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Special edition

Hygroelectricity through the use of Waste Supported Iron Particles

Higroeletricidade através do uso de partículas de ferro suportadas por resíduos

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ABSTRACT

In recent years, due to the increase in the consumption of electric energy worldwide, the generation of sustainable energy has become the focus of several scientific investigations. In this scenario, this project will propose a new technology for energy generation, based on the use of residue of Agate Stone Powder. It is worth noting that, currently, there is still no regulation for the disposal of these materials, occurring most of the time inadequately. Besides this, an iron-based particle will also be used, in order to build a cement artifact that works as an energy generator. It is expected that, at the end of the project, the developed prototype will be able to generate electrical energy in a satisfactory manner. The built prototype will have to be tested in a state of super humidity, that is, totally submerged in water, in order to evaluate its quality and efficiency. The final material confectioned, because it is a material capable of generating energy through humidity, receives the name of hygrogenerator and awakens great future possibilities for the development of new technologies, besides contributing to the sustainability of the environment.

Keywords: Hygrogenerator; Hygroelectricity; Electrical energy; Iron particles

RESUMO

Nos últimos anos, devido ao aumento do consumo de energia elétrica em todo o mundo, a geração de energia sustentável tornou-se o foco de diversas investigações científicas. Nesse cenário, este projeto propõe uma nova tecnologia para geração de energia, baseada no uso de resíduo de Pó de Pedra Ágata. Vale ressaltar que atualmente não há regulamentação para o descarte desses materiais, ocorrendo na maioria das vezes de forma inadequada. Além disso, uma partícula à base de ferro também será utilizada, a fim de construir um artefato de cimento que funciona como gerador de energia. Espera-se que, ao final do projeto, o protótipo desenvolvido seja capaz de gerar energia elétrica de maneira satisfatória.

O protótipo construído terá de ser testado em estado de superumidade, ou seja, totalmente submerso em água, a fim de avaliar sua qualidade e eficiência. O material final confeccionado, por ser capaz de gerar energia por meio da umidade, recebe o nome de higrogerador e desperta grandes possibilidades futuras para o desenvolvimento de novas tecnologias, além de contribuir para a sustentabilidade do meio ambiente.

Palavras-chave: Higrogerador; Higroeletricidade; Energia elétrica; Partículas de ferro

1 INTRODUCTION

Electricity is one of the most used forms of energy on the planet. This is due to the ease with which it can be safely and effectively transported and converted into any other form of energy over long distances. As such, it powers the most diverse types of machines, domestic appliances, cars, trains, as well as the lamps that illuminate houses and cities. This makes it fundamental to the lives of 7.9 billion people (Novackovic; Nasiri, 2016; Wobeto, 2022). Electricity can be obtained from two classes of sources, renewable sources and non-renewable sources. The first class of sources called renewable energy sources is characterized by being inexhaustible, for example, the sun, wind, biomass and water. The second class, on the other hand, are non-renewable sources, which, unlike renewable sources, are exhaustible and somehow cause damage to the environment, such as oil, natural gas, coal and uranium (Zohuri; Mcdaniel, 2021). Currently, the largest portion of electricity use worldwide comes from non-renewable sources (international energy agency, 2021). Thus, there is a need to develop new sources of energy generation. In this sense, the present study aims to study and propose a new alternative source of electricity generation from humidity, which is named as hygroelectricity, which will be discussed throughout the work, which was successfully studied by the chemist Fernando Galembeck (2010). For the solid development of this new source of electricity will also work with iron-based particles supported on industrial and agro-industrial waste, inserted in the concept of applied nanotechnology. Nanomaterials stood out in the late twentieth century, and were paramount in the development of nanoscience and nanotechnology. This area resulted in the expansion of possibilities in the industry, breaking away from established limitations, besides opening an unprecedented range of results. This was all possible thanks to the fact that the properties of materials, as we know them, are strongly dependent on the size of the particles that compose the material. In a direct way, all the properties of materials as we know them are manifested from an established size, called the critical size. Once the particles of this material are smaller than the critical size, these properties change and become differentiated. However, this critical value is not the same for all properties, the critical size for electrical properties is usually different for magnetic properties, and so on. Thus, it is possible to define nanomaterials as materials that have at least one dimension in the nanometric size range, below the critical size capable of changing any of their properties (ZARBIN, 2007). In view of the above, through the use of iron-based particles, with nanometric characteristics, it is intended to create a new source of electricity generation, which is a renewable energy source that uses the relative humidity of the air or even the rain itself, to generate electricity. These iron-based materials will be used in support materials rich in SiO_2, which are in the form of residue agate, which has no regulated disposal and is often disposed of incorrectly in nature. Thinking about the sustainable bias, we propose in this work the reuse of this waste, as it is a Silicon-based material, provides a unique chemical combination with the iron-based particles, enabling the generation of renewable energy. The residue of Agate Stone Powder is a residue resulting from the processing method of the precious stone Agate. It is also rich in silicon (SiO_2), about 98%, the Agate Stone Powder already presents studies of possible use in construction as a new filling material in mortar (Götze; Möckel, 2012). This may represent a better use and sustainability of buildings in the future, since construction today is one of the largest consumers of non-renewable energy in the world, consuming 20% to 50% of the planet’s natural resources (Brasileiro; Matos, 2015).

Figure 1 – illustrates the Agate Stone Powder waste (Götze; Möckel, 2012)

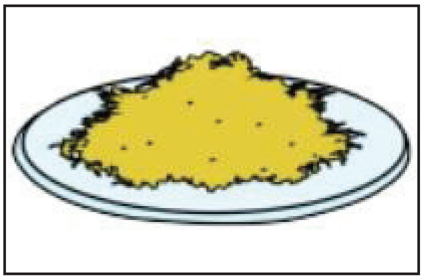


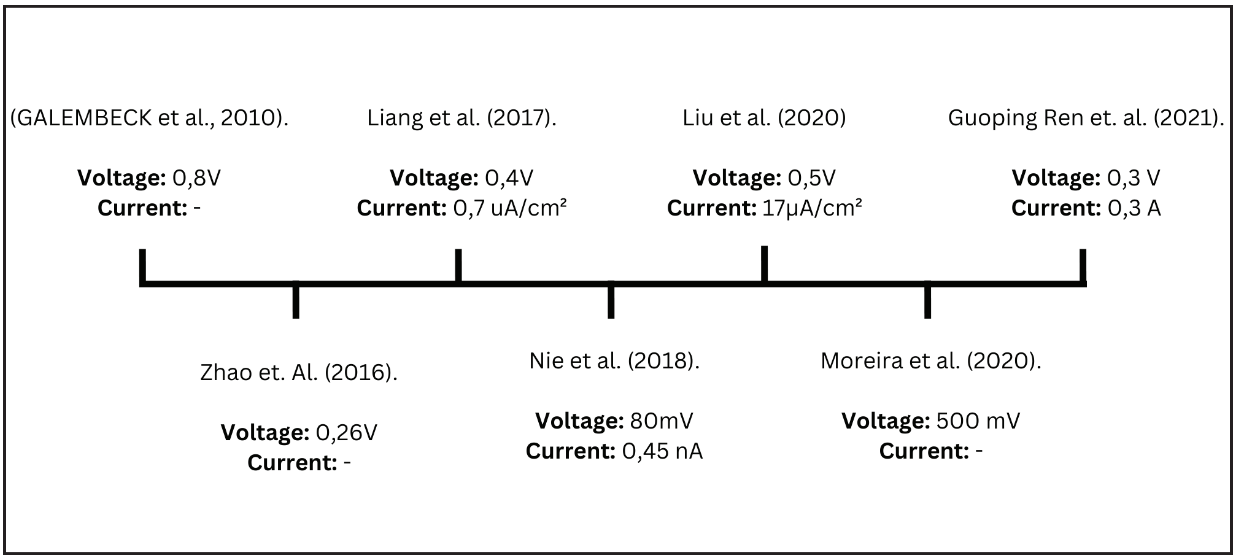
Figure 1: Resídue of AGR
Source: Authors, 2023

Hygroelectricity was widely studied in 2010 by the chemist Fernando Galembeck, who says that hygroelectricity is nothing more than the generation of electrical energy from the moisture present in the air or even the water itself (Galembeck et al., 2017).

The basic principle for the generation of hygroelectricity is the use of materials that can absorb the moisture present in the environment and that also have mechanisms to generate electrical charges. This is where the role of iron-based particles comes in, which when chemically combined with SiO2 , react in the presence of the charges contained in the moisture or water. When a material with hygroelectric characteristics absorbs humidity it ends up undergoing a physical change that generates electrical charges, charges which are used to generate electricity (Moreira, 2020). As a result, some authors have been studying the characteristics of hygroelectricity, in order to enable the use of this technology on an industrial scale and to originate, consequently, a new source of renewable electric energy. Figure 2 shows a general overview of studies already conducted in the literature on hygroelectric generators and their respective voltage and current characteristics.

Based on the literature, we can verify that the numerical values referring to voltage and current, already obtained by hygro generators, are low due to the fact that the studies are still in the beginning and that it is a recently discovered technology. As a result, through the data presented, it is intended to develop a bench scale hygro generator to begin studies of hygroelectric characteristics, with the main focus on the use of particles supported on waste, previously mentioned. Next, the initial methodology of the process of developing the first hygro-generator using waste and iron-based particles will be presented.

Figure 2 – Global picture of the hygrogeradore



Source: Authors, 2023

2 METHODOLOGY

The methodology of this study was divided into five main parts, the first part being the literature review, which encompasses the subjects: nanoparticles, waste and hygroelectricity, in Figure 3 is presented the flowchart of the methodology used. For its construction, we used the reagents described in Table 1.

Figure 3 – Reagents

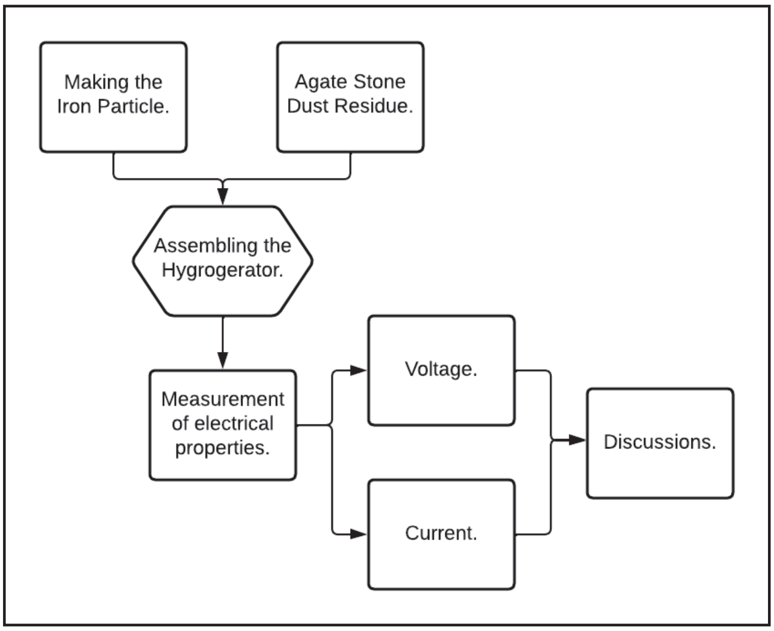
Metallic salt	Stabilizing agent	Encapsulating agent	Reducing Agent
a) Ferrous Sulfate ($FeSO_4.7H_2O$)	b) Sodium Citrate ($Na_3C_6H_5O_7.2H_2O$)	c) Polyvinylpyrrolidone (C_6H_9NO)	d) Ascorbic Acid ($C_6H_8O_6$)

Source: Authors, 2023

The first step in developing the iron solution consists of measuring the masses of the reagents, where each one of the elements uses an amount of mass and an appropriate amount of water to perform the dilution of the elements. Table 2 shows the masses of reagents and the amount of water used to dilute them.

Then, having the reactants, with their respective masses, and diluted in water, the mixing process was carried out as follows:

Figure 4 – Flow chart of the methodology



Source: Authors, 2023
(b) + (a); (c) + (ab); (d) + (abc).

Figure 5 – Reagents for the construction of the Iron solution

Reagents	Mass (mol)	Amount of Water (mol)
a) $(FeSO_4.7H_2O)$	0,004	0,222
b) $(Na_3C_6H_5O_7.2H_2O)$	0,002	0,222
c) (C_6H_9NO)	0,007	0,222
d) $(C_6H_8O_6)$	0,006	0,444

Source: Authors, 2023

This results in the final solution, as illustrated in Figure 4, which can be described as a dark colloidal solution.

The solution presented, has iron-based particles of small size. When the solution was properly mixed, the iron solution was stirred for 30 minutes. Next, the third stage began, where the mass of the residue and the cement were measured. The cement is a fundamental element when incorporated with the ASP, to obtain a solid structure for the hygrogenerator. The mass proportions used of ASP and cement were 1/1, and CPII-F32 cement, Votoran, was used in all works, with 35g for both, and after mixing, a homogeneous powder was obtained. The fourth stage consisted in the separation of two pieces of 4 mm copper wire, which are defined as the electrodes of the developed generator. Finally, after the phase of stirring the iron solution and mixing the ASP and cement, the assembly of the hygrogenerator was performed.

The powders (cement +ASP) were mixed with the colloidal iron solution; these elements were quickly mixed, leaving a satisfactorily homogeneous structure, where the two copper wires were inserted. Next, the hygrogenerator is left to rest, which is essential for the curing process, which lasts approximately five days. Then, with the hygrogenerator ready, the testing stage begins, where the voltage and current characteristics are analyzed in super humidity. To perform the voltage and current tests, a Minipa 4150 bench multimeter with Datalogger and a beaker with water were used. Figure 5 illustrates how the super humidity test was performed. Once the solution was properly mixed, the iron solution was stirred for 30 minutes. Then, the third stage began, where the mass of the residue and the cement were measured.

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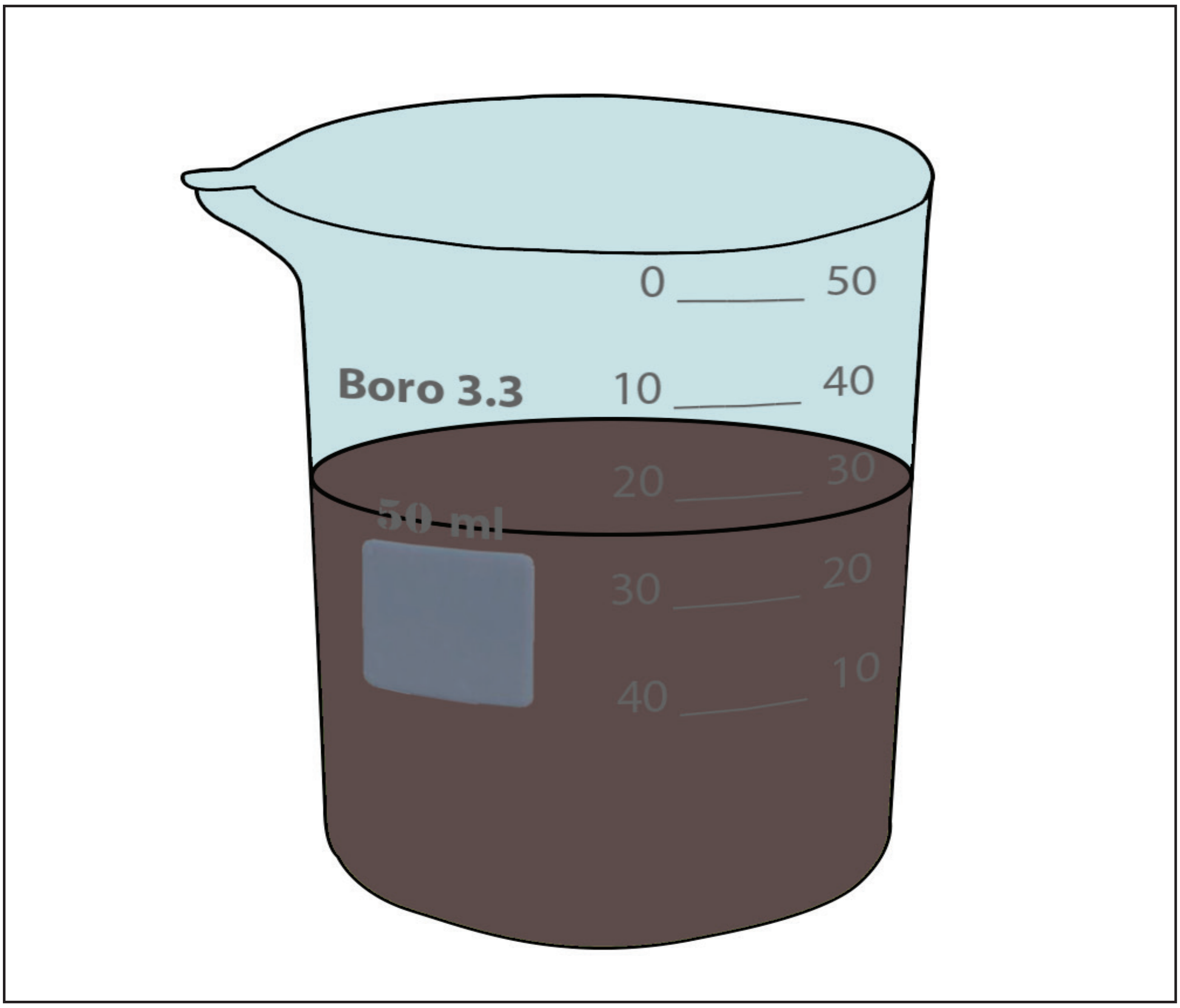
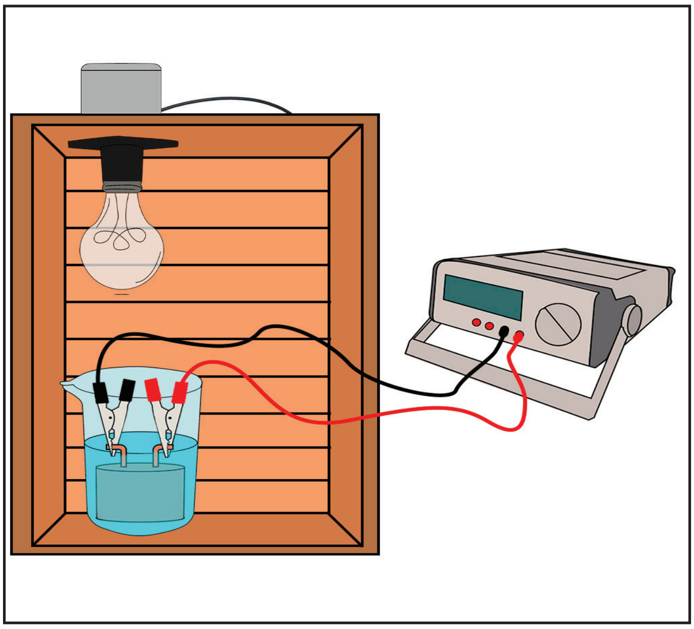
As seen in Figure 5, the hygrostat was submerged in water to reach a super humidity state. At the end of the tests, graphs were plotted for the analysis of current and voltage variations over.

Figure 6 – Dark colored iron solution



Source: Authors, 2023

Figure 7 – Ptototype testing in super humidity

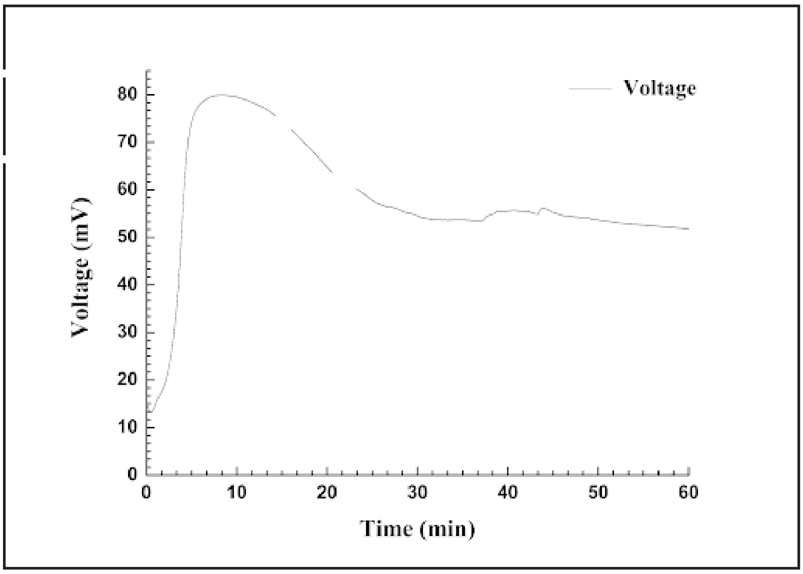


Source: Authors, 2023

3 RESULTS AND DISCUSSION

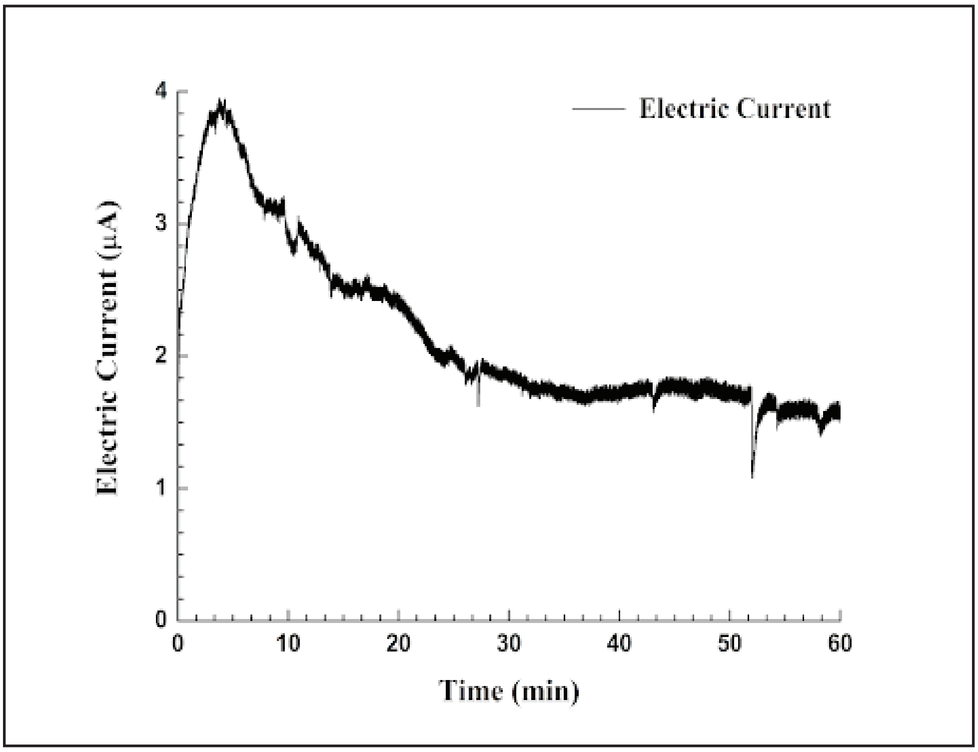
The results presented correspond to measurements of voltage and electrical current over a period of 60 minutes. The experiment was performed as shown in Figure 6, with voltage in the order of millivolts and amperage in the order of microampere. It is possible to notice an abrupt increase in the voltage generated in less than 10 minutes of measurement, which has a slight decrease after 20 minutes, remaining linear until the end of the measurements. We can see that by the area of 6.28 cm, that the nanogenerator produces the peak potential in an interval of 10 minutes, after which it is possible to notice the loss of potential over time, but remaining stable until the end. Figure 7 shows the collected measurements of electric current over the time of 60 minutes. Around 5 minutes, we have an abrupt increase in the electric current, followed by a slight decrease over time. This phenomenon fits as being a continuous and not constant current.

Figure 8 – Hygrogenerator voltage



Source: Authors, 2023

Figure 8 – Electrical current measurement of the hygro-generator



Source: Authors, 2023

4 FINAL CONSIDERATIONS

According to the experiments performed, it was possible to see some new developments in terms of electricity, first being the use of the waste with a prosperous purpose of generating energy in a hygroelectric way. The results point to an initial increase in both voltage and electric current; this may be happening mainly in the initial phase, due to the energy exchange between the existing charges in the device and those found in the water. As time goes by, we notice a saturation of growth, governed by the constant phase until the end of the experiment time. We show the efficacy of a new material that, besides using wasted waste until now, presents remarkable properties for the creation of a new technology. All of this opens up a range of possibilities for revolutionizing energy generation, as well as civil construction. Finally, having used the Agate Stone Powder residue and obtained positive values, we intend, later, to carry out tests using the rice husk ash residue and also, with different concentrations of the iron particle. Furthermore, we also aspire to perform tests to verify the possibility of photoelectric characteristics in the material, so that, perhaps, a hybrid device can be obtained, capable of generating energy through hygroelectricity and photoelectricity in parallel. Thus, resulting in an unprecedented technology capable of meeting residential energy needs, and revolutionizing the energy market. Since it will be a totally clean energy, capable of generating energy both during the day and at night.

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