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THE IMPACT OF NANOTECHNOLOGIES IN THE VIRTUAL WORLD

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Abstract: *The impact of nanotechnologies lies in the possibility of creatively combining technical progress, resource scarcity, and effective methods of environmental protection. In this context, investment values must increase because, according to Moore's law, the number of transistors on a circuit doubles every eighteen months, contributing to the increase in electronic performance (expected to be 500 times better than today, through silicon etching). One of the future trends is for nano-optics to replace microelectronics (laser transmissions avoid energy losses). According to specialists, the goods and services generated by the development of nanotechnologies (nano-electronics, nano-optics, nanobiotechnology etc.) have an annual value of approximately one trillion dollars. This scientific paper uses natural language processing techniques to analyze posts extracted from Twitter, written in English and French, which refer to words highlighting the creative combination of the three fields that have led to the global impact of nanotechnologies.*

Keywords: *nanotechnology, nanomaterial, nonconventional technology, nonconventional energy.*

1. INTRODUCTION

Nanotechnology is a cutting-edge field that has revolutionized various industries worldwide in the last 5 years, contributing to the modernization of several sectors, including nano-industries [1], medicine [2], biotechnology [3], the cosmetic industry [4], agriculture [5], the food industry [6], textiles [7], construction materials [8], environmental protection [9], the automotive industry [10], nanocomputer science and more [11].

In the medical field, both human and veterinary medicine, numerous interdisciplinary research efforts have highlighted applications of nanotechnology. These applications include personalized medicine, the development of tissue regeneration devices, less invasive treatments, more effective drugs, cancer diagnosis and treatment devices, and smart sensors, among others [12].

The study comprises the following sections: (i) introduction, (ii) background, (iii) applications of nanotechnologies, (iv) analysis of Twitter posts written in English and French

using natural language processing (NLP) techniques, (v) post similarity analysis and ChatGPT, (vi) results and discussion, (vii) conclusions, and future research directions. This work aims to identify ways to simplify the process of documentation, research, and learning (DRL) in the virtual world at both educational and industrial levels.

2. CONTEXT

The period from 2018 to 2023 was characterized by a significant level of interest among researchers in the field of nanotechnologies, as illustrated in Figure 1.



Fig. 1. Publications in Web of Science.

Table 1 highlights a substantial number of scientific works related to the topic of "nanotechnology," categorized according to the

Web of Science (WoS). It is observed that the highest number of scientific articles with an interdisciplinary focus fall within the fields of "Materials Science" and "Chemistry".

Table 1

Analysis of publications, grouped by WoS categories

Field: Web of Science Categories	% of 29,638
Materials Science Multidisciplinary	21.88%
Nanoscience Nanotechnology	20.77%
Chemistry Multidisciplinary	18.73%
Pharmacology Pharmacy	11.86%
Physics Applied	10.37%
Biochemistry Molecular Biology	6.49%
Environmental Sciences	5.03%
Biotechnology Applied Microbiology	4.54%
Materials Science Biomaterials	4.30%
Physics Condensed Matter	4.03%
Multidisciplinary Sciences	3.94%
Polymer Science	3.14%

In this context, agriculture utilizing nanotechnologies can potentially result in the creation of supercrops, enhancing both the quantity and quality of biodegradable packaging. This advancement aims to prevent food poisoning while reducing the reliance on genetically modified foods and minimizing waste. However, it is crucial to emphasize that the long-term safety of these technologies should be regulated and coordinated at the international level [13].

Within the European Union, the registration, evaluation, and authorization of chemical substances are governed by the REACH regulation, which was introduced in 2007 and initially lacked specific provisions for nanomaterials. These provisions came into effect on January 1st, 2020. Over the past three decades, the production of nanomaterials has seen significant development, both in laboratory settings and on an industrial scale.

Nanotechnologies are also rapidly advancing, relying on techniques and processes for manufacturing and handling nanomaterials. Depending on the nanoparticle manipulation technique employed, a variety of coating morphologies can be achieved, ranging from powders to nanoparticles (with average diameters ranging from 30 atoms to 20 nm, depending on the material). Assessing the risks

associated with the use of nanomaterials necessitates the development of new methods specific to substances in the molecular state. In many countries, legislation mandates the declaration of substances in nanoparticle form by manufacturers, importers, and distributors. This information is typically collected in a national register [14]. Additionally, it is crucial to underscore the importance of public dialogue regarding the development of nanotechnologies, as highlighted in numerous scientific papers and debates [15].

3. APPLICATIONS OF NANOTECHNOLOGIES

Numerous industrial processes are reliant on nanotechnologies, nanomaterials, and nano-objects. Among the fields that incorporate "nano" applications and technologies, can be mentioned:

- **Agriculture and the food industry:** Customized nanoscale systems based on precision chemistry; Silver nanoparticles combined with polymers; Smart packaging.
- **Electronics:** Graphene for TV screens.
- **Chemical industry:** Zinc oxide nanowires; Palladium nanoparticles.
- **Sports:** Sports equipment and products for tennis, golf, hockey, cycling etc.
- **Environmental quality:** Improving water and air quality.
- **Space science and research:** Aluminum nanopowder for rocket fuels; Carbon Nanotubes (CNTs).
- **Medicine:** Prostheses, cochlear implants, and heart valves made of biocompatible nanomaterials; Gene therapy (transfer of gene sequences); Cancer/AIDS treatment through targeted drug delivery within the human body; Nanosilver coating of surgical instruments; "In vitro" or "ex vivo" diagnostic tools; Nano-agents for medical imaging; Tissue engineering (nanofilaments or nanotubes used to construct artificial tissues); Dialysis machines made with nano-hollow fibers; Biochips (biological probes).
- **Automotive industry:** Natural Rubber-Organoclay; Nano-coatings for mirrors to

enable automatic adjustment of light levels; Tungsten nanospheres.

In the construction industry, similar to the automotive sector, nanoparticles are incorporated into materials, including insulating materials like plasters, windows, and paints. This is done to prevent the deposition of particles from other substances, creating a "lotus effect" that causes them to roll off. Non-stick coatings of this kind are also used for roof tiles.

In the electronics industry, the sizes of smartphones and computers have significantly reduced due to the miniaturization of circuits, microchips, and conductive tracks. Sunscreens produced by the cosmetic industry use nanoparticles of zinc oxide, magnesium oxide, and titanium dioxide (inorganic mineral sunscreens) [16]. Nanoparticles in catalysts, as employed in the automotive industry, filter pollutants from fuels, much like nanoporous membranes used in industrial unit chimneys.

Nanotechnology can help reduce the deterioration of asphalt due to water infiltration and freezing, among other benefits. Additional outcomes of nanotechnologies include replacing traditional light bulbs with LED (Light Emitting Diode) or OLED (Organic Light Emitting Diode) variants; utilizing components coated with nanocrystals for electric cars; substituting heavy metals with nanoceramic compounds in car paint manufacturing; employing nanoferrites in industrial adhesives for reversible adhesive connections (efficient bonding and easy peeling for recycling); producing water-repellent textile materials; miniaturizing electronic components like memory chips using ferromagnetic memory cells (MRAM - Magnetoresistive Random Access Memory); using nanoporous catalysts [17]; combining zeolites with tantalum to create modern catalysts [18]; crafting TCO (Transparent Conductive Oxide) plates with titanium dioxide nanolayers for dye-sensitized solar cells [19, 20]; and utilizing rhodopsin, a bacterial protein obtained through nanobiotechnology, which changes color from purple to yellow (reversible to dark) and is used to differentiate fake documents from genuine ones. Additionally, there are developments like bio2nano, which involves

using biological materials for producing functional nanotechnology, and nano2bio, which employs nanotechnology for analyzing and producing biological nanosystems. Apart from civilian applications, there are also numerous military applications, some of which are listed in Table 2 [21].

Table 2

Military applications of nanotechnologies and nanomaterials.

Domain	Activity / Products
Body Armour	Silicon (Si) or TiO ₂ nanoparticles embedded in epoxy matrix.
	Shear Thickening Fluid.
	Magnetorheological Fluid.
Nano-Enhanced Sensors	Highly sensitive infrared thermal sensors.
	Miniature high-performance camera systems.
	Biochemical sensors.
	Small, lightweight accelerometers and GPS for motion and position sensing.
	Health-monitoring sensors and drug/nutrition delivery systems.
Various fields	Stealth coatings.
	Smart skin materials.
	Nano-machines to mimic human muscle action in an exoskeleton.
	Adaptive structures.
	Adaptive camouflage.
	Self-healing (self-repair) material.

Currently, military research is primarily centered around drones and exoskeletons. The "Eurodrone" project, a collaborative effort involving Germany, Italy, France, and Spain, is expected to be completed by 2025. Israel employs "Heron TP" drones, while the "Hercule" exoskeleton, developed in France in 2014, serves the dual purpose of enhancing the physical capabilities of soldiers and addressing medical needs [22].

4. DATA ANALYSIS AND NATURAL LANGUAGE PROCESSING

Natural language processing (NLP) techniques are employed across various fields, enabling computers to comprehend, process, and generate human language. The data for the present study underwent processing using NLP

techniques. The data collections under analysis were manually gathered between April and June 2023, utilizing the "Advanced search" function on Twitter, with the keywords: "nanotechnology", "nanomaterial", "nonconventional technology" and "nonconventional energy". These collected data were processed using Cloud-CyberX [23] with scripts written in the Python 3.12 programming language. Following a cleaning operation [24, 25], only the unique messages that remained (after being cleaned using NLP methods) were retained for further analysis. The resulting database comprises 5522 records. Subsequently, the data were filtered for English records and then for records written in French. From the English records, were constructed two dictionaries: one containing the 50 most frequent words, denoted as D_{Eng50} (as shown in Figure 2), and another containing the 100 most frequent words, denoted as D_{Eng100} . There is a lot of research that uses NLP and Twitter data to generate bag words [26]. For each word in these dictionaries, the frequency of occurrence was calculated.

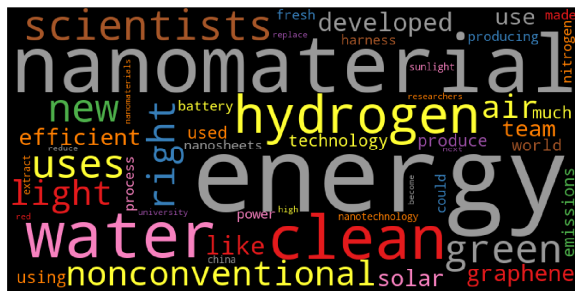


Fig. 2. The 50 most common words (English).

The word "nanotechnology," although it appears less frequently than the words "technology", "world", "produce", "emissions", "producing", "power", "battery", "could", "nitrogen", "extract", "sunlight" and "China" is among the 50 most frequent words found.

The list of words from D_{Eng100} that are not found in D_{Eng50} , arranged in descending order of word frequency, includes: {components, products, companies, carbon, vision, bite, see, work, aqualyte, fuel, source, production, say, south, morning, post, low, give, talk, robot, enough, oil, group, amherst, porous, bacteria, electricity, found, nanowires, quite, wrong,

considered, one, best, materials, provide, storage, applications, wind, heroes, even, sources, Steve, come, weapon, gives, major, velvet, vibes, someone}. Figure 3 highlights words not included in D_{Eng50} or D_{Eng100} , which have lower frequencies than those in D_{Eng100} but are still significant. These words are as follows: "concept, way, artificial, system, know, would, science, COVID, Ana, Mihalcea, worldwide, reduction, sustainable, microchip, antenna, ability, influences, personal, emotions".

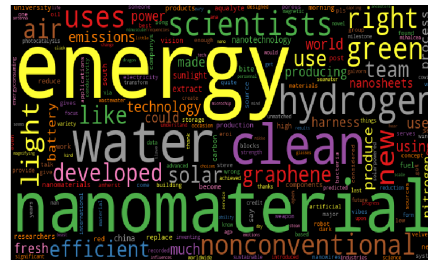


Fig. 3. Most common words found in English posts.

Similarly, to the analysis of posts written in English, was analyzed posts written in French. In order to achieve this, specific French stop words were removed, resulting in the creation of a French dictionary and the determination of the frequency of the words within the analyzed posts. Subsequently, Figure 4 displays the 50 most frequent words and Figure 5 presents all the words from the dictionary that correspond to the French-language posts.

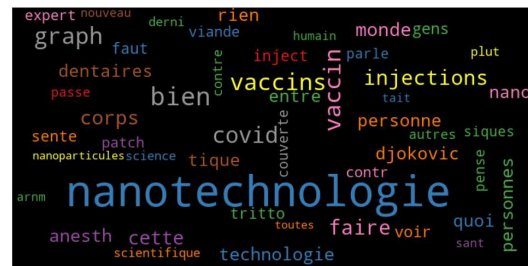


Fig. 4. The 50 most common words (French).

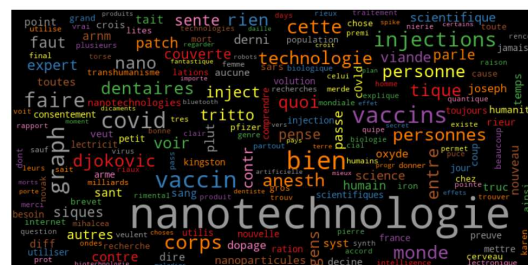


Fig. 5. All the words in the French language dictionary.

In the analyzed posts written in French, was noticed a smaller overlap of words compared to those found in English-language posts. This difference is primarily due to the prevalence of medical terminology in the French posts. These medical terms encompass a wide range of topics, including various types of injections, methods of administration, patient education for their use, immunization vaccines, vaccination schedules, COVID-19 (commonly referred to as "covid"), fatalities (referring to individuals who have succumbed during the COVID-19 pandemic), Pfizer (specifically mentioning the Pfizer-BioNTech COVID-19 Vaccine), blood-related discussions (covering blood's role, composition, transfusions, and laboratory analyses), medications (providing information, recommendations, and advice on drug usage), doping in sports, including genetic doping ("dopage"), dental-related topics (such as dental offices, dental products, and dental treatments), experimental matters (pertaining to Experimental and Therapeutic Medicine), mentions of Novak Djokovic (the renowned tennis player who was expelled from Australia in 2022 for not being vaccinated), mentions of "effets" (referring to side effects of bivalent COVID vaccines, the effects of receiving a fourth dose of vaccination, and the long-term effects of COVID virus infection on individuals), discussions about various diseases (including genetic, chromosomal, hereditary, and metabolic conditions), temperature-related topics (such as the survival of the COVID virus on different surfaces, influenced by temperature and humidity), and issues related to the human brain ("cerveau") and diseases that may affect it.

Understanding the frequency of words in texts related to non-conventional technology provides several advantages, including: Identifying trends and priorities within the non-conventional and related technology fields; Recognizing key concepts within the text to gain insights into relevant topics and sub-fields within non-conventional technologies; Grasping the overall context and dominant subjects in the realm of non-conventional technologies; Facilitating decision-making regarding research directions, development efforts, or applications

of the identified concepts within the field of non-conventional technologies.

5. SIMILARITY ANALYSIS OF POSTS AND ChatGPT

A subfield of natural language processing (NLP) is text similarity analysis [27]. Its primary purpose is to quantify the degree of similarity or dissimilarity between texts. Several specific algorithms are commonly used to measure the degree of content similarity in text, including: cosine similarity, the Levenshtein distance, Term Frequency-Inverse Document Frequency (TF-IDF) and the Jaccard Index coefficient. The study focus was the calculation of the Levenshtein distance between pairs of posts or tweets. The Levenshtein distance is a numerical value that indicates how different two strings are. A higher Levenshtein distance value signifies greater dissimilarity between the two strings. Figure 6 illustrates the results obtained from the dataset containing posts written in English.

Record1	Record2	Distance Levenshtein	Len Record 1	Len Record 2
A group of researchers from the University of Massachusetts at Amherst has developed a porous nanomaterial that uses water vapor in the air to continuously produce electrical energy. The idea of	The nanomaterials reduce or replace inefficient energy and emissions producing components or products. The company's goal is to profitably deploy its technology resetting our	226	276	278
A group of researchers from the University of Massachusetts at Amherst has developed a porous nanomaterial that uses water vapor in the air to continuously produce electrical energy. The idea of	bacteria of the species <i>Geobacter sulfurreducens</i> , which generate electricity. Experimentally, it was found out that these microbes are capable of producing ultrathin protein	216	276	275
A group of researchers from the University of Massachusetts at Amherst has developed a porous nanomaterial that uses water vapor in the air to continuously produce electrical energy. The idea of	You are quite right and wrong. Graphene, a carbon nanomaterial, is considered to be one of the best materials for supercapacitor electrodes. Stay with me supercapacitors provide	223	276	275

Fig. 6. File structure containing Levenshtein distance calculation.

In Table 3, the Levenshtein Distance reported in % was calculated for the posts in English and French.

Table 3
Levenshtein Distance Distribution for English and French posts.

Levenshtein Distance between posts	English %	French %
Levenshtein Distance $\geq 90\%$	0.00%	0.020%
Levenshtein Distance in [70%,90%)	0.25%	0.020%

Levenshtein Distance between posts	English %	French %
Levenshtein Distance in [50%,70%)	0.37%	0.041%
Levenshtein Distance in [30%, 50%)	0.62%	0.365%
Levenshtein Distance in [25%, 30%)	0.87%	14.208%
Levenshtein Distance in [20%, 25%)	4.84%	73.105%
Levenshtein Distance <20%	93.05%	12.242%

The low degree of similarity between the unique posts analyzed is observed.

Since today there is a high concern about the use of the ChatGPT application [https://openai.com/blog/ChatGPT] the following experiment was carried out. Submitted the following two requests to GhatGPT v3:

- "write 10 different tweets in English that refer to people's concerns about the use of nanotechnologies";
- "write in English 10 different tweets referring to the main applications regarding the use of nanotechnologies in industries". Table 4 contains a sequence of answers received for the 2 questions asked.

Table 4

ChatGPT response sequence.

Text written by ChatGPT
"Exciting as nanotech innovations may be, many of us share concerns about the potential risks involved. It's crucial to prioritize safety and ethical considerations. #Nanotechnology #Ethics"
"Nanotechnology offers incredible possibilities, but let's not forget the importance of responsible research and transparent regulations. Safety first! #NanotechSafety #ResponsibleInnovation"
"The power of nanotechnology in medicine is awe-inspiring, but we must ensure it's used for the benefit of all. Access and affordability should be priorities. #Nanomedicine #Accessibility"
"The automotive industry is embracing nanotech for lighter, fuel-efficient vehicles and improved safety features. Buckle up for a greener and safer ride! #NanotechCars #Automotive"
"Clean water is a global priority, and nanotechnology plays a vital role in water purification, removing contaminants, and ensuring safe drinking water for all. #CleanWater #NanotechSolutions"

The Levenshtein Distance was calculated for all 20 posts written by ChatGPT. Figure 7 illustrates that their similarity is almost non-existent.

This fact highlights that both the actual posts and those written by ChatGPT exhibit a high degree of novelty and do not require reinterpretation due to content deficiencies or issues.

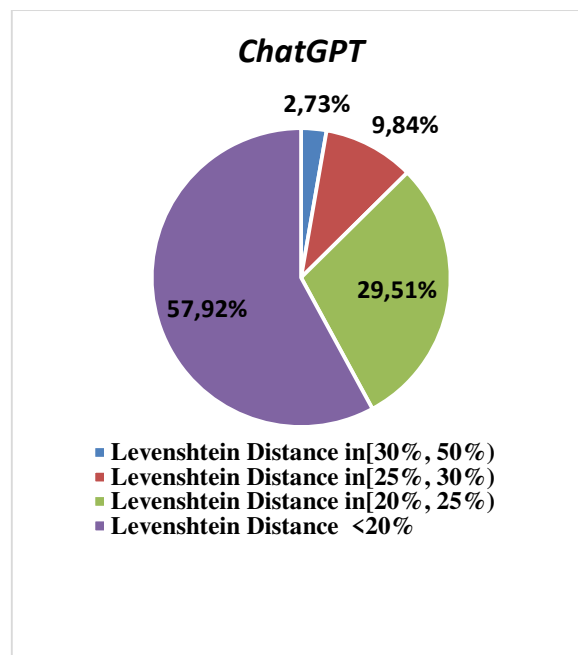


Fig. 7. Levenshtein Distance for ChatGPT.

6. RESULTS AND DISCUSSION

In the conducted study, Natural Language Processing (NLP) was employed to process the extracted tweets to identify keywords and their frequencies.

For the analyzed data, a three-dimensional space, denoted as S3, was created. This space includes the following elements: "lang," represents the language in which the tweet was written; he number of records corresponding to the "lang" field; the frequency of tweets written in the language corresponding to the "lang" field. The structure of the S3 space is as follows: { fr, 4025, 72.89%; de, 380, 6.88%; pl, 311, 5.63%; nl, 293, 5.3%; en, 135, 2.44%; blank, 87, 1.58%; cs, 93, 1.68%; qme, 70, 1.26%; zxx, 52, 0.94%; es, 18, 0.32%; qam, 18, 0.32%; art, 7, 0.12%; as, 6, 0.1%; und, 6, 0.1%; lt, 4, 0.07%;

qht, 4, 0.07%; it, 3, 0.05%; ja, 2, 0.03%; ro, 2, 0.03%; tl, 2, 0.03%; et, 1, 0.01%; in, 1, 0.01%; sl, 1, 0.01%; zh, 1, 0.01%; }. It is worth noting that more than 90% of the extracted tweets are in French, German, Polish, and English (i.e., "fr," "de," "pl," and "en"), as illustrated in Figure 8.

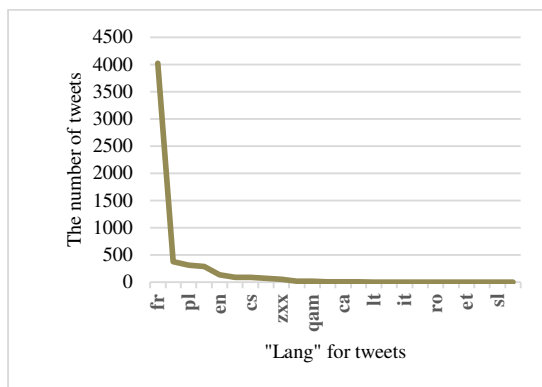


Fig. 8. Number of tweets by language.

Based on word frequency, a word cloud was generated where the size of each word is proportional to its frequency. Python 3.12 was utilized along with the following libraries and modules from the NLTK (Natural Language Toolkit) library: Pandas; Matplotlib; WordCloud; NLTK's "stopwords" module reduces noise and emphasizes relevant keywords; NLTK's "word_tokenize" module breaks down text into individual words or tokens. The word cloud highlights the most frequently used words in different colors and sizes. The study employed NLP to process and extract semantic information from the analyzed texts, which involved constructing word dictionaries and creating word clouds. In the word dictionary presented in Figure 2, it is evident that the most frequent words include: energy, nanomaterial, water, clean, hydrogen, scientists, uses, new, green, right, nonconventional, and light. "Energy," "nanomaterial," and "nonconventional" exhibit high frequencies and are included in the vector with data processing selection criteria.

Among the words identified in the word cloud in Figure 3, the significance of certain terms in the development of nanomaterials and nanotechnologies can be highlighted:

- **"Artificial":** The activation of nanotechnology through artificial

intelligence (AI) enables precise manipulation of matter at atomic, molecular, or supramolecular scales, leading to the rapid development of new materials (nanomaterials, advanced composites, etc.) and applications (advanced medical treatments, energy production, etc.). Combining this technology with AI-assisted nanorobotics will lead to new applications and materials. Nano-sensors (smart sensors) embedded in these materials will induce changes in their properties based on certain factors (e.g., temperature). The development of autonomous nano-robots is also a result of AI-assisted nanotechnology [28].

- **"Covid":** During the COVID-19 pandemic, nanotechnologies provided drug developers with new elements distinct from traditional small molecules or antibodies. Nanomaterials have proven effective as antiviral countermeasures, offering new opportunities for preparing for future viral pandemics [29].

- **"Emotions":** This study analyzes messages sent by internet users; messages influenced by emotional states different from those experienced when using other media sources. Online communication lacks the physical presence of interlocutors, thus missing the set of emotional exchanges specific to face-to-face communication. Online communication technologies, sharing, display, and performance represent new components of emotions [30]. This study can be extended to analyze the emotions experienced by internet users when engaging with nanotechnologies and their outcomes, especially in engineering and medicine. A constraint of the research is the limited volume of data due to the restrictions imposed by Twitter regarding the collection of tweets for research. For the "messages/posts" written by ChatGPT in section (v), was created a word dictionary. Among its words, 28 are common with the English words extracted from the Twitter posts forming the basis of this study. The list of these common words, in descending order of frequency in the posts, includes: {nanotechnology, industry, lets, aerospace,

future, electronics, innovations, nanomaterials, possibilities, power, stay, energytech, enhanced, environmental, fuefficient, horizon, longer, many, progress, purposes, removing, revolutionize, ride, safe, shelf, sustainability, tech innovation, us}. This can also be observed in Figure 9, representing the word cloud for the posts/messages written by ChatGPT according to the hypothesis stated in section (v).

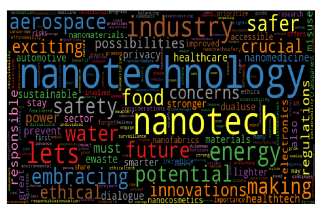


Fig. 9. Word cloud for posts written by ChatGPT.

A comparative study was conducted, utilizing Google search trends for the terms "Nanotechnology" and "Nanomaterial," in the context of the "Health" category. This study compared internet searches for the terms mentioned over the last 5 years, as illustrated in Figure 10.

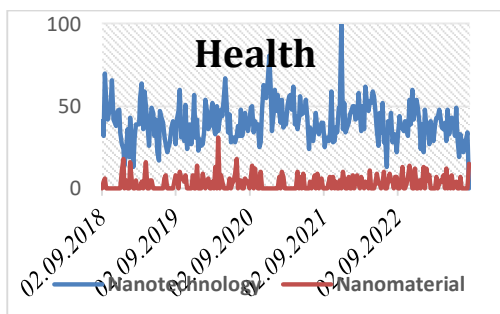


Fig. 10. Search trends for "Nanotechnology" and "Nanomaterial" in the last 5 years.

It can be observed that in recent years, compared to other fields of activity, nanotechnologies and nanomaterials have had a greater development in the medical field (nanomedicine), due to the large number of specific applications.

7. CONCLUSIONS

Nanotechnologies, nanomaterials, and nano-objects encompass techniques and tools facilitating the study and manipulation of phenomena occurring at the nanometric or

nanoscopic scale. This has led to rapid advancements across various sectors, including medicine, agriculture (driven by nanotechnological innovations in agrochemicals), energy, and electronics. The diversification of nanomaterials promises reduced consumption of raw materials such as metals, ceramics, polymers, aluminum and plastic while introducing new electronic, mechanical, magnetic, thermal, and catalytic properties. The development of nanotechnologies and nanomaterials involves intricate processes of research, development, and innovation. In medicine, nanotechnologies have presented numerous challenges and opportunities, including the design of biomimetic scaffolds, the utilization of synthetic polymer nanofibers, the application of bioactive hybrid nanofibers, and the enhancement of electrocatalytic properties for various nanomaterials. Word clouds, like the one generated in this study, serve as valuable tools for experts in swiftly gathering data from specific audiences. They aid in devising solutions to specific problems and presenting information in an easily comprehensible format for the intended recipients. Also, based on the dictionaries of words and their frequencies, it is possible to identify the tendencies of the virtual dialogue for a certain field of interest. Nanotechnology boasts universal applicability, and ongoing research continues to explore various usage scenarios, production methods, and approaches across multiple domains.

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Impactul Nanotehnologiilor în Lumea Virtuală

Abstract: Impactul nanotehnologiilor constă în posibilitatea combinării creative a progresului tehnic, deficitului de resurse și a metodelor eficiente de protecție a mediului înconjurător. În acest context, valorile investițiilor trebuie să crească, deoarece, conform legii lui Moore, numărul tranzistorilor pe un circuit se dublează la fiecare optsprezece luni, contribuind la creșterea performanței electronice (urmând să fie de 500 de ori mai mici decât în prezent, prin intermediul gravării pe siliciu). Una dintre tendințele viitoare este ca microelectronica să fie înlocuită de nano-optică (transmișiile cu ajutorul laserului evită pierderile de energie). Conform specialiștilor, bunurile și serviciile generate prin dezvoltarea nanotehnologiilor (nano-electronica, nano-optica, nanobiotehnologia etc.) au o valoare anuală de aproximativ un trilion de dolari. Prezenta lucrare științifică utilizează tehnici pentru prelucrarea limbajului natural, în analiza postărilor extrase din Twitter, scrise în limbile engleză și franceză, care se referă la cuvintele care pun în evidență combinarea creativă a celor trei domenii care au condus la impactul global al nanotehnologiilor.

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