Using Snow Melting Pipes to Verify the Water Sprinkling's Effect over a Wide Area

L'usage estival des réseaux d'aspersion servant à la fonte du verglas dans les villes soumises à des précipitations neigeuses

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RÉSUMÉ

Il est urgent de trouver des mesures pour réduire les ilots de chaleur urbains, phénomène grandissant et problématique dans de nombreuses villes japonaises. Les réseaux d'aspersion existants utilisés pour faire fondre le verglas sur la voie publique dans les villes soumises à des précipitations neigeuses pourraient être utilisés pour rafraichir l'atmosphère urbaine durant les périodes de forte chaleur, moyennant un bilan quantitatif qui reste à réaliser. Cette communication présente une expérience de l'utilisation des réseaux d'aspersion en période estivale qui en démontre les effets bénéfiques sur l'atténuation des effets d'ilots de chaleur urbains. Les résultats sont tout à fait probants : baisse de température dans les rues aspergées de 2°C le matin et de 4°C l'après-midi pour les journées où la température ambiante dépasse les 30°C. L'analyse menée permet de conclure que le double usage des réseaux d'aspersion peut s'avérer extrêmement profitable pour l'environnement urbain été comme hiver.

ABSTRACT

It is becoming most urgent to find solutions for the heat island phenomenon as it grows into a bigger problem in many cities in Japan. "Water sprinkling" is getting noticed as a possible countermeasure for this problem in Japan, but a quantitative analysis of its effectiveness has yet to be made. Therefore, an experiment using the "snow melting pipe" infrastructures in Japan's snowy areas was conducted to verify if the air temperature actually decreased at a city level by conducting water sprinkling. It was found that when the temperature was over 30°C, a temperature decrease of approximately 2° C in the morning and a decrease of approximately 4°C in the afternoon were recorded. We can deduce from these results that water sprinkling is a viable and effective countermeasure to the heat island phenomenon, and using snow melting pipes which allow automatic water sprinkling is a very efficient method.

KEYWORDS

Heat island, water sprinkling, snow melting pipe infrastructure

1 INTRODUCTION

Many of Japan's cities have undergone rapid urbanization in recent years (Narumi et al., 2009, Fujibe, 2008). This progress in urbanization increased the accumulation of artificial exhaust heat and heat in concrete: this accumulation of heat in enclosed areas causes the effects of the heat island phenomenon to grow more severe. This can eventually result in health hazards and severe rainstorm in localized areas (Aikawa et al., 2008, K.Meyn et al., 2009).

In Japan, "water sprinkling" is attracting attention as a possible countermeasure for this problem (KANO et al., 2004, Kinouchi et al, 2001). Water sprinkling is a traditional Japanese custom in which water is sprinkled on roads and yards, and is effective in preventing the formation of dust on the streets. Households used to sprinkle water on the roads to keep them cool during the summer, but most families no longer continue this old practice. In an effort to reduce electrical consumption from air conditioning, large cities like Tokyo ran campaigns to encourage citizens to start water sprinkling. (Okuma et al., 1986, Miyamoto, 1994) Unfortunately, there has not been any quantitative data on the effectiveness of water sprinkling over large areas, such as approximately how many liters of water will lower temperature by how many degrees Celsius, nor has there been an explanation for the most effective water sprinkling methods, such as suggestions for amount of water and separation distance.

There are infrastructures called "snow melting pipes" in the snowy regions in Japan that were only used in the winter, but have not been used in the summer. (Kinouchi et al, 2001, Okuma et al., 1986) Our research facility used this previously installed snow melting pipe infrastructure to measure the quantitative effect of water sprinkling in the summer in reducing the air temperature and the surface temperature of roads.

The objective of this research is to measure the quantitative effects of water sprinkling in reducing the air temperature and road surface temperature. To study the effects of water sprinkling, we conducted a preliminary experiment to investigate the height of measurement when measuring the humidity, air temperature, and the minimum amount of water that should be sprinkled to achieve the maximum effect. We used this experiment's results to conduct a feasible water sprinkling cycle experiment. Afterwards, we used the results of the preliminary experiment out on the field to conduct the experiment over a wide area.

2 SNOW MELTING PIPES

Snow melting pipes are unique infrastructures that are commonly seen in the snowy regions of Japan. These infrastructures are devices that pump underground water and sprinkle them on the roads to melt snow in the wintertime. Nagaoka city in Niigata prefecture is one of the foremost snowy regions with a population of 280,000 people. Pipes are installed not only around the Nagaoka station (Figure 1) located east of the Shinano river that runs down the center of Nagaoka city, but are also installed across the whole city with a total pipe length of about 520 km.

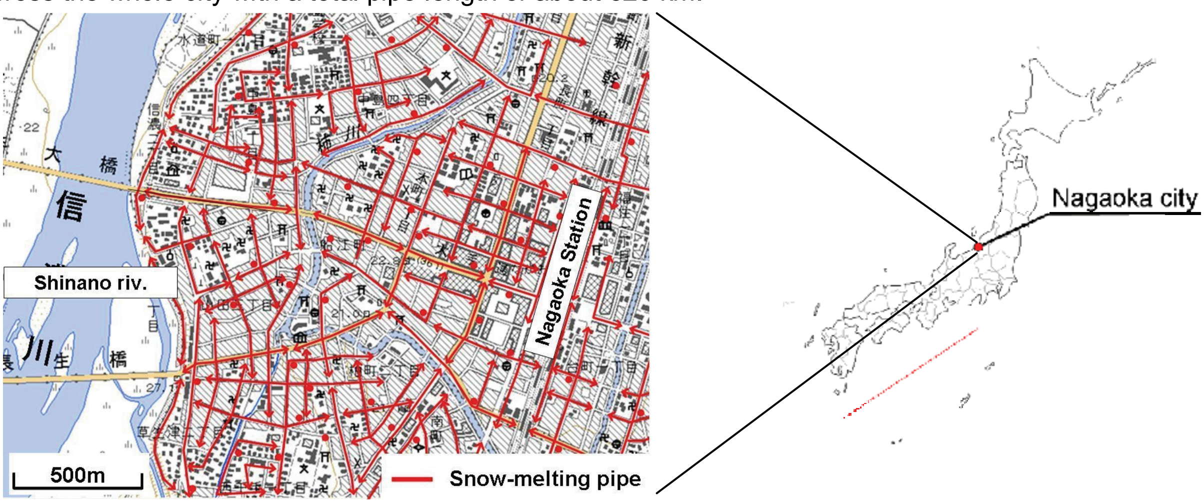

Figure 1 Central Nagaoka city snow melting pipe network

3 EXPERIMENTAL METHOD

3.1 Preliminary Experiment

3.1.1 Review method for Height of measurement

Air temperature is generally measured using a thermometer screen 1.2~1.5m from the ground. Similarly, we need to specify a height of measurement for both temperature and humidity upon water sprinkling for this experiment. We listed the height of the corresponding region of an average male to the right: foot=10cm, knee=40cm, abdomen=90cm, neckline=150cm, top of head=180cm.(in Table 1) We decided to measure the effect of water sprinkling at each height on humidity and air temperature to decide the height of measurement. For this preliminary experiment, we matched the road width, approximately 6m, and used a 6m x 6m area as the base. Snow melting pipes usually have 1 set with 4 nozzles every 1.5m. On a 6m road, there will be 3 sets of snow melting pipes with 12 nozzles (Figure 2), and about 1L/min of water is sprinkled from each nozzle. A total of 12L/min will thus be sprinkled in a 36m2 area. We made the above assumptions, and sprinkled water at a rate of 12L/min for 3 minutes. We then took measurements of the air temperature and humidity 5 minutes before water sprinkling, and every 30 seconds afterwards for 45 minutes.

measurement position	corresponding region
180cm	Top of the head
150cm	Neckline
90cm	Abdomen
40cm	Knee
10cm	Foot

Table 1 Observed height of measurement

Figure 2 Sprinkling water from snow melting pipes in snowy season.

3.1.2 Review Method for Optimal Water Sprinkling Volume

Snow melting pipes utilize underground water so overuse could sink the ground level and increase the operation cost of the snow melting pipes. It is therefore important to get the maximum results with the least amount of water. We created a simulated experiment to measure the optimal amount of water sprinkling.

We obtained five 36m^2 asphalt surfaces for the measurement surfaces (Figure 3). We labeled the partitions from A~D and adjusted the water sprinkling volume for each section. A "blank" section where no water was sprinkled was labeled E (36m^2). We used a water sprinkling rate of 12 L/min to match the rate of the snow melting pipes, and sprinkled the following amounts to each section. A: 1 minute, 0.33 L/m^2（0.33 L/m^2 ×36 m^2= 12 L）, B: 3 minutes, 1.00 L/m^2（1.00 L/m^2 ×36 m^2= 36 L）, C: 5 minutes, 1.65 L/m^2（1.66 L/m^2 ×36 m^2= 60 L）, D: 10 minutes, 3.30 L/m2（3.30 L/m2 ×36 m^2= 120 L）. A thermo-hygrometer is placed in the center of each partition to measure humidity and temperature. The thermo-hygrometer measurements were observed and recorded at 20 second intervals for 10 minutes, beginning from the start of the water sprinkling. For the following hour, measurements were recorded at every 30 second interval. We also started to measure the air temperature and humidity 5 minutes prior to water sprinkling to verify that the thermo-hygrometer did not have any errors.

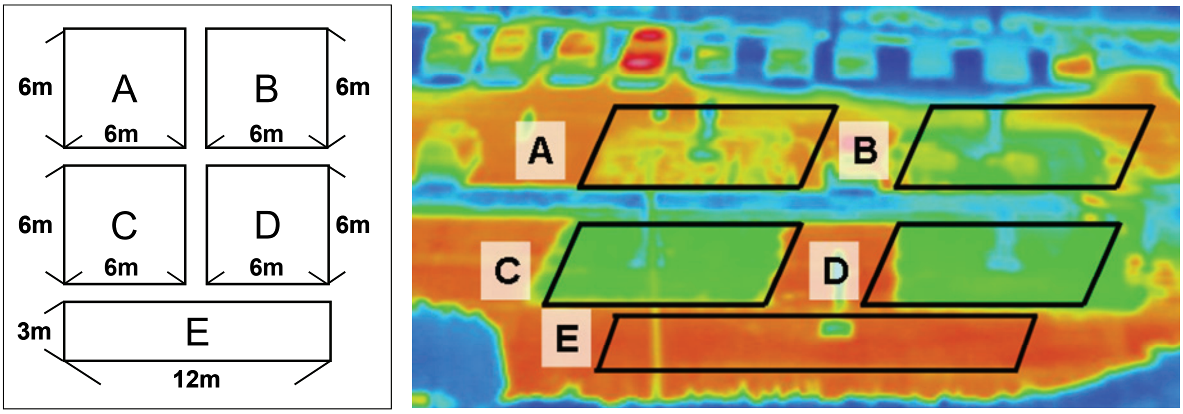

Figure 3 Five asphalt surfaces for the measurement (Left) , and snap shot of thermography 23 minuets after sprinkling (Right).

3.1.3 Review Method for Optimal Water Sprinkling Cycle

Similarly to the experiment above, we set up 6×6=36m^2 water sprinkling partitions and non-water sprinkling partitions as the measurement surfaces for this experiment. A thermo-hygrometer is placed in the center of each partition, and the measurements are recorded at 1 minute intervals for 20 minutes from the start of water sprinkling, 5 minutes intervals for the next 20 to 40 minutes, and 10 minute intervals for the following 40 minutes.

We measured the difference in temperature change between surfaces where we sprinkled water right after when the surface became visually dry (Sprinkle at Once Method) and sprinkling once every hour (Sprinkle at 1 Hour Interval Method).

3.2 Wide Area Water Sprinkling Experiment using snow melting pipes

This experiment was conducted by sprinkling water using snow melting pipes twice per day in the morning (8:30 a.m.~10:30 a.m.) and in the evening (5:10 p.m. ~9:10 p.m.) between August 6~18, 2009 in Nagaoka city (Figure 4. North Side: Area A, South side: Area B). The experiment also allocated non-water sprinkled locations near these sites where the snow melting pipes were not activated. This made it possible to observe the difference in the change in measurements with and without water sprinkling. The air temperature and humidity at all locations and the wind direction and wind speed at A-1 were all recorded in this experiment (Figure 4).

On August 12 (Wed) and 18 (Tues), water sprinkling was conducted in the morning and evening twice per hour for 5 minutes (30 minute intervals).

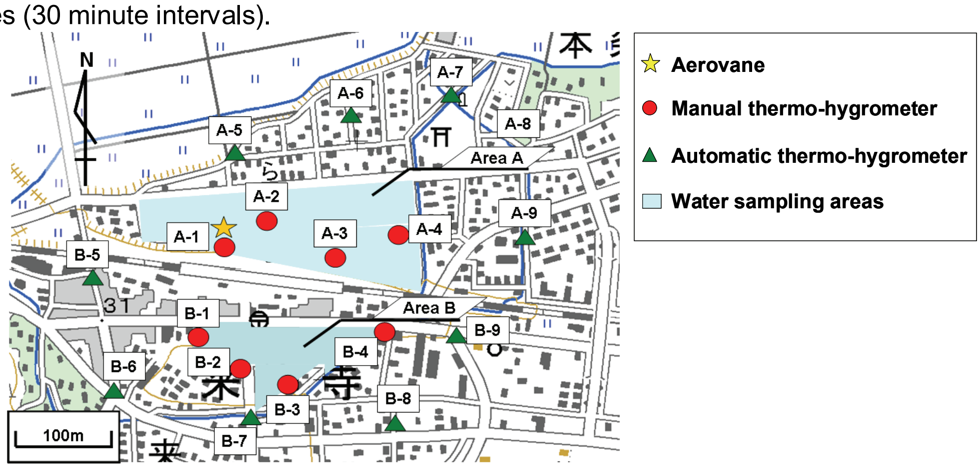

Figure 4 Figure of Target Experiment Area

4 RESULTS AND DISCUSSION

4.1 Height of measurement

The air temperature continued to drop at all four heights of 40, 90, 150, and 180cm (Figure 5). The air temperature drop at the 90cm height was especially high, and the change in temperature seemed to decrease the most consistently during the experiment. The experiment was decided to be measured at 90cm from the fact that the effects of water sprinkling were most definitive, and the measured humidity and temperature were consistent. It is also important to note that 90cm is about the average height of the head of children, who are most likely to be strongly affected by the heat island phenomenon.

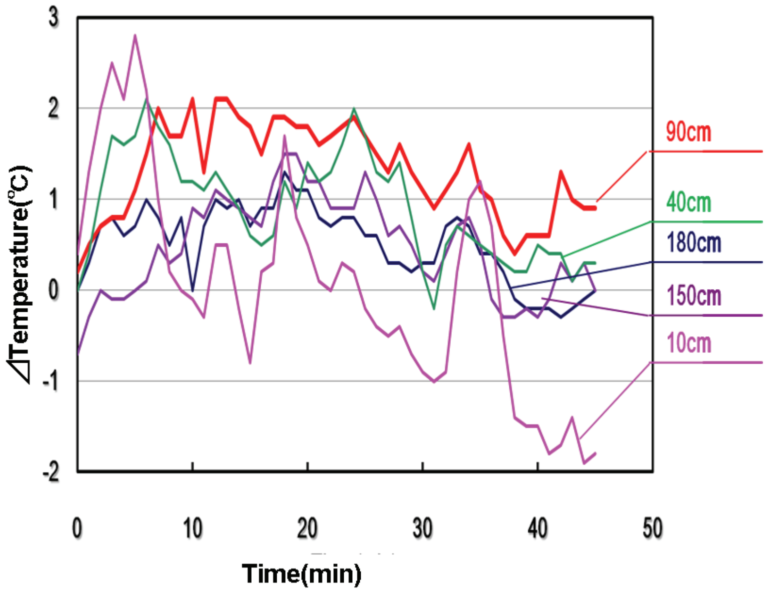

Figure 5 Air temperature change by height (T_{blank} - T)

4.2 Optimal water sprinkling volume

The experiment was able to verify that water sprinkling is effective since it confirmed that there is a difference in surface and air temperature between non-water sprinkled surfaces and water sprinkled surfaces. The volume of sprinkled water that showed the biggest change in air temperature compared to the blank (non-sprinkled area) was 0.33L/m^2 with a temperature drop of 2.5℃ (Figure 6). The sprinkled water amounts at 1.00, 1.65, and 3.30 were approximately the same in terms of surface temperature change (Figure 7). These findings verified that sprinkling too much water is ineffective. The volume of sprinkled water that showed the biggest change in surface temperature compared to the blank was 1.00L/m^2 (sprinkled water at 0.33L/m^2 for 3 minutes), yielding a surface temperature drop of 10℃. The first 15 minutes of water sprinkling for areas with higher rates of water sprinkling yielded similar results as the 0.33 L/m^2 for areas, but after these 15 minutes, the 0.33 L/m^2 had a higher rate at which the surface temperature rose and also showed different results from the other cases.

The surface temperature drop was the same for the water sprinkling volumes of 1.00 L/m2, 1.65 L/m^2, and 3.30 L/m^2 in the results above. We therefore decided to use 1.00 L/m^2 as the volume of water sprinkling for the experiment since it was the lowest volume among the three that yielded the highest temperature change.

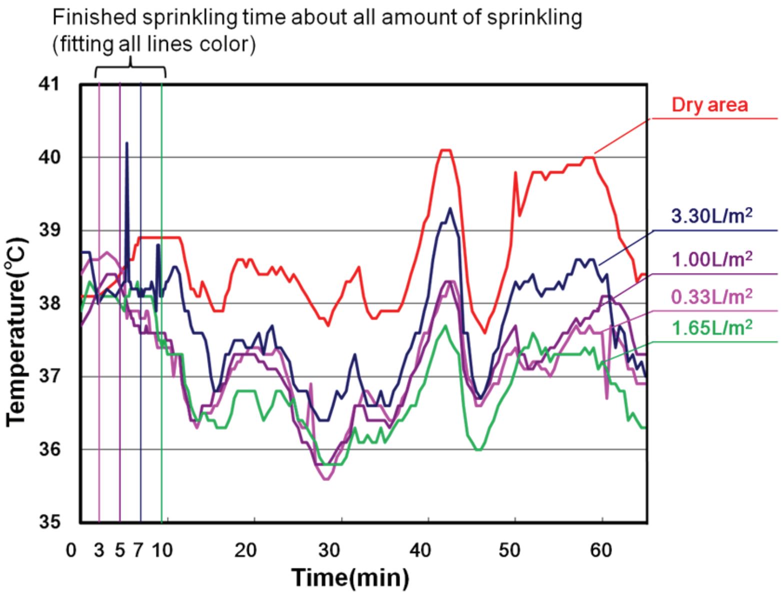

Figure 6 Change in temperature at 90cm height with different sprinkling water volume

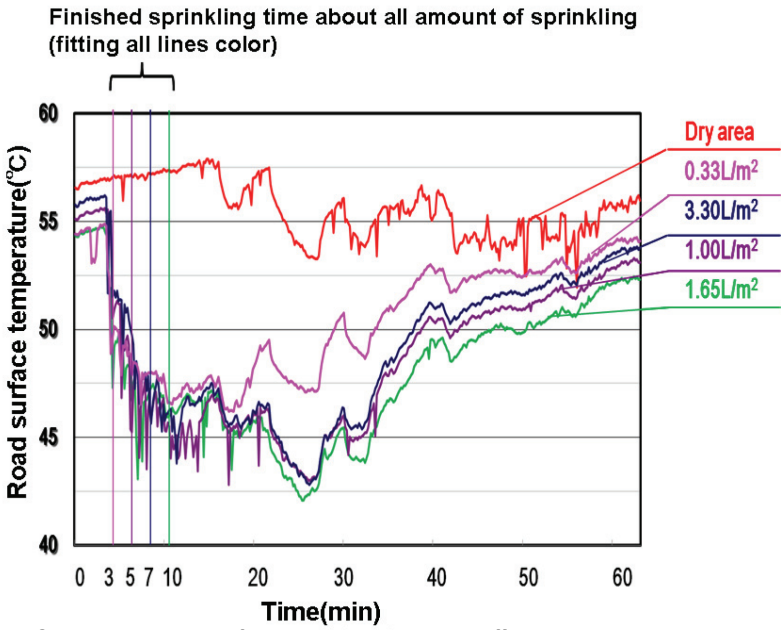

Figure 7 Change in road surface temperature with different sprinkling water volume

4.3 Optimal water sprinkling cycle

When comparing the Sprinkle at Once Method and the Sprinkle at 1 Hour Interval Method during 10:00~11:00, a drop in the air temperature was observed in both sections approximately 30 minutes after water sprinkling. When water sprinkling was continued on the Sprinkle at Once location, we were able to observe that the rise in temperature was more gradual compared to the area in which the 1 Hour Interval Method was used. There were also no significant differences in air temperature between these two locations between the hours of 11:00~15:00. After 15:00, we were able to see an air temperature difference of approximately 0.5℃ again. From this, we can induce that it is highly likely that the effect of water sprinkling is greatly diminished during the daytime.

When we looked at the water sprinkling cycle of the Sprinkle at Once Method, we were able to observe that it took approximately 30 minutes for the surface to return to its original condition before water sprinkling.

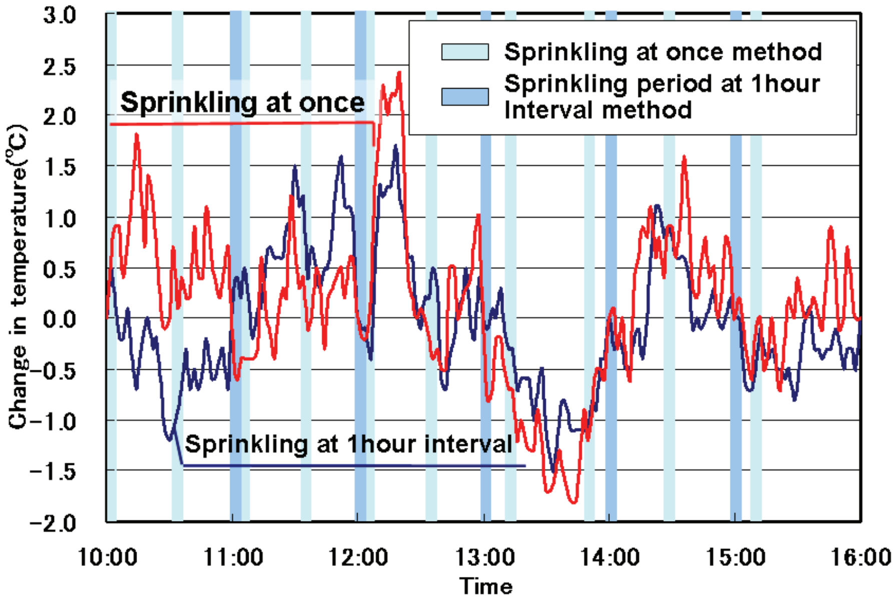

Figure 8.Difference in temperature in sprinkle at once method and sprinkle at 1 hour interval method.

4.4 Wide area experiments Ⅰ (August 12, 2009)

The average air temperature of each water sprinkled area and non-water sprinkled area is shown in Figure 9~12. In the mornings (Figure 9 and 10), the air temperature in the non-water sprinkled areas started to rise once the experiment started. On the other hand, the air temperatures in the water sprinkled areas show a slight drop during the water sprinkling and then displayed another drop 5~10 minutes after the water sprinkling stopped. This second drop in air temperature reduces the surface temperature of the asphalt from vaporization and is thought to have a larger drop at that time than during water sprinkling.

According to the results on Figure 9, we were able to observe that the water sprinkled area was approximately 2℃ lower than the non-water sprinkled area at the end of the observation period (10:30). In the results of Figure 10, we were able to observe an approximate 2℃ drop in temperature at the end of the experiment (10:30).

The results of the afternoon (Figure 11 and 12) showed that the air temperature in both non-water sprinkled areas and water sprinkled areas reduced as time passed. In the results from Figure 11, we were able to observe a rapid drop in air temperature both immediately after the first and second water sprinkling at 17:10 and 17:40 respectively. After the third and fourth water sprinkling at 18:10 and 18:40, the rapid drop in air temperature that was seen in the previous cases was not observed. When compared to the non-water sprinkled areas, the temperature difference became greater as time passed, and reached an approximate 4℃ difference by the end of the experiment (19:10).

In the results of Figure 12, the average temperature change in both areas were similar to Figure 11; it showed a rapid drop in temperature until the second water sprinkling, but did not show a huge drop afterwards. A 3℃ difference in temperature was observed at the end of the experiment (19:10). We were successfully able to observe the effects of water sprinkling at both areas and times.

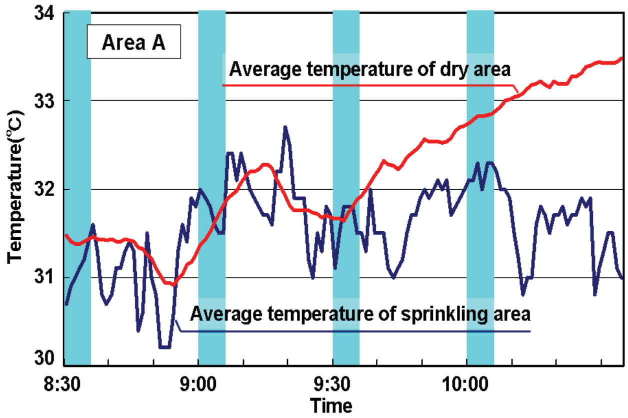

Figure 9 Difference in Air Temperature Change With and Without Water Sprinkling (Area A in the Morning)

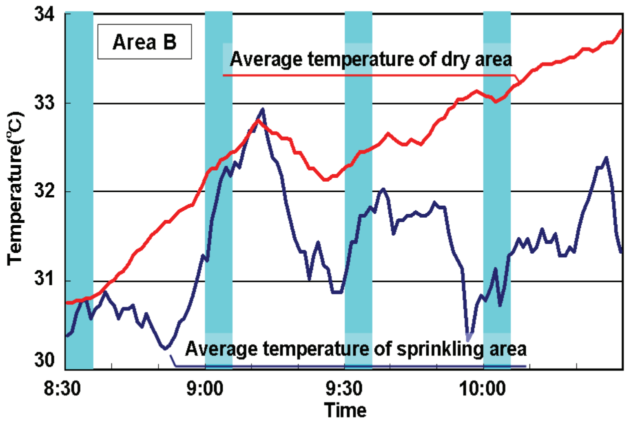

Figure 10 Difference in Air Temperature Change With and Without Water Sprinkling (Area B in the Morning)

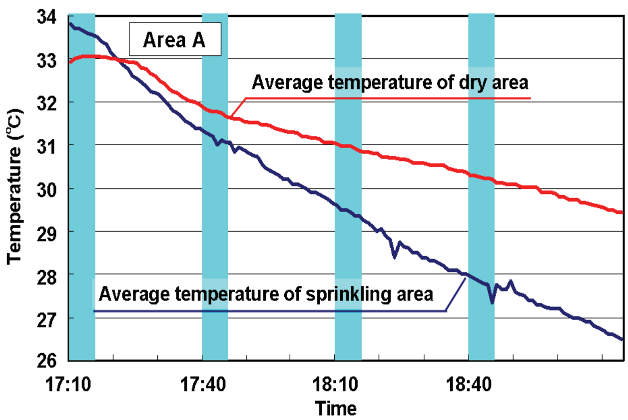

Figure 11 Difference in Air Temperature Change With and Without Water Sprinkling (Area A in the Afternoon)

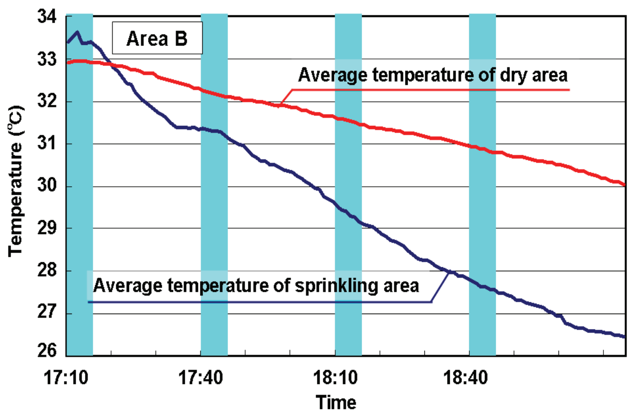

Figure 12 Difference in Air Temperature Change With and Without Water Sprinkling (Area B in the Afternoon)

4.5 Wide area experiments II (August 18, 2009)

We conducted water sprinkling, focusing on the sunny areas and shady areas for the experiment on August 18. From the experiment results in the area A (Figure13) and area B (Figure 14), a temperature difference of 1℃ can be seen between non-water sprinkled areas and water sprinkled areas in the sun, but a significant temperature difference could not be observed when water sprinkling was conducted in the shade. From this, we can say that water sprinkling is more effective when performed on sunny areas and is ineffective on shady areas.

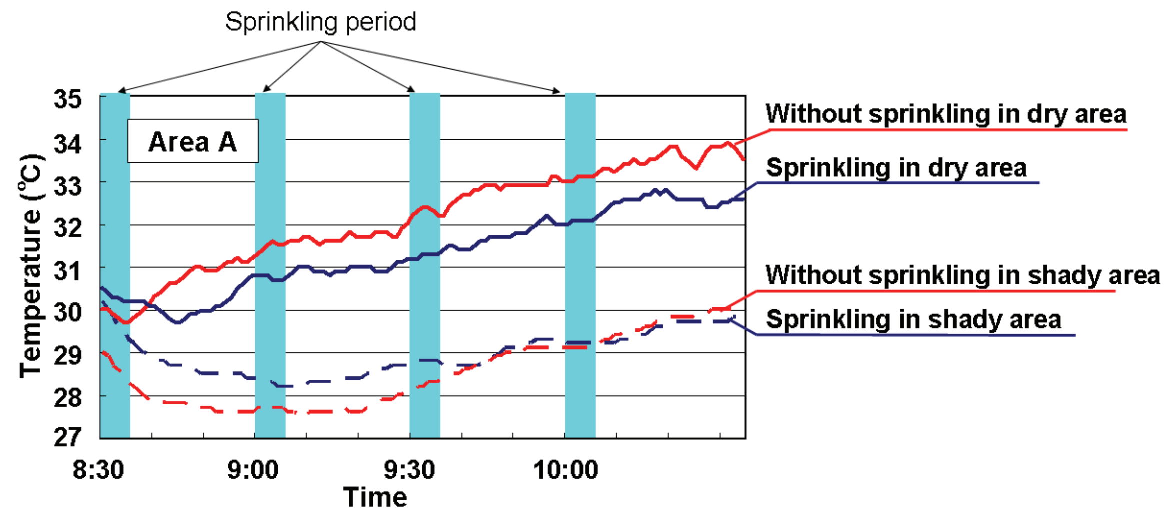

Figure 13 Difference in Air Temperature Change with sunny area and shady area (Area A in the Morning)

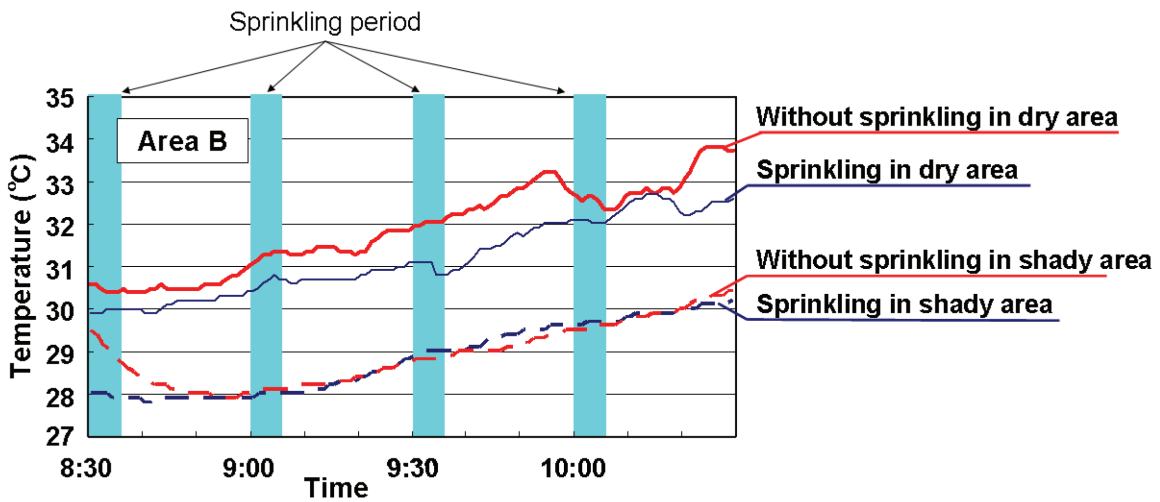

Figure 14 Difference in Air Temperature Change with sunny area and shady area (Area B in the Morning)

CONCLUSION

This paper shows that water sprinkling using the “snow melting pipe” infrastructure in Japan’s snowy areas is a viable and effective countermeasure to the heat island phenomenon. And the following conclusions were obtained.

1) The air temperature was different by 2℃ between non-water sprinkled areas and water sprinkled areas in the morning. This temperature difference was approximately 4℃ in the afternoon.

2) A measurement height of 90cm produces consistent measurements. The volume of water sprinkling that yields the maximum results with the least amount of water is 1.00L/m2. The water sprinkling cycle is most effective when performed in 30 minute intervals. Water sprinkling is not as effective during the day, so conducting water sprinkling in the morning till about 10:00 a.m. and after 4:00 p.m. in the afternoon will yield the maximum results.

3) When comparing water sprinkling at 1 hour intervals and 30 minute intervals, we saw that water sprinkling at 30 minute intervals caused its effects to last longer.

4) Water sprinkling in sunny areas yields prominent results, but water sprinkling in shady areas does not yield a significant air temperature difference.

5) Characteristics of the regions including human factors such as population and traffic amount did affect the rate of temperature drop from water sprinkling, but they never completely nullified the effect of water sprinkling.

We can deduce from these results that utilizing snow melting pipes which allow for automatic water sprinkling is a very efficient method to take against heat island problem.

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