Fertilizers as Explosives Simulants: Interaction with Low Frequency Electromagnetic Signals

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Abstract: - The aim of this paper is to demonstrate how different substances, in this case fertilizers, behave when exposed to ultra-low frequency (ULF) waves using an active inertia sensor. Specifically, the goal of the experiment is to find the resonant frequencies of some fertilizers and, afterwards, to identify the common frequencies at which fertilizers containing similar molecular components are detected. The frequency range used in the experiment is between 5 to 8 kHz. Through studies conducted using an active inertia sensor emitting ULF and VLF frequencies, and various substances, it has been observed that substances sharing common molecular components can be detected by common frequencies. In this experiment, it will be demonstrated that this also holds true for a group of inorganic materials, such as fertilizers. The future goal is to develop a database that includes multiple substances and the frequencies at which they can be detected. Additionally, the use of fertilizers as simulants for military applications, including training, research, technology development, airport scanners, robotic bomb disposal units, and other security technologies, is highlighted. Furthermore, the advantages of using fertilizers as simulants, compared to actual explosive materials, are emphasized.

Key-Words: - electromagnetism, ultra-low frequencies (ULF), inertia sensor, fertilizers, explosives' simulants, resonant frequency.

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1 Introduction

There are several methods of identifying the frequencies of materials or chemical substances. These spectroscopic methods can detect specific substances using their resonant frequencies or can analyze unknown substances by emitting certain frequencies. Some of these methods are Nuclear Magnetic Resonance (NMR), Nuclear Quadrupole Resonance (NQR), Infrared Radiation (IR), Raman, and others. [1], [2], [3], [4]. In this paper, we will focus on a new spectroscopic technique through which we are able to detect an unknown substance, to identify the substances that are contained in a sample, as well as to monitor the resonant frequencies of a material or a chemical compound.

In general, when no external magnetic field is applied, the number of nuclei in the spin-down state (m = -1/2) is approximately equal to those in the spin-up state (m = +1/2), with a slight numerical lack in the spin-down state. However, when a magnetic field is applied to a nucleus, this equilibrium changes. The magnetic moment of the nuclei interacts with the externally applied magnetic field, and the two spin states no longer have the same energy. The energy difference between the two states is given by the equation:

$$\boldsymbol{\Delta E = \gamma \hbar B_0}$$

where γ is the gyromagnetic ratio, ħ is the reduced Planck constant, and B_0 is the magnetic field strength.

Also:

$$\boldsymbol{\Delta E = \hbar \, \mathrm{x} \, f}$$

The frequency (*f*) that emerges from this formula is the resonant frequency of a substance and is known as the Larmor frequency [5]. Since the Larmor frequency depends on the magnetic field, the nuclear shielding effect reduces the intensity of the nuclear magnetic field, resulting in a shift in the Larmor frequency, known as chemical shift and is calculated by the equation:

$$\boldsymbol{\delta = \frac{(f_{substance} - f_{reference})}{f_{reference}} \, \mathrm{x} \, 10^6}$$

and is measured in ppm, which is independent of the applied magnetic field B, [6], [7].

This innovative method utilizes an active inertia sensor that emits ULF radiation. The sensor offers three distinct applications. First, it can identify the resonance frequencies of a known substance. Second, it can identify the type of an unknown sample based on known resonance frequencies. Lastly, it can pinpoint the location of a known substance based on its type and resonance frequencies. In this approach, a detector is moved in a circular motion around a vertical axis using a motor. When the antenna of the sensor aligns with the substance in study, a force that opposes the movement is exerted on the antenna, causing deceleration. This deceleration can be recorded using specialized software. By analyzing the diagrams of deceleration that is applied on the sensor's antenna, we can draw valuable information. The way we operate the sensor consists of many steps. Initially, we set the sensor to emit a certain frequency range. The interaction between the emitted frequencies and the sample under investigation leads to changes in the rotational dynamics of the sensor. It has been observed that when the emitted frequency resonates with the natural frequency of the substance, a distinct deceleration on the sensor's antenna is applied. This deceleration is meticulously recorded by the software, which then analyzes the data to extract the resonance frequency of the substance, [8], [9]. In the future we could improve this method by creating a library of resonant frequencies of additional substances or materials. A database of these frequencies would be extremely useful for identifying unknown samples by comparing their resonance frequencies with the ones in the database. Moreover, by scanning different areas and detecting resonance frequency signatures, it is possible to map the spatial distribution of specific substances within a given environment. This application is particularly useful in fields like environmental monitoring, where locating contaminants or hazardous materials is crucial, [10]. Additionally, the simplicity in use of this novel spectroscopic technique allows its use in multiple environments, different circumstances and various types of materials. It could be used not only in laboratories, but also in real conditions, providing a useful tool for researchers and industries in various fields. The method described in this paper allows for real-time analysis and detection of materials and substances in real time. This makes it a valuable tool for cases where immediate results are needed, such as forensics, quality control etc. In general, this method that consists of an active inertial electromagnetic sensor offers significant progress in detection and analyzation of chemical substances, [11], [12]. Applications such as identifying resonant frequencies of materials, analyzing unknown samples and detecting materials provide a useful tool that can be used in various fields. In Figure 1, a diagram of deceleration versus angle can be seen. The following is the description of the experimental procedure used to record the resonance frequencies of a substance.

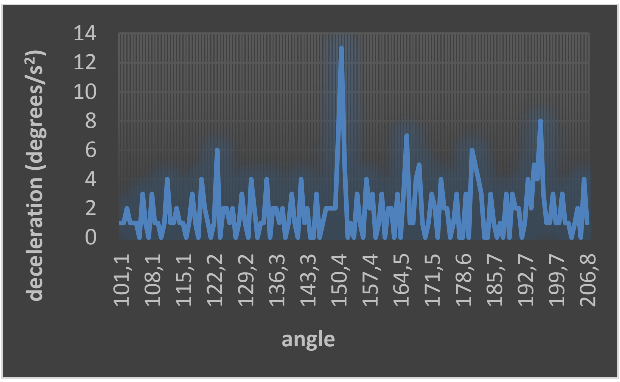

Fig. 1: Diagram of deceleration versus angle. We observe the deceleration acquired by the sensor depending on the angle at which it is positioned. The maximum deceleration that occurs during the sensor's motion indicates the presence of the material we are searching for in the specific direction (angle)

Source: Created by the authors

2 Experimental Procedure

Firstly, we choose the substance that is going to be studied and place it in front of the sensor. After that we activate the sensor and it starts rotating around a vertical axis, while emitting ULF electromagnetic signals. The generator of the sensor is programmed to increase the emitted frequency by 10 Hz every five seconds. As the detector rotates, it emits ULF radiation that continuously increases with a 10 Hz step. It has been observed that when the antenna of the detector aligns with the substance under study and the emitted frequency matches the substance's resonance frequency, an opposing force is exerted on the antenna, causing it to decelerate. This recorded frequency is one of the resonance frequencies of the substance. After detecting and recording these frequencies, they are then confirmed by placing the substance at different places relative to the initial position. Then, the sensor's settings are adjusted to emit a constant frequency -of the list of frequencies that had recorded before- and the substance is radiated in its new position. If the sensor's antenna shows deceleration during this process, it confirms the resonance frequency of the substance. If no deceleration is observed, the specific frequency is discarded. After this, the substance is positioned to a different position, and the sensor stops emitting frequencies that change over time. Instead, each of the previously detected frequencies is applied individually, and any deceleration detected in the antenna as it aligns with the material is recorded.

We repeat the same process for all the frequencies we found during the previous procedure, but this time the frequency is increased by 1 Hz every 5 sec. After that, we place the material in a new position, and the entire procedure is repeated. The remaining frequencies are the resonant frequencies of the substance in study

Below is a detailed description of the experimental setup and the materials that were used in the experiment.

3 Materials and Apparatus

The system of the sensor is based on an inertial mechanism that is able to move in a circular path. It consists of an electronic box, a telescopic antenna, a perpendicular axial fixed under the electronic box, and a base around which the sensor rotates. The electronic box houses a signal generator system that emits electromagnetic frequencies in the VLF band (5 kHz–8 kHz) through the antenna. The system can be divided into two main parts: the electronics box with the signal generator system and the antenna, and the perpendicular axis that allows the rotating movement. Below the axis, there is a base supporting the generator and the antenna. The emitted electromagnetic signals interact with materials, and the generator circuitry applies a signal to the antenna based on the material under study. The electronic box contains signal generator circuitry with an LCD screen for user interaction and selection, a micro-computer unit (MCU) processor, force detection circuitry, and a wireless communication module. The system is powered by a 3.3V lithium battery of 2700 mAh. When the MCU receives user commands, it instructs the Direct Digital Synthesis (DDS) Generator to produce the selected signal. When an external force is applied to the antenna, the inertia system mechanically vibrates at a specific frequency, and the signal is processed and transmitted to a second MCU. The sensor box is equipped with a wireless communication module that transmits the detected angle to a computer for data collection. Furthermore, an angular positioning system accurately measures the angles at which the antenna is oriented during its movement, using Gray code connected to a Raspberry Pi computer board (Figure 2). This data is processed using specialized software to generate various diagrams, providing a detailed analysis of the interactions between the emitted signals and the materials under study, [8].

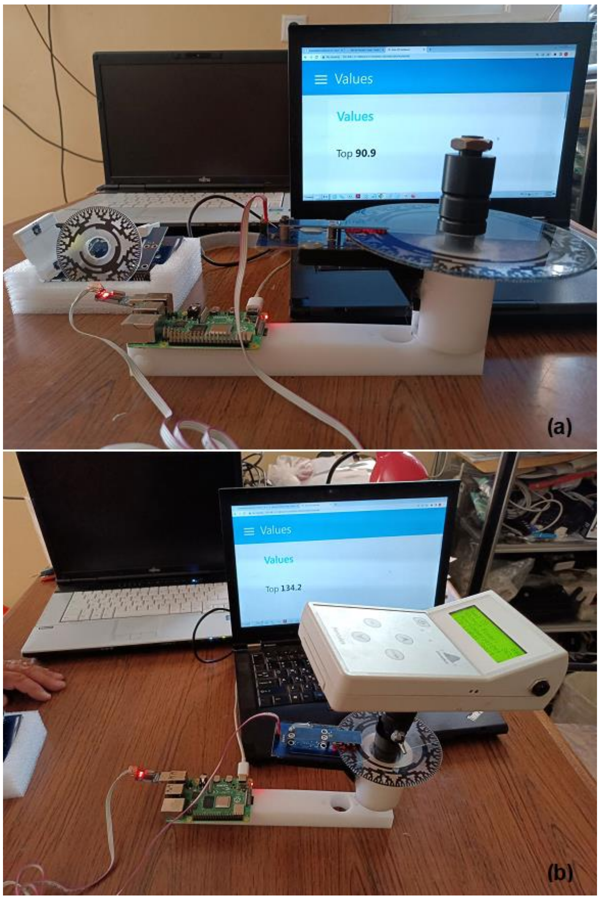

Fig. 2(a): Inertia system sensor, with Gray code disk and data transmission to a computer. It rotates in a circular movement around a vertical shaft. The sensor emits ultra-low (ULF) and very low frequencies (VLF) (3 Hz–30 kHz). (b) The setup showing the sensor, the Raspberry Pi, and the computer connected to them
Source: Created by the authors

The substances we will be studying fall into the category of fertilizers and include ammonium phosphate, potassium phosphate, ammonium nitrate, potassium nitrate, and ammonium sulfate. After examining the molecules of these chemical substances, it becomes clear that they share common components. Ammonium phosphate and potassium phosphate both contain the phosphate ion (PO_4^{3-}), which is essential for plant growth, photosynthesis, and nutrient transport within the plant. Ammonium nitrate and potassium nitrate contain nitrate ions (NO_3^{-}), which provide nitrogen necessary for the synthesis of amino acids, proteins, and chlorophyll. Ammonium sulfate includes sulfate ions (SO_4^{2-}), providing sulfur, an essential element for producing amino acids and enzymes.

By studying these compounds, researchers areable to understand the way fertilizer application may be improved, and sustainable farming practices can be accomplished. Additionally, analyzing their resonance frequencies can give us information about their structural integrity, which is important for safe storage and application. All in all, the study of these fertilizers contributes to the progress of agricultural science and the development of solutions to continuous farming challenges. Besides their agricultural uses, fertilizers can also be used as simulants in various fields, including military testing and the calibration of explosive detection instruments. Simulants are materials specifically designed to present similar properties of hazardous or illegal substances. In addition to research, they have been used for training and for operations. For instance, emergency response teams and military personnel can practice in environments that simulate the chemical conditions of the harmful chemicals without being in real danger. In the case of biological simulates, trainees are allowed to practice in bio-hazard situations without actual danger to them. Medical simulations mean we can research drug effects on patients without giving them any kind of harmful substances. Explosive simulants, in particular, are essential for testing detection systems in airports and other high-security locations. Commonly used simulants include diethylene glycol for industrial chemicals, Bacillus subtilis for simulating anthrax, and glycerin as a simulant for explosives. Using these simulants is important for carrying out safe and effective training, research, and development, as well as for improving security protocols. Explosive simulants are specifically formulated to replicate the physical and chemical properties of actual explosives, offering a safe alternative for a variety of critical applications. Their use allows security personnel at airports, border checkpoints, and other high-security areas to practice identifying, handling, and neutralizing explosive devices in realistic scenarios, without the risk of accidental detonation. Military units also benefit from these simulants by practicing bomb disposal techniques in a safe environment. Fertilizers' chemical composition often contains similar components found in real explosives. That makes them particularly effective as explosive simulants. This chemical similarity makes fertilizers an ideal substitute for explosives in training and testing scenarios, providing a safe yet realistic alternative. Furthermore, fertilizers are valuable in research and development for the testing and calibration of explosive detection systems, such as scanners and sensors. Fertilizer-based simulants are a great outcome for researchers as they allow us to analyze the sensitivity and reliability of these devices, making sure that the distinction between non-threatening substances and genuine threats is possible. If they can produce results that match up with reality, this will lead to improved safety and security in public spaces such as airports, seaports, and other high-risk areas, [13], [14], [15], [16], [17].

Returning once again to the materials to be studied for these specific experiments, a brief description of their use follows.

Also, two tables will be provided, Table 1 and Table 2 in Appendix. The first contains the chemical formulas of each substance, while the other consists of the shared components of each substance with the others.

The chemical formula for ammonium phosphate is $(NH_4)_3PO_4$ (Figure 3). It is a key compound for agricultural applications as well as industrial use. Ammonium phosphate belongs to a type of water-soluble ammonium phosphate salts, which are essential in the production of fertilizer and chemical products. Famous for its effect as a fertilizer, ammonium phosphate is generally used in soil amendment, where it aims to increase nutrients. In the initial stage, we usually see a temporary increase in soil acidity (PH), but over time it becomes more acidic when ammonium nitrate is used. Due to the fact that it converts ammonium ions into ammonia under alkaline conditions, it is not suitable for use with alkaline substances, [18], [19]. For a solution of ammonium phosphate, pH is typically about 7.5 ~ 8.

The chemical formula is as follows:

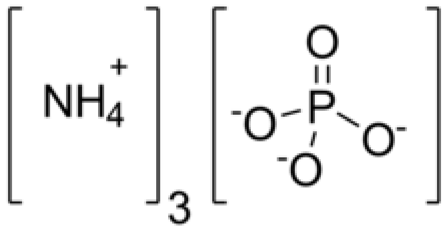

Fig. 3: The chemical formula of ammonium phosphate, which exhibits an ionic bond
Source: Created by the authors

Ammonium sulfate $(NH_4)_2SO_4$ is an important compound in various industrial applications. Its appearance is typical white or slightly yellow crystals, and in aqueous solution, it is acidic. The compound is insoluble in alcohol, acetone, and ammonia, [20], [21], [22]. It is also hygroscopic, which means that it absorbs moisture from the air and becomes solid. Ammonium sulfate decomposes completely into ammonia gas, nitrogen gas, sulfur dioxide, and water when heated above 513 C. It is a nitrogen-based fertilizer, and one of the most effective. Ammonium sulfate is well liked for its quick action and water solubility in a variety of soils and crops. It is especially popular as a chemical fertilizer for alkaline soils, [23]. It releases ammonium ions in soil, which help to lower pH levels while at the same time providing essential nitrogen for healthy plant growth.

The chemical formula for ammonium sulfate (Figure 4) is:

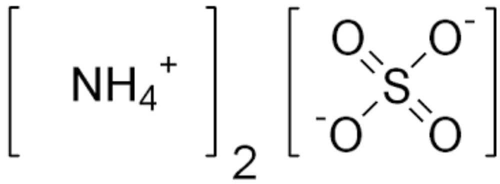

Fig. 4: Chemical Formula of Ammonium Sulfate
Source: Created by the authors

Potassium phosphate (Figure 5) is a highly effective fertilizer in crystalline form that is fully water-soluble and provides only phosphorus and potassium. Due to the important roles these nutrients play in enhancing crop quality, this fertilizer is widely used to improve harvest outcomes. Its complete solubility makes it ideal for a variety of intensive open-field crops, low-cover crops, greenhouse cultivation, and nurseries. It can be applied through both fertigation and foliar spraying. As it does not contain nitrogen, potassium phosphate is the preferred choice for supplying phosphorus and potassium when nitrogen levels need to be controlled. Its solubility increases with higher water temperatures, and it maintains a moderately low pH, [24], [25]. The chemical formula of potassium phosphate is as follows:

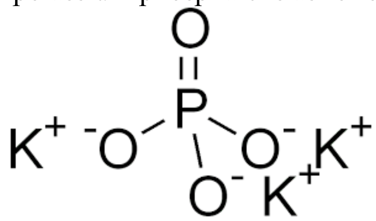

Fig. 5: Ionic compound of Potassium Phosphate
Source: Created by the authors

Potassium nitrate (KNO_3), a valuable inorganic compound, constitutes solid nitrogen and possesses extremely wide use, such as a fertilizer and in gunpowder production. White and odorless, this crystalline substance is orthorhombic at room temperature; however, it decomposes below 400°C and gives off nitrogen oxides, [26]. It is slightly soluble in water, but its solubility increases as the temperature rises above 40°C. Potassium nitrate in aqueous solution is almost neutral, and it has neither high hygroscopicity nor toxicity, [27], [28]. Although potassium nitrate is itself not intrinsically explosive, it can cause reducing agents to burn or even ignite.

Its chemical formula is as follows (Figure 6):

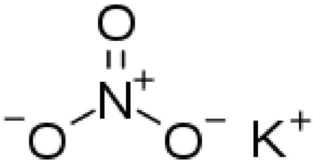

Fig. 6: Ionic compound of potassium nitrate
Source: Created by the authors

Ammonium nitrate (NH_4NO_3) is an inorganic compound widely used in various applications. It is a white, transparent solid that can easily dissolve in water. It is widely used in agriculture as a nitrogen-rich fertilizer, [29], [30], [31]. It is also a critical component in explosives used in mining, excavations, and construction. Ammonium nitrate is the main component of ANFO, which is a common explosive. For making ANFO, it is mixed with oil or other combustible substances to increase its effectiveness. Also, for ANFO production, a lower-density form of ammonium nitrate is used because it absorbs more fuel material, increasing its explosive effect, [32], [33].

Its chemical formula is as follows (Figure 7):

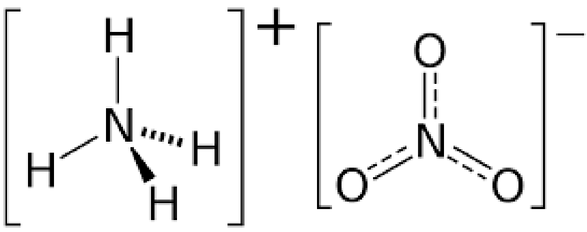

Fig. 7: Chemical formula of ammonium nitrate.
Source: Created by the authors

All the compounds mentioned earlier are classified as fertilizers, but they also have diverse applications in various fields beyond agriculture. The different forms of fertilizers as they are commercially available on the market can be seen in Figure 8 (Appendix), at the end of the paper. These fertilizers come in various physical states and compositions, designed to meet the specific nutrient needs of plants.

In the next section, we will describe the experiment and the procedure we are going to follow.

4 Problem Formulation

From a previous study on pharmaceutical products, it was found that substances with common molecular components are detected at similar frequencies, [11]. This finding has led to a new study into inorganic chemical compounds, such as fertilizers. Each of the selected fertilizers exhibits shared molecular fragments, which provides a good starting point for this research project. The aim of this study is to explore how the vibrational frequencies of a material can be used to identify other materials that are similar in molecular constitution. By understanding this phenomenon, we will be able to use it across a range of fields.

First, we place the first fertilizer, which is ammonium sulfate, in a position in front of the sensor. We set the sensor to an initial frequency and then put it into operation after programming it to change the existing frequency by 10 hertz every 5 seconds. This means that the initial frequency will be increased until it reaches the final frequency that we have set. This way, we will irradiate the material with a range of frequencies. When the frequency emitted by the sensor is the same as the vibration frequency of the molecule of the material, or a part of it, then the speed of the sensor will decrease, and deceleration will occur. The deceleration is measured through angular velocity, which is defined as the rate at which an object rotates around an axis, [34], [35], [36]. Essentially, it describes how fast an angle changes over time. We measure the angle using Gray Code, as described in the previous section.

$$\boldsymbol{\omega = \frac{\Delta\theta}{\Delta t}}$$

After calculating angular velocity, we use it to find angular deceleration, which is the rate at which an object's angular velocity changes over time, [37], [38].

The formula through which we calculate angular deceleration is:

$$\boldsymbol{\alpha = \frac{\Delta\omega}{\Delta t}}$$

This deceleration is measured as described below, and at the same time, the frequency that is being emitted at that moment is recorded. As we can see in Figure 1, the threshold for significant deceleration is to be able to stand out from the noise. This process is repeated many times in order to record all the resonant frequencies of a substance, and they are recorded in a table. Then, this process is repeated from the beginning for all the fertilizers we want to study, which are: ammonium nitrate, ammonium phosphate, potassium phosphate, and potassium nitrate.

Next, we will analyze the data from the recorded frequencies of deceleration. This analysis will help us to find the resonant frequency for each fertilizer. Using the information we have collected, a table of resonant frequencies for each fertilizer can be made. This information is vital to understanding the structural composition and behavior of the fertilizers when exposed to specific frequencies. After the measurements are over, we will find the resonant frequencies of the fertilizers mentioned above. In addition, we will record the common frequencies shared between different types of fertilizer. This data will give us a complete correlation table for all fertilizers. By obtaining the resonant frequencies of each fertilizer, we can use this data for various purposes. For example, through resonant frequencies, we can identify the quality of fertilizers and the degree of purity of a fertilizer. With the resonant frequencies known, we can develop innovative fertilizing techniques to save resources and minimize pollution caused by excess nutrients getting into groundwater or air. In addition, this method shows potential for fertilizer quality certification. Identifying resonant frequencies through ULF and VLF radiation permits compositional authentication to guarantee agricultural standards are fulfilled. Briefly, implementing this approach on fertilizers creates a valuable tool for both scientific research and practical applications within the agricultural and fertilizer industries.

5 Problem Solution

Experimental procedures have shown that fertilizers with similar components in their molecules have common resonant frequencies. For instance, ammonium nitrate and ammonium sulfate can be detected at 7260 Hz. We can assume then that this frequency detects the common part between ammonium nitrate and ammonium sulfate, that is, the ammonium cation (NH_4^+). Since we can detect these fertilizers at the same frequencies, it is obvious that they contain a common part in their molecule, which is the ammonium ion. Furthermore, potassium nitrate and potassium phosphate are both detected at the frequency of 6530 Hz. This observation suggests that the potassium cation (K^+) resonates at this specific frequency. If we have found the resonant frequency of this specific cation, we could after detect this cation in unknown substances. In addition, potassium phosphate and potassium nitrate are detected at the frequency of 6310 Hz. Because of the fact that both substances have the same molecular fragment and can be detected at the same frequency, we can safely assume that the frequency of 6310 Hz corresponds to phosphate anion (PO_4^{3-}). This allows us to detect and identify this ion in various fertilizers or materials in general. Lastly, potassium nitrate and ammonium nitrate are detected at the frequency of 7620 Hz. This frequency corresponds to the nitrate anion (NO_3^-), which is a shared component in these fertilizers. As we can see above, there is a high correlation between resonant frequencies and molecular fragments. The frequencies 5170 Hz and 7260 Hz are related to the ammonium cation, 6530 Hz to the potassium cation, 6310 Hz to the phosphate anion, and 7620 Hz to the nitrate anion. This way we can identify the components of fertilizers based on their resonant frequencies.

All the results of the resonant frequencies and the common frequencies of the substances that contain common molecular parts are presented in Table 3 and Table 4 in Appendix.

6 Conclusion

Experimental observations indicate that fertilizers with common molecular components are detected at the same frequencies. From this, we can conclude that the detected frequencies correspond to molecular fragments rather than entire molecules. Consequently, if we identify all the frequencies at which a substance resonates and emit these frequencies simultaneously, observing a deceleration of the sensor toward a substance would allow us to accurately determine its type. This discovery shows new possibilities for non-invasive substance identification, with significant applications in fields such as agriculture, environmental monitoring, and security. Further research of the sensor's capabilities is needed in order to use it as an advanced detection technology. This sensor can accurately and rapidly identify substances by detecting their resonant frequencies. It is a non-invasive method, which means it does not destroy the samples we want to study. This could be extremely useful in areas such as pharmaceuticals, agriculture, forensics, etc. Additionally, identifying the resonant frequencies of materials and substances could be very useful in fields such as materials science and chemical engineering. The sensor we described, along with the research on fertilizers, has considerable potential for environmental applications. Specifically, the ability to analyze fertilizers based on their resonance frequencies could facilitate more effective management of agricultural practices, reduce pollutant emissions, etc. Additionally, this method could help us monitor the quality of soil and water, providing data for environmental conservation. Furthermore, fertilizers offer a safe solution for testing innovative technologies in security and military fields. Researchers can utilize fertilizers to conduct experiments and develop novel detection techniques without the risks associated with real explosives. In conclusion, fertilizers are very effective as explosive simulants, as they offer safety and low-cost equipment. These advantages make them beneficial for training and development, as they simulate realistic training conditions, improving the effectiveness of security and military operations.

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

Artificial Intelligence was employed to refine the English language and enhance syntactic structure. All the work is original and based entirely on our own experimental research.

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APPENDIX

Table 1. Chemical and molecular formulas of the substances used in the experiments

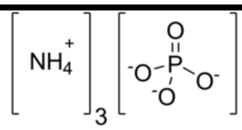
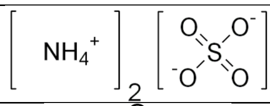
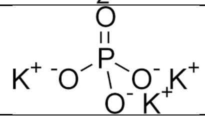
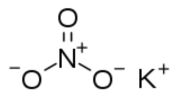
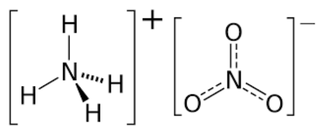
Substance	Molecular Formula	Chemical Formula
ammonium phosphate	$(NH4)_3PO_4$	
ammonium sulfate	$(NH_4)_2SO_4$	
potassium phosphate	K_3PO_4	
potassium nitrate	KNO_3	
ammonium nitrate	NH_4NO_3	

Table 2. The table above presents the common components of the molecules of the substances used in the experimental procedure

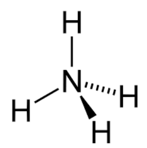
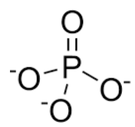
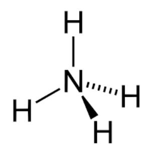
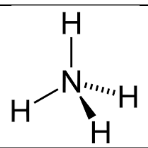
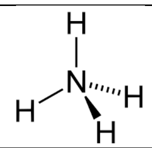
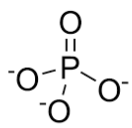
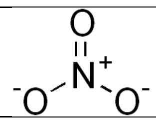
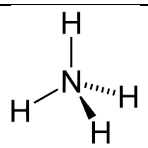
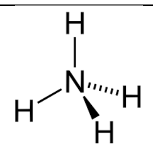
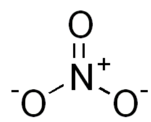
Substance/ Chemical formula	ammonium phosphate $(NH_4)_3PO_4$	ammonium sulfate $(NH_4)_2SO_4$	potassium phosphate K_3PO_4	potassium nitrate KNO_3	ammonium nitrate NH_4NO_3
ammonium phosphate (NH4)3PO4	–			No common parts	
ammonium sulfate $(NH_4)_2SO_4$		–	No common parts	No common parts	
potassium phosphate K_3PO_4		No common parts	–	K^+	No common parts
potassium nitrate KNO3	No common parts	No common parts	K^+	–	
ammonium nitrate NH4NO3			No common parts		–

Table 3. Resonant frequencies of each substance that was used in the experimental procedure

Chemical Compounds	ammonium nitrate	ammonium sulfate	ammonium phosphate	potassium nitrate	potassium phosphate
1.	5170	5060	5510	5460	5020
2.	7260	5170	6170	6060	5880
3.	7620	7260	6310	6530	6310
4.			7260	7250	6530
5.			7740	7620	6830

Table 4. Table with the common frequencies of the substances that share common molecular parts

Chemical Compounds	Ammonium Nitrate	Ammonium Sulfate	Ammonium Phosphate	Potassium Nitrate	Potassium Phosphate
Ammonium Nitrate		7260	7260		
Ammonium Sulfate	7260		7260		
Ammonium Phosphate	7260	7260			6310
Potassium Nitrate	–			7620	6530
Potassium Phosphate			6310	6530	

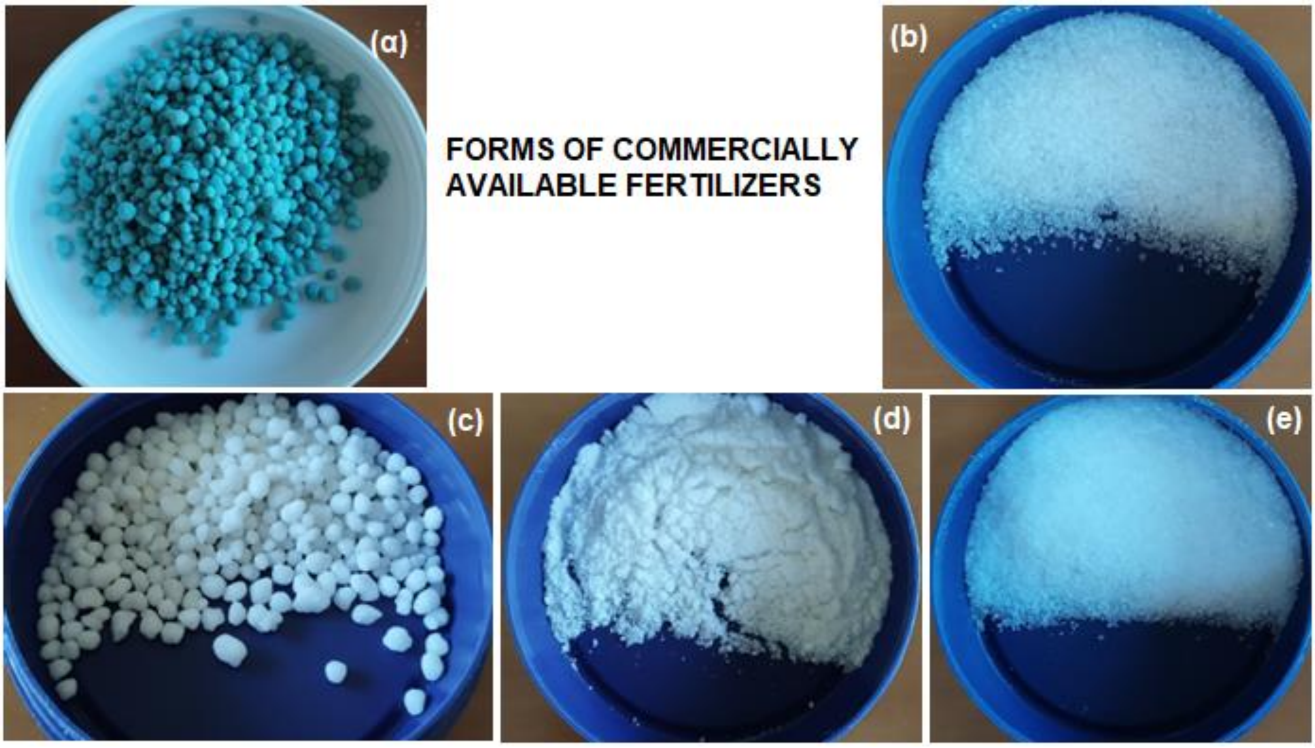


Fig. 8: The different forms of fertilizers as they are commercially available on the market. They come in various physical states and compositions. (a) ammonium phosphate, (b) ammonium sulfate, (c) ammonium nitrate, (d) potassium nitrate, (e) potassium phosphate

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

- Erietta Vasilaki organized and executed the experiments, carried out the data analysis, wrote and revised the original draft.
- Antonia Psaroudaki provided the resources and revised the final draft
- Diamanto Lazari revised the final draft
- Evaggelia Drakaki carried out the data analysis
- Chrysi Logaki Investigation and research
- Emmanuel Antonidakis supervised the experiments, provided the resources and revised the final draft.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.