JP1.6 ON THE ICE CONTROL PRODUCING 5th GENERATION WATER RESOURCES AND SUPPRESSING GLOBAL WARMING

Hi-Ryong BYUN *
Pukyong National Univ., Rep. of Korea

1. INTRODUCTION

At the beginning of the world, the only source of drinking water for human beings was clean underground water (first generation). As the geographical distribution of human beings increased, river water started being commonly used for drinking purposes (second generation). When human beings settled in regions that were insufficient in both underground water and river water supplies, they started drinking rainwater (third generation). Later, human beings began freshening seawater due to the increase in civilization and population explosion (fourth generation). However, water scarcity still remains one of the potential threats to the future existence of human beings (Gleik 2003, Oki and Kanae 2006, Yeston et al. 2006). As a solution to this problem, this research presents a proposal to prevent the evaporation of water and to condense the water vapor in the air into water. We would like to term it the fifth-generation water resources as it is yet to be practically implemented.

The detailed methodologies are categorized into four steps as follows. (1) Drastically increase the amount of freezing through "forced thickening of ice." This is done to store the unlimited cold air during winter as ice in order to store the water until summer. (2) Delay the thawing period until summer. During this process, we discovered the positive feedback mechanism of cold air generation. This process is noteworthy as a next-generation energy source because it can be generated without power supply. (3) Use ice to maintain a low water temperature and "suppress the evaporation" of reservoirs and water bodies. (4) By "promotion of condensation," condense the water vapor in the air into water. This process consumes a large amount of energy, so plans have been made to change this energy into water. This is problematic in terms of economical efficiency; therefore, there is an urgency to solve the technical problem. The combination of these four processes is referred to as the ice control process. As a side effect, we found that they can maintain a good level of water quality and directly control global warming. Further, we found that they have no harmful side effects.

* *Corresponding author address*: Hi-Ryong BYUN
Dept. of Environmental Atmospheric Sciences,
Pukyong National Univ., Namku, Busan, 608-737, Rep. of Korea
Email: hrbyun@pknu.ac.kr

2. MECHANISM OF EVAPORATION AND CONDENSATION

Evaporation of water on the earth's surface is a major reason for the loss of water; however, human beings have neglected it thus far. On the contrary, they have been more interested in global warming and the related implications (Ramirez and Hobbins 2005, Ohmura and Wild 2002, Roderick and Farquhar 2002, Hobbins et al. 2001). Recently published researches have revealed that the reduction in soil moisture due to evaporation is the reason for large-scale droughts (Hong and Kalnail 2000) and that evaporation from water bodies is the main reason for the insufficiency of water resources (Brikowskiand Anderson 2006). However, these researches failed to gather much attention.

Cho (1969) proposed a theory in which the amount of evaporation depended on the difference between the saturated vapor pressure on the water surface and the vapor pressure in the air according to the equation $E = (a + bU)(e_w - e_a)$. Here, a and b denote invariables and e_w and e_a are the vapor pressures (hPa) on the water surface and in the air (1 meter above the ground), respectively. U denotes the wind speed (m/s) and E denotes the amount of evaporation (mm/h). Han and Lee (2005) found through detailed observations that a and b were 0.0146 and 0.0063, respectively, in the mid-latitude regions. According to Cho's theory, the amount of evaporation is independent of the relative humidity of air and is determined by the difference between the water temperature and the dew-point temperature. In other words, when the water temperature is lower than the dew-point temperature, condensation occurs and there is no evaporation. Therefore, by lowering the water temperature, evaporation can be suppressed and we can secure additional water; this is a significant result. Ice decreases the water temperature and promotes condensation.

3. STUDIES ON ICE

Studies on ice thus far typically focused on the relationship between thawing in the polar and cold regions and global warming (Hurtley and Szuromi 2006; Curran et al., 2003, Thomas et al. 2000, Davis et al., 1998). There were a limited number of researches on the influence of ice on air circulation (Lukovich and Barber 2005, Lim and Byun 2000). However, no research has been performed thus far on the ice control in nature.

Researches on ice valleys (Byun et al. 2006a,b, 2004a, Tanaka et al. 2000, 2006, Hwang et al. 2005), ice caves (Turri et al. 2004, Pflitch and Piaseki 2003), ice lakes (SBS, 2004), ice spikes (Byun et al. 2004b), river ice (Morse and Hicks 2005, Prowse and Beltaos, 2002, Hirayama et al. 2002) and lake ice (Duguay et al. 2006) comprise only a very small part of the researches on ice. However, these researches revealed a phenomenon occurring in nature in which evaporation is suppressed and condensation is promoted; investigations into this phenomenon revealed that it enabled ice to be preserved until summer or where ice is frozen during summer. It has been suggested that the use of phenomena such as “forced thickening of ice,” “delayed thawing,” and “promotion of condensation” should be optimized.

4. FORECD THICKENING OF ICE

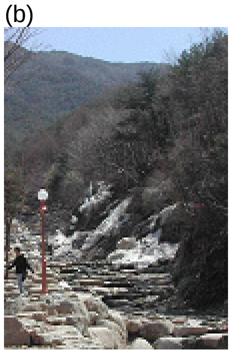
The formation of ice during winter is referred to as the forced thickening of ice. When the temperature falls below zero, freezing hardly occurs on the surface of water bodies; this is because of the heat in the earth. When water is sprinkled into the air at this time, freezing occurs. When a thin layer of insulator is placed on the surface of water, at the location where the frozen sprinkled water is falling, freezing is promoted. In Korea, which is situated at around 36° N, rivers start freezing from January 3; however, using the abovementioned method, freezing can be made to start from late October, when the temperature starts to decrease down below zero. The ice on the river melts by February 20 but the freezing can be preserved until April 7 since the air continues to remain at sub-zero temperatures.

Once ice is formed, it reflects 60 to 90% of the sunlight and maintains a low temperature; therefore, the ice can freeze more water in its vicinity. (Water reflects 8% of incident sunlight.) This feedback effect of freezing can sometimes increase the size of the ice naturally. The icy surface blocks the radiant heat coming from underground or below the water surface, and it also prevents the temperature in its neighborhood from increasing above zero. Under such conditions, water is easily frozen. Therefore, all we need to do is to transport the water from beneath the ice surface to above it. Sprinkling would further increase the freezing effect. When the air temperature increases above zero in the course of a day, the ice suppresses the temperature increase in its neighborhood until it melts. During nighttime, when the temperature falls, it again freezes the water. In this manner, we can obtain more ice as compared to the amount occurring naturally. This is why Mongolian ice valleys and Russian ice lakes have more ice as compared to that in other places.

Fig. 1 shows an example of the forced thickening of ice. On a hill, where ice is hardly formed in ordinary years, a pile of ice is observed. This ice takes considerable time to melt. The photograph shows that the ice was preserved until April 5 although it was exposed to sunlight, precipitation, and wind in a region where ice usually disappeared by February 10. Fig. 1c shows an ice valley in Mongolia on the edge of a desert where the temperature increases up to 30°C. It shows that the thick ice is preserved until July 17. This picture was taken on a rainy day. This is one reason why an oasis is formed in a desert.

(a)

(b)



(c)

Fig. 1. (a) Example of an ice hill formed by the forced thickening of ice; this picture was taken on February 10. (b) Delayed melting taken on April 5 in the same place in Korea. (c) On July 17 in Yolin-am, Mongolia.

5. DELAYED MELTING

In order to maintain ice until summer, a different consideration is needed. When the temperature increases above zero, condensation appears on the surface of ice, and the water its temperature is similar to the one of wet bulb, melts the ice. Further, when the ice with water on it is exposed to sunlight, it absorbs more sunlight and melts faster. The transport of water molecules between water and air occurs more often than that between ice and air. Therefore, water easily absorbs the heat in the air and melts the ice. Thus, the water on the surface of the ice needs to be separated from the ice as soon as it is formed in order to maintain the ice in its frozen state for a longer time. A simple experiment provides a clear explanation.

First, freeze 140 g of water in a paper cup inside a freezer; then, bore a hole at the bottom of the paper cup and fix the upper part of the ice to prevent it from sinking while melting. In this case, it takes 7 h and 20 min for the ice to melt completely. However, in a cup containing water and ice, it takes only 3 h and 30 min for the ice to melt completely at a temperature of 28°C and a humidity of 58%. In nature, this condition is realized when ice piles up on the slopes of a hill. When the hill has an underground space or an adiabatic layer over it is even better. If the ice is not exposed to sunlight, precipitation, or a strong wind, it lasts even longer. In conclusion, when ice is piled up on a high mountain or a field covered with stones in a shaded region without sunlight and precipitation, it is possible to flow cold water for one year and to prevent all the evaporation in waterways and reservoirs in that region. With this method, it is possible to prevent droughts that occur due to the lack of moisture in soil (Hong and Kalnail 2000). This method would be even more effective than the construction of an underground reservoir for controlling evaporation (Brikowskiand Anderson 2006).

6. POSITIVE FEEDBACK MECHANISM FOR COLD AIR GENERATION

The outcome of Byun et al. (2006a) is that it discovered a process in which ice produces more ice by itself. When melting, ice consumes latent heat, but the temperature does not decrease below the freezing point. Therefore, the air that once melted the ice cannot freeze it again. However, when the temperature around the ice is lower than that of the ice, the ice sublimates and dries, resulting in the formation of much colder air due to the consumption of latent heat. This cold air flows down because of gravity and when it comes in contact with ice, it is dried again; in this case, the air generated is even colder. When the cold air flowing down along the sloping surface of the hill again comes into contact with water, it not only freezes the water but also sublimates the ice. However, the latent heat that is radiated during the freezing process leaves the surface of the earth as soon as it is developed due to the freezing process. Therefore, only the cold air remains on the earth's surface. This process keeps generating cold air; therefore, it is called the cooling engine.

The cooling engine is an important basis of the theory that asserts it is possible to keep generating cold air only with water and ice without any power supply. The only discovery thus far is that this cold air generation is possible on the slopes of a hill. On a flat surface, cold air does not accumulate, and in a vertical plane, warm air going upward and cold air going downward collide with each other. The ice valley in Korea is noted for a strange phenomenon as it stores ice even during summer. In the ice valley, there is a cooling engine kept in a talus associated with a hill with a slope of 25°–45° and containing dacite welded tuff. There is a sloping stone field for approximately 1 km length and 200m breadth, which stores cold air in from winter. This cold air operates as the cooling engine that leads to the sublimation of ice until late spring. Such a cooling engine is rarely formed in the middle of summer although its effect is weak. Therefore, we can easily witness the freezing or breaking (not melting) of ice in the "ice valley" (Byun et al., 2006a,b). (There is another reason why the ice does not freeze during winter. We will skip its detailed explanation at present.)

7. SUPPRESSION OF EVAPORATION

Ice can prevent the water temperature from increasing beyond the dew point. That is, ice suppresses evaporation; therefore, a considerable amount of water is preserved. In the case of the central region of South Korea, the amount of water that is lost through evaporation reaches approximately 1,100 mm a year. When evaporation is prevented from November to June, 600 mm precipitation is expected as an effect. An immense amount of water is preserved as the suppression is effective not only in the area of reservoirs but also in the total area of the waterways flowing into the reservoirs. That is why there is no drought near a high mountain, and water is found abundantly near an ice valley.

8. PROMOTION OF CONDENSATION

Ice suppresses evaporation but it also promotes condensation. The amount of water vapor contained in the air increases with an increase in the dew point. The ice exposed to the air with a higher dew point can condense an increased amount of water vapor. How much water vapor is contained in the air that can be changed into water? In summer, the dew point of air reaches 15°C, and in this case, the amount of water in the air is 12 g kg^{-1}. When the dew point decreases to 0°C, only 3.7 g of water vapor is left in the air, and the remaining 8.3 g are converted into water. 1 mole of mixed air is approximately 28 g in mass and 22,400 cm^3 in volume. 1 kg of air is 35.7 moles and 800,000 cm^3 in volume. When a wind with a speed of 1 m s^{-1} blows through an air inlet of 1 m × 1 m, it travels at a speed of 1,000,000 cm^3 s^{-1}. When the entire water vapor in the air is converted into water, it is $8.3 \times 1.25 = 10.4$ g s^{-1}. This is 624 g min^{-1} and 37,440 g h^{-1}. In nature, it is difficult to condense this entire amount into water, but when the wind speed at the area of the inlet are controlled and the quality of condensation catalyst is improved, the efficiency increases.

However, in nature, a phenomenon in which water is added to the surface of ice is hardly observed. Hood et al. (1999) calculated that net condensation to the snow pack from May through mid-July was ranging from 5 to 16 mm of water equivalent. This is because, first, the layer of water on the surface of ice suppresses condensation and also increases the temperature of ice rapidly. Therefore, when the layer of water is removed as soon as it is formed, condensation continues. When ice has a sloping surface, the condensed water automatically drains away, thus removing the water layer. A sloping surface also prevents the potential heat, which is emitted from condensation, from melting the ice.

Second, when the ice is directly exposed to air, the potential heat from the condensation melts the ice and the cold air no longer exists. This phenomenon is prevented when there is a layer of catalyst when the cold air of ice comes into contact with the air. This theory states that by placing ice in a catalyst container and by continuing to collect condensed water on the surface of the catalyst container, we can keep obtaining water until the ice melts away (in theory, until the water temperature equals the dew point temperature). The experiment was successful in obtaining 4 g of water within 3 h from 100 g of ice using a container made of iron as a catalyst. In this case, we can assume that it is possible to obtain 40 kg of water from 1 ton of ice (1m × 1m × 1m). When the operation continues throughout the day, we can obtain 240 kg of water (24% day^{-1}). If we continue increasing the efficiency, we may be able to secure additional water amounting to more than 100% day^{-1}.

However, in order to continue providing ice, the use of energy is inevitable. The promotion of condensation is the process of converting energy into water. Economical efficiency can be achieved by using idle energy that is superfluous in limited regions due to energy produced by recycling. A clue to produce such energy from nature can be found in Korea's ice valley. The abovementioned cooling engine is an example of this. Vuddagiri and Eubank (1998) and Briggs and Sabaratnam (2003) made excellent studies on the condensation. Though focused on the water/vapor and air/steam interface respectively, they will be used importantly when technique upgrading is needed.

9. SUPPRESSION OF GLOBAL WARMING AND CONSERVATION OF WATER QUALITY

On the other hand, ice control has additional benefits besides securing water resources. First, it conserves water quality. If the water temperature is low, the growth of algae and bacteria is inhibited. Second, it reduces global warming. In a place where seawater freezes due to the forced thickening of ice in order to increase the area and thickness of the sea ice, the ice reflects the sunlight and prevents the temperature on earth from increasing. Liu et al. (2006) parameterized albedo of sea ice to 0.5~0.9 and calculated its impact on warming climate. Considering feedback mechanism of sea ice albedo, Curry et al. (1995) has also been interested not on the thickening but on the decaying ice cover. Though standing on the opposite side, these studies support the theoretical base for the idea suppressing global warming using thickened ice.

The earth is known to absorb an additional energy of 0.85 Wm^{-2} according to Hansen et al. (2005). This is prevented when an additional area of 4.8×10^6 km^2 is covered with ice. This area occupies approximately 40% of the total area of the region that is located above 35° latitude (N and S). To promote this project, cooperation on a pan-global level is required. Related with this subject, Hansen et al. (2005) additionally stated that when the disasters due to global warming begin to occur, it would take as many as 100 years to frame a policy to reduce greenhouse gases, even if the policy is implemented immediately. However, this forced thickening of ice can produce immediate effects, which is a noteworthy feature.

10. SIDE EFFECTS

A harmful side effect of ice control has not been discovered thus far. In the Republic of Slovakia, there are thousands of ice caves, and water flows in all seasons; this is due to the thawing of the ice. In the ice valleys of Korea and Mongolia, we witness the same phenomenon of water flowing from the thawing of ice. No side effect has been found so far in such regions.

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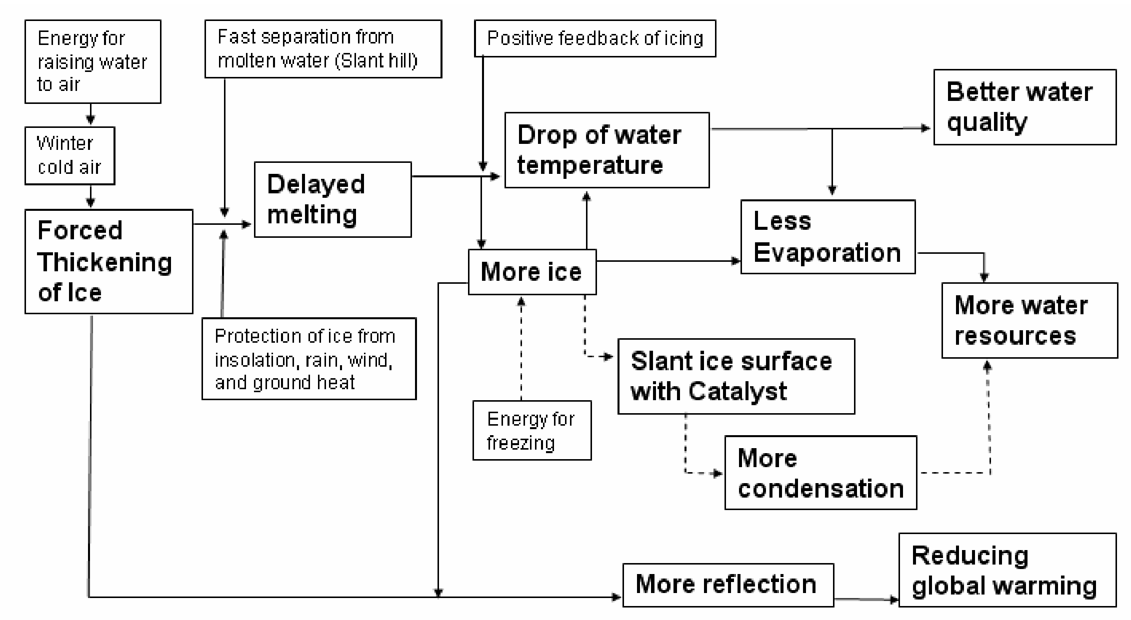

Fig. 2. Schematic diagram of ice control.