Ice nucleation by ordinary Portland cement

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ABSTRACT

Portland cement was studied for its nucleating ability by the freezing behaviour exhibited of drops produced from aqueous suspension of Portland cement vis-a-vis of drops produced from suspensions of AgI, $2AgI \cdot NaI$ and PbI_2. It is revealing to note that, at temperature colder than $-5°C$, Portland cement is as potent an ice nucleant as is either $2AgI \cdot NaI$ or PbI_2. At temperatures approaching $-5°C$, Portland cement alone is effective as nucleant but not the latter two. However, as compared to AgI, its effect is small at all the temperatures considered.

1. Introduction

Portland cement is used as a seeding agent in weather modification experiments in USSR (Battan, 1969; 1970). Clouds seeded with Portland cement are reported to dissipate twice as fast as those seeded with crystal-producing agents (Gaivoronskii et al., 1968). According to the theory put forward in this connection, which seems to take into account the hygroscopic property of Portland cement, downward motions develop in the cloud under unstable stratification conditions and compensate the updraughts present, thus contributing to intensive evaporation of the cloud. But, this material is said to be somewhat of a mystery, it being not clear how it works, why it works or even if it works (Battan, 1969).

Portland cement, which is produced from lime and clay minerals, is a randomized chemical complex polymer in which all the metallic atoms are joined through oxygen. The main compounds entering into the composition of Portland cement are: tricalcium silicate ($3CaO \cdot SiO_2$), dicalcium silicate ($2CaO \cdot SiO_2$), tricalcium aluminate ($3CaO \cdot Al_2O_3$) and tetracalcium aluminoferrite ($4CaO \cdot Al_2O_3 \cdot Fe_2O_3$) (Czernin, 1962). In the presence of water, cement changes into an equally complex colloidal product.

As the threshold nucleating temperature of aluminium oxide (Al_2O_3) is $-6.5°C$ (Fukuta, 1958) and as the majority of the natural ice-forming nuclei are clay mineral particles (Kumai, 1961), the possibility of Portland cement possessing ice nucleating property cannot be ruled out. With a view to investigating this possibility, and also in pursuit of new and cheap reagents for weather modification, the authors have examined the drop-freezing activities of aqueous suspensions of Portland cement and simultaneously, of certain substances, known for their nucleating ability, for comparison. The study pointed that Portland cement is a good ice nucleant, as anticipated, and also it is next only to AgI in its ice nucleating ability. The results of the preliminary experiments are reported.

2. Equipment and method of examination

Drops, of diameter 2.2 mm produced from freshly prepared aqueous suspension of ordinary Portland cement and of the given substance, are placed in equal numbers (30 each) in two identical metal dishes, the inside bottoms of which have been coated with Dow Corning silicone lubricant. The dishes are sealed with glass covers and subjected to identical rates of cooling by transferring them simultaneously on to a cold stage which was precooled to the desired temperature by a suitable refrigerator system (Fig. 1). The number of drops freezing, as shown by opacity, are noted with naked eye at successive one minute time intervals

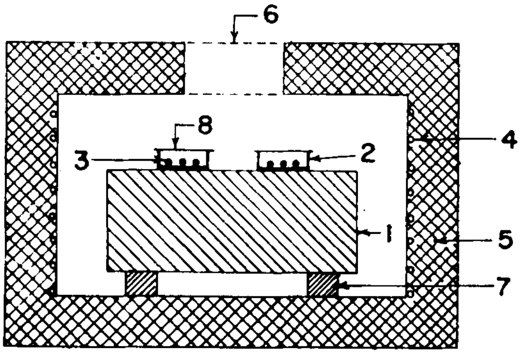

Fig. 1. Cold chamber. (1) cold stage, (2) metal dish, (3) suspension drops, (4) cooling coils, (5) glass-wool insulation, (6) perspex window, (7) metal stand and (8) glass cover.

until all the drops taken in both the dishes have frozen. The temperature attained by the pair of dishes at successive intervals is measured by thermocouples made from SWG-36 copper-constantan wires.

All the suspensions examined are of concentration 10 g per litre prepared with double distilled water. The suspensions examined for comparison are of (1) silver iodide plus sodium iodide, in 2 to 1 molar ratio (2AgI·NaI), with silver iodide in 10 gm per litre, (2) silver iodide (AgI) and (3) lead iodide (PbI_2). The experiment is conducted, at a time, with drops of the cement suspension in one dish and the drops of each of the other suspensions in the other dish. The sample of cement used is from the consignment supplied by M/s. Mysore Cements Ltd., Bangalore, India. Each set of the experiment conducted has been repeated four times, and in the case of cement suspension as many as ten times. Also, in another set of experiments conducted, drops of double distilled water used in the preparation of the suspensions have been tested along with the suspension drops of the different composition considered.

3. Results

The initial temperatures of the cold stage considered for the experiments are $-10°C$ and $-5°C$. Under these temperatures of the cold stage the experimental dishes attained, in the quasi-equilibrium conditions, temperatures of

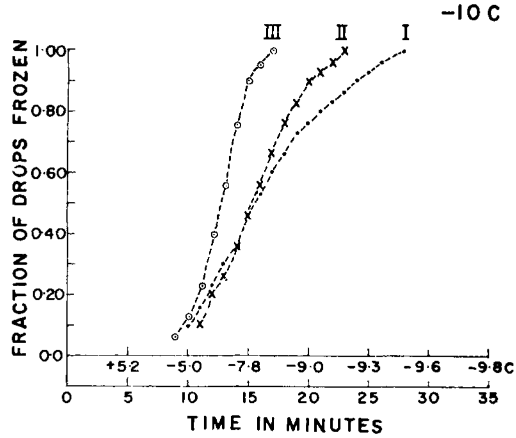

Fig. 2a. Ice nucleation of aqueous suspensions when the cold stage initially was at $-10°C$. (I) Portland cement, (II) 2AgI·NaI and (III) AgI.

$-9.8°C$ and $-4.7°C$ respectively. The fraction of drops frozen, on the mean, at successive intervals of time, in the case of the suspensions tested, are given in Figs. 2 and 3 for cold stage temperatures initially at $-10°C$ and $-5°C$ respectively. For clarity, the value of temperature at which the first freezing event occurred and the total time taken for all the drops to freeze, in each case, are also given in the Table. The dish temperatures indicated are given at 5-minute intervals in the figures.

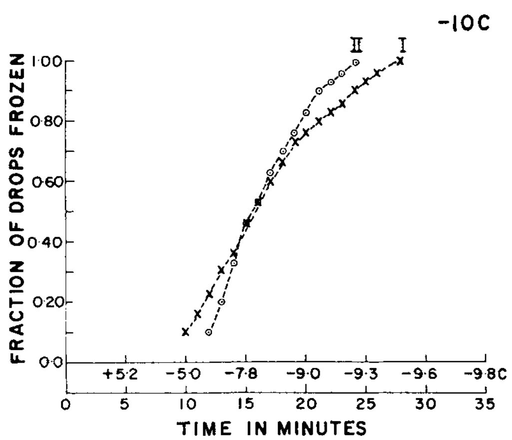

Fig. 2b. Ice nucleation of aqueous suspensions when the cold stage initially was at $-10°C$. (I) Portland cement and (II) PbI_2.

Table 1. *Freezing behaviour of drops from different aqueous suspensions under given initial temperatures of cold stage*

	Cold stage temperature			
	$-10°C$		$-5°C$	
Aqueous suspension	First freezing event (°C)	Last freezing event (min)	First freezing event (°C)	Last freezing event (min)
Portland cement	-5.0	28	-4.6	55
$2AgI \cdot NaI$	-5.8	23	No freezing	No freezing
PbI_2	-6.5	24	No freezing	No freezing
AgI	-4.2	17	-4.0	49

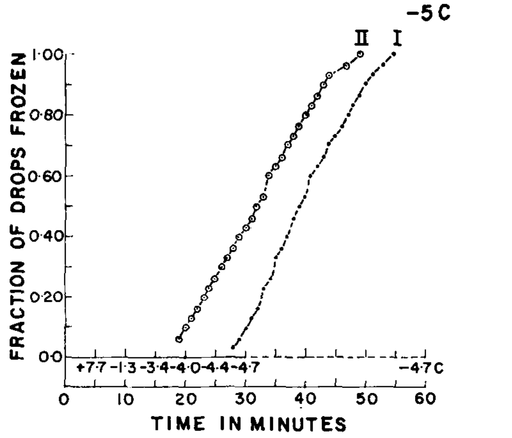

Fig. 3. Ice nucleation of aqueous suspensions when the cold stage initially was at $-5°C$. (I) Portland cement and (II) AgI. None of the drops from the suspensions of 2 AgI. NaI and PbI_2 showed freezing.

(a) *Portland cement versus* $2AgI \cdot NaI$

Under the temperature condition of the cold stage initially at $-10°C$, Portland cement and $2AgI \cdot NaI$ exhibited nucleating activities which are nearly alike (vide curves I and II of Fig. 2*a* and figures under columns 2 and 3 of the Table for Portland cement and $2AgI \cdot NaI$). Portland cement showed a small lead over $2AgI \cdot NaI$ in the very early stages of the commencement of nucleation events, corresponding to the temperature range $-5°C$ to $-7°C$. In the later stages, however, $2AgI \cdot NaI$ showed a lead.

When the temperature of the cold stage initially was at $-5°C$, only Portland cement showed nucleation (curve I of Fig. 3) but not $2AgI \cdot NaI$.

(b) *Portland cement versus* PbI_2

Under the temperature condition of the cold stage initially at $-10°C$, Portland cement and PbI_2 exhibited nucleating activities which are also nearly alike (vide curves I and II of Fig. 2*b* and figures under columns 2 and 3 of the table for Portland cement and PbI_2). As before, Portland cement showed a small lead in the very early stages corresponding to the temperature range $-5°C$ to $-7°C$. In the later stages, however, PbI_2 showed a small lead.

When the temperature of the cold stage initially was at $-5°C$, PbI_2 did not show any activity whereas the cement did.

(c) *Portland cement versus AgI*

Under both the temperature conditions of the cold stage, namely, $-10°C$ and $-5°C$ initially, Portland cement exhibited less activity than AgI (vide curves I and III of Fig. 2*a* and curves I and II of Fig. 3 and figures in rows 1 and 4 of the Table).

(d) *Suspension drops versus distilled water drops*

Only the suspension drops froze in the manner as shown in Figs. 2*a*, 2*b* and 3. Drops of double distilled water never froze even under the colder temperature conditions of the cold stage, namely, $-10°C$ initially.

(e) *Repeatability of results*

With the drops of any given composition tested, the temperature corresponding to the first freezing event varied by $\pm 0.5°C$ and the time corresponding to the last freezing event varied by ± 3 minutes.

4. Discussion

The temperatures indicated of the first freezing event in the case of AgI and PbI_2 in the present experiments are respectively about $-4°C$ ($-4.0°$ to $-4.2°C$) and $-6.5°C$. The values agree very closely with the widely accepted threshold nucleation temperatures for these substances which are respectively −4°C and −6°C (Mason, 1971). It is considered, therefore, that the method used in the present study is a valid one for examining the threshold nucleation temperatures of substances. This view is further confirmed by the observational evidence reported, namely, that powdered materials, in 1 % aqueous suspensions, nucleated bulk water (1 mm drops) at temperatures very close to the threshold temperatures at which the respective substances were found active in a cold chamber (Mason & Van Den Heuvel, 1959). The present experiments, which are conducted with 1 % aqueous suspensions, help suggest that the threshold nucleation temperature of Portland cement is around −5°C (−4.6° to −5.0°C).

The temperatures of the first freezing event noticed under conditions of cold stage temperature initially at −10°C (these are −4.2°C and −5.0°C for AgI and cement respectively) are slightly lower than the corresponding temperatures noticed under conditions of cold stage temperature initially at −5°C (these are −4.0°C and −4.6°C for AgI and cement respectively). The shifts in the temperatures noticed, although small, are in the right direction if it is kept in view that the cooling rate experienced by the drops in the first case (the mean cooling rate in the temperature range 0°C to −4°C was 1.9°C/minute) was more than that experienced by them in the second case (the mean cooling rate in the corresponding temperature range was 0.32°C/minute).

At temperatures colder than −5°C, Portland cement is as good an ice nucleant as is either $2AgI \cdot NaI$, which is one of the most widely used chemical systems in the present day weather modification experiments, or PbI_2 which is also a widely used chemical for such purposes. Under conditions of temperature approaching −5°C, only Portland cement and AgI are active while $2AgI \cdot NaI$ and PbI_2 remain ineffective. As between Portland cement and AgI it is the latter which is more effective, Portland cement is to be reckoned only next to AgI in its ice-forming ability.

5. Conclusion

The present study has shown that Portland cement is a definite ice nucleant. This material, which is being used hitherto for the purpose of cloud dissipation, could also be now considered for use in weather modification experiments which seek to increase rainfall. However, the relative scope of its use for such purposes has to be examined in the light of the very high aerosol production rates which are found possible in practice in the case of seeding with crystalline reagents like AgI. In any case, the factors responsible for the observed ice nucleating behaviour of Portland cement merit investigation.

Acknowledgement

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НУКЛЕАЦИЯ ЛЬДА СТАНДАРТНЫМ ПОРТЛАНДСКИМ ЦЕМЕНТОМ

Нуклеационная способность портландского цемента изучалась путем сравнения поведения при замерзании капель, полученных из водных суспензий цемента, и капель, полученных из суспензий AgI, 2AgI·NaI и PbI_2. Найдено, что при температурах, меньших −5°C, портландский цемент обладает той же способностью к нуклеации льда, как и 2AgI·NaI или PbI_2. При температурах, приближающихся к −5°C, только портландский цемент остается эффективным нуклеантом, но не два последних реагента. Однако его эффективность мала по сравнению с эффективностью AgI при всех рассмотренных здесь температурах.