seedling emergence and development as a parameter. The samples were analyzed based on the RAS (RULES FOR SEED ANALYSIS), i.e., they were considered germinated when they showed the development of a normal seedling. The data will be submitted to analysis of variance (ANOVA) and Tukey's test in the Sisvar software. The results allowed us to visualize the excellent germination and growths of the seedlings when using the temperature of 25°C and wetting of 2.5 ml in the substrate. Germination is impacted when the low availability of water in the substrates, as well as milder temperatures, influences the speed of development of meristematic tissues.*

I. INTRODUCTION

Soya (Glycine Max (L.) Merrill) stands out as one of the most important crops in the world economy. Its grains are widely used by the agro-industry (production of vegetable oil and animal feed), the chemical industry and the food industry. It is also used as an alternative source of biofuel (COSTA NETO; ROSSI, 2000).

In Brazil, the first report of soya being grown dates back to 1882, in the state of Bahia (BLACK, 2000).

The cultivar began on the Asian continent and spread to the Americas (FREITAS, 2011).

According to Castro et al. (1983), the reduction in germination speed due to sub-optimal temperatures results in a reduction in the uniformity of emergence in the field, prolonging the time the seeds are exposed to pathogens and increasing the risk of contamination.

Ensuring the best performance of a given crop depends fundamentally on the quality of the seeds (Motta et al., 2000), characterised by germination and vigour.

Therefore, the main objective of this study was to assess the germination capacity of seeds under different temperature conditions and specific amounts of water.

II. VIGOUR AND GERMINATION OF SOYA BEANS: A DETAILED ANALYSIS

Evaluating seed vigour is a fundamental step for the successful production of soybean seeds, which are recognised for their sensitivity to deterioration and less

suitable handling practices after maturity (Marcos Filho, 1999a).

Viability is mainly measured by the germination test and aims to determine maximum seed germination under favourable conditions (Marcos Filho, 1999).

One of the limitations of vigour tests is related to the time required to carry them out and the subjectivity of their assessment (Pinto et al., 2015).

According to the observations of Carvalho and Nakagawa (2000), larger or denser seeds tend to harbour well-developed embryos and more abundant reserves, which suggests a higher potential for vigour.

III. MATERIAL AND METHODS

The experiment was conducted in the seed laboratory of ITPAC Porto Nacional in the second half of 2023. Located at geographical coordinates 10º41'46" S 48º23'03" W, altitude 230 m, in the city of Porto Nacional, in the state of Tocantins and country Brazil.

Initially, 1600 seeds were selected for the test. The seeds were supplied by the GDM company and belong to the OLIMPO IPRO cultivar, of maturity group 8.0, adapted for the Tocantins region.

We began the process by meticulously sanitising the site and the equipment to be used in the test. For each test, the seeds were sown on germ paper moistened with distilled water as a substrate. The germ paper was then moistened with different amounts of water (1.5 ml, 2.0 ml, 2.5 ml and 3.0 ml). 200 seeds were used per treatment, with 4 replicates containing 50 seeds each.

The tests were kept in a germination chamber for 5, 8 and 20 days at two different temperatures: 10°C with 4 treatments and 25°C with 4 treatments. The results were expressed as a percentage of normal seedlings, in accordance with the requirements of the Rules for Seed Analysis (Brazil, 1992). The data obtained was analysed using the sisvar application, using the variation test and the ANOVA test. The analysis included checking the significance of the results, the means of the treatments and the significance between them, and was conducted in accordance with the guidelines established by the RULES FOR SEED ANALYSIS (RAS).

Ferreira (2008) highlights the advantages of Sisvar, including its interactivity with the user, which provides an efficient and accurate environment. He hopes that future versions of the programme will address limitations, such as compatibility problems, and extend its capabilities, making it compatible with operating systems other than Windows. Sisvar is relevant, with previous versions often cited in technical and scientific contexts.

IV. RESULTS AND DISCUSSION

We can see that a temperature of 25°C seems to favour the vigour of the tests compared to 10°C in most cases. In addition, an increase in water availability also tends to improve vigour, especially at higher temperatures. The treatments (2 ml of water at 25°C), (3 ml of water at 25°C) and (2.5 ml of water at 25°C) show the highest averages (83 Bb, 85 Bb and 93 Aa, respectively), indicating the most favourable conditions for testa vigour, based on the data and Tukey's test, as shown in Table 1.

The 1.5 ml Water at 10°C (0 Cc) treatment shows an average vigour of 0 Cc, which suggests that under this condition, the vigour of the tests is very low. The 1.5 ml of Water at 25°C (0 Cc) treatment again has an average vigour of 0 Cc, indicating that even with the higher temperature, vigour does not improve. The 2 ml Water at 10°C (0 Cc) treatment, as in the previous treatments, the average vigour is 0 Cc. This suggests that the availability of 2 ml of water at 10°C is not enough to improve vigour.

Treatment 2 ml Water at 25°C (83 Bb), in this treatment, the average vigour is 83 Bb. This is significantly higher than the previous treatments, indicating that an increase in temperature from 10°C to 25°C improves the vigour of the tests. The 2.5 ml Water at 10°C (0 Cc) treatment, once again, the average vigour is 0 Cc, even with an increase in water availability to 2.5 ml. The 2.5 ml Water at 25°C treatment (93 Aa), here, the average vigour is 93 Aa, which is the highest among the treatments so far. This suggests that a temperature of 25°C and an availability of 2.5 ml of water are favourable conditions for testing vigour.

The treatment 3 ml of Water at 10°C (0 Cc), Again, the average vigour is 0 Cc, even with an increase in the amount of water available. Treatment 8 - 3 ml of Water at 25°C (85 Bb), in this treatment, the average vigour is 85 Bb, suggesting that an increase in water availability to 3 ml, combined with a temperature of 25°C, improves vigour compared to the 10°C conditions (Table 1).

Table 1- Average vigour over 5 days of testing

water availability in ml	1,5 ml	2 ml	2,5 ml	3 ml
temperature 10 °C	0 Cc	0 Cc	0 Cc	0 Cc
temperature 25 °C	0 Cc	83 Bb	93 Aa	85 Bb

In the column, means followed by equal letters do not differ according to the Tukey test (5%). Uppercase letters in the column and lowercase letters in the row.

According to Ferreira and Borghetti (2004), when seeds are exposed to higher temperatures, they accelerate their germination as long as there is tolerance, because at the same time as they accelerate the resumption of growth, high temperatures affect the metabolic process, reducing the possibility of germination itself. According to Ferreira and Borghetti (2004), this phase is critical and can be influenced by intrinsic and/or extrinsic conditions, emphasising that water is the most important factor in the germination process.

Garcia et al. (2007), on the other hand, says that soya beans, when sown, develop best at temperatures of 25ºC.

Table 2 shows the average germination results of the 8-day tests, considering water availability in ml and temperature in °C as independent variables.

As in Table 1, the capital letters in the columns indicate means that do not differ from each other, according to the Tukey test at a significance level of 5 per cent. The lower case letters in the rows represent the specific averages for each combination of water availability and temperature.

It can be seen that at a temperature of 10°C, regardless of the amount of water available (1.5 ml, 2 ml, 2.5 ml or 3 ml), the average germination is 0 Cc. This indicates that, under these conditions, germination was inhibited or very low.

However, at a temperature of 25°C, the results are remarkable. In all the water availability conditions (1.5 ml, 2 ml, 2.5 ml and 3 ml), the average germination is equal to 100 Aa. This suggests that at higher temperatures, germination is optimised and water availability does not seem to affect germination, at least within the limits tested.

Table 2- Average 8-day germination of the tests

disponibilidade de água em ml	1,5ML	2 ML	2,5 ML	3 ML
temperatura 10 °C	0 Cc	0 Cc	0 Cc	0 Cc
temperatura 25 °C	0 Bb	100 Aa	100 Aa	100 Aa

In the column, means followed by equal letters do not differ according to the Tukey test (5%). Uppercase letters in the column and lowercase letters in the row.

The temperature of 25ºC with the moistening of 2.0 to 2.5 ml of water favoured the germination process of the treatments, with their germination potentials being observed in the last 8 days, as most of the seeds resulted in normal seedlings.

Water absorption plays a fundamental role at the start of the germination process, as highlighted by Marcos Filho (1986), culminating in the protrusion of the radicle through the seed coat.

Table 3 shows the results of the 20-day average germination of the tests, considering the availability of water in 1.5 ml and temperature in °C as independent variables.

Again, the capital letters in the columns indicate means that do not differ from each other, according to Tukey's test at a significance level of 5%. The lower case letters in the rows represent the specific means for each combination of water availability and temperature.

It can be seen that at a temperature of 10°C, the average germination is 0 Dd, which indicates that germination is quite low under this condition, even with 1.5 ml of water available.

On the other hand, at a temperature of 25°C, the average germination is 0 Bb. This suggests that at a higher temperature, germination was also inhibited, with an average of zero. In this case, both the temperature and the availability of water in 1.5 ml do not seem to be adequate to promote germination after 20 days of testing.

To summarise, the results in Table 3 indicate that germination is rather low or inhibited under both temperatures (10°C and 25°C) and with 1.5 ml of water available after 20 days of testing. This could have significant implications for understanding the influence of these conditions on the early stages of seed development.

Table 3- Average germination after 20 days of testing

water availability in ml	1,5 ml	2 ml	2,5 ml	3 ML
temperature 10 °C	0 Dd	75 Cc	81 Bb	86 Aa
temperature 25 °C	0 Bb	100 Aa	100 Aa	100 Aa

In the column, means followed by equal letters do not differ according to the Tukey test (5%). Uppercase letters in the column and lowercase letters in the row.

V. CONCLUSION

The effect of temperature and the availability of water in the substrate revealed a significant variation between the treatments, highlighting the importance of these factors in seed development.

Notably, the combination of a temperature of 25 °C and moistening the substrate with 2.5 ml proved to be the most effective, resulting in the highest germination percentages.

Under this condition, excellent development of the meristematic structures was observed, including the

hypocotyl, plumule and radicle, which culminated in the formation of seedlings with the capacity to continue their normal growth and become healthy plants.

This study confirms the significant influence of temperature and water availability on the vigour of germination tests. Conditions with higher temperatures, notably 25°C, and a greater availability of water, either 2.5 ml or 3 ml, proved to be favourable for stimulating seed vigour.

These results have crucial implications for optimising test conditions and can be applied in various contexts where obtaining vigour is a critical factor.

It is worth emphasising that the use of plastic bags proved to be an effective strategy for reducing moisture loss in the treatments, keeping the seeds adequately hydrated and enabling them to go through the three-phase germination process, moving towards healthy development. On the other hand, the warmer temperatures slowed down the seeds' rate of development. The lack of water had a significant negative impact on the germination of the samples subjected to this treatment, since they did not receive the essential amounts of hydration to start the subsequent germination process.

The study's conclusions highlight that temperature plays a critical role in vigour and germination tests, with higher temperatures being preferred for these processes. In addition, water availability is a vital element, especially with regard to test vigour.

These results provide valuable information for optimising test conditions and promoting successful seed development, while respecting the specific demands of temperature and humidity at each stage of the germination process.

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Equations of a Synchronous Machine in Phase Coordinates for Asymmetrical Short Circuits and their Solutions

Huseyngulu Guliyev[1], Famil Ibrahimov[2]

[1]Faculty of Energy and Automation, Azerbaijan Technical University, Azerbaijan
[2] Energy Research Institute, Azerbaijan Technical University, Azerbaijan

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***Keywords*— asymmetrical short circuits, infinite power system, equations in phase coordinates, transient processes, synchronous machine**.

***Abstract*—** *A methodology is proposed for studying, using digital technology, asymmetrical transient modes of a synchronous generator operating on infinite power systems. The initial equations of a synchronous machine and sequential transformations for their solution are presented. Differential equations of synchronous machines are compiled in phase coordinates. When solving the equations, the parameters of the electrical network included between the generator and the system are taken into account. The results of calculations using the obtained equations for the 14-node IEEE test circuit are presented, confirming the effectiveness of this approach.*

I. INTRODUCTION

The analysis of asymmetrical transient processes of synchronous machines becomes of great importance, especially for highly used powerful turbo and hydro generators. As a rule, modern heavy-duty generators operate in fairly large power systems and therefore it is necessary to analyze asymmetrical processes not of single-phase generators (to which a large number of works are devoted and this issue is sufficiently covered in the press), but the operation of generators that lose connection with the power system (for example, with single-phase or two-phase short circuits, with phase-by-phase automatic restarts, etc.) (Basmanov & Votinsev, 2021) (Biswas, Pal, Werho, & Vittal, 2021) (Dong, Tian, & Ding, 2021). Additional difficulties for the analysis are presented by taking into account the reactivity connected between the generator and the system (the reactivity of transformers and power transmission lines (PTL)). Differential equations describing transient asymmetric processes of a synchronous machine contain periodic coefficients and therefore their complete analytical solution using known tabulated functions is practically impossible.

An analytical study of asymmetrical transient processes of a synchronous machine operating on an infinite power network through reactance was carried out quite fully only in (Goldberg, Bul, Sviridenko, & Helemskaya, 2001). The author provides analytical expressions for the stator current only for a two-phase short circuit of the generator and a single-phase short circuit to the neutral of the system and the generator.

The difficulties of solving a complete system of differential equations with periodic coefficients are overcome by numerically solving the problem using computer technology (CT). This work is devoted to the creation of a technique for numerical analysis of some transient asymmetric modes of a synchronous generator operating on an infinite power network using CT (Hugo, Gloria, Alvaro, Jesus, & Nikolas, 2022) (Jaramillo Serna

& López-Lezama, 2019) (Krishna, Sasikala, & Ganesh, 2017) (Pai, 2014).

The article presents the basic equations for calculating transient asymmetric modes on a CT, information on their programming, as well as the results of calculations on a CT.

II. BASIC EQUATIONS FOR CALCULATING ASYMMETRICAL MODES OF A SYNCHRONOUS GENERATOR

The initial equations for the stator winding are compiled in the system of axes a, b, c; for rotor quantities, the system of axes d, q, 0 is used. Periodic coefficients in the equations of a synchronous machine are calculated at each interval of the numerical solution of the equations as a function of the angle between the stator and rotor axes. In this case, its periodic coefficients are expressed only in terms of and calculating them on a CT is not difficult. (Dong, Tian, & Ding, 2021) (Grigsby, 2001) (Guo, Bao, Xiao, & Chen, 2021) (Guseinov & Ibrahimov, 2012)

The advantage of the used axis system over any other is that all current values correspond to real values and do not require recalculation of the results to obtain phase values.

When drawing up equations for calculating asymmetrical transient modes of a synchronous machine, the following assumptions were made:

1. The phase windings of a synchronous machine are symmetrical, i.e. they have the same number of turns, active resistance and mutual shift of magnetic axes.

2. When considering the magnetic fields of the self-induction of the stator windings and the mutual induction of these windings with the rotor windings, only one harmonic of this distribution is taken into account.

3. The magnetic permeability of the machine's magnetic core steel is assumed to be constant. Saturation is taken into account by choosing constant saturated parameter values.

4. It is accepted that on the rotor, in addition to the excitation winding, there is one damper circuit along the longitudinal and transverse axes.

The initial equations for calculating the modes of a synchronous machine in coordinates a, b, c are the following differential equations for the stator winding voltages:

$$\left.\begin{aligned} p\psi_a &= e_a - i_a r_a \\ p\psi_b &= e_b - i_b r_b \\ p\psi_c &= e_c - i_c r_c \end{aligned}\right\}, \quad (1)$$

where ψ_a, ψ_b, ψ_c – flux linkage of stator winding phases; i_a, i_b, i_c – stator winding phase currents; r_a, r_b, r_c – active phase resistance of the stator winding; e_a, e_b, e_c – voltage at the terminals of the generator stator phase windings; $p = \frac{d}{d\tau}$ – differentiation operator with respect to synchronous time $\tau = 2\pi ft$.

To this system of equations one should add the stress equations for the rotor circuits and the rotor motion equations:

$$\left.\begin{aligned} p\psi_f &= e_f - i_f r_f \\ p\psi_{kd} &= -i_{kd} r_{kd} \\ p\psi_{kq} &= -i_{kq} r_{kq} \\ pS &= \frac{1}{H}\left(M_m + M_e\right) \\ p\theta &= S \end{aligned}\right\}, \quad (2)$$

where $\left.\begin{matrix} \psi_f, \psi_{kd}, \psi_{kq} \\ i_f, i_{kd}, i_{kq} \\ r_f, r_{kd}, r_{kq} \end{matrix}\right\}$ – current flux linkage and active resistance of the excitation winding and damper circuits along the longitudinal and transverse axes; e_f – voltage applied to the excitation winding; S – slip; H – inertial constant in electric rads; M_m – torque of the load on the shaft of a synchronous machine; M_e – electromagnetic torque of synchronous machine; θ – working angle (the angle between the transverse axis of the rotor and the representing vector of phase voltages).

To solve systems of equations (1) and (2) using any of the well-known numerical methods of Runge–Kutta, Adams Euler, etc. (Zakaryukin & Kryukov, Complex asymmetric modes of electrical systems, 2005), it is necessary that the number of variables equals the number of equations. Experience shows that it is expedient to express all currents through the flux linkages of the circuits. For this purpose, known relations are used, obtained in the calculations of symmetrical modes using the Park-Gorev equations (Goldberg, Bul, Sviridenko, & Helemskaya, 2001) (Lupkin, 1985) (Kryuchkov & others, 2009) (Kundur) (Yusifbeyli, 2019).

$$\left.\begin{aligned} i_d &= a\psi_d - b\psi_f - c\psi_{kd} \\ i_q &= g\psi_q - h\psi_{kq} \\ i_f &= -b\psi_d + d\psi_f - e\psi_{kd} \\ i_{kd} &= -c\psi_d - e\psi_f + f\psi_{kd} \\ i_{kq} &= -h\psi_q + k\psi_{kq} \\ i_0 &= \frac{\psi_0}{x_0} \end{aligned}\right\}, \quad (3)$$

where coefficients a,b,c,d,e,f,g,h,k are expressed through machine parameters as follows :

$$\left.\begin{aligned} a &= \frac{X_f X_{kd} - x_{ad}^2}{\Delta}; d = \frac{X_d X_{kd} - x_{ad}^2}{\Delta}; g = \frac{X_{kq}}{X_q X_{kq} - x_{aq}^2}; \\ b &= \frac{x_{ad} X_{kd} - x_{ad}^2}{\Delta}; e = \frac{X_d x_{ad} - x_{ad}^2}{\Delta}; h = \frac{x_{aq}}{X_q X_{kq} - x_{aq}^2}; \\ c &= \frac{x_{ad} X_f - x_{ad}^2}{\Delta}; f = \frac{X_d X_f - x_{ad}^2}{\Delta}; k = \frac{X_q}{X_q X_{kq} - x_{aq}^2}; \end{aligned}\right\} \quad (4)$$

$$\Delta = X_d\left(X_f X_{kd} - x_{ad}^2\right) - x_{ad}\left(x_{ad} X_{kd} - x_{ad}^2\right) - x_{ad}\left(x_{ad} X_f - x_{ad}^2\right).$$

The parameters included in these expressions represent the mutual or total reactivity of the circuits:

$$X_f = x_{ad} + x_f; \quad X_{kd} = x_{ad} + x_{kd}; \quad X_{kq} = x_{aq} + x_{kq};$$
$$X_d = x_{ad} + x_e; \quad X_q = x_{aq} + x_l;$$

To transition from stator currents i_d, i_q, i_0 to phase quantities i_a, i_b, i_c, we use the known relationships equations (Goldberg, Bul, Sviridenko, & Helemskaya, 2001) (Lupkin, 1985) (Prabha & Lei) (Soldatov & Popov, 2004) (Soldatov & Popov, 2005) (Zakaryukin, Kryukov, & Le, 2013).

$$\left.\begin{aligned} i_a &= i_0 + i_d \cos\gamma - i_q \sin\gamma \\ i_b &= i_0 + i_d \cos(\gamma - \rho) - i_q \sin(\gamma - \rho) \\ i_c &= i_0 + i_d \cos(\gamma + \rho) - i_q \sin(\gamma + \rho) \end{aligned}\right\}, \quad (5)$$

$$\left.\begin{aligned} \psi_0 &= \frac{1}{3}(\psi_a + \psi_b + \psi_c) \\ \psi_d &= \frac{2}{3}[\psi_a \cos\gamma + \psi_b \cos(\gamma - \rho) + \psi_c \cos(\gamma + \rho)] \\ \psi_q &= \frac{2}{3}[\psi_a \sin\gamma + \psi_b \sin(\gamma - \rho) + \psi_c \sin(\gamma + \rho)] \end{aligned}\right\}, \quad (6)$$

where $\rho = \frac{2\pi}{3} = 120°$ for a machine with symmetrically arranged three phase windings, $\gamma = \tau + \theta + \frac{\pi}{2}$ – angle between the fixed phase axis a and the rotating longitudinal axis of the rotor.

After the transformation, we obtain expressions for currents i_a, i_b, i_c through flux linkages and trigonometric functions of angle γ :

$$i_a = \frac{1}{3x_0}(\psi_a + \psi_b + \psi_c) + \psi_a\left[\frac{2}{3}a - \frac{2}{3}(a-g)\sin^2\gamma\right] + \psi_b\left[-\frac{1}{3}a + \frac{1}{3}(a-g)\sin^2\gamma + \frac{\sqrt{3}}{3}(a-g)\cos\gamma\cdot\sin\gamma\right] + \psi_c\left[-\frac{1}{3}a + \frac{1}{3}(a-g)\sin^2\gamma - \frac{\sqrt{3}}{3}(a-g)\cos\gamma\cdot\sin\gamma\right] - \psi_f b\cdot\cos\gamma - \psi_{kd} c\cdot\cos\gamma + \psi_{kq} h\cdot\sin\gamma \quad (7)$$

$$i_b = \frac{1}{3x_0}(\psi_a + \psi_b + \psi_c) + \psi_a\left[-\frac{1}{3}a + \frac{1}{3}(a-g)\sin^2\gamma + \frac{\sqrt{3}}{3}(a-g)\cos\gamma\cdot\sin\gamma\right] + \psi_b\left[\frac{2}{3}a - \frac{1}{2}(a-g) + \frac{1}{3}(a-g)\sin^2\gamma - \frac{\sqrt{3}}{3}(a-g)\cos\gamma\cdot\sin\gamma\right] + \psi_c\left[-\frac{1}{3}a + \frac{1}{2}(a-g) - \frac{2}{3}(a-g)\sin^2\gamma\right] - \psi_f b\left(\frac{\sqrt{3}}{2}\sin\gamma - \frac{1}{2}\cos\gamma\right) - \psi_{kd} c\left(\frac{\sqrt{3}}{2}\sin\gamma - \frac{1}{2}\cos\gamma\right) - \psi_{kq} h\left(\frac{1}{2}\sin\gamma + \frac{\sqrt{3}}{2}\cos\gamma\right) \quad (8)$$

$$i_c = \frac{1}{3x_0}(\psi_a + \psi_b + \psi_c) + \psi_a\left[-\frac{1}{3}a + \frac{1}{3}(a-g)\sin^2\gamma - \frac{\sqrt{3}}{3}(a-g)\cos\gamma\cdot\sin\gamma\right] + \psi_b\left[-\frac{1}{3}a + \frac{1}{2}(a-g) - \frac{2}{3}(a-g)\sin^2\gamma\right] + \psi_c\left[\frac{2}{3}a - \frac{1}{2}(a-g) + \frac{1}{3}(a-g)\sin^2\gamma + \frac{\sqrt{3}}{3}(a-g)\cos\gamma\cdot\sin\gamma\right] + \psi_f b\cdot\left(\frac{1}{2}\cos\gamma + \frac{\sqrt{3}}{2}\sin\gamma\right) + \psi_{kd} c\cdot\left(\frac{1}{2}\cos\gamma + \frac{\sqrt{3}}{2}\sin\gamma\right) - \psi_{kq} h\left(\frac{1}{2}\sin\gamma - \frac{\sqrt{3}}{2}\cos\gamma\right) \quad (9)$$

$$i_f = -\frac{2}{3}\psi_a b\cdot\cos\gamma + \psi_b b\left(\frac{1}{3}\cos\gamma - \frac{\sqrt{3}}{3}\sin\gamma\right) + \psi_c b\left(\frac{1}{3}\cos\gamma + \frac{\sqrt{3}}{3}\sin\gamma\right) + d\psi_f - e\psi_{kd} \quad (10)$$

$$i_{kd} = -\frac{2}{3}\psi_a c\cdot\cos\gamma - \psi_b c\cdot\left(\frac{1}{3}\cos\gamma - \frac{\sqrt{3}}{3}\sin\gamma\right) + \psi_c c\cdot\left(\frac{1}{3}\cos\gamma + \frac{\sqrt{3}}{3}\sin\gamma\right) - e\psi_f + f\psi_{kd} \quad (11)$$

$$i_{kq} = \frac{2}{3}\psi_a h \cdot \sin\gamma + \psi_b h\left(\frac{1}{3}\sin\gamma + \frac{\sqrt{3}}{3}\cos\gamma\right) + \\ + \psi_c h\left(\frac{1}{3}\sin\gamma - \frac{\sqrt{3}}{3}\cos\gamma\right) + k\psi_{kd} \quad (12)$$

The magnitude of the electromagnetic torque in the a, b, c axes is obtained after substitution into the well-known formula

$$M_e = \psi_q i_d - \psi_d i_q$$

currents and flux linkages i_d, i_q, ψ_d, ψ_q expressed through $i_a, i_b, i_c, \psi_a, \psi_b, \psi_c$ in the following form:

$$M_e = \frac{2\sqrt{3}}{9}\left[\psi_a(i_c - i_b) + \psi_b(i_a - i_c) + \psi_c(i_b - i_a)\right] \quad (13)$$

Substituting the expressions for currents i_a, i_b, i_c through flux linkages ψ_a, ψ_b, ψ_c, we obtain the final expression for the electromagnetic torque used in calculating transient modes at the CT:

$$M_e = \frac{2\sqrt{3}}{9}(\psi_b - \psi_c)\left\{\frac{1}{3x_0}(\psi_a + \psi_b + \psi_c) + \right.$$
$$+ \psi_a\left[\frac{2}{3}a - \frac{2}{3}(a-g)\sin^2\gamma\right] +$$
$$+ \psi_b\left[-\frac{1}{3}a + \frac{1}{3}(a-g)\sin^2\gamma + \frac{\sqrt{3}}{3}(a-g)\cos\gamma\cdot\sin\gamma\right] +$$
$$+ \psi_c\left[-\frac{1}{3}a + \frac{1}{3}(a-g)\sin^2\gamma - \frac{\sqrt{3}}{3}(a-g)\cos\gamma\cdot\sin\gamma\right] -$$
$$\left. - \psi_f b\cdot\cos\gamma - \psi_{kd}c\cdot\cos\gamma + \psi_{kq}h\cdot\sin\gamma\right\} +$$
$$+ \frac{2\sqrt{3}}{9}(\psi_c - \psi_a)\left\{\frac{1}{3x_0}(\psi_a + \psi_b + \psi_c) + \right.$$
$$+ \psi_a\left[-\frac{1}{3}a + \frac{1}{3}(a-g)\sin^2\gamma + \frac{\sqrt{3}}{3}(a-g)\cos\gamma\cdot\sin\gamma\right] +$$
$$+ \psi_b\left[\frac{2}{3}a - \frac{1}{2}(a-g) + \frac{1}{3}(a-g)\sin^2\gamma - \right.$$
$$\left. - \frac{\sqrt{3}}{3}(a-g)\cos\gamma\cdot\sin\gamma\right] + \psi_c\left[-\frac{1}{3}a + \frac{1}{2}(a-g) - \right.$$
$$\left. - \frac{2}{3}(a-g)\sin^2\gamma\right] - (\psi_f b + \psi_{kd}c)\left(\frac{\sqrt{3}}{2}\sin\gamma - \frac{1}{2}\cos\gamma\right) -$$
$$\left. - \psi_{kq}h\left(\frac{1}{2}\sin\gamma + \frac{\sqrt{3}}{2}\cos\gamma\right)\right\} +$$
$$+ \frac{2\sqrt{3}}{9}(\psi_c - \psi_a)\left\{\frac{1}{3x_0}(\psi_a + \psi_b + \psi_c) + \right.$$
$$+ \psi_a\left[-\frac{1}{3}a + \frac{1}{3}(a-g)\sin^2\gamma - \frac{\sqrt{3}}{3}(a-g)\cos\gamma\cdot\sin\gamma\right] +$$
$$+ \psi_b\left[-\frac{1}{3}a + \frac{1}{2}(a-g) - \frac{2}{3}(a-g)\sin^2\gamma\right] +$$
$$+ \psi_c\left[\frac{2}{3}a - \frac{1}{2}(a-g) + \frac{1}{3}(a-g)\sin^2\gamma + \right.$$
$$\left. + \frac{\sqrt{3}}{3}(a-g)\cos\gamma\cdot\sin\gamma\right] + (\psi_f b + \psi_{kd}c)\left(\frac{1}{2}\cos\gamma + \right.$$
$$\left. + \frac{\sqrt{3}}{2}\sin\gamma\right) - \psi_{kq}h\left(\frac{1}{2}\sin\gamma - \frac{\sqrt{3}}{2}\cos\gamma\right)\Big\}.$$

III. TAKING INTO ACCOUNT THE EXTERNAL REACTIVITY OF THE SYSTEM

The system of equations (1) is compiled for the operation of a synchronous machine in parallel with an infinite power system. In this case, e_a, e_b, e_c - are the voltages on the tires of infinite power.

The reactance and active resistances of transformers and lines from a synchronous machine to infinite power buses are included in the leakage reactance of the stator winding and in the active resistances of phase windings. If an accident occurs somewhere in the middle of a power line, then the voltage at the place of the accident will differ from the voltage of the buses of infinite power. In this case, part of the reactivity of the line from the generator to the point of the short circuit is added to the leakage reactivity and the machine is connected to the network through additional resistance Z_A, Z_B, Z_C, which represents the resistance of the remaining part of the line from the point of the short circuit to the infinite power buses with voltages e_A, e_B, e_C that do not depend on the mode. Let us consider a special case when $z(p) = r + xp$. The system of voltages e_a, e_b, e_c applied to the phases of the stator winding is determined from the Kirchhoff equations and depends on the mode under consideration. Kirchhoff's equations with the assumption in Fig. 1 emf direction and currents have the following form:

$$\left.\begin{aligned} e_a &= -e_A - i_A z_A = -e_A - i_A r_A - x_A \rho i_A \\ e_b &= -e_B - i_B z_B = -e_B - i_B r_B - x_B \rho i_B \\ e_c &= -e_C - i_C z_C = -e_C - i_C r_C - x_C \rho i_C \end{aligned}\right\}. \quad (14)$$

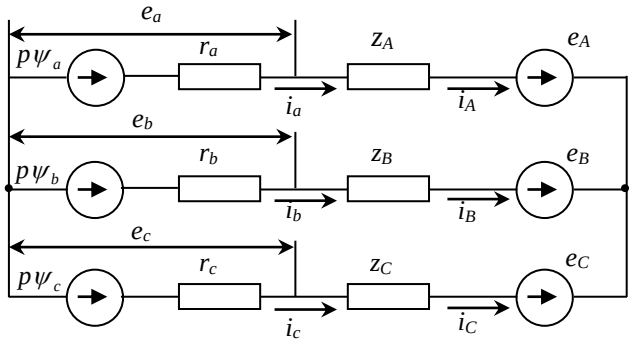

Fig. 1: The direction of emf and currents in system

After substituting (14) into (1), we obtain equations for the analysis of asymmetric modes, taking into account the resistances between the generator and the system.

Phase voltages on buses of infinite power are determined by the well-known expressions:

$$\left.\begin{aligned} e_A &= e\cdot\sin\tau \\ e_B &= e\cdot\sin(\tau-\rho) = -e\left(\frac{1}{2}\sin\tau+\frac{\sqrt{3}}{2}\cos\tau\right) \\ e_C &= e\cdot\sin(\tau+\rho) = -e\left(\frac{1}{2}\sin\tau-\frac{\sqrt{3}}{2}\cos\tau\right) \end{aligned}\right\}. \quad (15)$$

IV. ADDITIONAL RELATIONS FOR CALCULATING SOME ASYMMETRIC MODES

To solve system (1) taking into account (14), it is necessary to establish a connection between the currents of the generator i_a, i_b, i_c and the currents in the buses i_A, i_B, i_C or introduce additional relationships characterizing the operating mode of the synchronous machine.

1. Asymmetry of the resistance system between the generator and the system $Z_A \neq Z_B \neq Z_C$. In this case, as follows from Fig. 1

$$i_a = i_A; i_b = i_B; i_c = i_C. \quad (16)$$

System of equations (1) taking into account (14) is simplified

$$\left.\begin{aligned} p\psi_a &= -e_A - i_a(r_a + r_A) - x_A p i_a \\ p\psi_b &= -e_B - i_b(r_b + r_B) - x_B p i_b \\ p\psi_c &= -e_C - i_c(r_c + r_C) - x_C p i_c \end{aligned}\right\}. (17)$$

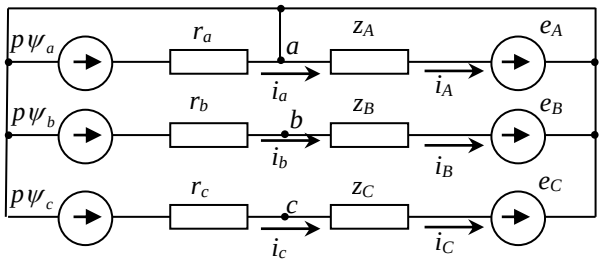

Fig 2: Single-phase generator phase short circuit to common neutral generator-system

2. Single-phase short circuit of the generator phase to the common neutral generator-system. In general, the short circuit mode can be calculated in the presence of resistance asymmetry $Z_A \neq Z_B \neq Z_C$.

Additional relations are obtained from Fig. 2.

$$i_b = i_B; i_c = i_C; e_a = 0. \quad (18)$$

The system of equations (1) takes the form:

$$\left.\begin{aligned} p\psi_a &= -i_a r_a \\ p\psi_b &= -e_B - i_b(r_b + r_B) - x_B p i_b \\ p\psi_c &= -e_C - i_c(r_c + r_C) - x_C p i_c \end{aligned}\right\}. \quad (19)$$

Short circuit of two phases of the generator to a common neutral generator-system. As follows from Fig. 3, when phases a and b of the generator are shorted to neutral, we obtain the following additional relations:

$$i_c = i_C; e_a = 0; e_b = 0. \quad (20)$$

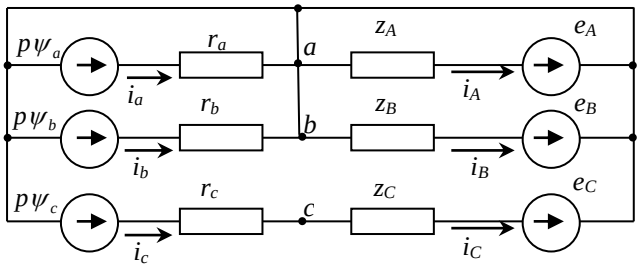

Fig. 3: Short circuit of two phases of the generator to a common neutral generator-system

Taking them into account, system of equations (1) takes the form:

$$\left.\begin{aligned} p\psi_a &= -i_a r_a \\ p\psi_b &= -i_b r_b \\ p\psi_c &= -e_C - i_c(r_c + r_C) - x_C p i_c \end{aligned}\right\}. \quad (21)$$

4. Two-phase short circuit. With a short circuit of phases a and b, we obtain only one obvious relationship from Fig. 4:

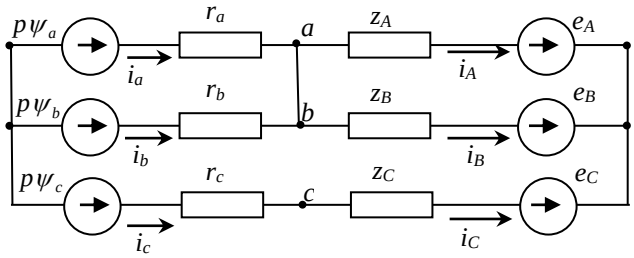

Fig. 4: Two phase short circuit

$$i_c = i_C \quad (22)$$

The other two relations are obtained after introducing an additional assumption:

The values of active and reactive resistances between the short circuit point and infinite power buses in short-circuited phases are equal to

$$Z_A = Z_B = Z_C,\ r_A = r_B = r_C;\ x_A = x_B = x_C.$$

The introduction of this assumption allows us to obtain differential equations for stator circuits, which are easily solved by numerical methods.

From expressions

$$\left.\begin{aligned} e_a &= -e_A - i_A z_A \\ e_b &= -e_B - i_B z_A \end{aligned}\right\}. \quad (23)$$

we obtain expressions for $e_a + e_b$ и $e_a - e_b$:

$$\left.\begin{aligned} e_a + e_b &= -\left(e_A + e_B\right) - z_A\left(i_A + i_B\right) \\ e_a - e_b &= 0 \end{aligned}\right\}. \quad (24)$$

Using known relations $e_A + e_B + e_C = 0$ and $i_A + i_B + i_C = 0$, get

$$e_A + e_B = -e_C \ \text{ и } \ i_A + i_B = -i_C \quad (25)$$

After substituting (25) into (24) we get

$$\begin{aligned} e_a + e_b &= e_C + z_A i_C; \\ e_a - e_b &= 0. \end{aligned}$$

From here

$$\begin{aligned} e_a &= \frac{e_C}{2} + \frac{z_A}{2} i_C; \\ e_b &= \frac{e_C}{2} + \frac{z_A}{2} i_C. \end{aligned}$$

The system of equations (1) takes the form:

$$\left.\begin{aligned} p\psi_a &= \frac{e_C}{2} + \frac{x_A \rho i_c}{2} - i_a r_a + \frac{i_c r_A}{2}; \\ p\psi_b &= \frac{e_C}{2} + \frac{x_A \rho i_c}{2} + \frac{i_c r_A}{2} - i_b r_b; \\ p\psi_c &= e_C - x_C \rho i_c - i_c\left(r_c + r_C\right). \end{aligned}\right\} \quad (26)$$

5. Phase failure a.

Phase loss is a special case of asymmetry of the resistance system, when the resistance is $Z_A = \infty$. However, it is not possible to introduce such a resistance value into the CT. We can limit ourselves to including a finite, but sufficiently large value Z_A in the phase. Its value is limited by the scale factors adopted for resistances.

This technique can also be used to consider the operating mode during phase failure. Consider the current in phase a to be equal to zero $i_a = i_A = 0$, which corresponds to the physics of the process, and the flux linkages of phase a, determined by solving the first equation of system (1), are found using the equation

$$\psi_a = i_b x_{ab} + i_c x_{ac} + i_f x_{af} + i_{kd} x_{af} + i_{kq} x_{akq},$$

where $x_{ab}, x_{ac}, x_{af}, x_{akq}$ – mutual reactivity of phase a and the corresponding circuits, determined by the following relations through the known parameters of the machine:

$$\left.\begin{aligned} x_{ab} &= \frac{1}{3}x_0 - \frac{1}{6}\left(X_d + X_q\right) - \frac{1}{3}\left(X_d - X_q\right)\cos\left(2\gamma - \rho\right) \\ x_{ac} &= \frac{1}{3}x_0 - \frac{1}{6}\left(X_d + X_q\right) - \frac{1}{3}\left(X_d - X_q\right)\cos\left(2\gamma + \rho\right) \\ x_{af} &= x_{ad} \cdot \cos\gamma \\ x_{akq} &= x_{aq} \cdot \sin\gamma \end{aligned}\right\}. \quad (27)$$

6. Single-phase short circuit of the generator to the neutral of the system (Fig. 5) is accepted: $r_a = r_b = r_c$, locked phase a.

We obtain relations for currents

$$i_b = i_B, i_c = i_C \quad (28)$$

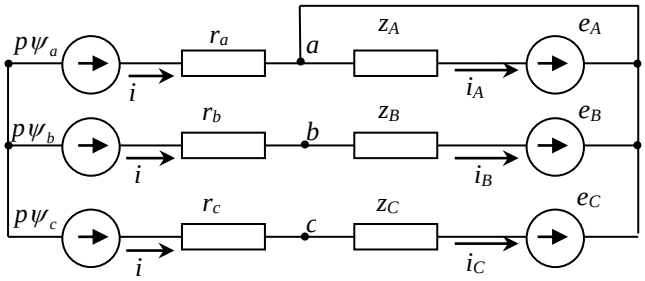

Fig. 5: Phase failure a

To obtain the third necessary relationship, we compose the Kirchhoff equations for stresses:

$$\begin{aligned} p\psi_a + i_a r_a - p\psi_b - i_b r_b - e_B - i_b z_B &= 0; \\ p\psi_a + i_a r_a - p\psi_c - i_c r_c - e_C - i_c z_C &= 0. \end{aligned} \quad (29)$$

Adding equations (29) and using the relations:

$$p\psi_a + p\psi_b + p\psi_c = 0; \quad i_a + i_b + i_c = 0. \quad (30)$$

get:

$$3p\psi_a + 3i_a r_a = e_C + i_c z_C + e_B + i_b z_B,$$

where

$$p\psi_a = \frac{1}{3}\left(e_C + i_c z_C + e_B + i_b z_B\right) - i_a r_a. \quad (31)$$

The equations for phases b and c are obtained similarly:

$$\begin{aligned} p\psi_b &= -\frac{1}{3}\left(2e_B - e_C + 2i_b z_B - i_c z_C\right) - i_b r_B \\ p\psi_c &= -\frac{1}{3}\left(2e_C - e_B + 2i_c z_C - i_b z_B\right) - i_c r_c. \end{aligned} \quad (32)$$

7. We consider a two-phase short circuit of the generator to the system neutral (Fig. 6) to be equal to the active resistance of the generator phases $r_a = r_b = r_c$; Phases a and b are shorted.

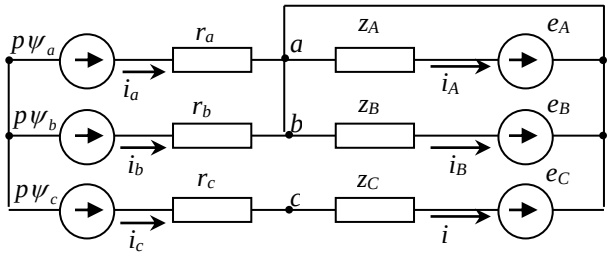

Fig. 6: Single-phase short circuit of the generator to neutral

Composing, as in the previous case, the Kirchhoff equations

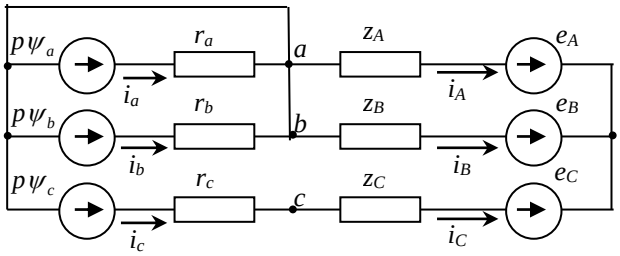

Fig. 8: Two-phase short circuit to generator neutral

$$\left.\begin{aligned} &p\psi_a + i_a r_a - p\psi_c - i_c r_c - e_C - i_c z_C = 0 \\ &p\psi_a + i_a r_a - p\psi_b - i_b r_b = 0 \\ &p\psi_b + i_b r_b - p\psi_c - i_c r_c - e_C - i_c z_C = 0 \end{aligned}\right\} \quad (33)$$

get

$$\left.\begin{aligned} p\psi_c &= -\frac{2}{3}\left(e_C + i_c z_C\right) - i_c r_c \\ p\psi_a &= \frac{1}{3}\left(e_C + i_c z_C\right) - i_a r_a \\ p\psi_b &= \frac{1}{3}\left(e_C + i_c z_C\right) - i_b r_b \end{aligned}\right\}. \quad (34)$$

8. Single-phase short circuit to generator neutral (Fig. 7). Phase a is short-circuited. For phases b and c with a ratio of $i_b = i_B$ and $i_c = i_C$, from the Kirchhoff equations we obtain:

$$\left.\begin{aligned} p\psi_a &= -i_a r_a \\ p\psi_b &= e_A + i_A z_A - e_B - i_b z_B - i_b r_b \\ p\psi_c &= e_A + i_A z_A - e_C - i_b z_C - i_c r_c \\ i_A &= -\left(i_B + i_C\right) \end{aligned}\right\}. \quad (35)$$

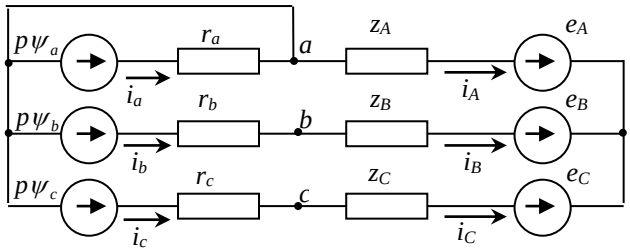

Fig 7: Single-phase short circuit to generator

9. Two-phase short circuit to the neutral of the generator (Fig 8). Phases a and b are closed. For phase c, the relation holds $i_c = i_C$. Compose the Kirchhoff equations (Wood & Wollenberg, 1996) (Yakimchuk, 2000) (Yan & Xu, 2020).

$$\left.\begin{aligned} &p\psi_a = -i_a r_a \\ &p\psi_b = -i_b r_b \\ &i_A + i_B + i_C = 0 \\ &p\psi_c + i_c r_c + e_C + i_C z_C - e_A - i_A z_A = 0 \\ &p\psi_c + i_c r_c + e_C + i_C z_C - e_B - i_B z_B = 0 \end{aligned}\right\}. \quad (36)$$

From the last two equations, under the condition $Z_A = Z_B = Z_C$, we obtain

$$p\psi_c = -\frac{3}{2}\left(e_C + i_C z_C\right) - i_c r_c. \quad (37)$$

Taking into account the reactivity between the generator and the infinite power system led to the appearance of derivatives of the stator phase currents on the right sides of the differential equations of phase voltages.

V. SIMULATION RESULTS OF ASYMMETRIC TRANSIENTS

The results of analytical studies of the considered asymmetrical transient processes (with asymmetrical short circuits) on phase coordinates are summarized in Table 1.

Table 2 and Fig. 9 present the numerical results of computer calculations based on the obtained solutions for transient asymmetrical short-circuit processes in the electrical system. The table data confirms the effectiveness of the proposed approach to studying asymmetric transient processes on phase coordinates.

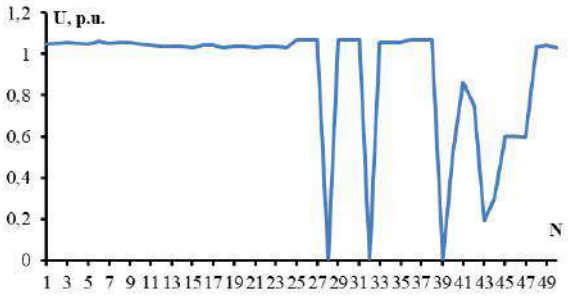

Fig. 9: Voltage profile for a synchronous generator-grid network with asymmetrical short circuits

As can be seen from Table 2 and Fig. 9, in case of short circuits on buses 28, 32 and 39, the voltage on these buses $\dot{U} = 0$ and in consumer nodes 1-9, 25-32 and 36-50 active and reactive loads is zero. On buses 40-47 the voltage is within $(0{,}520 - 0{,}594)U_{nom}$ The results obtained confirmed the pre-modeled modes for the asymmetric transient modes considered above

VI. CONCLUSION

1. Using phase coordinates, a method for calculating asymmetrical transient modes of a synchronous generator operating on an electrical network is presented. As a result of transformations, differential equations of a synchronous machine were obtained in axes a, b, c for stator quantities and axes d, q, 0 for rotor quantities. The variable coefficients included in these equations are functions of $\sin\gamma$ and $\cos\gamma$, therefore their calculation on a CT does not greatly complicate the calculation task compared to the calculation of symmetric modes in the d, q, 0 axes.

2. Equations are given that make it possible to take into account, under certain assumptions, active and inductive resistance, the connection between the generator and the system of infinite power. Based on the conditions characterizing asymmetrical modes, equations for the stator circuits of a generator operating on infinite power systems for various asymmetrical short circuits are obtained.

3. Numerical results of computer calculations based on the obtained solutions for transient asymmetrical short circuit processes in the electrical system are presented. The table data confirms the effectiveness of the proposed approach to studying asymmetric transient processes on phase coordinates.

Table 1: Results of analytical studies of asymmetrical transient processes

Types of asymmetrical short circuits	**System equation (1)**		
	$p\psi_a = e_a - i_a z_a - i_a r_a$	$p\psi_b = e_b - i_b z_B - i_b r_b$	$p\psi_c = e_C - i_c z_C - i_c r_c$
Single-phase short circuit to common neutral	$p\psi_a = -i_a r_a$	$p\psi_b = -e_B - i_b r_b - i_b z_B$	$p\psi_c = -e_C - i_c z_C - i_c r_c$
Two-phase short circuit to common neutral	$p\psi_a = -i_a r_a$	$p\psi_b = -i_b r_b$	$p\psi_c = -e_C - i_c z_C - i_c r_c$
Two-phase short circuit	$p\psi_a = \frac{e_C}{2} - i_a r_a + \frac{i_c z_A}{2}$	$p\psi_b = \frac{e_C}{2} + \frac{i_c z_A}{2} - i_b r_b$	$p\psi_c = -e_C - i_c z_A - i_c r_c$
Single-phase short circuit to system neutral	$p\psi_a = \frac{1}{3}(e_C + i_c z_C + e_B + i_b z_B) - i_a r_a$	$p\psi_b = -\frac{1}{3}(2e_B - e_C + 2i_b z_B - i_c z_C) - i_b r_b$	$p\psi_c = -\frac{1}{3}(2e_C - e_B + 2i_c z_C - i_b z_B) - i_c r_c$
Two-phase short circuit to system neutral	$p\psi_a = \frac{1}{3}(e_C + i_c z_C) - i_a r_a$	$p\psi_b = \frac{1}{3}(e_C + i_c z_C) - i_b r_b$	$p\psi_c = -\frac{2}{3}(e_C + i_c z_C) - i_c r_c$
Single-phase short circuit to generator neutral	$p\psi_a = -i_a r_a$	$p\psi_b = e_A + i_A z_A - e_B - i_b z_B - i_b r_b$	$p\psi_c = e_A + i_A z_A - e_C - i_c z_C - i_c r_c = e_A + i_B z_A - e_C - i_c(z_A + z_C) - i_c r_c$

Two-phase short circuit to generator neutral	$p\psi_a = -i_a r_a$	$p\psi_b = -i_b r_b$	$p\psi_c = -\frac{3}{2}(e_C + i_C z_C) - i_c r_c$

Table 2: Calculation results based on the obtained solutions for asymmetrical short circuit

Node No.	Node type	U (p.u.)	Angle (deg)	P_g (MW)	Q_g (MVAR)	P_l (MW)	Q_l (MBAP)
1	3	1,050	-1,916	0,000	0,000	0,000	0,000
2	3	1,051	-121,674	0,000	0,000	0,000	0,000
3	3	1,055	116,154	0,000	0,000	0,000	0,000
4	3	1,052	68,661	0,000	0,000	0,000	0,000
5	3	1,050	-30,575	0,000	0,000	0,000	0,000
6	3	1,062	-150,839	0,000	0,000	0,000	0,000
7	3	1,053	87,380	0,000	0,000	0,000	0,000
8	3	1,056	-32,461	0,000	0,000	0,000	0,000
9	3	1,056	-152,688	0,000	0,000	0,000	0,000
10	6	1,046	87,388	0,000	0,000	9,111	5,466
11	6	1,044	-33,011	0,000	0,000	9,089	5,453
12	6	1,037	-152,765	0,000	0,000	8,968	5,361
13	6	1,041	87,096	0,000	0,000	10,833	6,861
14	6	1,039	-33,436	0,000	0,000	10,791	6,834
15	6	1,029	-153,101	0,000	0,000	10,587	6,705
16	6	1,042	87,080	0,000	0,000	12,676	7,965
17	6	1,045	-32,377	0,000	0,000	12,625	7,934
18	6	1,032	-153,073	0,000	0,000	12,428	7,809
19	6	1,040	87,025	0,000	0,000	10,820	6,352
20	6	1,038	-33,469	0,000	0,000	10,778	6,525
21	6	1,029	-153,152	0,000	0,000	10,588	6,706
22	6	1,040	87,014	0,000	0,000	14,420	9,012
23	6	1,038	-33,458	0,000	0,000	14,368	8,980
24	6	1,029	-153,148	0,000	0,000	14,129	8,830
25	1	1,070	0,000	38,839	23,199	0,000	0,000
26	1	1,070	-120,072	32,511	21,553	0,000	0,000

Table 2 (continue)

Node No.	Node type	U (p.u)	Angle (deg)	P_g (MW)	Q_g (MVAR)	P_l (MW)	Q_l (MBAP)
27	1	1,070	120,072	37,072	16,920	0,000	0,000
28	5	0,000	0,000	0,000	0,000	0,000	0,000
29	4	1,070	90,856	24,543	11,722	0,000	0,000
30	4	1,070	-29,168	16,229	13,057	0,000	0,000

31	4	1,070	-149,192	19,228	5,183	0,000	0,000
32	5	0,000	0,000	0,000	0,000	0,000	0,000
33	6	1,055	87,412	0,000	0,000	6,680	2,598
34	6	1,058	-32,443	0,000	0,000	6,710	2,610
35	6	1,058	-152,634	0,000	0,000	6,714	2,611
36	4	1,070	85,282	10,083	9,429	0,000	0,000
37	4	1,070	-31,670	8,970	7,914	0,000	0,000
38	4	1,070	-151,694	10,947	7,732	0,000	0,000
39	5	0,000	0,000	0,000	0,000	0,000	0,000
40	3	0,520	-93,147	0,000	0,000	0,000	0,000
41	3	0,863	82,090	0,000	0,000	0,000	0,000
42	3	0,751	-9,572	0,000	0,000	0,000	0,000
43	3	0,192	-72,025	0,000	0,000	0,000	0,000
44	3	0,297	-167,711	0,000	0,000	0,000	0,000
45	3	0,601	67,024	0,000	0,000	0,000	0,000
46	3	0,599	-33,474	0,000	0,000	0,000	0,000
47	3	0,594	-153,152	0,000	0,000	0,000	0,000
48	3	1,034	-122,883	0,000	0,000	0,000	0,000
49	3	1,042	116,762	0,000	0,000	0,000	0,000
50	3	1,032	-3,459	0,000	0,000	0,000	0,000

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A robust controller design for a robotic system

Lafi Alnufaie

Department of Electrical Engineering, Engineering College, Shaqra University, Shaqra 11961, Saudi Arabia
Email: lalnufaie@su.edu.sa

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***Keywords*—Roboticsystems, nonsingular fast terminal sliding mode control.**

***Abstract*—** *This paper proposes a nonsingular fast sliding mode control based on a fuzzy model applied to a robotic system. The objective of the proposed approach to guarantee the convergence of the system to desired trajectories quickly and in finite time in presence of uncertainties and external disturbances. Simulation results are given to see the obtained performances.*

I. INTRODUCTION

Modem industrial systems become more and more complex to modeling and subject to both uncertainties and external disturbances, which makes their controlling difficult.

Sliding mode control can be considered a very popular approach to ensure good tracking performances against external disturbances[1],[2]. Despite its performances sliding mode control suffers from two principal drawbacks: presence of chattering phenomena due to presence of signum function, and time convergence cannot imposed. To overcome the first drawback, many works have been developed. In [3]–[5], the switching signal is smoothed by using a low-pass filter. Authors of [6]–[8] proposed to use an adaptive fuzzy system to substitute the switching control and, hence, to eliminate the chattering phenomenon. Other techniques have been developed in the literature. However, this improvement needs a trade off between the smoothness of the switching signal and tracking performances. Second order sliding mode control have been also presented a good solution to chattering but the design procedure is complex and the requires a good knowledge of the studied system [9]–[11].

Other improvements of classical sliding mode control like terminal sliding mode control have been developed, where a non linear surface is used [12], [13]. However, these kinds of controllers suffer from singularity problem due to presence of terms with negative fractional powers [14]. This problem can resolved by using a nonsingular terminal sliding mode controller [15], [16] Nevertheless, this improvement was obtained at the expense of the convergence time which becomes slower. Nonsingular fast terminal sliding mode controller have been developed to overcome singularity and to obtain fast convergence time [17], [18].

Thus, in this paper, we propose a nonsingular fast terminal sliding mode controller for a robotic system which guarantees finite-time convergence, fast speed when the states are far from the origin, avoidance of singularity and without chattering. The control is developed using a fuzzy nominal model witch avoids using approximating system dynamics [19]–[21].

The remainder of this paper is organized as follows : In Section 2, problem statement of controlling a robotic system is treated. Section 3 is dedicated to the controller design and stability analysis. Simulation and results are given in Section 4 to show the effectiveness of the proposed approach. Finally, the conclusion is provided.

II. ROBLEM STATEMENT

Let us consider the dynamic equation of n degree-of-freedom robotic manipulators as follows:

$$M(q)\ddot{q} + C(q,\dot{q})\dot{q} + G(q,\dot{q}) = \Gamma(t) + \Gamma_{ext}(t) \quad (1)$$

Where:

q, $\dot{q}$ and $\ddot{q} \in \mathbb{R}^n$ are the vector of joint position, joint velocity, and joint acceleration, respectively.

$M(q) \in \mathbb{R}^{n\times n}$ is a symmetric and positive definite inertia matrix,

$C(q,\dot{q}) \in \mathbb{R}^{n\times n}$ is the matrix of centrifugal and Coriolis forces,

$G(q) \in \mathbb{R}^n$ is the vector of gravitational forces,

$\Gamma(t) \in \mathbb{R}^n$ is the vector of input joint torque and $\Gamma_{ext}(t) \in \mathbb{R}^n$ is the vector of unknown external disturbances.

For practical applications, it is impossible to know the exact dynamic model of the robotic manipulators. Hence, the above dynamic quantities can be expressed as:

$$\begin{aligned}\mathbf{M(q)} &= \mathbf{M_0(q)} + \Delta\mathbf{M(q)}\\ \mathbf{C(q,\dot{q})} &= \mathbf{C_0(q,\dot{q})} + \Delta\mathbf{C(q,\dot{q})}\\ \mathbf{G(q)} &= \mathbf{G_0(q)} + \Delta\mathbf{G(q)}\end{aligned} \quad (2)$$

Where:

$\mathrm{M_0(q)}$, $C_0(q,\dot{q})$, $G_0(q)$ are the nominal values of $\mathrm{M(q)}$, $C(q,\dot{q})$, $\mathrm{G(q)}$ respectively and

$\Delta\mathrm{M(q)}$, $\Delta C(q,\dot{q})$, $\Delta G(q)$ are the uncertain parts of $\mathrm{M(q)}$, $C(q,\dot{q})$, $\mathrm{G(q)}$ respectively.

Using equation (2), the dynamic model of the robotic manipulators can be expressed as:

$$M_0(q)\ddot{q} + C_0(q,\dot{q})\dot{q} + G_0(q,\dot{q}) = \Gamma(t) + \delta(q,\dot{q},\ddot{q}) \quad (3)$$

Where:

$$\delta(q,\dot{q},\ddot{q}) = \Gamma_{ext}(t) - \Delta\mathrm{M(q)}\ddot{q} - \Delta C(q,\dot{q})\dot{q} - \Delta G(q)$$

Let define the tracking error $e = q - q_d$ and its time derivative $\dot{e} = \dot{q} - \dot{q}_d$ where q_d the desired trajectory. Then the error dynamic of the robotic manipulators with the uncertainties and disturbances can be written as:

$$\ddot{e} = f(e,\dot{e}) + g(e,\dot{e})\Gamma(t) + D(e,\dot{e}) \quad (4)$$

Where

$$f(e,\dot{e}) = -M_0^{-1}(q)[C_0(q,\dot{q})\dot{q} + G_0(q,\dot{q}) - \ddot{q}_d,$$

$$g(e,\dot{e}) = M_0^{-1}(q) \text{ and}$$

$$D(e,\dot{e}) = M_0^{-1}(q)\,\delta(q,\dot{q},\ddot{q})$$

As given in [14], the upper bound of lumped uncertainty can be expressed as:

$$|D(e,\dot{e})| \le a_0 + a_1|q| + a_2|\dot{q}|^2 \quad (5)$$

Where b_0, b_1 and b_2 are positive scalars.

The next task is to develop a robust controller based on nonsingular fast terminal sliding mode control allowing to tracking objectives.

III. CONTROLLER DESIGN

To design our controller, let consider the following nonsingular terminal sliding surface:

$$S(t) = e + k_1|e|^{\alpha}sign(e) + k_2|\dot{e}|^{\beta}\,sign(\dot{e}) \quad (6)$$

Where $\mathbf{k_1}$ and $\mathbf{k_2}$ are positive constants,

$1 < \beta < 2$ and $\alpha > \beta$.

The structure of this surface allows us to attain fast convergence of the tracking error to zero. Indeed, if the position initial value is far from the desired one, then the term $k_1|e|^{\alpha}sign(e)$ will be dominant, which leads to a fast convergence. In the case where the system is near the desired trajectory, the term $k_2|\dot{e}|^{\beta}\,sign(\dot{e})$ must ensuring a finite time convergence.

The time derivative of the sliding surface can be written as:

$$\dot{S}(t) = \dot{e} + \alpha.k_1|e|^{\alpha-1}\dot{e} + \beta.k_2|\dot{e}|^{\beta-1}.\ddot{e} \quad (7)$$

Our control law will be composed from two terms. The first one, named equivalent control $\Gamma_e(t)$, is dedicated to maintain the system on the sliding surface. The second term, $\Gamma_s(t)$ called switching signal, must force the system to converge to the sliding surface. Then, to design the equivalent control law $\Gamma_e(t)$, we consider that the system is on the surface ($S(t) = 0$) and remains on ($\dot{S}(t) = 0$). In this case, the system is considered insensitive to uncertainties and external disturbances [1].

Using (4) equation (7) can be rewritten as:

$$\dot{S}(t) = \dot{e} + \alpha.k_1|e|^{\alpha-1}\dot{e} + \beta.k_2|\dot{e}|^{\beta-1}.[f(e,\dot{e}) + g(e,\dot{e})\Gamma_e(t)] \quad (8)$$

Then the expression of equivalent control law can be expressed as:

$$\Gamma_e(t) = -g^{-1}(e,\dot{e}).\left[f(e,\dot{e}) + [\beta.k_2]^{-1}|\dot{e}|^{2-\beta}(1 + \alpha.k_1|e|^{\alpha-1})\,sign(\dot{e})\right] \quad (9)$$

Note that, we used the fact that $\dot{e} = |\dot{e}|.sign(\dot{e})$ to writ equation (9) in a compact form.

Our next task is to determine the expression of the switching signal $\Gamma_s(t)$ allowing to force the system to reach the sliding surface in presence of uncertainties and external disturbances.

In this case, equation (7) becomes:

$$\dot{S}(t) = \dot{e} + \alpha.k_1|e|^{\alpha-1}\dot{e} + \beta.k_2|\dot{e}|^{\beta-1}.[f(e,\dot{e}) + g(e,\dot{e})\Gamma(t) + D(e,\dot{e})] \quad (10)$$

Using (9), we can rewrite (10) as:

$$\dot{S}(t) = \dot{e}+\propto\cdot k_1|e|^{\propto-1}\dot{e} + \beta\cdot k_2|e|^{\beta-1}\cdot [f(e,\dot{e}) + g(e,\dot{e})\Gamma_s(t)]\beta.k_2|\dot{e}|^{\beta-1}.[g(e,\dot{e})\Gamma_s(t) + D(e,\dot{e})] \quad (11)$$

According to the definition of the equivalent control, equation (11) can be simplified to:

$$\dot{S}(t) = \beta.k_2|\dot{e}|^{\beta-1}.[g(e,\dot{e})\Gamma_s(t) + D(e,\dot{e})] \quad (12)$$

To deduce the expression of $\Gamma_s(t)$ allowing the switching condition, we consider the following Lyapunov function:

$$V(t) = \frac{1}{2}S^2(t) \quad (13)$$

Differentiating $V(t)$ with respect to time and using (12) lead to:

$$\dot{V}(t) = S(t).\beta.k_2|\dot{e}|^{\beta-1}.[g(e,\dot{e})\Gamma_s(t) + D(e,\dot{e})] \quad (14)$$

Choosing $\Gamma_s(t)$ as:

$$\Gamma_s(t) = -g^{-1}(e,\dot{e})[k_{01}.S(t) + (k_{02} + a_0 + a_1|q| + a_2|\dot{q}|^2).sign(S(t))] \quad (14)$$

Where k_{01} and k_{02} are two positive scalars.

The time derivative of the Lyapunov function becomes:

$$\dot{V}(t) = S(t)\cdot\beta\cdot k_2|\dot{e}|^{\beta-1}\cdot[g(e,\dot{e})\Gamma_s(t) + D(e,\dot{e})]$$

$$= \beta.k_2|\dot{e}|^{\beta-1}.[-k_{01}.S^2(t) - (k_{02} + a_0 + a_1|q| + a_2|\dot{q}|^2).|S(t)| + D(e,\dot{e})] \quad (15)$$

Using the assumption (5), we obtain the following inequality:

$$\dot{V}(t) \le \beta.k_2|\dot{e}|^{\beta-1}.[-k_{01}.S^2(t) - k_{02}.|S(t)|] \le 0 \quad (16)$$

Based on the Lyapunov theorem, the system converges asymptotically to the sliding surface and remains on.

To prove convergence in finite time, let us take up inequality (17):

$$\dot{V}(t) \le -\beta.k_{01}.k_2|\dot{e}|^{\beta-1}.S^2(t) - \beta.k_{02}.k_2|\dot{e}|^{\beta-1}.|S(t)| \quad (18)$$

$$\dot{V}(t) = \frac{dV(t)}{dt} \le -\underbrace{2.\beta.k_{01}.k_2|\dot{e}|^{\beta-1}}_{\beta_1}.V(t) - \underbrace{\sqrt{2}\beta.k_{02}.k_2|\dot{e}|^{\beta-1}}_{\beta_2}.V^{\frac{1}{2}}(t) \quad (17)$$

Then we can obtain:

$$dt \le \frac{-dV(t)}{\beta_1.V(t)+\beta_2.V^{\frac{1}{2}}(t)} = -2.\frac{dV^{\frac{1}{2}}(t)}{\beta_1.V^{\frac{1}{2}}(t)+\beta_2} \quad (18)$$

If we consider that the system converges to 0 at $t = t_r$ implies that:

$$\int_0^{t_r} dt \le \int_{V(0)}^{V(t_r)} \frac{-2.dV^{\frac{1}{2}}(t)}{\beta_1.V^{\frac{1}{2}}(t)+\beta_2} = \left[-\frac{2}{\beta_1}ln\left(\beta_1V^{\frac{1}{2}}(t) + \beta_2\right)\right]_{V(0)}^{V(t_r)} \quad (19)$$

Hence,

$$t_r \le \frac{2}{\beta_1}ln\left(\frac{\beta_1V^{\frac{1}{2}}(0)+\beta_2}{\beta_2}\right) \quad (20)$$

Consequently, the control law $\Gamma(t) = \Gamma_e(t) + \Gamma_s(t)$, whose terms are defined by equations (9) and (15), guarantees the asymptotic stability of the closed loop system and the convergence of the tracking error in a finite time.

IV. FIGURES SIMULATION AND RESULTS

To show the performances of the performances of the proposed approach, we consider a two-link robot, shown in figure 1, whose dynamics equation is given by [15]:

$$\begin{bmatrix}M_{11}(q) & M_{12}(q)\\ M_{21}(q) & M_{22}(q)\end{bmatrix}\begin{bmatrix}\ddot{q}_1\\ \ddot{q}_2\end{bmatrix} + \begin{bmatrix}C_{11}(q,\dot{q}) & C_{12}(q,\dot{q})\\ C_{21}(q,\dot{q}) & C_{22}(q,\dot{q})\end{bmatrix}\begin{bmatrix}\dot{q}_1\\ \dot{q}_2\end{bmatrix} + \begin{bmatrix}G_1(q)\\ G_2(q)\end{bmatrix} = \begin{bmatrix}\Gamma_1(t)\\ \Gamma_2(t)\end{bmatrix} + \begin{bmatrix}\Gamma_{ext1}(t)\\ \Gamma_{ext2}(t)\end{bmatrix}$$

Where:

$$M_{11}(q) = (m_1 + m_2)l_1^2$$

$$M_{12}(q) = M_{21}(q) = m_2l_1l_2(\sin(q_1)\sin(q_2) + \cos(q_1)\cos(q_2))$$

$$M_{22}(q) = m_2 l_2^2$$

$$C_{11}(q,\dot{q}) = -m_2 l_1 l_2(\cos(q_1)\sin(q_2) - \sin(q_1)\cos(q_2))\dot{q}_2$$

$$C_{21}(q,\dot{q}) = -m_2 l_1 l_2(\cos(q_1)\sin(q_2) - \sin(q_1)\cos(q_2))\dot{q}_1$$

$$C_{11}(q,\dot{q}) = C_{22}(q,\dot{q}) = 0$$

$$G_1(q) = -(m_1 + m_2) l_1 g.\sin(q_1)$$

$$G_2(q) = -m_2 l_2 g.\sin(q_2)$$

$$m_1 = m_2 = 1Kg; l_1 = l_2 = 1m; g = 9.8ms^{-2}$$

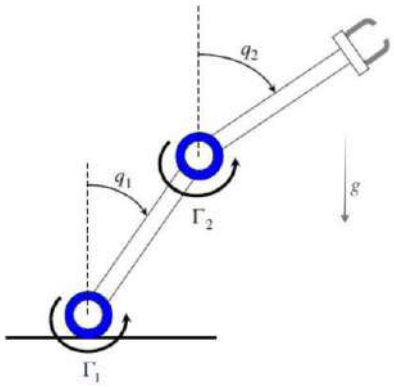

Fig.1: Two link robot manipulators.

To construct the type 2 fuzzy nominal model, we consider that the positions q_1 and q_2 are constrained within $\left[-\frac{\pi}{2};\frac{\pi}{2}\right]$, witch leads to nine fuzzy rules. Each one of them gives the relation between the equilibrium point and the corresponding local model. Then, each rule uses a type 2 fuzzy sets in the antecedent part to describe the equilibrium point and the consequent part the corresponding local model. Using the product as an interference engine, the method of center set for the reduction type and center of gravity for defuzzification, the output fuzzy system will be giving the type 2 fuzzy nominal model [19] [22].

From Figure 2, we can see that the system converges to the desired trajectories quickly and achieves good tracking performance. Furthermore, both the position and velocity tracking errors tend to zero after a short transient due to errors in initial conditions (figure 3). Figure From 5 shows the applied torques with smooth variation without chattering. Phase portraits of figure 4 illustrate that system states reach the sliding surface in finite-time, and then they converge to 0 along the pre-described surface. Thus, we can conclude that the proposed approach ensures high tracking precision, fast response, singularity avoidance and strong robustness to external disturbances and modeling uncertainties[9], [18].

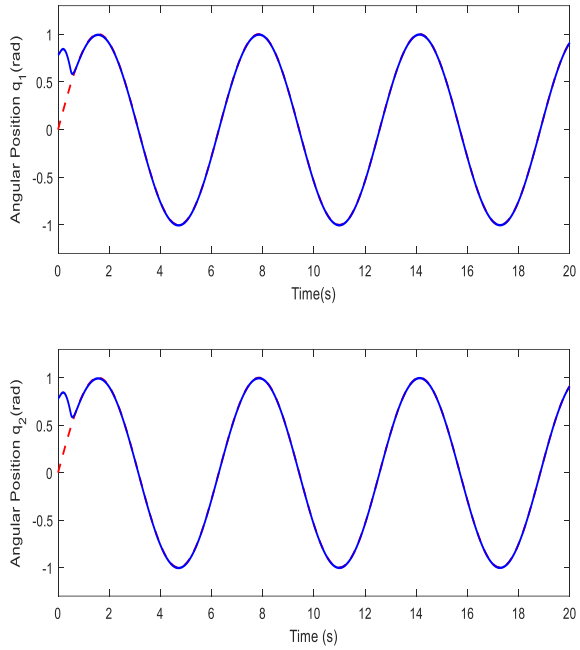

Fig.2: Angular position Tracking.

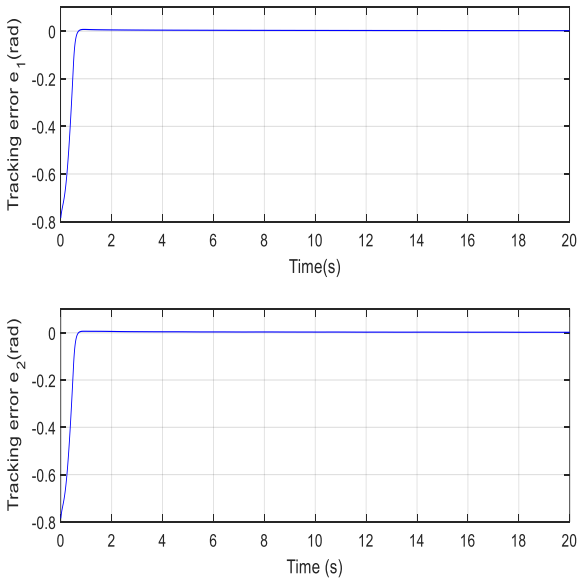

Fig.3: Angular position tracking error.

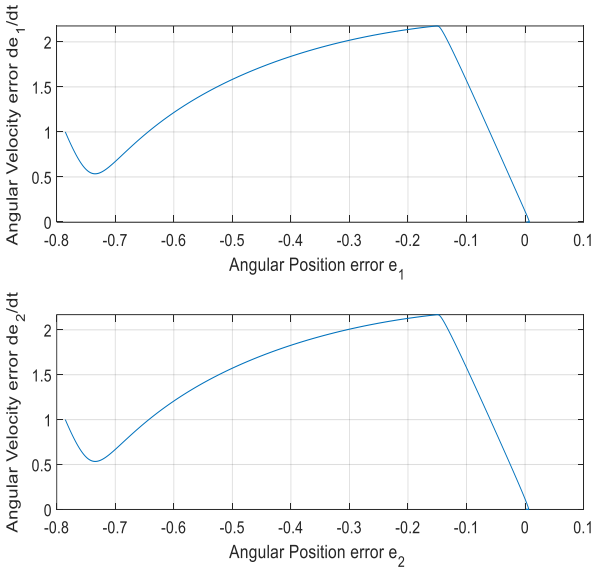

Fig.4: Phase portrait of two joints.

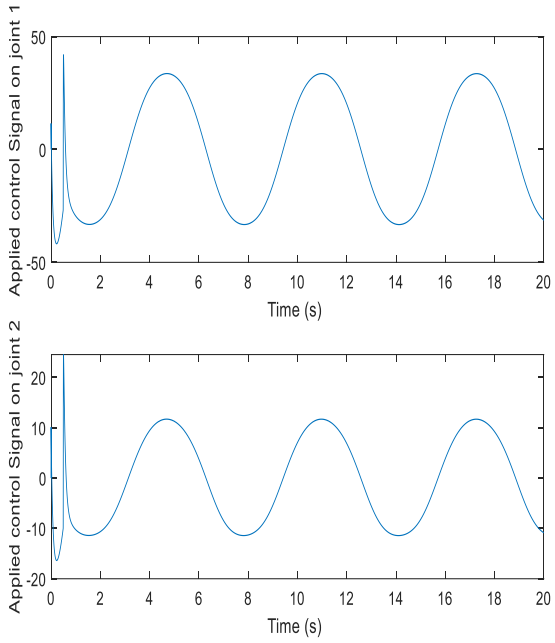

Fig.5: Applied control signals.

V. CONCLUSION

In this work, a nonsingular fast sliding mode control based on a fuzzy model for robotic systems is presented. Using a type fuzzy model allows to obtain a simple nominal model to simplify the control law deduction. This later has been developed such that it guarantees the convergence of the system to desired trajectories quickly and in finite time. Simulation results have been given to show the tracking performances (convergence to the desired trajectory and finite time convergence) despite the presence of modeling uncertainties and external disturbances. As perspective of this work to improve the control law design by reducing number of used parameters.

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Production and study of polymeric composite based on recycled waste from civil construction

Produção e estudo de compósito polimérico a base de resíduos reciclados provenientes da construção civil

Carina Imaculada Ferreira, Franciely Benfica Arcanjo, Priscila Alves da Silva Machado

Universidade do Estado de Minas Gerais - Unidade João Monlevade

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***Palavras-chave*— Compósitos, Resíduos de construção e Demolição, Poliestireno Expandido**

***Abstract*—** *As awareness of environmental issues grows, society recognizes the need for change, and more consumers advocate for environmentally friendly products. Consequently, the construction industry is compelled to devise new strategies to meet these demands. Construction and Demolition Waste (CDW) arises from construction, renovation, or demolition activities, constituting a residual product that has a significant negative impact on the environment. Expanded Polystyrene (EPS), also known as "Styrofoam," is a polymer-based material characterized by its low density, high flexibility, exceptional thermal, acoustic, and chemical resistance, in addition to being entirely recyclable. Composites refer to materials created by combining one or more materials with a matrix, also known as a reinforcement or filler load. This work aimed to conduct research by producing composite materials with a polymer matrix based on expanded polystyrene reinforced with CDW particles. The incorporation of CDW into expanded polystyrene was proposed through its dissolution in the solvent "acetone," enabling the mixing of CDW particles into the polymer matrix. Through structural characterization and mechanical properties, it is intended that the study of this new material can fill gaps in research on the reuse of construction and demolition waste in the field of civil engineering.*

***Resumo*—** *À medida que cresce a conscientização sobre as questões ambientais, a sociedade reconhece a necessidade de mudança e mais consumidores defendem produtos ecologicamente corretos, consequentemente, a indústria da construção civil é compelida a traçar novas estratégias para atender a essas demandas. O resíduo de construção e demolição (RCD) é proveniente das atividades de construção, reforma ou demolição, sendo produto residual que gera impacto negativo significativo no meio ambiente. O poliestireno expandido (EPS), também conhecido como "isopor", é um material à base de polímeros caracterizado por sua baixa densidade, alta flexibilidade, excepcional resistência térmica, acústica e química, além de sua composição totalmente reciclável. Os compósitos referem-se a materiais que são criados combinando um ou mais materiais com uma matriz, também conhecida como carga de reforço ou carga de*

enchimento. Este trabalho teve como objetivo desenvolver uma pesquisa através da produção de materiais compósitos de matriz polimérica a base de poliestireno expandido reforçado com partículas de RCD. Foi proposta a incorporação do RCD ao poliestireno expandido através da dissolução do mesmo em solvente "acetona", possibilitando assim a mistura das partículas de RCD na matriz polimérica. Através de caracterização estrutural e de propriedades mecânica, pretende-se que o estudo desse novo material possa preencher lacunas nas pesquisas sobre reaproveitamento de resíduos de construção e demolição na área de engenharia civil.

Palavras-chave— Compósitos, Resíduos de construção e Demolição, Poliestireno Expandido.

I. INTRODUÇÃO

A urbanização e o desenvolvimento de tecnologias construtivas têm incentivado cada vez mais o investimento no setor da construção civil, oferecendo melhores condições de saúde para população, expansão da mobilidade urbana promovendo praticidade, conforto e qualidade de vida para a população. No entanto, a construção civil tem sido responsável por 50% do volume total de resíduos produzidos nos grandes centros urbanos. Como consequência, o meio ambiente sofre processo de deterioração devido a esses impactos (DUAN *et al*., 2020b; RYOU; LEE, 2014; XIAO *et al*., 2018a; ZHANG *et al*., 2015).

Em um canteiro de obras, pode-se citar alguns resíduos de diferentes categorias que são classificadas na Resolução nº 307 do Conselho Nacional do Meio Ambiente (CONAMA) como: materiais cerâmicos, concreto, solos, madeiras, plásticos entre outras dezenas de diferentes tipos de materiais que são descartados no meio ambiente. É importante também mencionar as interferências nos meios antrópico, biótico e físico nas vizinhanças onde as construções são edificadas. A Associação Brasileira para Reciclagem de Resíduos da Construção Civil e Demolição (ABRECON, 2022) destaca que o contexto atual oferece oportunidades para empreendimentos sociais e sustentáveis, ou seja, aqueles que trazem benefícios tanto para a sociedade quanto para o meio ambiente.

O ramo da construção civil oferece amplo espaço para ideias inovadoras, mas nem sempre é o mais receptivo a mudanças. Para superar esse obstáculo, os projetos nessa área devem se alinhar a novos processos ou formulações que reduzam o tempo de construção e o desperdício. Além disso, é fundamental que esses projetos agreguem valor sem inflar custos, ao mesmo tempo em que defendem os princípios da sustentabilidade por meio da responsabilidade ambiental, equidade social e viabilidade econômica.

À medida que a competitividade no setor se intensifica, os empreendedores reconhecem a importância da sustentabilidade e se esforçam para adotar práticas ecologicamente corretas. Eles concebem e exploram ideias, técnicas e materiais inovadores, enfatizando a viabilidade econômica da reciclagem. No meio dessa empreitada, os resíduos, em particular o resíduo de construção e demolição (RCD), merecem atenção, uma vez que são provenientes das atividades de construção, renovação ou demolição.

A consciência ambiental tem aumentado nos últimos anos, levando a sociedade a ter uma abordagem mais criteriosa sobre o assunto. A gestão e destinação inadequada de entulho, resíduos de construção e demolição têm se destacado como um grande problema para as áreas urbanas, causando impactos socioambientais, incluindo degradação do solo, contaminação de corpos hídricos, aumento do risco de enchentes, poluição do ar e proliferação de vetores transmissores de doenças em centros urbanos. Além disso, os resíduos são frequentemente dispostos em condições insalubres nas ruas e em bota-foras clandestinos (BESEN *et al*., 2017).

Entre os vários atributos do engenheiro civil, é esperado que os profissionais incentivem a implantação na busca de novas tecnologias construtivas sustentáveis, como a implantação de materiais reciclados nas construções válida a eliminação de uma parte desses resíduos acumulados incorretamente na natureza. Logo, constitui-se fator de extrema relevância a busca e o estudo de materiais que apresentem propriedades específicas com baixo custo e que beneficiem a preservação da natureza.

Os compósitos são materiais heterogêneos e multifásicos, criados pela mistura de um ou mais materiais com uma carga de reforço ou matriz de carga de enchimento. O objetivo de combinar esses materiais é fundir as propriedades únicas de seus componentes individuais, a fim de criar um desempenho estrutural superior, adaptado às condições específicas de uso (CALLISTER, 2020).

O poliestireno expandido (EPS), um polímero, conhecido no Brasil como "isopor", é considerado um plástico celular rígido gerado a partir da polimerização do estireno em água

(ABQUIM, 2020). É normalmente utilizado em elementos estruturais como lajes, nivelamento de terrenos e revestimentos. Considerado um resíduo de diversos setores, inclusive do setor da construção civil, no Brasil, cerca de 36,6 mil toneladas desse material são descartadas de maneira inconveniente, acabando por ser destinadas a aterros sanitários (ROCHA; FIGUEIREDO; ALTRAN, 2016).

Dada a importância da reciclagem para a sociedade atual, há um crescente interesse na reutilização desses materiais por profissionais e acadêmicos da área de engenharia.

Dessa maneira, esse trabalho teve como objetivo a fabricação de compósitos poliméricos à base de EPS e avaliação da influência dos RCD incorporados como reforço na sua matriz. Após a produção, foi realizada a caracterização estrutural do material utilizando técnicas de microscopia eletrônica de varredura (MEV), a análise da porosidade, a determinação da dureza e da resistência à compressão do material.

II. REFERENCIAL TEÓRICO

2.1 Construção civil

Segundo o Instituto Brasileiro de Geografia e Estatística (IBGE, 2022), o Produto Interno Bruto (PIB) da construção civil cresceu 9,7 % em 2021. Foi o melhor desempenho do setor desde 2010, quando a indústria da construção civil foi responsável pela geração de mais de 329 milhões de vagas formais no mercado de trabalho e por um aumento de 13,1 % no PIB, o melhor resultado dos últimos 24 anos. De acordo com a Câmara Brasileira da Indústria da Construção (CBIC, 2022) a construção civil é a indústria que mais impulsiona a economia nacional.

No entanto, o crescimento da indústria da construção acarreta alguns problemas, como a geração de resíduos que, quando são descartados inadequadamente, causam alto impacto negativo ao meio ambiente. Vários autores apontam que o setor da construção civil consome cerca de 50% de todos os recursos naturais, além de gerar volume elevado de resíduos. Somando-se a isso, cerca de 60% do "lixo" que é produzido diariamente nas cidades têm origem do setor da construção civil (SILVA; FERNANDES, 2012; SEGANTINI; WADA, 2011).

Segundo GOLDEMBERG *et al*. (2012), a construção civil é responsável pela transformação do ambiente natural, o que requer manutenção permanente. Métodos de gerenciamento de resíduos produzidos durante a construção têm despertado muito interesse e têm sido alvo de inúmeros estudos nesse contexto (IBRAHIM *et al*., 2010; ANGULO *et al*., 2011).

O impacto ambiental causado pela construção civil está normalmente ligado a todas as suas etapas de produção, incluindo extração de recursos, produção e transporte de materiais, concepção e execução de projetos, construção, práticas de uso e manutenção, demolição e desconstrução, bem como o destino final dos resíduos produzidos ao longo de sua vida útil. As fases mencionadas têm impactos ambientais, econômicos e sociais que afetam todas as cidades, empresas e organizações governamentais (IBRAHIM *et al*., 2010; ANGULO *et al*., 2011).

2.2 Compósitos ecoeficientes

Os materiais compostos são produzidos a partir de dois componentes essenciais: um material principal denominada matriz e um elemento de reforço ou carga que está disperso na matriz. A matriz é frequentemente referida como fase contínua, enquanto o reforço é conhecido como fase dispersa. Embora esses materiais sejam separados por uma interface, eles ainda mantêm uma capacidade significativa de adesão entre si. A matriz incorpora, fortalece e dá forma ao componente. Já o material de reforço confere resistência e pode ser constituído de fibras curtas, contínuas, pós ou esféricas (PAULESKI, 2005). O efeito de sinergia que se observa nos sistemas é uma característica dos compósitos que deve ser observada, sendo os principais constituintes dos compósitos utilizados na construção civil categorizados como estruturais e matriciais (PAULESKI, 2005).

Os elementos estruturais são feitos por componentes orgânicos ou inorgânicos, com formas regulares ou assimétricas, podendo ser fibrosos ou pulverulentos (esféricos ou cristalinos), com fragmentos achatados (flocos) ou fibras extremamente curtas, quase moleculares, de material monocristalino. Os blocos de construção são quase sempre feitos de um polímero orgânico que pode ser macio ou duro, termoplástico ou de temperatura fixa. Sua responsabilidade principal é manter o espaçamento e a orientação das fibras, transmitir as forças de cisalhamento entre as camadas da fibra para tornar o material resistente a rasgos e torções e proteger as fibras contra danos superficiais (PAULESKI, 2005). A Figura 1 esquematiza um compósito.

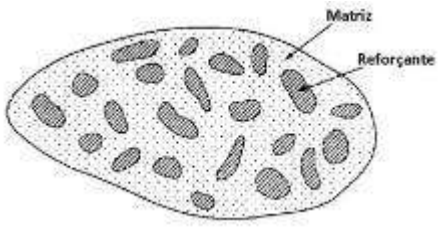

Fig.1- Esquematização de um compósito

Fonte: Nota Positiva, 2010.

2.3 Polímeros

As macromoléculas conhecidas como polímeros se distinguem por seu tamanho, composição química e

interações intra e intermoleculares. Possuem unidades químicas conectadas por ligações covalentes repetidas que percorrem toda a extensão da cadeia. Podem ser sintéticos, ou naturais como seda, celulose, fibras de algodão, etc. (WAN, 2002).

Os polímeros são classificados como termoplásticos (plásticos), termofixos, borrachas e fibras. Plásticos são materiais que, apesar de estarem sozinhos em temperatura ambiente seu estado final, tornam-se fluidos e moldáveis quando aquecidos acima da temperatura de "amolecimento" por uma ação isolada ou combinada de calor e pressão. Alguns exemplos de termoplásticos incluem polipropileno (PP), polietileno (PE), politereftalato de etileno (PET), policloreto de vinila (PVC) e poliestireno (PS). As propriedades dos termoplásticos incluem maleabilidade quando expostos ao calor, baixa densidade, boa estética, isolantes térmicos e elétricos, resistência ao impacto e baixo custo; como resultado, eles têm uma ampla gama de aplicações (WAN, 2002).

2.4 Poliestireno expandido

O isopor, ou poliestireno expandido, como é conhecido no Brasil, é criado pela expansão da resina de PS com um expansor de gás. Esse plástico celular rígido é formado a partir da polimerização do estireno em água. O EPS é mais utilizado na construção civil, onde ganhou ampla popularidade (BERLOFA, 2009). Para transformar o isopor, o pentano é usado como agente expansor. Esse hidrocarboneto é capaz de se deteriorar rapidamente devido a uma reação fotoquímica causada pela luz solar, sem representar qualquer ameaça ao meio ambiente. O produto resultante é composto por pérolas de até 3 mm de diâmetro, que podem expandir até 50 vezes seu tamanho original por meio de vapor, fusão e moldagem em várias formas. As pérolas expandidas são compostas por 98% de ar e apenas 2% de poliestireno. Por exemplo, em um metro cúbico de EPS, existem entre 3 e 6 bilhões de células fechadas e com ar (ABRAPEX, 2016).

O EPS é um polímero termoplástico que encontra uso abundante no setor industrial como material de embalagem para diversos produtos, bem como como isolante térmico na engenharia civil. O EPS pós-consumo é um material reciclável que pode ser empregado na produção de compósitos (POLETTO, 2008).

A Associação Brasileira do Poliestireno Expandido (ABRAPEX) lista uma série de vantagens associadas ao poliestireno expandido, que incluem:

a) O isopor apresenta excelentes propriedades de isolamento devido à sua baixa condutividade térmica; a estrutura de célula fechada cheia de ar impede a transferência de calor;

b) As densidades do isopor variam de 10 a 30 kg/m3, resultando em construções significativamente mais leves devido ao baixo peso;

c) O isopor possui notável resistência mecânica apesar de sua leveza, tornando-o uma escolha adequada para aplicações que exijam tal característica;

d) O isopor possui baixa capacidade de absorção de água. Isso porque não é higroscópico. Mesmo quando totalmente submerso em água, o isopor absorve apenas quantidades minúsculas de água. Esse atributo garante que o isopor mantenha suas características mecânicas e térmicas, mesmo quando submetido a condições úmidas;

e) O isopor é um material que pode ser facilmente manuseado com ferramentas comumente disponíveis, tornando-o altamente adaptável para qualquer trabalho. Sua natureza leve permite um manuseio sem esforço no local de trabalho, tornando as operações de movimentação e colocação muito mais rápidas e simples;

f) A versatilidade do isopor reside em sua capacidade de ser moldado em uma variedade de formas e tamanhos que são adaptados aos requisitos exclusivos de qualquer projeto de construção;

g) O isopor possui resistência ao envelhecimento, o que lhe permite manter suas propriedades inalteradas durante toda a sua vida útil;

h) Capacidade de absorver choques;

i) A sua resistência à compressão é de 2 kg/cm²;

j) O isopor é quimicamente compatível com vários materiais utilizados na construção civil, incluindo, entre outros, cimento, gesso, cal e água.

No Brasil, em 2017, a produção de EPS alcançou 44,9 mil toneladas, enquanto o consumo total foi de 91,74 mil toneladas (conforme dados da ABIQUIM, 2020). No cenário global, o mercado de EPS foi avaliado em 9,7 bilhões de dólares em 2019, com uma perspectiva de crescimento anual de 4,6% prevista para o período entre 2020 e 2027, chegando a um valor estimado de 12,9 bilhões de dólares (GRAND VIEW RESEARCH INC, 2021). Vale ressaltar que o poliestireno expandido é reciclável, e algumas empresas brasileiras já tentaram reutilizá-lo. O processo de reciclagem envolve a transformação do isopor, que tem as mesmas propriedades iniciais do poliestireno utilizado na produção inicial. No entanto, o custo de investimento em uma unidade de revalorização para posterior venda é proibitivamente alto, tornando-se inviável em menor escala (ABRAPEX, 2016).

2.5 Resíduos de construção e demolição

De acordo com Pimentel *et al.* (2010) *apud* Figueiredo *et al.* (1995), a concepção comum de eliminação, lixo ou sobra envolve a reunião de materiais diferentes que, quando combinados, resultam em uma massa sem valor comercial e com potencial de impacto ambiental variável, dependendo de sua composição. No âmbito da construção civil, a sustentabilidade é influenciada por diversos fatores, entre eles o uso de água e a utilização de estratégias bioclimáticas.

A maioria dos resíduos sólidos produzidos em áreas urbanas está diretamente relacionada às operações de construção e demolição, representando cerca de metade de todos os resíduos urbanos gerados nas grandes cidades (KWON *et al.*, 2015, e LIU *et al.*, 2014).

Os RCD, são categorizados como resíduos sólidos e não reativos, que podem consistir em rochas, solo, areia ou agregados, processados ou não processados. De acordo com a Resolução 307 CONAMA (2011), os resíduos da construção civil são definidos como os resíduos gerados na construção, reforma, geração e demolição de obras de construção civil, bem como os resultados da preparação do solo e escavação. Esses resíduos incluem materiais de construção como concreto, tijolos, blocos cerâmicos, metais, solo, resinas, colas, tintas, madeira, forros, argamassa, compensados, gesso, telhas, fiação elétrica, plásticos tubulações, vidros e pavimento asfáltico. Esses materiais são comumente referidos como entulhos de construção, calcário ou estilhaços (CONAMA, 2011). O Quadro (1) da resolução CONAMA 307 classifica o RCD em quatro categorias.

Quadro 1 - Classificação dos Resíduos conforme a Resolução CONAMA n°307/2011

Classe A	I. De construção, demolição reformas e reparos de pavimentos e outras obras de infraestrutura, inclusive solos provenientes de terraplanagem. II. De construção, demolição reforma e reparos de edificações: componentes cerâmicos (tijolos, telhas, placas de revestimento, etc.) argamassa e concreto. III. De processo de fabricação e/ou demolição de peças pré-moldadas em concreto (blocos, tubos, meio fios, etc.) produzidos nos canteiros de obra.
Classe B	Resíduos recicláveis para outras destinações, tais como plástico, isopor, papel, papelão, metais, vidros, madeiras, gesso e outros.
Classe C	Resíduos para os quais não foram desenvolvidos tecnologias ou aplicações economicamente viáveis que permitam a sua reciclagem/recuperação.
Classe D	Resíduos perigosos oriundos do processo de construção, tais como: tintas, solventes, óleos e outros, ou aqueles contaminados oriundos de demolição, reformas e reparos de clínicas radiológicas, instalações industriais e outros.

Conforme o Quadro 1, é possível observar que os materiais a serem elaborados no compósito são compostos por resíduos classe A e isopor (EPS) classe B.

No Brasil, o gerenciamento adequado dos RCD foi estabelecido por meio da aprovação da Resolução 307 em 2002 (CONAMA, 2011). Essa resolução define claramente os papéis do setor público e das organizações privadas (PINTO; GONZÁLEZ, 2005), garantindo que todas as partes tenham responsabilidades compartilhadas no processo.

A Política Nacional de Resíduos Sólidos (PNRS) de 2010 estabeleceu uma definição para resíduos da construção civil em seu Artigo 13, inciso I, alínea h. Essa definição inclui os resíduos gerados pela construção, reforma, reparo e demolição de obras de construção civil, bem como os resíduos resultantes da preparação e escavação de terrenos para obras civis (BRASIL, 2010).

A publicação da NBR 15116 pela Associação Brasileira de Normas Técnicas (ABNT) em junho de 2021 trouxe várias inovações importantes. Uma delas é a permissão para a utilização parcial de agregado reciclado de concreto em substituição ao agregado natural na fabricação de concretos estruturais, uma prática anteriormente não permitida na versão de 2004 da norma. Além disso, essa atualização da NBR 15116 estabelece uma classificação dos resíduos da construção civil em quatro categorias: A, B, C e D. Dentro dessa classificação, apenas os agregados pertencentes à classe A são autorizados para uso em concreto estrutural. Para se qualificar como classe A destruição deve consistir em, no mínimo, 90% em massa de fragmentos à base de cimento Portland e rochas. Além disso, a eliminação deve pertencer à subclasse denominada "Agregado Reciclado de Concreto" (ARCO) para ser aceito. Existem duas outras subclasses dentro da classe A, nomeadamente "Agregado Reciclado Cimentício" (ARCI) e "Agregado Reciclado Misto" (ARM), mas a norma não permite o uso dessas subclasses na produção de concreto estrutural. A norma também estabelece um limite de 20% de substituição dos agregados convencionais pelos reciclados quando se trata de concretos das classes de agressividade I e II.

Os resíduos produzidos nas atividades de demolição e construção representam um problema quando se trata de sua disposição final devido à sua composição física e grande volume. Esses materiais não podem ser depositados em aterros sanitários e muitas vezes são deixados em caçambas em áreas urbanas, o que além de degradar o visual da paisagem urbana, também favorece a formação de pequenos lixões a céu aberto. Esses lixões provocaram a disseminação de vetores patogênicos que podem prejudicar a saúde pública, além de obstruir os sistemas de drenagem (PASCHOALIN; GRAUDENZ, 2012).

A utilização de RCD tem um efeito positivo no meio ambiente e ajuda a reduzir o esgotamento dos recursos naturais. Isso ocorre porque o RCD reduz o impacto de seu descarte na natureza e minimiza a retirada de agregados de suas fontes naturais. O uso de RCD aconteceu no pós-guerra durante a década de 1940, principalmente na Alemanha, quando as cidades foram destruídas ou parcialmente destruídas pelos bombardeios dos Aliados, principalmente no final da guerra.

A escassez de espaço para depósitos de agregados *"in natura"* e a abundância de entulho, deram origem à ideia de utilizar o RCD. Isso não apenas resolveu o problema da deposição de resíduos, mas também resultou na minimização do uso de agregados naturais (JOHN; AGOPYAN, 2000).

2.6 Incorporações de resíduos de construção civil em compósitos poliméricos a base de poliestireno expandido

A indústria da construção civil, influenciada tanto pelo crescimento da economia em seu setor de atuação quanto pela necessidade de desenvolvimento sustentável e certificação ambiental na edificação, iniciou uma aposta na inovação tecnológica como forma de aumentar sua competitividade. Essa estratégia também serve para prolongar a atual fase de crescimento do setor e estabelecer um ponto de venda único no mercado (TYKKÄ et al., 2010; AR, 2012; HARRIS *et al.*, 2013).

A pesquisa sobre a incorporação de RCD como agregados reciclados (AR) é amplamente explorada, embora seu uso prático ainda seja limitado no âmbito nacional. No entanto, devido às enormes quantidades de resíduos gerados globalmente e ao crescente desafio de sua destinação final, torna-se essencial a busca por novas técnicas de reciclagem desses materiais (SALLES, 2023).

De acordo com ABRECON (2022), a reciclagem de resíduos de construção e demolição no Brasil ainda está em sua fase inicial, e a reciclagem é vista atualmente como a forma mais eficaz de reduzir o impacto ambiental dos resíduos.

Nos últimos anos, a demanda por materiais de construção aumentou significativamente devido ao aumento da população. Isso tem resultado em uma escassez crônica desses materiais, tornando a reciclagem e a reutilização de resíduos industriais uma solução atraente e sustentável. Os especialistas estão explorando os avanços tecnológicos para atender à demanda por materiais de construção necessários para atender à crescente população e aos padrões de vida. Essa abordagem também visa reduzir a quantidade de resíduos enviados para aterros sanitários, o que é especialmente importante em países que lutam para obter terras disponíveis e gerenciar essas áreas (MADURWAR *et al.*, 2013).

No campo da engenharia civil, já é obrigatório considerar a redução de custos, energia e consumo de reservas naturais no desenvolvimento de materiais direcionados para novas soluções tecnológicas (PICANÇO; GHAVAMI, 2008).

Os resíduos provenientes da construção e demolição, mesmo após a segregação, apresentam propriedades distintas em comparação com os agregados naturais. Grande parte dessa discrepância está relacionada à composição dos agregados reciclados, que consistem principalmente em cerâmicas vermelhas e materiais cimentícios. Esses materiais apresentam propriedades significativamente diferentes quando comparados às rochas naturais. Outro fator relevante é a presença de argamassa aderida em parte dos agregados reciclados, o que apresenta propriedades como alta porosidade e baixa resistência à abrasão e variação em comparação com os agregados naturais (AN). Além disso, a mistura de AR e AN cria uma quantidade de zonas de transição interfacial (ZTI), conforme observado em diversos estudos (DUAN *et al*., 2020; FERREIRA, BARRA; DE BRITO, 2011; KOU; POON; ZHAN, 2011; THOMAS *et al*., 2020).

Vários estudos visam substituir os agregados, miúdos e graúdos, por resíduos de diferentes naturezas. Alguns exemplos são os estudos realizados por BARBOSA *et al*.,2011;LINTZ *et al.*,2012;SANTOS,2010. Entre outras descobertas, esses estudos avaliaram a possibilidade de utilização de agregado reciclado no lugar do agregado natural e descobriram que as propriedades do concreto com agregados reciclados podem ser influenciadas pelas características dos resíduos usados. Muitos autores têm confirmado esses achados, como LEITE, 2001**;** AWASTHI, 2011**;** CHAUHAN, 2011; VIDAL *et al*., 2010; ISSAI *et al*., 2011.

Algin e Turgut (2007) realizaram um estudo sobre resíduos de construção. Especificamente, eles exploraram a potencialidade de usar pó de calcário e serragem de madeira, que são comumente abandonados em todos os países e representam riscos ambientais e de saúde para a

população. Sua pesquisa se concentrou em um experimento paramétrico que visava combinar os dois materiais residuais para formar um compósito leve e barato que poderia ser utilizado na construção civil. Os resultados do experimento indicaram que a combinação dos dois resíduos se mostrou uma alternativa bem-sucedida aos tijolos tradicionais, pois podem ser utilizados na construção de paredes com menor custo.

A busca por um material que seja adequado para uso na construção civil e que possua atributos físicos e mecânicos, como resistência térmica, acústica e mecânica, tem sido foco de pesquisas científicas. Com esse intuito os compósitos poliméricos que incorporam EPS recebem atenção significativa, devido a grandes lacunas que existem na influência do EPS na produção e propriedades dos compósitos (LEÃO, 2021).

Embora haja uma extensa pesquisa sobre a integração de RCD em concreto, argamassa e tijolos, há uma falta de exploração de sua integração em plásticos usados na construção civil. Portanto, há uma necessidade de materiais inovadores, como os que podem ser produzidos a partir de compostos poliméricos constituídos por poliestireno expandido e RCD.

III. METODOLOGIA

A presente pesquisa é classificada como aplicada quanto à sua natureza, pois, caracteriza-se pela utilização imediata dos resultados da pesquisa na solução de problemas que ocorrem na realidade (LAKATOS; MARCONE, 2017). Quanto a seus objetivos, a pesquisa classifica-se como explicativa, com o objetivo básico de identificar fatores que determinam ou contribuem para a ocorrência de um fenômeno (GIL, 1999 *apud* OLIVEIRA, 2011). Em relação ao enfoque, o estudo trata-se de pesquisa quali-quantitativa, existindo uma abordagem que usa tanto os métodos quantitativos quanto qualitativos para a realização de uma análise aprofundada do estudo (CRESWELL, 2010).

E por fim, em relação aos procedimentos técnicos, classifica-se como uma pesquisa experimental, adotando critério de manipulação de uma ou mais variáveis independentes, interferindo na realidade com intenção de testar o impacto de uma intervenção sobre um resultado (CRESWELL, 2010).

3.1. Aquisição de material

Foram obtidos resíduos de construção e demolição (RCD) em uma obra de reforma na cidade de João Monlevade. Esses resíduos passaram por uma triagem inicial, onde foram separados e selecionados, para fins de estudo, apenas os tipos A e B de RCD.

a) O RCD tipo A: materiais como revestimento cerâmicos, blocos, telhas, argamassa, concreto.

b) O RCD tipo B: poliestireno expandido.

3.2. Beneficiamento do resíduo

Os resíduos de construção e demolição foram processados como agregado reciclado, seguindo as diretrizes estabelecidas pela norma NBR 15116 (ABNT, 2021). O objetivo desse processo foi reduzir o tamanho das partículas coletadas, utilizando um britador de mandíbulas seguido de um moinho de bolas.

O material resultante foi submetido a um processo de secagem em estufa por 24 horas, em seguida, peneirado e foram utilizadas as partículas passantes na peneira de malha 150µm, objetivando a produção de partículas de reforço (MACHADO, 2017).

3.3. Caracterizações do resíduo de construção e demolição

O RCD tipo A passou por uma caracterização morfológica utilizando a técnica de MEV em conjunto com o Sistema de Energia Dispersiva (MEV/EDS). Essa análise teve como objetivo obter informações qualitativas sobre a composição química básica do material. Além disso, foi determinada a massa específica aparente utilizando o método descrito na NM 52 (ABNT, 2009) e o teor de umidade superficial seguindo a NBR 9775 (ABNT, 2011).

3.4. Produção dos compósitos

Os compósitos foram produzidos utilizando o método de evaporação de solvente, também conhecido como "*casting*". Essa técnica é empregada para a análise de amostras em escala laboratorial e envolve a solubilização do material em um solvente. O processo de evaporação do solvente consistiu em dissolver o EPS em propanona estruturando uma dispersão polimérica, que atua como uma matriz. Durante a evaporação do solvente, ocorreu a solidificação da fase interna da emulsão, resultando na formação de micropartículas. Essa abordagem permitiu a incorporação de partículas, as quais podem ser associadas a matriz polimérica (MACHADO, 2010).

As amostras foram moldadas em corpos de prova, secos em temperatura ambiente por 30 dias e conformadas em concomitância à análise a ser realizada.

3.5. Caracterizações dos compósitos

Os compósitos produzidos com 5 e 10% (m/m) foram submetidos a análise para caracterização:

a) MEV: utilizado para investigar a interação na matriz do compósito polimérico, após a incorporação do RCD tipo A. Essa técnica permite analisar a microestrutura e as propriedades da interface entre os materiais.

b) Absorção de água: segundo a norma técnica ASTM 570-22, a absorção de água dos compósitos secos é determinada através da imersão em água destilada em temperatura ambiente. Depois de 24 horas, as amostras são retiradas da água, secas com papel de baixa absorção e pesadas em uma balança analítica. O teor de água absorvida é calculado comparando as massas inicial e final das amostras.

c) Dureza de Rockwell: de acordo com a norma técnica ASTM E18-22, o ensaio é um dos diversos métodos de medição de dureza de materiais. O ensaio de dureza de Rockwell detecta pequenas diferenças de durezas em pequenos tamanhos de impressão, e consiste em aplicação de carga em etapas, de modo que, *a priore*, uma pré-carga inicialmente aplicada garanta estabilidade para o contato firme entre o penetrador e a amostra e, em seguida, seja aplicada a carga total do ensaio. Os penetradores utilizados na máquina de ensaio de dureza Rockwell são do tipo esférico (esfera de aço temperado) ou cônico (cone de diamante com 120º de conicidade. O valor indicado na escala do mostrador é o valor da dureza Rockwell, que corresponde à profundidade alcançada pelo penetrador, subtraídas a recuperação elástica do material após a retirada da carga maior, e a profundidade decorrente da aplicação da pré-carga.

IV. RESULTADOS E DISCUSSÕES

4.1. Caracterizações dos resíduos de construção e demolição (RCD)

O resultado médio de três determinações da composição do RCD após moagem é mostrado por intermédio da curva granulométrica apresentado na Figura 2.

A Figura 2 apresenta a curva granulométrica do RCD.

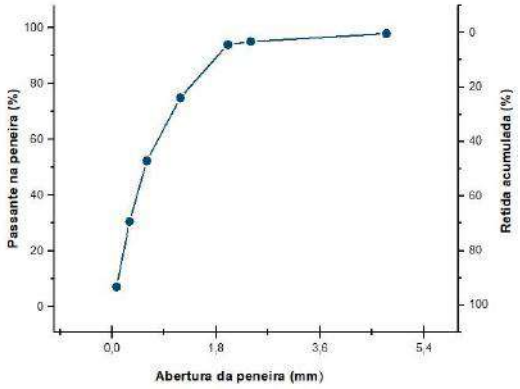

Fig.2- Curva granulométrica do RCD

Fonte: Autores, 2023.

Após o ensaio de granulometria, o material foi selecionado e levado para análise no MEV, que possibilitou observar que o RCD apresenta diferenças significativas no tamanho da partícula. Destaca-se a diferença de formatos entre as partículas.

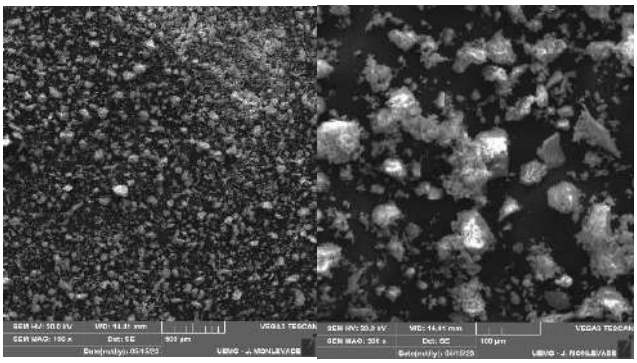

Fig.3 – Fotomicrografia do RCD

Fonte: Autores, 2023.

O EDS mostrou que o RCD possui composição de C (5,92%), O (49,05%), Mg (0,66%), Al (11,81%), Si (17,41%), k (1,12%), Ca (7,01%), Ti (0,81%), Fe (6,22%).

O Quadro 2 apresenta valores relacionados à massa específica, à umidade superficial e a umidade hidroscópica do RCD analisado. A massa específica é a proporção da massa do material seco para o seu volume, excluindo os poros permeáveis.

Quadro 2 – Propriedades do RCD

Propriedade	Valor
Massa específica	2,5g/cm³
Umidade superficial	0,51%
Umidade hidroscópica	1,25%

Fonte: Autores, 2023.

Segundo John (2000), a massa específica de partículas de RCD pode ser influenciada pelos compósitos presentes na amostra, pela técnica de britagem e até mesmo pela localidade de aquisição do resíduo.

4.2 Caracterizações dos compósitos produzidos a partir dos resíduos de construção e demolição (RCD)

A Figura 4 apresenta as fotomicrografias dos compósitos, onde (a) representa a amostra sem adição de resíduo, onde há presença de poros, devido ao processo de expansão do poliestireno. A Figura 4 (b) retrata o compósito com 5% de resíduo, verificando grande diferença no aspecto da amostra com o preenchimento de parte dos poros com o RCD. Também foi notado que existem vazios entre o resíduo e a matriz polimérica. Na Figura 4 (c), o compósito tem 10% de resíduo em sua constituição, e foi observado que o RCD teve melhor aderência à matriz, reduzindo

consideravelmente a quantidade de vazios na estrutura do compósito. Ademais, não se observa nenhum tipo de aglutinação.

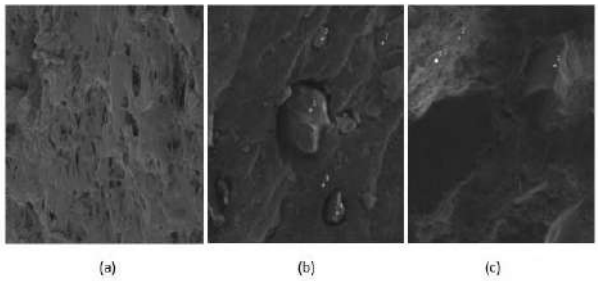

Fig.4 – Fotomicrografia (a) do corpo de prova a base de poliestireno, (b) do corpo de prova a base de poliestireno com adição de 5% de RCD e, (c) do corpo de prova a base de poliestireno com adição de 10% de RCD.

Fonte: Autores, 2023.

É importante atentar à interface reforço-matriz. Para garantir que as forças sejam transmitidas de um estágio para outro, deve ser fornecida uma forte adesão entre o material utilizado como matriz e o material utilizado como reforço. Sem interações fortes, o material irá falhar e a propagação da trinca ocorrerá em uma área maior (SHACKELFORD, 1996 *apud* MACHADO, 2017).

A Figura 5 apresenta o gráfico dos valores obtidos por meio do ensaio de absorção de água. A absorção de água por imersão é o processo pelo qual a água tende a ocupar todos os vazios permeáveis presentes em um corpo poroso. Portanto, quanto menos poros, menor será o percentual de água absorvida pelo material. O ensaio apresentou um aumento na absorção de água para o corpo de prova com 5% de resíduo com 25% de absorção de água, e diminuição na amostra com 10% de resíduo incorporado para 11% de absorção de água. O compósito base sem a presença de resíduo obteve 12% de absorção de água. Isso ocorre devido à presença das partículas de RCD incorporadas e a quantidade de vazios.

COSTA *et al.* (2014) analisaram a taxa de absorção de água em compósitos produzidos a partir de matriz polimérica de resina poliéster reforçados com fibras vegetais de açaí. Os autores concluíram que houve uma queda significativa na taxa de absorção de água quando quantidades maiores de fibras eram incorporadas à matriz.

O ensaio de dureza Rockwell no compósito apresentou falha. O corpo de prova não resistiu à carga aplicada, ocorrendo deformação devido à baixa ductilidade do material e alta deformação plástica.

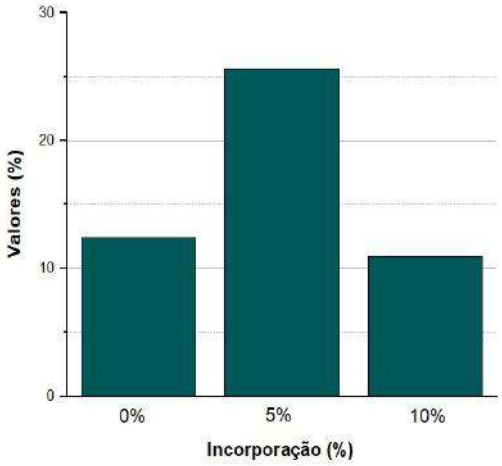

Fig.5 – Gráfico de absorção de água do compósito

Fonte: Autores, 2023.

Como sugestão para trabalhos futuros, o ensaio de Dureza Shore, utilizando a escala Shore A ou Shore D, é o método preferido para borrachas e elastômeros termoplásticos, e também é comumente usado para plásticos "mais macios", como poliolefinas, fluoropolímeros e vinílicos. Devido à indisponibilidade de recursos, não foi possível realizá-lo nesta pesquisa.

V. CONCLUSÃO

Foi desenvolvido material compósito e analisada a interação de resíduos de construção e demolição como partículas de reforço em uma matriz polimérica de poliestireno expandido.

Os compósitos surgem como uma alternativa sustentável à construção civil, pois o impacto ambiental da disposição final dos resíduos pode ser minimizado. Porém, novos estudos devem ser realizados para otimizar o percentual de RCD na matriz e os métodos de obtenção dos compósitos.

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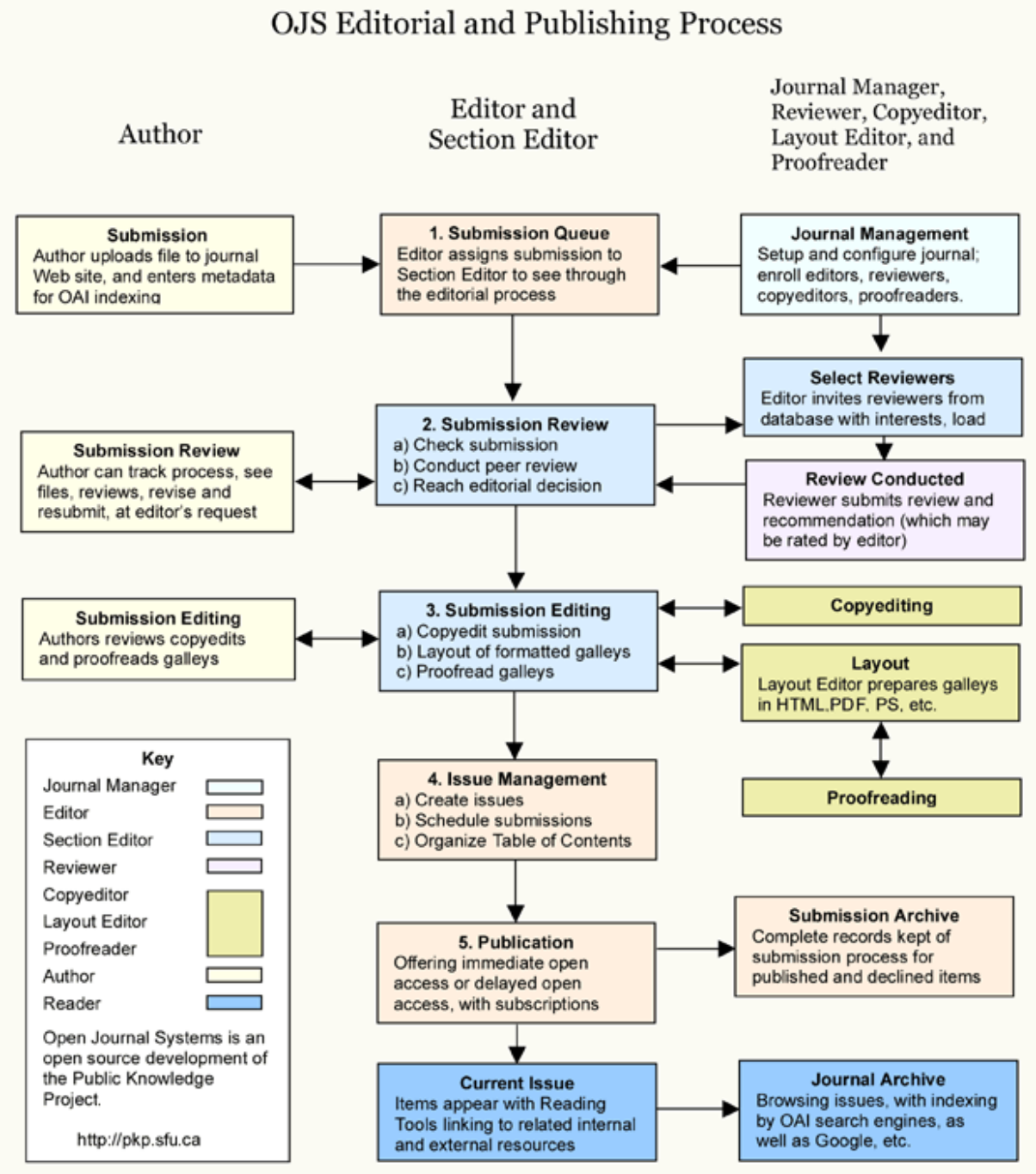

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