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Alternate Chemical Compounds as a Condensation Nucleus in Cloud Seeding

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ABSTRACT

Cloud seeding involves boosting precipitation by releasing substances into the air that act as cloud condensation or ice nuclei. These substances encourage the development of clouds and precipitation. It's like giving Mother Nature a gentle push to assist with rainfall in specific areas. The current work aimed to suggest Al_2O_3 as an alternate compound in cloud seeding rather than silver iodide. In this research, a unique approach is used to identify condensation nuclei, which play a crucial role in cloud formation and droplet growth. Various samples and four sources were included in the current study; refrigerated helfa powder, Himalayan salt, generator powder, and pollen, were analyzed using different physicochemical instruments. The proportions of chemical compounds in the samples show that there is 1.392% of Al_2O_3 in Refrigerated helfa which is the highest than in the other 3 sources, while the proportions of elements in the samples indicate that refrigerated helfa contains the lowest toxic compound, and although Al_2O_3 is insoluble in water, it is hygroscopic and can absorb 6.4% of humidity within 24 hours. As for the surface tension, refrigerated helfa shows lower density and surface tension than the other three sources with values of 0.9480 and 47.89 respectively. Al_2O_3 shows high humid absorptivity and refrigerated helfa can be used as a main source for Al_2O_3 which has a low effect on biota and is recommended for use in cloud seeding. However further work is recommended to be carried out in using Al_2O_3 as an alternative compound to silver iodide in cloud seeding.

INTRODUCTION

Clouds consist of small droplets of water or ice crystals that form when water vapor cools in the atmosphere layers and condense around particles known as condensation nuclei which usually are dust, sodium and magnesium salts, silicates, and carbon (AL-Saleem et al. 2019), the presence of these particles participate in the formation of raindrops or snowflakes.

Artificial cloud seeding stands to act as a crucial method for modifying the atmosphere. Its objective is to regulate nature through a certain quantity of precipitation by releasing these substances into the air. These materials serve as condensation nuclei, increasing the possibility of rain or snow, and targeting it to specific locations at specific times (Mielke Jr et al. 1971).

Cloud seeding is a technique used to modify weather by altering the precipitation that falls from clouds. This is achieved by dispersing substances into the air, which act as cloud condensation or ice nuclei, thus influencing the microphysical processes within the cloud. Ground-based generators or aircraft can be employed for cloud seeding, with commonly used chemicals including silver iodide, potassium iodide, dry ice, and liquid propane. Silver iodide, for instance, is often employed to facilitate the formation of ice crystals, providing a foundation for the development of snowflakes. Despite being utilized for decades, the effectiveness of cloud seeding is still a subject of debate, and its success can be different (Wondie 2023, Sadeghi & Yaghoubi 2024).

In 2018, French and his colleagues conducted an experiment related to cloud seeding. Their aim in glaciogenic seeding of orographic clouds was to introduce aerosols into the clouds, thereby influencing the natural progression of cloud particles and boosting winter precipitation in a specific area. They suggested a sequence of events ie., injection of silver iodide aerosol into cloud areas with supercooled liquid water. This triggers the formation of ice crystals, which then grow into sizable particles, eventually causing snowfall (French et al. 2018). However, when exposed to 0.43 µM of AgI, a notable reduction in photosynthetic activity occurred, primarily linked to respiration (with an 80% inhibition) and, to a lesser degree, net photosynthesis (with a 40% inhibition) in both strains of phytoplankton. Additionally, there was a moderate decline in the viability of soil bacteria. These findings indicate that the impact of AgI from cloud seeding on terrestrial and aquatic ecosystems may be moderate when cloud seeding is regularly practiced in a particular region, leading to the accumulation of substantial amounts of seeding materials in the environment (Fajardo et al. 2016).

In 2006, Gou and his coworkers did a project to use CO_2 as an alternate substance to silver, the research project examined the dynamic and microphysical impacts of cloud seeding through liquid carbon dioxide (liquid CO_2) and compared it with AgI, the investigation utilized a 3D cloud model that incorporated seeding processes, the finding was that when liquid CO_2 is introduced into the area of maximum supercooled water, with temperatures ranging from 0 to -5°C, it can generate a significantly more potent dynamic effect and precipitation Gou et al. 2006).

In 2022, Dr. Ghassan published a review study about cloud seeding, in his review, he mentioned that cloud seeding can be executed through various methods, with the most commonly utilized chemicals being dry ice and potassium iodide (Ghassan 2022).

Each droplet of liquid water in a cloud without ice originally began as a minuscule aerosol particle in the atmosphere. These particles belong to the category known as cloud condensation nuclei (CCN), characterized by favorable physical and chemical attributes. These CCN can rapidly expand through the condensation of water vapor when the air's relative humidity exceeds 100% (referred to as water supersaturation). However, to enhance comprehension of the CCN activation process, an investigation delved into the impact of various controlling factors. These factors encompass the formation rate, growth rate, background particle distribution, hygroscopicity, and surface tension of the particles (Ovadnevaite et al. 2017, Cai et al. 2021).

The primary goal of this study was to identify Aluminum oxide as an alternative material serving as condensation nuclei in cloud seeding.

MATERIALS AND METHODS

This study employs a novel method for identifying condensation nuclei, a crucial factor in cloud formation and droplet growth. Three powder variants-Refrigerated helfa powder, Himalayan salt, and generator powder-along with pollen were utilized as samples and analyzed using different physicochemical apparatuses.

Tables 1 show the compounds that are present in the three sources, while Table 2 shows the toxic element concentrations in the three salt sources in ppm. Yet, all the samples must be dried in an oven for one and to ensure precise data collection, the samples underwent desiccation in a desiccator before analysis.

Physical and chemical tests were carried out using different physicochemical instruments; Table 3 shows the solubility of the isolated inorganic salts from the four sources, while Table 4 shows the hygroscopicity of the alternative compounds that could be used in cloud seeding.

Table 1: The proportions of chemical compounds in the samples.

No.	Sample	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	Na_2O %	K_2CO_3 %	MgO %	MnO %	TiO_2 %	P_2O_5 %
1.	Refrigerated helfa	4.761	**1.392**	1.128	26	4.722	0.131	2.152	0.008	0.072	0.33
2.	Carbon generators	0.67	0.249	0.792	**0.891**	0	0	0	0.011	0.06	0.197
3.	Himalayan salt	0.387	0.217	0	0.071	**38.5**	0.067	0.819	0	0.017	0.028
4.	Pollen grains	0.685	0.214	0.357	3.658	0.032	**4.296**	0.38	0.031	0.061	4.866

Table 2: The proportions of elements in the samples.

No	S ppm	Cl ppm	Ba ppm	Co ppm	Cr ppm	Cu ppm	Mo ppm	Nb ppm	Ni ppm	Pb ppm	Rb ppm	Sr ppm	V ppm	Y ppm	Zn Ppm	Zr ppm	As ppm
1.	37	23306	2133	N	N	45	644	299	44	116	291	1612	25	718	1031	660	12
2.	42890	107	5837	17	N	129	839	375	182	223	444	1302	28	1064	479	841	25
3.	**2802**	**59.50%**	**512**	**N**	**N**	**5**	**544**	**272**	**N**	**79**	**241**	**670**	**10**	**603**	**94**	**536**	**6**
4.	6911	3080	5285	14	N	127	842	375	175	219	422	1301	27	1056	434	840	26

1 = Refrigerated helfa , 2 = Carbon generators , 3 = Himalayan salt , 4 = pollen grains

Table 3: The solubility rates of some chemical compounds.

Chemical compounds	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	K_2CO_3	MgO	MnO	TiO_2	P_2O_5
solubility rates in water	0.012g.100 mL^{-1}	Insoluble	Insoluble	React	react	112g.100 mL^{-1}	Acid	Insoluble	Insoluble	hydrolysis

One gram of each compound, and they were tested in laboratory conditions at a relative humidity of (95%) and a temperature of (21°C), Al_2O_3 was heated at a temperature of (115°C) in the oven for an hour, and then the sample was placed in the desiccator to monitor its weight. Table 5 shows the values of surface tension of each salt source and its density.

RESULTS AND DISCUSSION

Table 1 shows the proportions of chemical compounds in the samples in the four sources, and it appears that Al_2O_3 is the main compound in Refrigerated helfa while Table 2 shows the percent of toxic compounds in the four sources by which Himalayan salt is contained in the highest percentage. Despite Table 3 showing that Al_2O_3 is insoluble in water, Table 4 shows the high hygroscopicity of the Al_2O_3 (0.94 g) compound that could be used in cloud seeding.

Table 5 indicates the data of surface tension measured in Newton meter (mN.m^{-1}), refrigerated helfa shows the lower surface tension (0.9480). The correlation between surface tension and cloud seeding is related to the role of surface tension in the formation of cloud droplets.

A study carried out by Facchini et al. 2000, found that a reduction in surface tension compared to that of pure water was noted in wet aerosol and cloud/fog samples. The observed decrease in surface tension is directly linked to the concentration of total soluble organic compounds present in the samples.

Another study carried out by Davies et al. 2019 has shown that the evolving surface tension, particularly due to the presence of organic compounds, plays a significant role in the activation of aerosol particles into cloud droplets. Hence, the examination of surface tension, particularly its changes influenced by different factors, plays a crucial role in comprehending the mechanism of cloud droplet formation,

Table 4: Hygroscopicity of certain compounds.

No.	Compound	Wt. Before Heating	Wt. After Heating	Wt. (after 24hr)	Recommendation	Solubility in water
1.	Al_2O_3	1	0.94	1	Hygroscopic	Insoluble
2.	MgO	1	0.90	0.90	Hygroscopic	
3.	TiO	1	1	1	Non-Hygroscopic	Insoluble
4.	K_2CO_3	1	0.70	1	Hygroscopic	Soluble
5.	Fe_2O_3	1	1	1	Non-Hygroscopic	Insoluble
6.	CaO	1	1	1	Non-Hygroscopic	
7.	Na_2O	1	1	1	Non-Hygroscopic	
8.	MnO	1	0.90	0.90	Hygroscopic	Insoluble
9.	SiO_2	---	---	---	Hygroscopic	Soluble
10.	CaO	---	---	---	Hygroscopic	

Table 5: Value surface tension in Newton meter (mN.m^{-1}) unit.

Samples	Wight.g^{-1}	Density (kg.L^{-1})	Surface tension (mN.m^{-1})
Pollen grains	0.5	0.9811	51.67
Pollen grains	1	0.9790	43.95
Pollen grains	1.5	0.9794	46.27
Pollen grains	2	0.9811	42.03
Refrigerated helfa	0.5	0.9692	55.35
Refrigerated helfa	1	0.9807	52.49
Refrigerated helfa	1.5	0.9475	49.40
Refrigerated helfa	2	0.9480	47.89
Carbon generators	0.5	0.9459	67.17
Carbon generators	1	0.9465	70.08
Himalayan salt	0.5	0.9476	68.30
Himalayan salt	1	0.9942	62.11
Himalayan salt	1.5	0.9856	56.42
Himalayan salt	2	0.9772	49.44

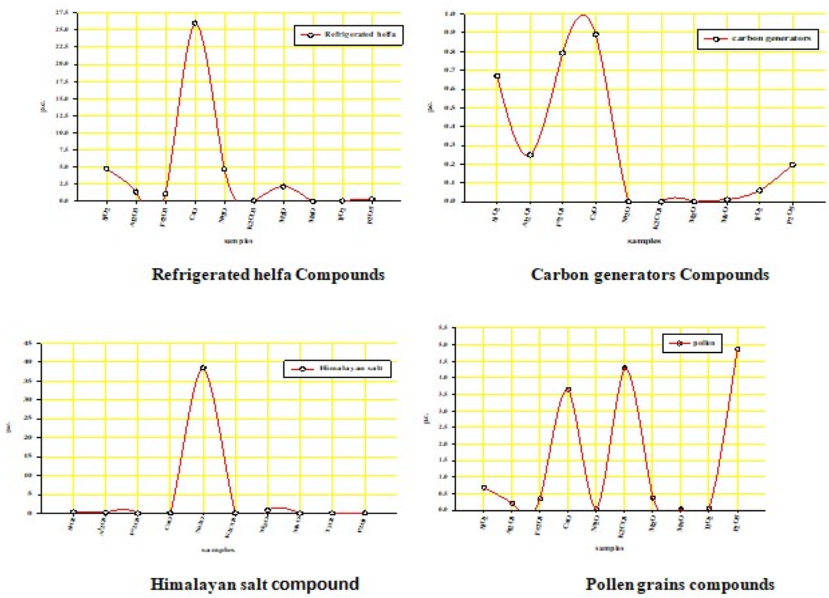

Fig. 1: The main compounds in the four compounds.

a key aspect in the realm of cloud seeding techniques. Nevertheless, establishing a precise connection between surface tension and the practices of cloud seeding may necessitate additional focused research and analysis.

Fig. 1 supports the data in Table 1 and shows the main compounds in each source, and it is clear from the figure that the main compound in Refrigerated helfa is Al_2O_3, while in Carbon generators are CaO, however, in Himalayan salt is NaO, and Pollen grains is K_2CO_3.

The possibility of utilizing aluminum oxide in cloud seeding involves dispersing fine particles of this compound into clouds to encourage precipitation. The aluminum oxide particles can serve as nucleation sites, promoting the coalescence of water droplets and enhancing the likelihood of rainfall. This technique is employed in weather modification efforts to potentially increase precipitation in targeted areas, although its effectiveness and environmental impact remain subjects of ongoing research and discussion.

Repeated application of cloud seeding with AgI may have a moderate impact on the biota residing in terrestrial and aquatic ecosystems, particularly when substantial amounts of seeding materials accumulate in the environment (Fajardo et al. 2016), this expectation of the hard effect of silver iodide on the biota of soil in addition to its toxicity

In 2021, Li and his coworkers (Li et al. 2021) studied the effect of silver ions on human lungs; the research indicates that silver ions released from nanoparticles caused cell necrosis by facilitating the influx of Na^+ and Ca^{2+} ions, leading to pulmonary inflammation through the elevation of mitochondrial-related contents released from these necrotic cells.

Hill et al. (2012) mentioned that it is possible to use aluminum oxide in cloud seeding. Cloud seeding is a weather modification technique that involves spraying microscopic particles into clouds to encourage the formation of ice crystals, which can lead to precipitation. Aluminum oxide, along with other substances such as silver iodide and dry ice, has been used as a seeding agent in various cloud seeding efforts

In 2015, the National Research Council confirmed that the use of aluminum oxide for cloud seeding is mentioned as a part of experiments and operations to modify weather, such as increasing snowfall or suppressing lightning

In 2020, an article published in SBS Indonesian (Source: Australian Geographic) stated that Aluminum Oxide is a substance capable of serving as the essential nuclei where moisture gathers to create precipitation.

Godlee (2022) declared that aluminum oxide is a potential substance for cloud seeding to induce rain and its effectiveness and environmental impact of using aluminum oxide for cloud seeding are subjects of ongoing research and debate.

CONCLUSIONS

- Four sources were investigated in the current study; refrigerated helfa powder, Himalayan salt, generator powder, and pollen.

- The hygroscopicity and solubility of compounds were measured in the four sources.
- Refrigerated helfa can be used as a main source for Al_2O_3.
- Al_2O_3 shows high humid absorptivity.
- Due to the specifications of Al_2O_3, it is recommended to be used in cloud seeding due to its low effect on biota.

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