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Electrical and Magnetic Properties of Strontium Ferrite and Barium M-Hexaferrite Based on Natural Iron Sand as Power Plant Generator Materials: A Systematic Review

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Abstract: Research in the field of materials, especially the magnetic properties of materials, continues to increase. This research aims to identify and analyze research trends of electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand as power plant generator materials. This research method is descriptive and analytical. The data used in this research was obtained from documents indexed by Google Scholar from 2015-2024 using Publish or Perish and Dimension.ai. Research procedures use PRISMA guidelines. The data identified and analyzed are the type of publication, publication source, and the title of research electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand as power plant generator materials that is widely cited. The data analysis method uses bibliometric analysis assisted by VOS viewer software. The results of the analysis show that research trend indexed by Google Scholar from 2015 to 2024 has experienced ups and down. There are many documents in the form of articles, chapters, preprints, monograph and edited books that discuss research about electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand. Key words that are often used in research about it are synthesis, characterization, permanent magnet, etc.

Keywords: Generator; Barium m-hexaferrite; Natural iron sand; Strontium ferrite

Introduction

Research in the field of materials, especially the magnetic properties of materials, continues to increase. This is because Indonesia is one of the countries whose technological developments are developing very rapidly, where the amount of energy use is on a large scale, so that human needs for renewable energy sources must be met properly (Adistia et al., 2020; Azhari et al., 2021). This research continues to develop by looking at the development of technology related to renewable energy sources by utilizing natural materials that are very unlimited in nature until the future. One of the areas of study in this research is to develop two basic materials that have been used, namely Barium M-Hexaferrite (BaM) and Strontium ferrite (SrM) and natural iron sand as a comparison of the magnetic properties of materials to see the stability of permanent

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magnets as a generator material for electricity generation.

Generators can be interpreted as converting mechanical energy into electrical energy. This generator usually uses electromagnetic induction. In its application, the generator is usually combined with a motor as mechanical energy that drives the generator. Hydroelectric power plants, wind turbines, conventional power generators (coal, oil, gas, nuclear) and vehicles, all use rotary generators. Permanent magnet generators are not as popular as induction generators. Because of several advantages of using induction generators, such as the absence of a separate DC source, and low maintenance, requiring low initial investment frequency control. The disadvantage of induction generators is that regulating the voltage requires a magnetizing current for excitation. Voltage regulation, power factor and efficiency of generating electrical energy can be improved by using permanent magnets.

The operating principle of the generator uses the Faraday experimental principle (Basir et al., 2022; Ali et al., 2019). That is, moving the magnet in the coil and vice versa. When the magnet moves in the coil, the magnetic flux changes (the direction of the magnet changes). Because it is inside the coil (magnetic field propagation) and enters perpendicular to the coil, it creates a potential difference between the two ends of the coil. Barium M-Hexaferrite with its hexagonal structure ($BaFe_{12}O_{19}$) is known as a permanent magnetic material that has high performance. Barium M-Hexaferrite (BaM) is a permanent magnet with high magnetic anisotropy (Fatimah et al., 2022; Sasria et al., 2017; Susilawati et al., 2017; Halik et al., 2016). The high crystal anisotropy of BaM makes it have a resonance frequency of around 50-60 Hz and is considered very high.

Strontium (SrM) has a crystal structure with a chemical formula of type M. A chemical element with atomic number 38 located in group IIA, period five of the periodic system of elements. Strontium has physical and chemical properties similar to its two vertical neighbors in the periodic table, Calcium and Barium (Weber et al., 2020; Cavazzini et al., 2022; Zhong et al., 2023; Coelho et al., 2017). Iron sand (Fe) contains magnetic minerals such as magnetite (Fe3O4), hematite (α- (Fe_2O_3) and maghemite (γ Fe_2O_3) (Nengsi et al., 2016), which can be applied in various fields and can be used as raw materials that have nano-sized particles (Widianto et al., 2018; Melinia et al., 2022; Setianto, 2017). Ferrite magnetic material has mixed properties of several metal oxides. This material is widely used for transformer cores, computer memory, microwaves and others.

Hard ferrite is widely used in electronic components (Saputra et al., 2016; Sobirin et al., 2016), including generators, small DC motors, loudspeakers and others. To form magnets in parallel domains, it is necessary to add BaM and SrM magnets with additional doping. When doping, it is necessary to add a small amount of impurity atoms. The addition of doping affects both the crystal structure, morphological structure, electrical properties, and magnetic properties of strontium ferrite artificial magnets in the material. The doping that is added is Neodymium (Nd) metal (Yüksel, 2017; Van De Flierdt et al., 2016; Skripka et al., 2019). Neodymium is a ductile and malleable silvery-white metal. It oxidizes readily in air to form the oxide, Nd2O3, which is easily flaked off, exposing the metal to further oxidation. Naturally occurring neodymium is a mixture of seven different isotopes. Five of these are stable—neodymium-142, neodymium-146, neodymium-143, neodymium-145, and neodymium-148—and two are stable (Bhat & Want, 2016; Pagoti et al., 2021; Vo et al., 2021; Ma et al., 2017; Sahlam et al., 2019).

Therefore, this research wants to know the research trend of the electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand as power plant generator materials. It is hoped this research can become a reference in developing further research related to natural iron sand as power plant generator materials.

Method

This research method is descriptive and analytical, which aims to understand and describe research trends in the electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand as power plant generator materials. The data used in this study was obtained from information sources indexed by Google Scholar using analytical tools such as Publish or Perish and Dimension.ai.

In this research, an analysis was carried out on 1,000 documents that had been indexed by Google Scholar between 2015 and 2024. The Google Scholar database was chosen as a place to search for documents because Google Scholar applies consistent standards in selecting documents to be included in its index, and Google Scholar displays more documents than the top databases. Others, especially research in the field of education (Hallinger & Chatpinyakoop, 2019; Hallinger & Nguyen, 2020; Zawacki-Richter et al., 2019). To filter data that has been collected via Publish or Perish, researchers used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Result and Discussion

This research aims to describe research trends on the electrical and magnetic properties of strontium

ferrite and barium m-hexaferrite based on natural iron sand as power plant generator materials conducted from 2015 to 2024. Figure 1 shows that the trend in research on the electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand from 2015 to 2024 experiencing ups and downs. The most publications occurred in 2024, namely 5 publications. This proves that research to find renewable energy is being carried out more and more frequently. Many studies have explored natural elements to be used as renewable energy sources, one of which is Strontium Ferrite and Barium M-Hexaferrite Based on Natural Iron Sand. Below are also table 1 presented research of electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand as power plant generator materials based on the type of publication.

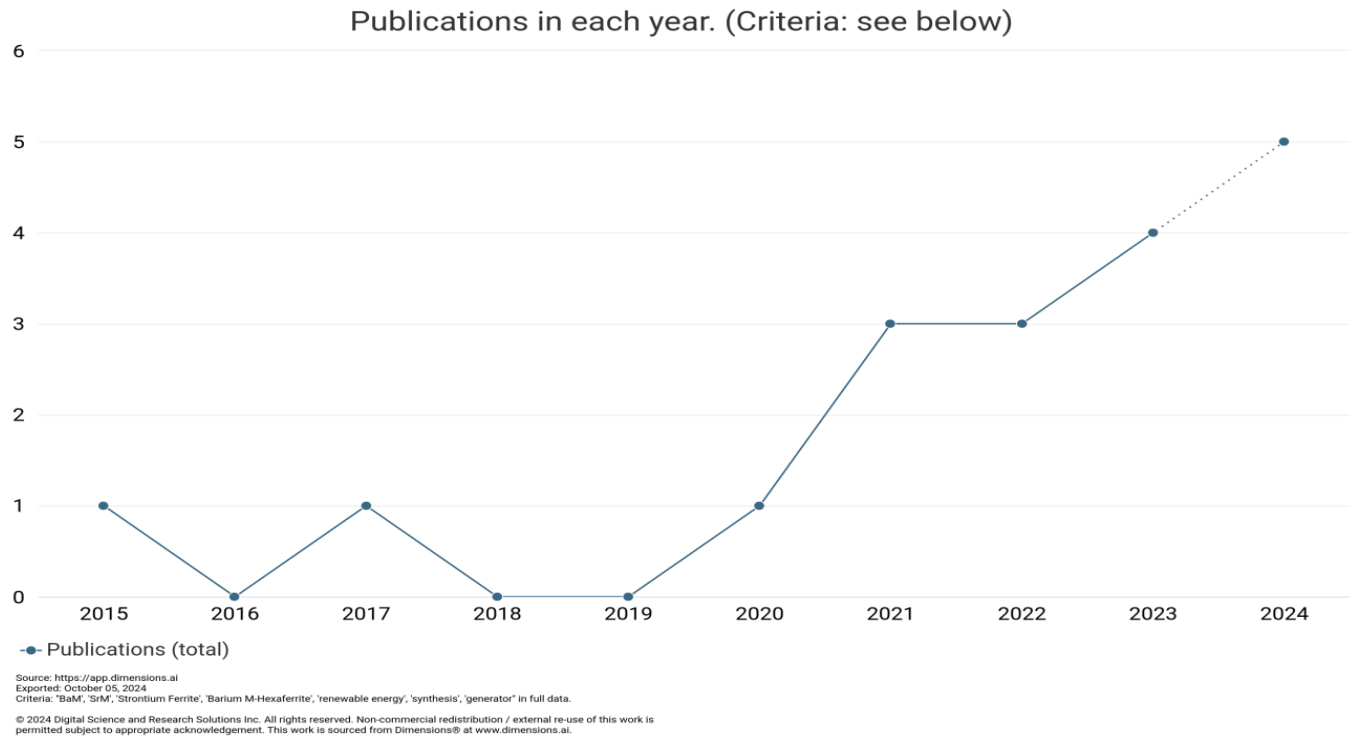

Figure 1. Research trends in electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand

Table 1. Trends in Electrical and Magnetic Properties of Strontium Ferrite and Barium M-hexaferrite Based on Natural Iron Sand Research Based on Publication Types

Publication Type	Publications
Article	9
Edited Book	8
Monograph	2
Chapter	1
Preprint	2

Based on Table 1, it is known that research electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand from 2015 to 2024 contained in 5 types of publications. In the form of articles there were 9 documents, chapter only 1 document, edited books as many as 8 documents, preprints as many as 2 documents and also 2 documents from monograph. Research trends electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand in article form is the type of publication that contains the most research compared to other types of publications (Singh et al., 2018; Anjelh Baqiya et al., 2020). Meanwhile, the type of publication contains the least amount of research results is a chapter. Research conducted by (2019) states that an article is a complete factual essay of a certain length created for publication in online or print media (via newspapers, magazines or bulletins) and aims to convey ideas and facts that can convince and educate. These articles are usually published in scientific journals both in print and online (Suseno & Fauziah, 2020). Below are also table 2 presented top sources title trends in research on electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand which are often cited by other researchers related to this matter.

Table 2 shows that the most widely published source of research trends on the electrical and magnetic properties of strontium ferrite and barium m-hexaferrite

based on natural iron sand is the Journal of Physics D, namely 2 publications with 151 citations and an average citation of 75.50. Journal of Physics D is an international journal publishing high quality work concerned with all aspects of applied physics research, from biophysics, magnetism, plasmas, semiconductors, energy materials and devices to the structure and properties of matter. Below are also table 3 presented top article title trends in research on electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand which are often cited by other researchers related to this matter.

Table 2. Top Sources Title Trend of Electrical and Magnetic Properties of Strontium Ferrite and Barium M-hexaferrite Based on Natural Iron Sand Research in 2015-2024

Name	Publications	Citations	Citations Mean
Journal of Physics D	2	151	75.50
Materials Science and Engineering B	2	19	9.50
Ceramics International	1	4	4
Progress in Solid State Chemistry	1	19	19
Materials Today Communications	1	0	0
Jurnal Penelitian Pendidikan IPA	1	0	0
arXiv	1	0	0
Journal of Central South University	1	0	0

Table 3 shows that research on the electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand that is widely cited by other researchers is about "Novel iron sand-derived α-Fe2O3/CaO2 bifunctional catalyst for waste cooking oil-based biodiesel production" which is 13.00 (Prameswari et al., 2022). Then the research entitled "Synthesis and structural characterization of iron chromite nanoparticles: A preliminary study" was cited 1.50 times (Amelia et al., 2020). Research by Hakim et al. (2023) entitled "Synthesis of Strontium Based on Natural Iron Sand North Lombok Coastal Club Doping Co and Cu Metal Ions As Power Generating Materials " is also widely cited by other researchers, namely 1.00 per year.

This research data is comparable to data on the increasing trend of research on the electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand from 2015 to 2024. This means that in that year, research related to it was continuously cited by other researchers. In the articles researched and written by these researchers, there are many terms related to electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand (Gupta & Roy, 2023; Widanarto et al., 2015). Below are presented the most popular keywords related to electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand.

Table 3. Top Citations on Trend of Electrical and Magnetic Properties of Strontium Ferrite and Barium M-Hexaferrite Based on Natural Iron Sand Research in 2015-2024

Cites/year	Year	Author	Title
13.00	2023	J Prameswari et al.	Novel iron sand-derived α-Fe2O3/CaO2 bifunctional catalyst for waste cooking oil-based biodiesel production
1.50	2020	T Amelia et al.	Synthesis and structural characterization of iron chromite nanoparticles: A preliminary study
1.50	2020	M Effendi, E Nugraha, W T Cahyanto, W Widanarto	The effects of milling time on structure, magnetic properties and microwave absorption capability of strontium lanthanum ferrite compounds
1.00	2023	Susilawati, Aris Doyan, Saprizal Hadisaputra , Lalu Muliyadi	Synthesis of Strontium Based on Natural Iron Sand North Lombok Coastal Club Doping Co and Cu Metal Ions as Power Generating Materials
1.00	2023	Z Huang, Y Shu, Y Li, B Huang, L Yi, T Jiang	External moisture enhanced synergistic conversion of biomass and iron sand for the green production of metallic iron

Table 4 shows that the keywords that often appear related to research on the the electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand are synthesis process, 3 times with a level of 2.77. To find out the electrical and magnetic properties of a compound, synthesis must be carried out. Table 4 also shows that characterization is also one of the keywords that appears frequently in research trends on the electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand, namely 7 times with a relevance of

1.02. Synthesis is usually performed in conjunction with catheterization.

Table 4. Keywords on Trend of Electrical and Magnetic Properties of Strontium Ferrite and Barium M-hexaferrite Based on Natural Iron Sand Research in 2015-2024

Terms	Occurrences	Relevance
Synthesis process	3	2.77
Permanent magnet	3	2.69
Hydrogen chloride	3	2.01
Renewable energy	6	1.15
Characterization	7	1.02
Magnetic properties	3	0.68

Below are the visualization is accomplished by generating a landscape map, which offers a visual representation of subjects related to scientific studies. The outcomes of bibliometric mapping for the co-word network in articles related to the topic electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand are illustrated in Figure 2. Figure 2 shows the results of bibliometric keyword mapping on research trends on the electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand. In Figure 2 there are 56 keyword items that are often used in research on the electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand from 2015 to 2024. Figure 2 also contains 4 clusters, where the first cluster is colored red and consists of 8 keyword items, namely investigation, iron sand, magnetic property, etc. The second cluster in green consists of 7 keyword items, namely characterization, development, synthesis, etc. The third cluster in blue consists of 6 keyword items, namely ferrogel, effect, hydrogen chloride, etc. The fourth yellow cluster consists of 3 keyword items, namely Fe_3O_4, raw material, structure.

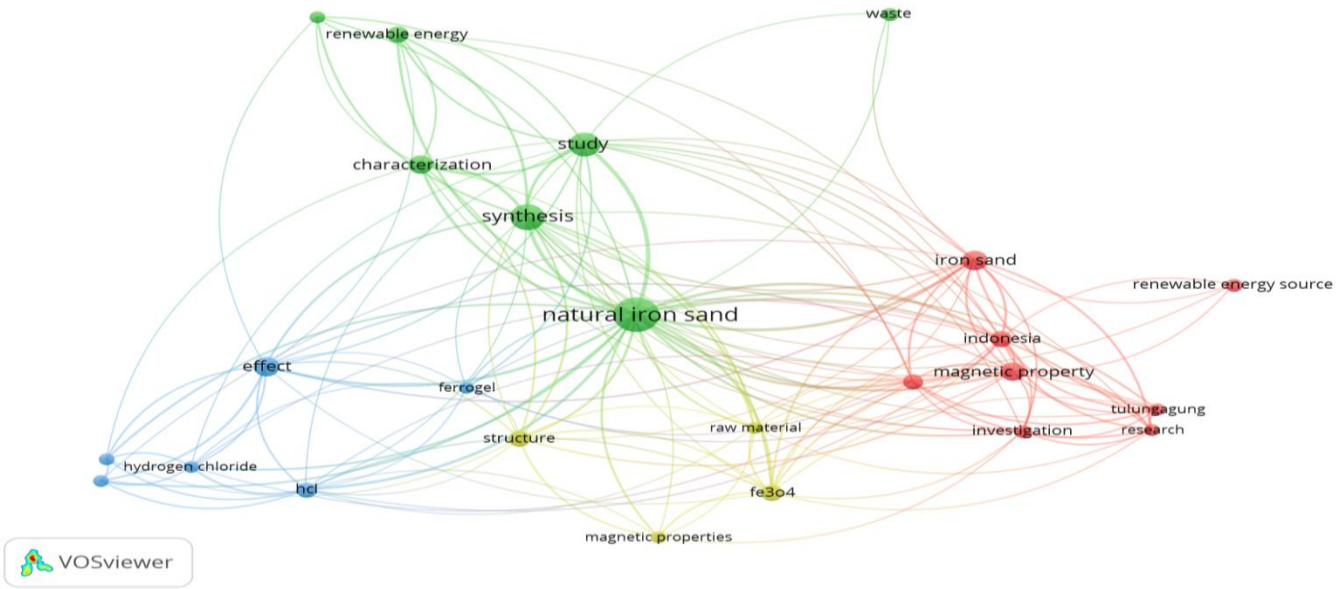

Figure 2. Network visualization on trend electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand research

Figure 2 above also shows that network visualization shows the network between the terms being visualized. Keywords classified into four clusters are arranged in a color chart showing the divisions that are connected to each other. The results of this analysis can be used to determine keyword research trends in the last year. This analysis shows several keywords that are often used in research on the electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand. The more keywords that appear, the wider the visualization displayed. Below are also presented keywords regarding the electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand based on overlay visualization. Figure 3 shows the trend of keywords related to electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand in Google Scholar indexed journals from 2015 to 2024.

Trends in the themes of writing articles related to electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand from the oldest to the newest year are marked with purple, blue themes, turquoise, dark green, light green and yellow. In the picture below you can see that magnetic property, hydrogen chlroide, etc. This shows

that these keywords were widely used by researchers in 2020. In 2021, the keywords that frequently appeared were iron sand, Fe_3O_4, etc. While in 2022, there were keywords like synthesis, characterization, renewable energy, etc that frequently appeared.

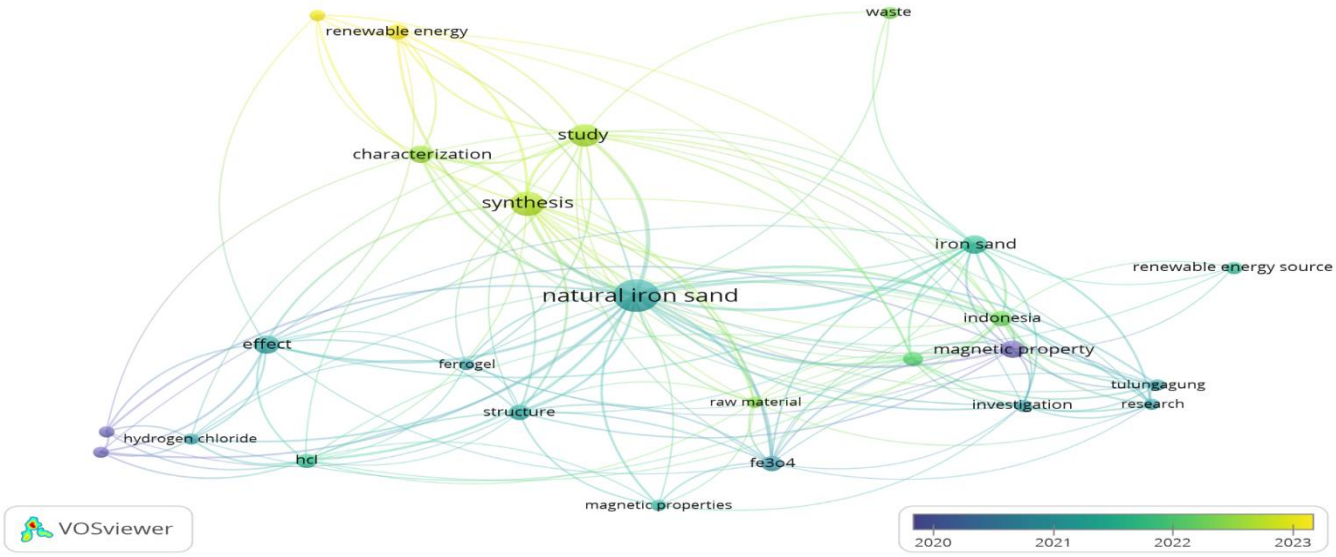

Figure 3. Overlay visualization on trend electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand research

Research on electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand is one area of research that has developed rapidly in recent years. The following also presents keywords for electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand research based on density visualization. Figure 4 shows density visualization. The density of research themes is shown in bright yellow. The brighter the colors of a theme, the more research is done. The fainter the color means the theme is rarely researched (Kaur et al., 2022; Liao et al., 2018). Faintly colored themes such as permanent magnet, ferrogel are dimly colored keywords. This shows that these keywords can be used as a reference for further research. Dudchenko et al. (2022) stated that yellow indicates keywords that are currently and frequently used in research, like natural iron sand, synthesis, magnetic property, etc.

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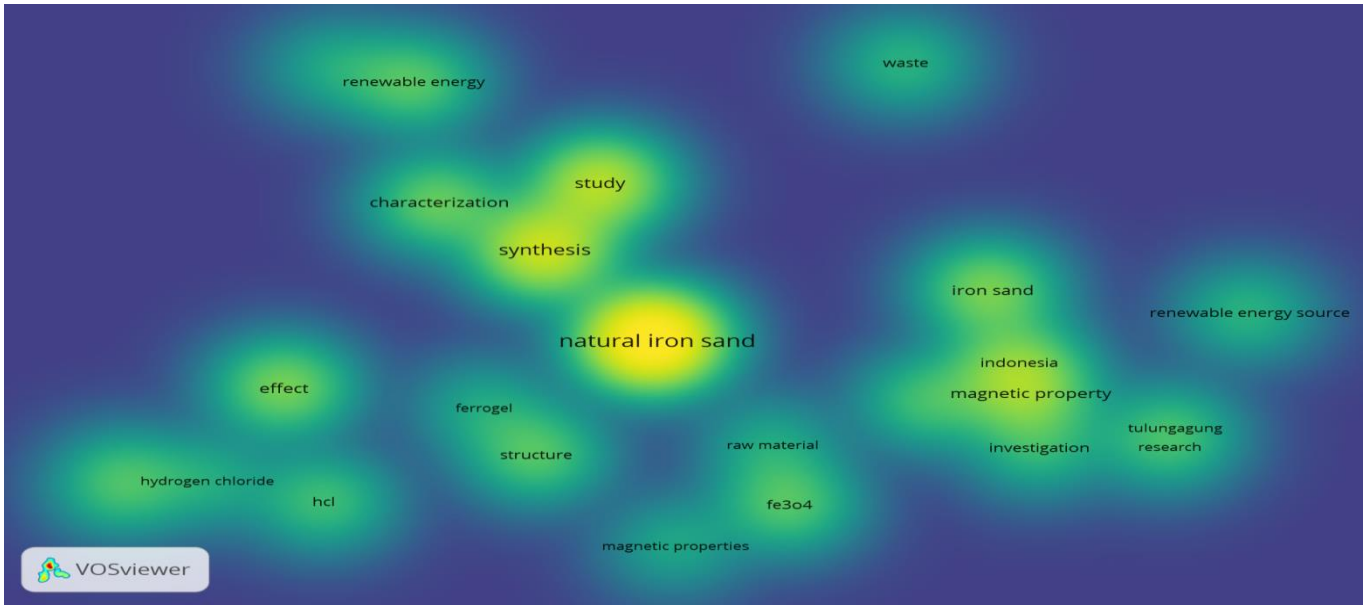

Figure 4. Density visualization on trend electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand research

Overall, Research in the field of materials, especially the magnetic properties of materials, continues to increase. This is because Indonesia is one of the countries whose technological development is developing very rapidly, where the amount of energy use is on a large scale, so that human needs for renewable energy sources must be met properly (Nguyen et al., 2023; Owusu & Asumadu-Sarkodie, 2016; Pambudi et al., 2023; Jaiswal et al., 2022). Research can be conducted with the aim of synthesizing and characterizing hard magnetic materials that will be used as one of the renewable energy as a generator material for electricity generation. A generator is an electrical machine that converts mechanical energy into electrical energy by utilizing permanent magnets as the basic material (Shettigar et al., 2018; Hidayat et al., 2021); (Ahamed et al., 2022). The materials that can be used are Barium M-Hexaferrite (BaM) and Strontium Ferrite (SrM). So that research is conducted to determine the electrical and magnetic properties of BaM and SrM made from natural iron sand in Indonesia, one of which is on the island of Lombok as a generator material for electricity generation.

Conclusion

Research on trends in the electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand has urgency high because it can be used as one of the renewable energy sources as a material for power generators. The research trend on the electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand indexed by Google Scholar from 2015 to 2024 has experienced ups and downs. There are many documents in the form of articles, chapters, preprints, monograph and edited books that discuss research into the electrical and magnetic properties of strontium ferrite and barium m-hexaferrite based on natural iron sand. Key words that are often used in research about it are synthesis, characterization, permanent magnet, etc.

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Author Contributions
Conceptualization, S.; methodology, A. D.; validation, M. T.; formal analysis, S. A.; investigation, M. I.; resources, N. R. A.; data curation, R. A. E.: writing—original draft preparation, S.; writing—review and editing, A. D.: visualization, M. T. All authors contributed to writing this article.

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No conflict interest.

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