# THE EFFECT OF AIR POLLUTION ON ICE NUCLEI CONCENTRATION IN ISRAEL

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## 1. INTRODUCTION AND BACKGROUND:

Air pollution aerosols as well as aerosols from natural sources affect our health, our environment and our climate on both local and global scales. The effects of aerosols from air pollution on the formation of clouds containing only water drops are fairly well understood. On the other hand the effects of air pollution aerosols on the formation and growth of ice crystals in clouds is still not clear. Some papers claim that air pollution can enhance ice crystal concentration (DeMott et al., 2003) while others like Braham and Spyers-Duran (1974) claim that the air pollution can de-activate them.

Ice crystals play an important part in the generation of precipitation in many types of clouds and greatly affect the global climate by influencing the global radiation balance (IPCC, 2001, 2007). They are formed in clouds by nucleation on very special particles called Ice Nuclei (IN). The ice nuclei are airborne, aerosol particles that vary from place to place and from season to season. Their sources and composition are still being debated. In addition, according to Levin and Cotton (2007) the ice formation in clouds is not well understood, there is a great deal of uncertainty in measurements of their concentrations and even in their characterization. The connection between ice crystal concentration in clouds, temperature and supersaturation is not clear. Therefore, it is not yet possible to forecast correctly the role of ice in clouds and in precipitation, and to estimate its effect on climate.

In this research we investigate the role of air pollution in modifying the concentrations of ice nuclei in Israel. We collected aerosols on filter samples from three locations (Fig 1) 1) near the shores of Tel Aviv, up wind of pollution sources; 2) on the campus of Tel Aviv University, inside the polluted area about 3 km from the sea shore, 3) east of the city of Tel Aviv and downwind of the pollution centers. For this purpose we used Nitrocellulose filters with a diameter of 47 mm and 0.45 pore sizes, 300L (for deposition and condensation freezing) and 400L (for immersion freezing) of air were sampled on each filter. During the sampling, an aerosol concentration was measured using the TSI Condensation Particle Counter Model 3010.

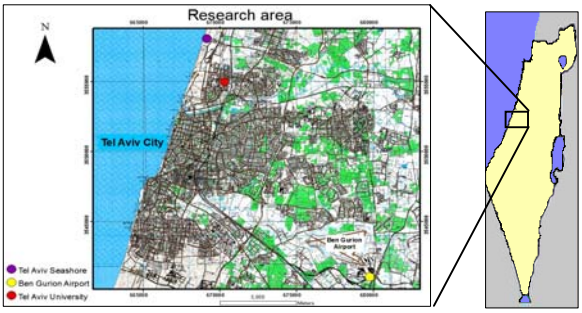


Figure 1: Research area.

## 2. METHODS AND EXPERIMENTAL SET UP

Three modes of heterogeneous nucleation have been investigated: immersion, deposition and condensation freezing. The analysis has been made in the newly designed IN-Counter called FRIDGE-TAU (Frankfurt Ice-nuclei Deposition freezing Experiment - the Tel Aviv University version), see Fig 2a-b.

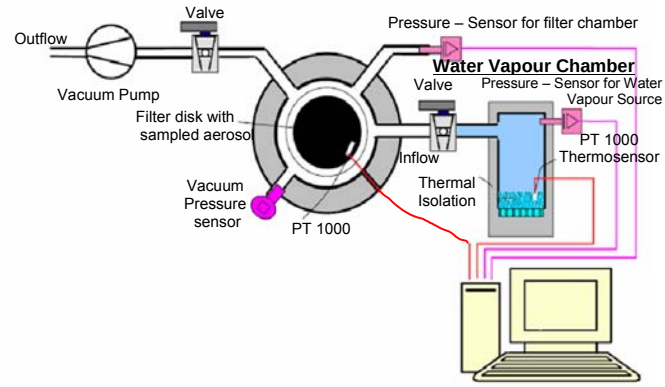


Figure 2a: Schematic diagrams of the FRIDGE-TAU instrument top view.

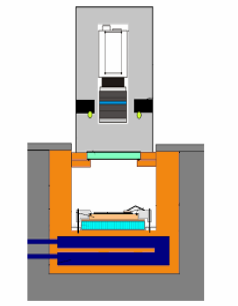

Figure 2b: Schematic diagram of the FRIDGE-TAU ice nucleation chamber, side view.

The procedure for operating this chamber can be found in (Nillius et al, 2008). In brief, the filters are exposed to the desired and known vapour pressures at each temperature, thus allowing for determination of the ice nuclei concentrations active at these temperatures. Measurements were performed from around 0°C down to -30°C, with a number of different values of vapour pressure at each temperature, from ice saturation to just above water saturation. The ice crystals that are formed are recorded with a computer controlled CCD camera.

In addition to the samples collected on the filters for the analysis described above, we also collected aerosols on filters for evaluating the immersion freezing properties, using the drop freezing method (e.g. Vali, 1985; Levin et al, 1987). The filters with the collected aerosols were washed with 10 ml of double distilled water. From the mixture of water and aerosols, about 100 small drops (2 µl) were placed on

the substrate of the chamber in the FRIDGE-TAU. As the chamber is cooled, the number of frozen drops at each temperature is recorded with the CCD camera.

## 3. PRELIMINARY RESULTS

### 3.1 IMMERSION FREEZING:

We compared the average temperatures at which the drops froze at each of the three locations on the same day (about 1 hour apart between samples). As can be seen from Fig 3, the freezing temperature (average of three samples) at which 50% of the drops froze varies by about 3 degrees between samples collected at the three sites. The freezing temperatures of the drops containing aerosols collected downwind of the polluted area are the highest (about -22°C), suggesting that the pollution sources of Tel Aviv may contain some efficient IN. The drops containing particles from TAU (inside the polluted area) exhibit an intermediate freezing spectrum with a modal freezing temperature of -23˚C. It can be concluded that air which comes from the Mediterranean and is up wind of the pollution of Tel Aviv contains less efficient IN.

Our results are similar to those reported by Hobbs and Locatelli (1970), but in contradiction to Borys and Duce (1979) who found no detectable effects of the urban atmosphere on the IN concentration.

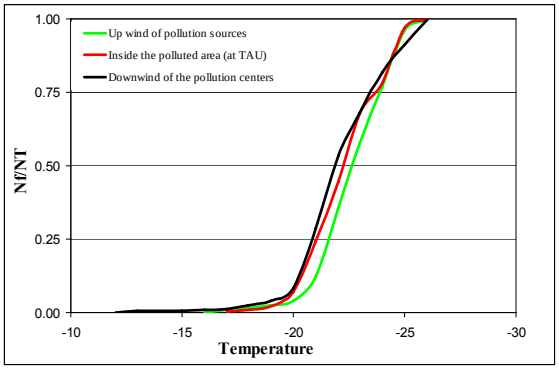


Figure 3: immersion freezing result for comparison of freezing spectrum as a function of air pollution concentration.

Comparing immersion freezing efficiency between two days with dust (090308 & 170308) reveals differences in the IN activity spectrum of the dust particles (Fig 4). Dust particles collected on 090308 are more effective as freezing nuclei (freezing occurs at higher temperatures) than those collected on 170308. The difference in the freezing temperatures of the drops could possibly be explained by the different source and composition of the dust particles.

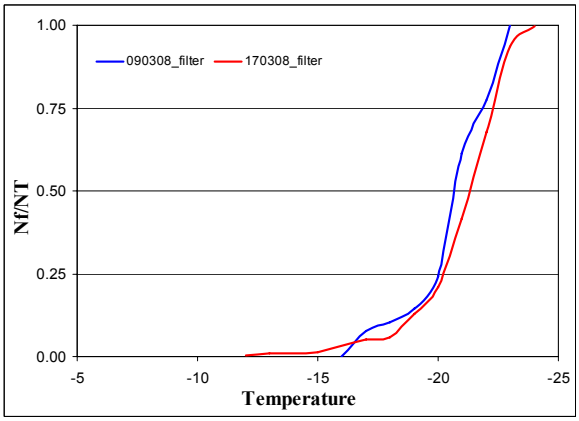


Figure 4: comparison immersion freezing between two days with dust.

### 3.2 DEPOSITION AND COCDENSATION FREEZING RESULT:

Using the FRIDGE-TAU we also compared the deposition and condensation freezing of filter samples taken during the same two days with dust, 090308 and 170308 (Fig 5). It can be seen that at the same supersaturation with respect to water, the colder the temperature the higher the number of ice crystals that appear on the filter. The highest concentrations of ice crystals appear close to, or at water saturation. It is interesting to point out that the slope of the curves (although only a few measurements are available) is smoothly approaching water saturation. This is a puzzling observation, since at low water saturation ratio one would expect deposition. At water saturation, or close to it, immersion freezing is expected. The fact that in most cases the slope is smooth as water saturation is approached, may imply that condensation freezing occurs already below water saturation. Such conditions could occur if the particles contain some soluble material on them. Levin et al (2005) reported that dust passing over the Mediterranean contains high concentrations of dust coated with sea salt. One cautionary note is in order; the FRIDGE experiments for deposition and immersion freezing in the setup described above seem to undercount the ice nucleation by about two orders of magnitude as compared with the measurements with a number of Continuous Flow Diffusion Chambers, as illustrated in the AIDA workshop in October 2007. The reasons for the undercount may have to do with the petroleum jelly that is used to improve the contact between the filter and the cold substrate. Apparently, some of the petroleum jelly penetrates through the filter holes, coats some of the particles and deactivates the ice nuclei. An attempt to collect the aerosols on metal substrate by electrical deposition is now underway.

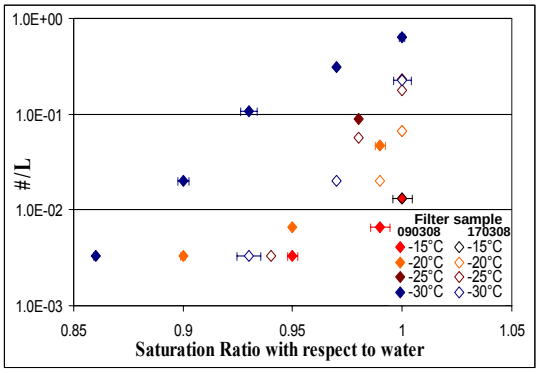


Figure 5: Comparing the Deposition and Condensation freezing for two days with dust.

Elemental composition of suspended mineral dust (d<100μm) using the EM-EDS method described by Levin et al (1996), showed that the dust particles from 090308 contained more soluble material, probably sea salt, then the dust particles collected on the 170308 (Fig 6). This would support the hypothesis that many of the dust particles passing over the Mediterranean Sea are coated with sea salt. Thus these are good condensation freezing nuclei, which form ice

more efficiently than pure dust particles that require higher water saturation ratio before ice nucleation can occur.

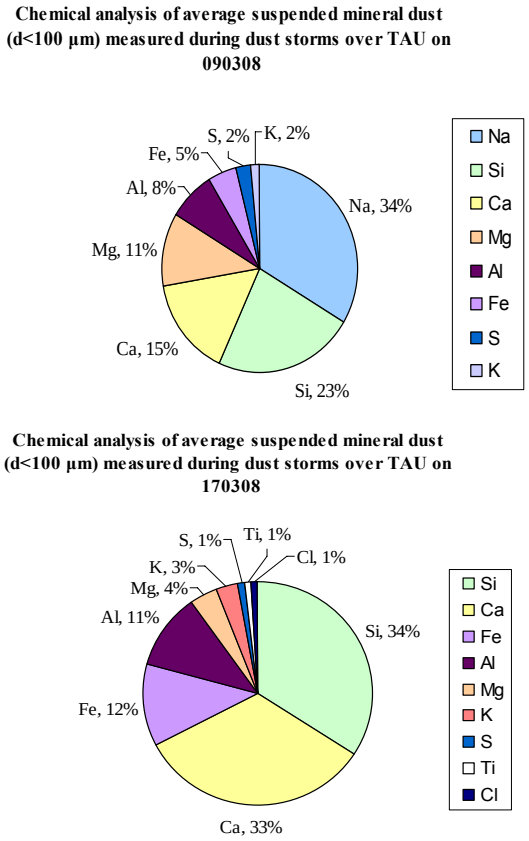


Figure 6: Elemental composition of suspended mineral dust (d<100µm) for the two days with dust.

Back trajectory analysis (Fig. 7) of these two days confirms that the air reaching Tel Aviv at the low levels on the 090308 passed over the sea, probably picking up some of the sea salt. In contrast, the air reaching Tel Aviv at the low levels on the 170308 came directly from the east, without passing over the Sea.

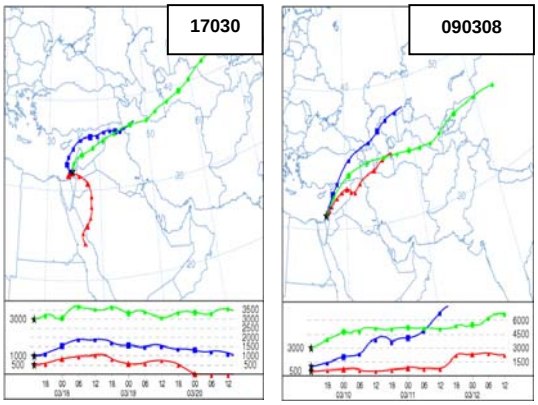


Figure number 7: Back trajectory analysis for the two days with dust, Source: http://www.arl.noaa.gov.

## 4. CONCLUSIONS

In this study we are trying to measure the ice nuclei upwind and down wind of urban areas in Israel in order to determine the effects of pollution on ice nucleation in Israel. The results will then be compared with similar measurements carried out in Europe, in order to determine the geographical distribution of these particles. The present preliminary results show some effects of the city of Tel Aviv on enhancement of effective IN. Furthermore, immersion freezing of drops seems to be a much more effective ice nucleation process than deposition nucleation. The filter method, in which deposition could be separated from immersion freezing, indicates that condensation freezing on dust particles starts at water sub-saturation due to the presence of soluble material on the dust particles. Elemental analysis and back

trajectory calculations confirm the presence of soluble material on the dust particles.

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