Challenge to Effective Drought Measures by Utilizing a New Artificial Rainfall Device

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INTRODUCTION

It is said that about 1.4 billion km^3 of water exists on the earth, but water in rivers and lakes which people can easily access accounts for only about 0.01% (about 0.1 million km^3) of it. In addition, the United Nation has highlighted various water issues in recent years, including the growing world population and climate change.

Japan's average precipitation is roughly twice the world's average. However, because Japan has a large population in a small land area, the precipitation per capita is about one third of the world's average. Also, the flow of rivers sharply fluctuates due to steep terrain and a considerable amount of rainfall being concentrated in a limited season, so Japan has unfavorable conditions for the use of water.

Large-scale droughts occurred in Japan in the 1950s, so the Bureau of Waterworks, Tokyo Metropolitan Government constructed four ground-based AgI generators in 1966, and has operated them for a total of 800 days. It has been half a century since their construction and these devices have aged severely, so we decided to develop a new ground-based AgI generator.

In this paper, we report on a newly developed device and a quantitative evaluation of rainfall enhancement by cloud seeding derived from numerical simulations. This research was conducted in cooperation with the Meteorological Research Institute, Japan Meteorological Agency.

Overview of the Artificial Rainfall Device (Ground-based AgI Generator)

◆Artificial Rainfall (Rainfall Enhancement)

- Rainfall enhancement is made by artificially stimulating clouds to promote the formation of precipitation in clouds
- Cloud droplets that constitute clouds sometimes exist in a liquid phase even at temperatures < 0° C (super-cooled)
- Super-cooled cloud water sometimes does not converts to precipitation due to insufficient number of naturally-formed ice crystals in clouds.
- Rainfall enhancement is made by sending artificial ice nuclei into super-cooled clouds and promoting ice crystal growth into snow/graupel at consumption of cloud water. Snow/graupel melt into rain during their fall

◆Location of Artificial Rainfall Devices

The Tokyo Waterworks ground-based AgI generators are located at 4 sites around Ogouchi Reservoir

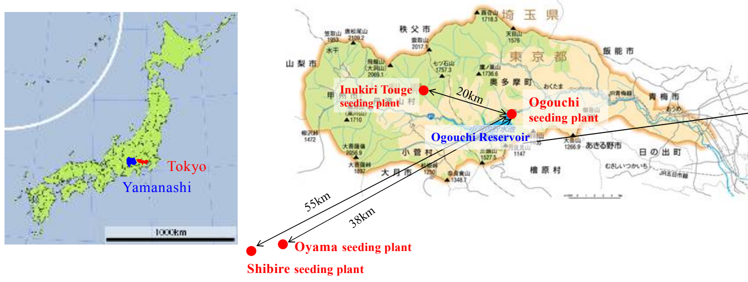

Figure 1. Location of Ground-based AgI Generators

Figure 2. Ogouchi Reservoir
- A waterworks dam built with the purpose of securing tap water supply for Tokyo, the capital
- Construction completed in 1957

◆Mechanisms of the Tokyo Waterworks Artificial Rainfall Devices

- The Tokyo Waterworks chose a method of burning silver iodide (AgI) acetone solution, sending AgI particles to the sky with a blower, and increasing rainfall by making ice crystals in clouds
- After combustion, acetone decomposes into carbon dioxide and water, but AgI turns into particles and is released into the atmosphere, where it diffuses
- As artificial ice nuclei, diffused AgI particles promote the precipitation formation via ice crystal processes.

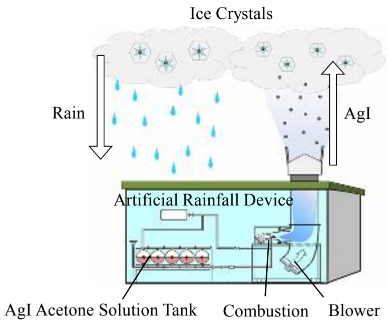

Figure 3. Mechanism of the Artificial Rainfall Device

Figure 4. The Tokyo Waterworks Artificial Rainfall Device

Quantitative Evaluation of Rainfall Enhancement

◆Evaluation of seedable clouds by weather observation

[Purpose]
Assess the occurrence frequency of cold clouds suitable for AgI seeding

[Method]
We conducted year-round ground-based observations using several remote sensors, near Ogouchi AgI seeding site

[Results]
- Cold clouds suitable for AgI seeding (type 1, 2) occur at a higher frequency than warm clouds (Type 3) suitable for hygroscopic seeding
- Especially from spring to summer, occurrence frequency of seedable clouds is high and more than 10% of time in June

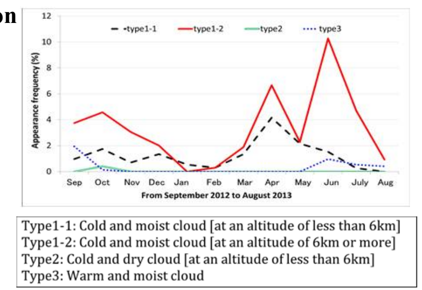

Figure 5. Occurrence frequency of seedable clouds

◆Seeding effects observed by an instrumented aircraft

[Purpose]
Find the ground-based AgI seeding effects on convective clouds and precipitation

[Method]
Generate and disperse AgI particles and observe the advection/diffusion state of AgI particles using an instrumented aircraft

[Results]
Compared with unseeded convective clouds (Figure 6, left), more ice crystals formed by AgI particles were observed in the convective cloud near ground-based AgI seeding site (Figure 6, right), demonstrating the effect of AgI seeding

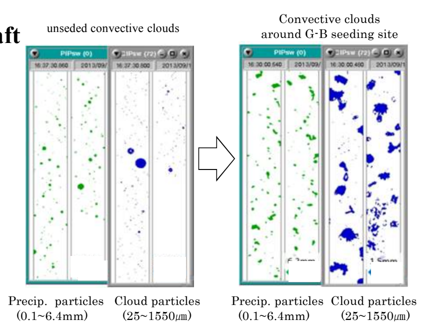

Figure 6. Comparison of ice crystals

◆ Evaluation of AgI seeding effect by numerical simulations

[Purpose]
Quantitatively evaluate the effects of ground-based AgI seeding on rain enhancement

[Method]
- We evaluate the AgI seeding effects only for clouds occurred under favorable weather conditions
- On the supercomputer of the Meteorological Research Institute, we conducted AgI seeding experiments using the Meteorological Agency non-hydrostatic model (NHM)
- Target area: 30 km × 20 km area and 80 km × 80 km area centering on the Ogouchi Reservoir drainage area

[Result]
- In the region 30 km × 20 km, the average seeding effect in rain enhancement was about 5% (Fig. 7)
- AgI sometimes reaches an altitude where it acts as ice nuclei (Figure 8)

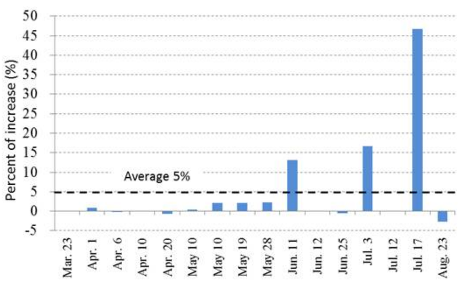

Figure 7. Effects of ground-based AgI seeding on rainfall over the Ogouchi Reservoir drainage area

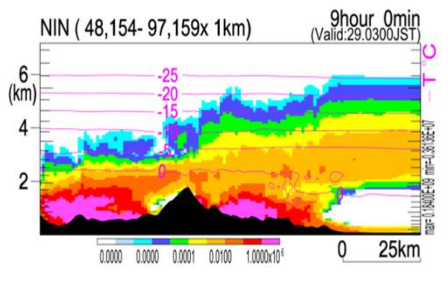

Figure 8. Typical example of number concentration of AgI particles released from ground-based generators

New Artificial Rainfall Device

- Change combustion method from self-burning of acetone solution to forced burning by LP gas ⇒ Stable burning condition
- Change the chemical composition of seeding materials⇒ Increase CCN and INP ability and decrease AgI particle size
- 10 to 100 times as much ice nucleus formation compared with the current method
- Use generic parts as much as possible in order to improve maintainability

Ccomparison items	Existing device	New-type device
Combustion method	To ignite and burn an acetone solution	To ignite LPG To burn LPG and acetone
AgI acetone solution used amount	7.2 liter per hour	1.25 liter per hour
Acetone tank capacity	About 400 liter (about 50 hours)	Less than 200 liter (about 160 hours)
Comparison between new and old combustion materials	5% acetone solution of silver iodide (weight ratio)	2% acetone solution of silver iodide (weight ratio)
Component	・Silver iodide (AgI) ・Pottasium iodide（KI） ・Acetone（C2H6O）	・Silver iodide (AgI) ・Sodium iodide (NaI) ・1,2-Dichlorobenzene（C6H4Cl2） ・LPG（C3H8） ・Acetone（C3H6O）
Ice nucleus formation capability（-15℃）	1	10～100 If the figure of an existing device is set as one (1)

Figure 9. Comparison of existing device and new device

Figure 10. Appearance of new artificial rainfall device (prototype)

CONCLUSIONS

- Japan has disadvantageous conditions for water use and experienced serious water shortage in the 1950s, so the Tokyo Waterworks developed four ground-based AgI generators in 1966
- In order to update the aging artificial rainfall devices, we quantitatively verified their effect and developed a new artificial rainfall device
- We conducted weather observations and numerical simulations, which showed that an average increased rainfall effect of 5% was obtained by the operation of the artificial rain unit
- We confirmed that the new devices use a more efficient method than the existing devices, and that the production rate of ice nuclei is 10 to 100 times greater than the existing devices
- In the future, we will update the four ground-based AgI generators and implement effective drought countermeasures