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Cloud Seeding Technology: An Alternative Way to Get Rains

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Abstract

Water is one of the most basic commodities on earth sustaining human life. In many regions of the world, traditional sources and supplies of ground water, rivers and reservoirs, are either inadequate or under threat from ever-increasing demands on water from changes in land use and growing populations. Only a small part of the available moisture in clouds is transformed into precipitation that reaches the surface. This has prompted scientists and engineers to explore the possibility of augmenting water supplies by means of cloud seeding. Cloud seeding is a form of weather modification, a way of changing the amount or type of precipitation that falls from clouds, by dispersing substances into the air that serve as cloud condensation or ice nuclei, which alter the microphysical processes within the cloud. The most common chemicals used for cloud seeding include silver iodide, potassium iodide and dry ice. Liquid propane, which expands into a gas, has also been used. Cloud seeding is done to enhance the amount of precipitation that falls in a region, disperses fog and clouds so that a place can remain dry through precipitation, minimize the sum of cloud cover, purify the air of pollutants, and assist in extinguishing wildfires through rain.

Keywords: Cloud Seeding; Types of Cloud Seeding; Rain Enhancement

Introduction

Water is a necessity on Earth, and global water consumption is increasing significantly. In many regions of the world, traditional sources and supplies of ground water, rivers and reservoirs, are either inadequate or under threat from ever-increasing demands on water from changes in land use and growing populations. Water is the most significant naturally occurring renewable resource. Water availability has been steadily deteriorating across a large portion of the globe in recent years. Numerous nations, many of which are in semiarid parts of the world, are currently engaged in climate engineering projects in the hope of expanding their access to freshwater resources. Only a small part of the available moisture in clouds is transformed into precipitation that reaches the surface. This has prompted scientists and engineers to explore the possibility of augmenting water supplies by means of cloud seeding. Cloud seeding is a 75 year old used to modify suitable clouds with 'seed' particles to increase rainfall [1]. These seed particles are 'cloud condensation nuclei (CCN), a particle on which water vapour condensates' or 'ice nuclei particles, a particle on which water freezes', a subset of suspended particulates in the atmosphere named aerosol particles. These CCNs have an affinity for water vapour to form cloud droplets. The ice nuclei particles can form ice particles. Typically an aircraft is used to dispense these particles near the cloud base or cloud top. Cloud base seeding is where particles are released below the base of cumulus clouds (appear as a cauliflower) that have a warm base (the temperature of the cloud base

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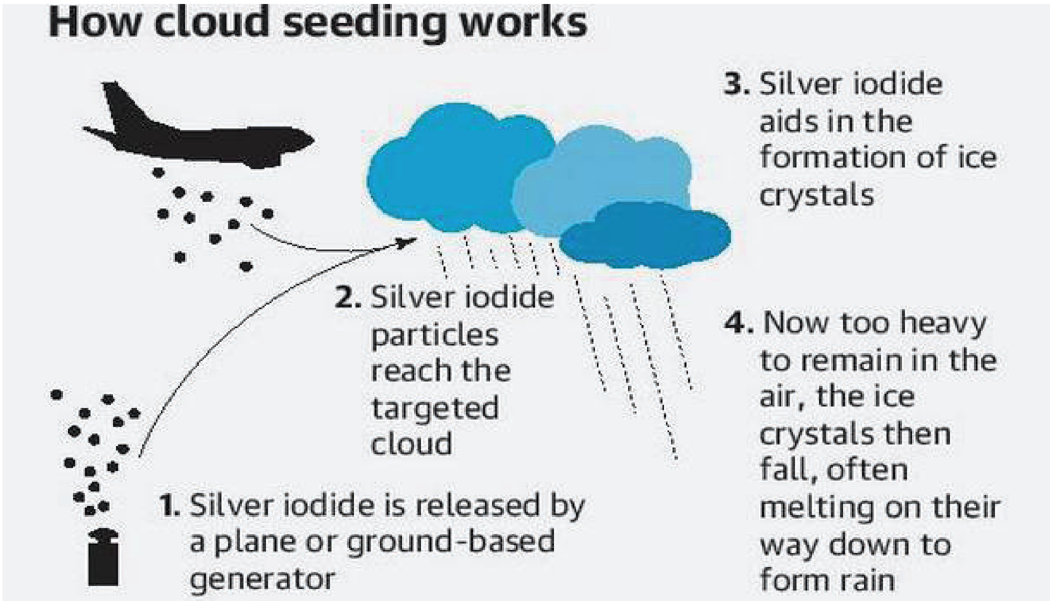
is warmer than zero degrees). Cloud top seeding is done in cold clouds (where the temperature is below zero degrees). Warm cloud base seeding is called hygroscopic seeding and cold cloud seeding is called glaciogenic seeding (Figure 1).



Source: Salem (2022) [2].

Figure 1: Cloud Seeding using Silver Iodide.

Hygroscopic Seeding

The term "hygroscopic seeding" has been associated with warm cloud seeding. The objective is to enhance rainfall by promoting the coalescence process using hygroscopic particles. In warm clouds, sodium chloride (NaCl), potassium chloride (KCl), or calcium chloride ($CaCl_2$) are used as the seeding agents, and this method is called hygroscopic cloud seeding.

In hygroscopic seeding, coalescence (drop spectrum broadens and during the nucleation process by seeding with larger than natural CCN of 0.5µm to 3µm dry diameter) of water droplets is promoted to improve the efficiency of rain formation. Hydroscopic particles (salt powders and hygroscopic flare-produced particles) are injected into a cloud to increase the concentration of "collector drops" that can grow into raindrops by collecting smaller droplets and enhancing the formation of raindrops.

- Seeder aircraft dispenses salt or pyrotechnic flared aerosol particles as seeding material at the cloud base.
- Aerosol particles transform to CCN.
- Water vapor condenses on to CCN to form cloud droplets.
- Droplets grow by accumulating more water vapor by diffusion.
- When droplet diameter exceeds the threshold value, collision and coalescence of droplets takes place,
- Large droplets form and rain out

Glacigenic Seeding

This involves the injection of ice-producing materials into a super cooled cloud to stimulate precipitation by ice particle growth. The objective of glaciogenic seeding is to introduce seeding material that will produce the optimum concentration of ice crystals for precipitation formation. In a cloud with a temperature below freezing (0˚C), typically, silver iodide (AgI) is used as the seeding agent, and the seeding method is called glaciogenic seeding. Silver Iodide (AgI) is used as a cloud-seeding agent because it has a crystalline structure similar to an ice crystal; it acts as an effective ice nucleus at T = - 4˚C and lower. The idea is to trigger ice production in supercooled clouds and enhance precipitation. The seed particles (AgI pellets) will act as sites where water in the subzero temperatures (supercooled water) deposits and forms ice crystals. These ice crystals grow by depositing more water as well as colliding with other ice crystals falling from above. They further fall through the warmer temperatures and melt to form raindrops.

Brief description of Cloud Seeding Technology

Cloud seeding mainly requires advanced equipments and facilities, including aircraft, a meteorological station network to monitor the clouds, a rainfall monitoring ground network, a network for data collection and processing, and a satellite image transmission networks. Materials used for cloud seeding include silver iodide (in the form of pyrotechnique), azotic cooling liquid, dry ice (CO2) and propane. Cooling materials and silver iodide are usually used at a concentration of 2%, for seeding clouds with a graded microstructure. Dispensing the material from the top of the cloud produces better results than dispensing it from the bottom. This is typically done by airplanes or ground generators, with the goal of facilitating the optimal distribution of seeding material among the clouds components containing the largest portion of super cooled water. Cloud seeding projects require establishment of a technical and administrative organization containing:

- A radar and electronic maintenance division.
- Aviation affairs division.
- A data collection division.
- An education and training division.

Source: Bhutwani et al., 2024 [3].

Figure 2: Cloud Seeding Process.

The interaction between cloud dynamics and its microphysics is the most challenging topic in understanding the impact of seeding. The hydrodynamic changes within a cloud upon introduction of cloud seeding particles is envisioned as an aerosol-cloud-precipitation interaction, where more aerosol particles (cloud condensation nuclei) depending on their cloud activation properties may form cloud droplets or ice particles and grow by diffusion at different super saturations as available. There is 26 mm m-2 of water in each column of air with a cumulative amount of 13×103 km3 of water vapour in the atmosphere. Not all water is removed from the atmosphere in the form of rain at the surface. The global warming scenario introduces the idea that dry places get drier and wet places get wetter. The need for freshwater resources is sought in various ways, including rain enhancement through cloud seeding [4].

Need of Cloud Seeding

Drought in India is a regular event occurring almost every year in some Indian states. Because droughts are a normal part of virtually any climate, it is important to develop plans to reduce their impacts. Drought declaration and response management in India have always been a large and complex operation, requiring close, often challenging and coordination between various government levels. It has been observed that affected rural communities suffer from scarcity of drinking water, non-availability of fodder for cattle, migration along with families, and increased indebtedness. Each of these situations has a negative impact on education, nutrition, health, sanitation and the care and protection of children. Drought has resulted in tens of millions of deaths over the course of the 18th, 19th, and 20th centuries in India. Indian agriculture is heavily dependent on the climate of India as a favorable southwest summer monsoon is critical in securing water for irrigating Indian crops. In some parts of India, the failure of the monsoons result in water shortages, resulting in below-average crop yields. This is particularly true of major drought-prone regions such as southern and eastern Maharashtra, Karnataka, Andhra Pradesh, Gujarat, Odissa, Telangana and Rajasthan. Meteorological drought adversely affects the recharge of soil moisture, surface runoff and ground water table. Soils dry up, surface runoff is reduced and ground water level is lowered. Rivers, lakes, ponds and reservoirs tend to dry up wells and tube-wells are rendered unserviceable due to lowering of the ground water table. Indian agriculture still largely depends upon monsoon rainfall where about two-thirds of the arable land lack irrigation facilities and is termed as rain fed. The effect is manifested in the shortfalls of agricultural production in drought years. Social and economic impact of a drought is more severe than the physical and agricultural impacts. A drought is almost invariably associated with famine which has its own social and economic consequences. The total drought-prone area in India amounts to 10.7 lakh square kilometers. On an average, one in every five years is a drought year.

Water covers 70% of our planet, and it is easy to think that it will always be plentiful. However, freshwater we drink, bath in, and irrigate our farm fields is incredibly rare. Only 3% of the world's water is fresh water, and two-thirds of that is tucked away in frozen glaciers or otherwise unavailable for our use. As a result, some 1.1 billion people worldwide lack access to water, and a total of 2.7 billion find water scarce for at least one month of the year. Inadequate sanitation is also a problem for 2.4 billion people; they are exposed to diseases, such as cholera and typhoid fever, and other water-borne illnesses. Two million people, mostly children, die each year from diarrheal diseases alone. Many of the water systems that keep ecosystems thriving and feed a growing human population have become stressed. Rivers, lakes and aquifers are drying up or becoming too polluted to use. More than half of the world's wetlands have disappeared. Agriculture consumes more water than any other source and wastes much of that through inefficiencies. Climate change is altering patterns of weather and water around the world, causing shortages and droughts in some areas and floods in others. At the current consumption rate, this situation will only get worse.

By 2025, two-thirds of the world's population may face water shortages and ecosystems around the world will suffer even more. The Himalayan state of Jammu and Kashmir receives 30% of its annual rainfall in the winter. Several studies indicate that most parts of the Himalayas are getting warmer at a rate faster than the average warming of the earth. Patterns of rain and snow vary throughout the mountains as weather is controlled by dramatic changes in topography and the presence of distinct microclimates in many parts. Climate change also magnifies intense weather making it more destructive. When weather conditions are leading to a very heavy event, even a 10% boost because of climate change could be extremely damaging and could lead to a disaster.

In the run-up to the 2008 Olympics in Beijing, more specifically the opening ceremony, Chinese government openly operated their cloud seeding program so that the first day of the Olympic Games would not be marred by rain or any other unsavory weather. Over 1,000 rockets were fired into the air in the days leading up to the ceremony in an effort to disperse rain clouds that were threatening to dampen the event. The Government of Andhra Pradesh has declared nearly 555 Mandals under Rain Shadow in the year 2005. Cloud seeding was done from 2004-2009. Farmers have been instructed to dial a helpline if they sight clouds that appear to be rain-bearing, so that the moisture can immediately be precipitated through aerial seeding. Two aircraft loaded with flares were equipped to take off at a moment's notice to seed the clouds. Cloud Seeding has ben effective in Ananthapur, Cuddapah, Kurnool, Mahbubnagar, Nalgonda and Ranga Reddy districts.

Thus, cloud seeding holds immense significance in addressing global water scarcity especially in the context of climate change. This technology helps to mitigate the impact of prolonged droughts by boosting rainfall in arid regions. It also contributes to ecosystem restoration and replenishes depleted aquifers, reducing the need for unsustainable groundwater extraction. Essentially, cloud seeding strengthens water resource management and enhances climate resilience, marking it a valuable tool in combating climate change.

Global Cloud Seeding Market

The global cloud seeding market size was valued at USD 375.6 million in 2023 and is projected to grow from USD 406.4 million in 2024 to USD 684.2 million by 2032, exhibiting a CAGR of 6.7% during the forecast period. Asia Pacific dominated the cloud seeding market with a market share of 77.93% in 2023 [5]

Asia Pacific: Asia Pacific held the largest market share in 2023, with a market value of USD 292.7 million. The region ranked 1st due to increasing natural hazards and environmental pollution, with China leading cloud seeding efforts to combat droughts and power shortages.

North America: North America captured the second largest market share in 2023. The region's strong position is driven by significant government investments and the presence of key industry player, placing it in 2nd position.

Europe: Europe is expected to grow moderately during the forecast period, with rising concerns over wildfires and agricultural enhancement. As a result, the region held the 3rd position in the global cloud seeding market in 2023.

Middle East and Africa: The Middle East and Africa is projected to be the fastest growing region over the forecast period. High adoption rates of cloud seeding for agriculture and tourism made this region the 4th dominant player in 2023.

Latin America: Latin America is expected to experience significant growth due to increasing drought and heat wave challenges. In 2023, the region ranked 5th in the global cloud seeding market.

International Status of Cloud Seeding

Weather modification is receiving more attention around the world. As many as 56 countries are involved in such activities for rainfall enhancement, fog suppression, pollution dispersion, weather management, etc. The current comprehensive state of precipitation enhancement science is depicted in Flossmann, et al. [6] in the World Meteorological Organization (WMO) peer review report by the WMO Expert Team on Weather Modification.

The Chronology of Events in the Weather Modification around the World

1940	Dry ice into super cooled liquid cloud cause glaciation [1] Silver iodide (AgI), glaciated supercooled clouds National Academy of Sciences reports, WMO reports, and more. Special Commission on Weather Modification (1966) Statistical analyses using target and control approaches were flawed
1970	Airborne optical array probes and use of radars (polarization) advancing Indian cloud physics studies and cloud seeding experiments by IITM
1980-90s	(After the report by Kerr 1982), no funding for cloud seeding research Orographic cloud systems in Wyoming and Idaho, Rainfall enhancement research from convective storms from South Africa and Thailand Chinese hail suppression experiment in 1980. Currently, the Beijing Weather Modification Office, China is believed to be the world's largest with 37,000 people nationwide working on the cloud seeding aspect 11 year cloud seeding by IITM [7]
2003	NAC Report: Potential application of new technology for evaluating cloud seeding Physical evaluations for cloud structure with aircraft and radar and to model these clouds
2008	Beijing Summer Olympic rain suppression program Cloud Aerosol Interactions and Precipitation Enhancement Experiment (CAIPEEX) Phase I 2009, CAIPEEX Phase II (2010-2011)
2015	Significant advances (radars of different types, radiometers, airborne probes) in observing technologies and modeling capabilities [8] CAIPEEX Phase III (2014-15) pilot experiment
2016	56 countries had active weather modification operations
	WMO Peer review Report 2018: Physical chain of events demonstrated the need for further research on ice and mixed-phase clouds. More research studies are recommended. 36 active weather modification programs in the USA. About half of the projects operate in summer and the other half in winter. Projects are funded by the state government, local government, private sector, and insurance companies. Some projects incorporate a research component.
2019	Several programs exist: The Wintertime cloud seeding to increase snowpack reservoirs, Hail-suppression operations in North Dakota, Rain enhancement from convective storms in Texas, Orographic clouds for the Snowy Mountains of Australia [9]
2020	Documented evidence on snow enhancement on the ground from SNOWIE for glaciogenic seeding
2021	Documented evidence for convective cloud hygroscopic seeding from CAIPEEX using randomization experiment. Seed particle tracking in the cloud

Indian History of Cloud Seeding

In India, pioneering attempts in the field of rainmaking were made by Tata firm in 1951 over Western Ghats using ground based silver iodide generators. Dr. Banerji in the year 1952 attempted cloud seeding with salt and silver iodide by means of hydrogen filled balloons released from the ground. The committee on the Atmospheric Research of the Council for Scientific and Industrial Research (CSIR) recommended in 1953 that a Rain and Cloud Physics Research (RCPR) unit be set up for undertaking extensive scientific studies on cloud physics and rainmaking. RCPR conducted long term cloud seeding programme over North India using ground based salt generators during the period 1957-1966. The results showed an increase in rainfall by 20%. RCPR later became part of IITM (Indian Institute of Tropical Meteorology). IITM conducted similar experiments over Tiruvallur (state of Tamilnadu) during 1973, 1975-1977. The seeding experiments were also done over Mumbai in the monsoon seasons 1973 and 1974. In the same years, IITM carried out cloud seeding operations over Rihand Dam catchment in the state of Uttar Pradesh. In 1975, operational programme of cloud seeding was conducted over Linganamakki catchment area in the state of Karnataka. These programs were operational; hence their effect in increase in rainfall could not be assessed. IITM carried out cloud seeding experiment over Baramati region of the Maharashtra state during the period 1973-74, 1976, and 1979-86. Murthy [7] conducted cloud seeding experiments over 100 km inland from the west coast of India during 1973-74, 1976, 1979-86; over an 11 year period cloud seeding and resulted in an increase in rainfall of 24% at 4% level with certain conditions. It was found that hygroscopic particle seeding accelerated collision coalescence. Since 2003, operational cloud seeding programs by various state governments (Gujarat, Maharashtra, Karnataka and Andhra Pradesh, Tamil Nadu) have been conducted. All experiments in the past are based on area seeding and do not apply to the approach of isolated cloud seeding and are challenging to make conclusions.

Indian water resources are declining and India is going to be water stressed country by 2025. 16 percent of total area is drought prone and farmers are committing suicides, therefore cloud seeding is required for tackle this critical situation.

Cloud Physics and weather modification research experiments in India

1955	Rain and Cloud Physics Research (RCPR) was established at the Council of Scientific and Industrial Research (CSIR), New Delhi
1967	The RCPR transferred to IITM, Pune in 1967 and the following developments took place at IITM Laboratory studies and field studies on the microphysics of clouds and precipitation mechanisms in tropical monsoons The study of warm cloud modification for enhancement of rain Laboratory experiments for ice nucleation, freezing of water drop under super cooling conditions and ice multiplication in super cooled clouds. Identification of seeding material and their efficiency for the collision-coalescence of water drops under the influence of an electric field The role of the electric field in precipitation formation was attempted with laboratory experiments. 1968 to 1975 Cold Cloud Seeding Experiment during the winter seasons using silver iodide as a seeding agent and radar observations of aerial echo-coverage and echo height of clouds within 50 km around Delhi. The analysis based on echo height indicated 11% increase in rainfall as a cumulative result and was statistically significant.
1973 and 1977	Thirunallar (near Chennai) field experiment during the South- West and North-East monsoon seasons based on using ground-based generators, results were not significant for rain enhancement.
1973-1985	Pune Aerial experiment for warm cloud seeding to assess seed ability criteria for possible rain enhancement. The seeding under a randomized process using sodium chloride powder as the seeding agent. The experiments were inconclusive regarding the efficiency of warm cloud seeding for rain enhancement. However, seed ability criteria were identified. The potential for enhancing rain was found to be higher for aerial cloud seeding systems.
The following State Governments have undertaken operational cloud seeding	
• 2012: Three river basin project in Karnataka state	
• 2003-2016: Andhra Pradesh Cloud seeding	
• 2017, 2019: Varshadhaare project in Karnataka state	
• 2019: Maharashtra Rainfall Enhancement Project	

(Ref. 50 years of IITM by D. R. Sikka and IITM Publications).

Benefits of Cloud Seeding: Cloud seeding is primarily used in areas experiencing drought or where there is a desire for additional rainfall. A few examples are the United Arab Emirates' use of cloud seeding to address water challenges and China's use of it to regulate rainfall in Beijing. The scientific process is often considered for its potential benefits in various contexts:

Rain production: In areas where rain is desperately needed, cloud seeding may be the only way to produce rain. In areas where there is little precipitation, silver iodide is used to induce rain production. Rain is necessary to keep the area hydrated and fertile for the growth of crops and other plants. Improvement in Economy: Where there is rain, there is farm produce. Farms that yield better can help the local economy and feed the people (and even animals). Cloud seeding can greatly improve the living conditions in dry, arid places.

Weather Regulation: Cloud seeding, in some ways, allows us to control the weather in a specific area. It does more than just produce rain; it also regulates water vapor, preventing damage caused by destructive hail and storms.

More Habitable Dry Places: Local people have an impressive way of adapting to their natural environment. But inhospitable places rarely visited by rain can be inhospitable to tourists and foreigners. Such places can be made habitable through cloud seeding.

Agricultural benefits: Increased precipitation from cloud seeding can benefit agricultural productivity by providing necessary water for crops during dry periods. It creates rain, providing relief to drought-stricken areas e.g. Project Varshadhari in Karnataka in 2017.

Hydropower generation: Increased precipitation can contribute to higher water levels in reservoirs used for hydropower generation, increasing electricity production. Cloud seeding experiments have shown to augment production of hydroelectricity during the last 40 years in Tasmania, Australia.

Wildfire mitigation: In fire-prone areas, boosted precipitation from cloud seeding can help dampen dry conditions and reduce the risk of wildfires. For example, domestic cloud seeding drones built by Sichuan Tengden Technology put out mountain fires in Yibin (a city in China).

Improved air quality: Cloud seeding promotes rainfall that removes pollutants and particulate matter from the atmosphere, which can improve air quality.

Water Pollution Control: Cloud seeding can help to maintain minimum summer flows of the rivers and dilute the impact of treated wastewater discharges from municipalities and industries. Cloud seeding can potentially be used to settle down toxic air pollutants through the rain. Recently, the Central Pollution Control Board in India along with other researchers mulled the use of cloud seeding to tackle Delhi's air pollution.

Fog Dispersal, Hail Suppression, and Cyclone Modification: During the winter, the cloud seeding programme is used to increase the mountain snowpack so that additional runoff is received during the spring melt season. "Project Sky Water" of the U.S.A. in 1962 for weather modification through cloud seeding aimed at fog dispersal, hail suppression, and cyclone modification.
Tourism: Cloud seeding can transform typically dry areas much more hospitable to enhance tourism.

Before using cloud seeding, governments and people should adopt and implement various water-source management strategies, such as rainwater harvesting, artificial recharge of aquifers, and concurrent use of surface and groundwater.

Challenges Involved in Cloud Seeding

Requires potentially harmful chemicals: The chemicals used in cloud seeding might be potentially harmful to plants, animals, and people, or the environment. There is no substantial study done on the implications of silver iodine on the environment. Silver iodine may cause iodism, a type of iodine poisoning where the patient exhibits running nose, headache, skin rash, anemia, and diarrhea, among others. It has been found to be highly toxic to fish, livestock and humans.

Is not fool proof: Cloud seeding necessitates the presence of rainclouds. It will not work on any other cloud formation. Furthermore, seeded clouds may travel to another location and cause precipitation in the intended location. As a result, whether cloud seeding is truly effective in producing rain can be debated.

Expensive: It is very expensive to produce artificial rain. It involves processes such as delivering chemicals to the sky and releasing them into the air by flare shots or airplanes, which involves huge costs and logistic preparation. Poverty-stricken areas suffering drought or famine may need external funding to have cloud seeding.

Poses weather issues: If not properly regulated or controlled, cloud seeding can result in undesirable, if not entirely destructive, weather conditions such as flooding, storms, hail risks, and so on. Places with meager or no rain usually do not have the infrastructure to handle too much rain. These areas may get quickly flooded as a result of cloud seeding, causing more harm than good.

Abnormal Weather Patterns: It might ultimately change climatic patterns on the planet. Places that normally receive moisture might start experiencing drought due to the artificial process of adding chemicals to the atmosphere to stimulate rain.

Pollution: As artificial rain falls, seeding agents like silver iodide, dry ice or salt will also fall. Residual silver discovered in places near cloud-seeding projects is considered toxic. As for dry ice, it can also be a source of greenhouse gas that contributes to global warming, as it is basically carbon dioxide.

Cloud seeding has been discovered to be ineffective now because it primarily affects clouds that are already showing signs of rain. As a result, it is unknown whether it is the cause of the rain. In general, trying to cure drought is an ongoing battle, and cloud seeding is the most recent technology used for this. Determining whether a technique is good or bad may be more difficult than is thought. The opportunities for achieving high rates of progress in agriculture and industrial growth are directly related to a nation's availability of water resources, so cloud seeding becomes a necessity to address this critical situation [10-15].

Cloud Seeding and the Water Wars of Tomorrow

Fueled by the climate crisis and El Nino, 2024 has been a year of global extreme temperatures. Australia suffered a string of heat waves through its summer months and, in February, parts of West Africa reported 50 Degree C temperatures that made "time stand still." From March, heat waves hit Mexico, the southern United States and Central America, then India, southern Europe, Japan, and Saudi Arabia, where 1,300 people died during the Hajj pilgrimage [16]. At the beginning of July, the temperatures in Antarctica were 28 Degree C higher than usual on some days in July. The number of people exposed to extreme heat is growing exponentially due to climate change in all world regions. Heat-related mortality for people over 65 years of age increased by approximately 85% during 2000–2004 and 2017–2021. From 2000–2019, studies show that about 489,000 heat-related deaths occurred each year, with 45% in Asia and 36% in Europe. In Europe alone in the summer of 2022, an estimated 61,672 heat-related excess deaths occurred. High-intensity heat wave events can bring high acute mortality; in 2003, 70,000 people in Europe died as a result of the June–August event. In 2010, 56,000 excess deaths occurred during 44 day heat wave in Russia. Birds were falling off the sky due to the heat and reptiles come out seeking shade. Mammals and other wild animals got affected by severe water shortage [17].

Looking 100 years into the future, technologies related to cloud seeding will be undoubtedly highly advanced and at that point, barring a global regime outlining their rightful use, the richest countries, would be able to invest most heavily and ultimately control the clouds. Apart from everything else, a fundamental problem remains with cloud seeding. The technique works – to the extent that its effects can actually be set apart from natural processes – when there are clouds. But what if there are no clouds in the sky? What will be squeezed then to make rain? And what can guarantee that the available clouds will always be able to deliver as much as is necessary for crops? Further, even if a cloud is seeded successfully, it does not mean that the rain or the snow will fall exactly on the spot where it is wanted. And finally, with regard to the expensive process of desalinization, this establishes economic and political dependencies for countries that have no direct access to oceans and seas. How could cloud seeding thus be applied effectively and equitably in a world of growing politico-economic hostilities and fragmentation?

Conclusion

It may be concluded that cloud seeding operations are boon to the farmers especially where rain fed agriculture is followed and cloud seeding is an opportunity to fill the reservoirs paving way towards increasing the ground water levels at favorable conditions. More the water resource of a nation the higher will be the opportunities for achieving high rates of progress in agriculture sector and industrial growth. Apart from rain making, we can save the crops by suppressing the hail storms well in advance during the pre-monsoon showers along with the advantage of dissipating the profuse rainfall during the floods. In the context of more droughts and floods due to climate change, cloud seeding techniques can be effectively used to augment the adverse effects and help the society in multifariously.

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