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COLD REGIONS AIR POLLUTION BIBLIOGRAPHY AND SUMMARY

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Prepared for the

COLD CLIMATE ENVIRONMENTAL RESEARCH PROGRAM
ENVIRONMENTAL PROTECTION AGENCY

by

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Front Cover: An aerial photograph of shallow ice fog over Fairbanks on 3 January, 1975 at the start of a severe ice fog episode. Later during this episode the two lower exhaust plumes from power plants merged with the ice fog. (photo by Carl S. Benson)

PREFACE

Through a series of workshops on cold-climate environmental research priorities, conducted in 1982 by Battelle for the Environmental Protection Agency and the Department of Energy, air pollution was identified as the topic of highest priority. The current state of knowledge on air pollution in cold climates was considered to be incomplete, and available information was believed to be widely scattered in the published and "grey" scientific literature. One of the high priority projects of air pollution research was therefore identified to be the compilation of a bibliography and synthesis of what is known and what is not known about air pollution in the cold regions.

This document is the result of that recommendation. It was prepared by the Geophysical Institute of the University of Alaska under Subcontract No. B-A3543-A-U to the Pacific Northwest Laboratory (PNL) of Battelle Memorial Institute. PNL manages the Cold Climate Environmental Research Program as an agent of the Department of Energy through DOE's inter-agency agreement (No. DW 89930699-01-1) with the Corvallis Environmental Research Laboratory of the Environmental Protection Agency. The "cold regions" referred to in this document are defined as the arctic and sub-arctic areas roughly north of 60°N latitude. This includes most of Alaska, northern Canada (particularly the Yukon and Northwest Territories), northern Europe, Siberia and the Arctic Ocean.

The bibliography on air pollution compiled for these "cold regions" includes papers on the sources, species, concentrations, pathways and effects of various kinds of air pollution, including phenomena such as ice fog and arctic haze which are peculiar to the region. Most of the listed references apply to Alaska; Fairbanks in particular is strongly repre-

sented in the literature on ice fog, carbon monoxide, automobile emissions and other topics. The references on Arctic Haze, a phenomenon which pervades the entire Arctic Basin, are fairly extensive as are references from northern Europe on haze, acid rain and other pollution problems. The smallest number of papers comes from Northern Canada and the Soviet Union. The considerable literature on pollution in Southern Canada (Toronto, Ottawa, etc.,) was not included because it did not come under our definition of "cold regions", Soviet literature, if it exists, does not appear to be available in translation, as indicated by our computer and other searches.

We would like to acknowledge the assistance of the following people in providing help in compiling the bibliography: Richard Joy, Environmental Services Division, North Star Borough; Barbara Sokolov, Arctic Information and Data Center, Anchorage, and Judie Triplehorn, librarian of the Geophysical Institute, who provided numerous references through extensive computer searches of the literature on the subject. Jim B. States of Battelle Alaska Operations in Anchorage was the technical administrator of the project and his help in all phases of the work is acknowledged and appreciated.

Availability of the Listed References

Many of the listed references are "grey literature", i.e., they are reports which have not been published or extensively distributed. Microfiches of these reports which are otherwise difficult to obtain (marked Ⓜ on each reference) are at the following locations:

Library, Geophysical Institute, University of Alaska,
Fairbanks, AK 99701

Alaska Resources Library, Federal Building, 701 C Street,
Box 36, Anchorage, AK 99513

Library, Arctic Environmental Information and Data Center,
707 A Street, Anchorage, AK 99501

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TABLE OF CONTENTS

I. SUMMARY

This section attempts to summarize and synthesize the available information (contained in the bibliography of Section II of this report) on the various aspects of air pollution in the cold regions. Information gaps are identified and recommendations on further research are made. It should be stressed that the recommendations are intended to fill present data and information gaps, regardless of the cost involved or the relation of the recommended research to the missions of EPA or DOE in reducing pollution. Research priorities for these agencies have recently been established (J. B. States, 1983, Assessment of Cold-Climate Environmental Research Priorities, Battelle PNL-4581, 50 pp.).

NOTE: Page numbers after references refer to pages in the bibliography where the abstracts for the referenced papers can be found.

CHARACTERISTICS OF COLD REGIONS AIR POLLUTION

Problems of air pollution in high latitudes, especially during winter, have attracted ever increasing attention during the past two decades, (Benson, 1965, p. 74; Benson, Bowling and Weller, 1983, p. 196). Winter air masses become very stable and tend to stagnate to the extent that air quality problems exist throughout northern Canada, Siberia, Scandinavia, and Alaska.

As seasonal temperature decreases in the northern cities of these regions the need for increased heat and power causes an increase in all sources of pollution. Unfortunately, it is in these times that the stability of the air mass becomes most extreme (Bilello, 1966, p. 59). Thus, natural and man-made factors reinforce one another in ways which invariably lead to intensification, never mitigation, of the air pollution problem (Benson, 1970, p. 75).

In addition, during winter, water becomes a component of the air pollution because it condenses into tiny droplets and/or crystals even when the quantity involved is quite small (air at +20°C can hold about 250 times more water vapor than air at -40°C). At temperatures below -35° to -40°C ice fog is produced which severely restricts visibility but also serves as an indicator that man-made pollutants are present (Benson, 1970, p. 75; Ohtake, 1970, p. 92).

Air pollution problems in the North can be severe, as illustrated by the air quality of the Fairbanks air shed, which is unique for several interrelated reasons stemming from the extreme stability of the air mass and its tendency to stagnate. Indeed, a special stability class "Pasquill G" was established to describe extreme cases like the Fairbanks air shed.

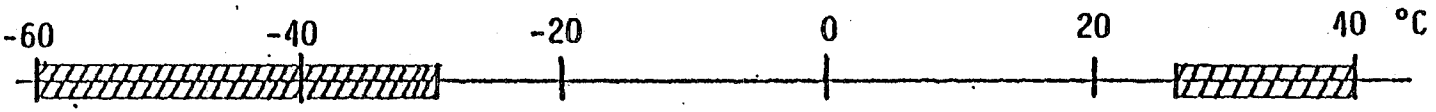
The air mass is so stable that the per capita air pollution is 10 to 100 times greater than in the Los Angeles area. This statement is based on the observation that levels of carbon monoxide, and total hydrocarbons measured in Fairbanks (Jenkins, et al., 1975, p. 166), are comparable to values measured in Los Angeles, New York and Detriot where populations are much higher. The national ambient air quality standards for carbon monoxide are, in fact, frequently exceeded in Fairbanks (see p. 31).

The problems of air chemistry have generally been studied in temperate latitudes and mostly at high temperatures. The Los Angeles problems quickly come to mind as being at the opposite end of the spectrum from Fairbanks problems (Table 1). The problems in Los Angeles stem from automobile exhaust and industrial chemicals which are cooked in the intense sunlight and form photochemical smog, characterized by products of oxidation (O_3, etc.). To have this occur, high temperatures, lots of sunlight, water vapor (for OH and O_2H radicals) as well as plenty of hydrocarbon and NO_x sources are required. In Fairbanks, we have low temperatures, and almost no sunlight (less than 6 hours per day for 70 days, and less than 4 hours per day for 25 days). Therefore, even though significant hydrocarbon concentrations are present (Jenkins et al., 1975, p. 166) we do not expect photochemical reactions to be important in winter although this may become a problem in summer because of the many hours of sunlight. In winter a different mix of pollutants become trapped in the surface inversion layer. Because of the snow cover, natural aerosols are at a minimum, and only those from combustion of coal, oil, natural gas and wood are present; they interact with an abundant supply of ice crystals and supercooled water droplets (Benson, 1970, p. 75; Ohtake, 1970, p. 92).

TABLE 1

SPECTRUM OF AIR POLLUTION SETTINGS

(showing the two end members)

	Fairbanks in Winter Low Temperature Icefog/Pollution	Los Angeles in Summer Smog
Temperature		
Temp Inversions	30°C/100m (Surface)	10°C/100m (Above Ground)
Radiation	None during winter (~980 W m^{-2} at the summer solstice)	High (>1000 W m^{-2})
Saturation Vapor Pressure	Low (0.05 mb at -50°C)	High (42.43 mb at 30°C)
Chemistry	Reducing atmosphere No photochemical reaction "Wet" air chemistry (Low absolute water content but condensed form present)	Oxidizing atmosphere Max. photochemical reaction "Dry" air chemistry (High absolute water content but condensed form absent)

The main questions to be answered deal with the nature and effects of this interaction between ice crystals, or super-cooled water droplets and combustion aerosols and gases. What is the physical state of the fog particles, supercooled droplets or ice crystals, as a function of temperature and different pollutant levels? Do the pollutants cause more nucleation of smaller ice crystals and thicker ice fog? Are pollutants selectively removed from the air by the fogs due to their physical and chemical interaction? Are the "inert" gases such as CO and CO_2 incorporated into the ice crystals? How do the reactive gases SO_2, NO, NO_x and O_3 behave relative to each other and is their conversion to $SO_4^=$, NO_3^- and O_2 enhanced or decreased by ice fog? Do ice crystals in the respireable size range trap contaminants and actively transport them into the lungs? Are certain particle size ranges removed preferentially by ice crystals, or are they responsible for the enhancement of ice fog? How will hydrocarbons affect the growth and dissipation of ice fogs; do they form hydrophobic layers on crystals? What different effects are observed when power plant emissions are mixed downward into the lower air mass, compared with the more normal case when they remain aloft?

These questions need to be answered before we will have enough information to begin to understand the implication of increased development in cold climates. Several studies on the concentrations of specific pollutants have been carried out in the Fairbanks area including:

(i) Winchester, et al., (1967, p. 56): lead and halogens

(ii) Kumai, (1964, p. 83); Ohtake, (1970, p. 92; 1970, p. 94): chemical composition of ice fog nuclei

(iii) Holty, (1973, p. 199): lead, oxides of nitrogen, CO, $SO_4^=$, NH_4^+, Cl^-

(iv) Jenkins, et al., (1975, p. 166): total hydrocarbons, CO, CO_2, NO_x

(v) Coutts, (1979, p. 163): NO - NO_2 - O_3 interactions

(vi) Reichardt and Reidy, (1980, p. 51): polycyclic aromatic hydrocarbons (PAH).

Information of this kind for other northern cities is much less complete or totally absent (see also section on monitoring). With trends towards accelerated exploitation of arctic resources it becomes increasingly important to know the effects of growth on an area so that corrective steps can be taken. Some of these corrective steps are discussed in later sections.

Recommendations for Further Research

Enough information has already been gathered to date to point out some broad problem areas. In very general terms, the most important gaps in our knowledge will require research in the following areas:

1. A detailed study of low temperature air chemistry in the presence of fogs consisting of supercooled water droplets and/or ice crystals.
2. An integrated study of the structure, dynamics and time history of the very stable winter atmosphere and the diffusion processes which affect its atmospheric pollutants.

These recommendations will be discussed in greater detail in the following sections.

THE CHEMICAL NATURE OF COLD REGIONS AIR POLLUTION

The chemistry of air pollution in cold climates is quite different from that at lower latitudes, as shown in the preceding section. The photochemical smog typical of Los Angeles does not exist in Fairbanks, but there are reports (e.g. Schjoldager et al., 1978, p. 52) and Bottenheim and Strausz, 1980, p. 46), that photochemical activity could occur in the Arctic, particularly during the summer solstice. Schjoldager (1954, p. 54) indicates that local production of ozone occurs in Norway. Peake and Sandhu (1983, p. 50) have shown that another photochemical product, PAN (peroxyacetyl nitrate), is produced in winter in Alberta at about 25% of the summer level. An interesting paper on photochemical mechanism for high latitudes is the one by Bottenheim and Strausz. Other photochemical papers are by Schjoldager et al., (1978, p. 52 and 1979, p. 52), (see also Monitoring section for more comments about ozone, p. 39).

More exotic pollution products may be present in large quantities in northern cities. Reichardt and Reidy (1980, p. 51), for example, demonstrated that polycyclic aromatic hydrocarbons (PAH) concentrations in Fairbanks under strong winter inversions can be equal to those of large urban areas of the world. This study occurred before the recent increased use of wood stoves. Daisey et al., (1981, p. 104) showed that PAH material in remote areas of the Arctic are within an order of magnitude of concentrations found in large urban areas.

There is a fairly large body of literature on various trace elements, all pointing to long range transport of anthropogenic pollution from low latitudes into the Arctic (see the section on Arctic haze, p. 25).

Rasmussen et al., (1982, p. 51), show that carbon monoxide is enriched in snow as compared to methane; this finding is of greater interest in long range research, however, than in urban pollution studies (see monitoring section for other remarks about CO, p. 36). Cavanaugh et al., (1969, p. 104), show startlingly high n-butanol concentrations in arctic air (~ 0.1 ppm) which do not appear to be an experimental artifact.

The report by McCandless (1982, p. 159), on Whitehorse urban air problems confirms the growing evidence for the significant woodsmoke contribution to both TSP and PAH levels. Formaldehyde in ice fog samples are high (0.5 - 1.16 $\mu g\ ml^{-1}$) presumably due to combustion, as reported by Grosjean and Wright (1983, p. 48). Formate and acetate are found in precipitation (Galloway et al., 1982, p. 171) in Alaska in normal quantities.

The pH records of precipitation in Alaska's remote areas tend to be normal to slightly acid (~ 6.3 down to 4.7; NADP, 1983, p. 167, Galloway et al., 1982, p. 171). The most unusual pH conditions have been found within the city of Fairbanks during winter. The pH of ice fog and snow on the ground can go as high as 10.2 (presumably due to metal oxide ash fallout from woodstoves, and possibly from power plants; (Gosink, 1981, 1983, p. 47; Grosjean and Wright, 1983, p. 48).

A discussion of the concentrations of the more common chemical compounds and elements present in the polluted air masses of northern latitudes is contained in the section on monitoring (p. 36).

Gaps in the Technical Literature

We have no data on indoor air pollution in the cold regions. This aspect of air pollution studies is just beginning, so the gap is under-

standable. It is anticipated that the only unusual features may deal with aspects of air exchange with the outside. Many homes are being insulated more carefully and madé airtight.

Photochemical data for ~ 70°N are missing. The only papers available are for 60°N and farther south.

Power plant emission data are incomplete, but it is not certain that there will be any unusual features in the cold regions as opposed to what is already known about emissions at lower latitudes.

Air pollution data for the vast Soviet sector of the Arctic and Subarctic are almost entirely missing. As noted in the preface, such papers, if they exist, do not appear to be available in translation. An exception is the paper by Morachevsky et al. (p. 49).

Recommendations for Further Research

The following topics need to be addressed in future studies:

1. Indoor air pollution:
   (a) possible trapping of pollutants inside by overly tight construction and/or lack of ventilation,
   (b) transfer of pollutants from polluted urban air to the inside.
   (c) dependence of indoor pollution on height of inlet air vents in tall buildings.
2. Photochemistry at high latitudes:
   (a) ultraviolet radiation,
   (b) ozone and PAH data for clean and dirty sites at all times of the year,
   (c) information about hydroxy and peroxy free radicals.
   (d) oxidation of NO, SO_2 etc.

3. Particulate matter:
   (a) the mass loading, numbers and size distribution of particulates,
   (b) chemical information about possible selective partitioning of pollutants on the different size ranges of pollutants,
   (c) The scavenging efficiency of snow and ice fog.
4. A statistical study of health records for the months of January and July for eye and respiratory disease. (This should discriminate between people living and working in polluted urban areas versus people who spend part of their time in polluted areas and those who remain outside the polluted urban centers).
5. More chemical and biological data about carcinogenic factors in urban pollutants.
6. More chemical details about the pollutants trapped in snow and their potential for pollution of streams during thaw.

METEOROLOGY OF COLD REGIONS AIR POLLUTION

High latitude air pollution is principally a cold-season phenomenon, and is due directly to the extreme stability of the air at high latitudes in winter (Bowling, 1984, p. 63). This stability is in turn a result of the solar radiation regime. At 60° North, for instance, the true solar elevation angle at noon at the winter solstice is only 6° 33' and the day is only 5 hours and 52 minutes long, which allows almost no solar heating. (This noon solar elevation corresponds to a solar elevation of less than forty minutes after sunrise in Los Angeles.) At 68° N, the sun no longer rises at all at the winter solstice. The result is that nighttime radiation conditions extend throughout the part of the day with maximum pollutant emissions. Mixing heights as low as 6 m have been measured in downtown Fairbanks.

Inversions

A typical high-latitude inversion differs substantially from those responsible for air pollution problems in locations such as Los Angeles (Benson, 1970, p. 75). In a Los Angeles-type (or elevated) inversion, the temperature normally decreases with height for the first few hundred meters above the ground, then increases rather sharply in a layer known as a capping inversion. An inversion of this type may be due to warm air overrunning cold air, to subsidence above a surface layer, or to limited heating from below of a stable air mass. Inversions of this type may occur at high latitudes, but it is rare for them to be associated with episodes of poor air quality (Bowling, 1983, p. 63). High pollutant levels occur with surface-based inversions, i.e., those in which the temperature increases from the ground up. The maximum temperature in an

Alaskan sounding is frequently as much as 2 km above the surface, and ground temperatures may be only a few degrees higher than those at the tropopause (Bowling, 1967, p. 60).

Surface inversions are common world-wide on clear, calm nights, and are often referred to as nocturnal inversions. These inversions, however, are normally broken by solar heating during the daylight hours when emissions are highest. In Fairbanks, more than 80% of all soundings (2 am and 2 pm) show surface inversions during December and January (Bilello, 1966). Furthermore, some of these inversions are extremely steep--lapse rates of -10°/100m are common, and value as high as -30°/100 have been recorded over the first 30m (Wendler and Nicpon, 1975, p. 71; Bowling et al., 1968, p. 61). The presence of such inversions is readily explained: in the absence of solar heating, the thermal structure near the ground is controlled entirely by long-wave radiation and mechanical turbulence. Long-wave radiation tends to produce an isothermal near-ground lapse rate if dense clouds are present and a steep ground inversion (gradually weakening with elevation) when skies are clear. In exposed areas with substantial pressure gradients, wind-induced turbulence will push these radiative equilibrium states toward the adiabatic. Most high-latitude settlements, however, are located in sheltered areas such as river valleys where wind speeds are often low even with strong regional winds. Furthermore, the clear skies which allow development of inversions are often due to anticyclonic systems with light winds. The observed high frequency of strong surface inversions is the inevitable result.

An elevated inversion allows for a substantial amount of vertical mixing below the inversion "cap", but this is not true of a surface-based

inversion. In a rural area, vertical dispersion of pollutants is due almost entirely to the heat and/or mechanical turbulence associated with pollutant injection. This can be remarkably small: plumes from trucks with exhaust pipes above the cab can frequently be seen to spread in a well-defined layer just above the trailer height (unpublished observation, Bowling). In a town of the size of Fairbanks (population ~ 50,000) there is normally enough heat and traffic-generated turbulence to produce a shallow mixed layer. Just how shallow is indicated by tethered balloon measurements carried out in December 1981 (Bowling, 1983, p. 63). Rural inversion strengths were on the order of 10°C/100m. Downtown Fairbanks had developed isothermal layers varying from 6 to 30m in depth. Some additional mixing may have been occurring through updrafts along building sides. Since neither inversion strengths nor CO concentrations were extreme for the Fairbanks area, however, it seems unlikely that the true mixing depth on the worst day of an average year would exceed 10m. (In comparison, Los Angeles mixing depths are normally several hundred meters, Benson, 1970, p. 75.) In addition to affecting the vertical dispersion, the mixing layer is responsible for an intense heat island. Downtown temperatures may be as much as 10° to 14° higher than those in the surrounding rural area (Bowling and Benson, 1978, p. 62).

Ice fog (section 3) influences the radiative process directly, resulting in greatly weakened inversions or even normal lapse rates within the ice fog, with a relatively steep inversion near the fog top (Benson, 1970, p. 75; Bowling, 1970, p. 60). As this will improve vertical mixing, ice fog may be indirectly responsible for reducing CO concentrations. CO emissions may also be lower during ice fog due to diminished traffic and

the almost universal use of preheaters at ice fog temperatures. This may be partly offset, however, by the very large number of unattended cars left idling at -40° and colder. Regardless of the cause, it is an observed fact that CO levels almost never reach violation levels (9ppm) when ice fog is present (Bowling, 1983, p. 63).

Winds

Winds are important for air pollution both because they carry pollutants away horizontally and because they generate turbulence which weakens the inversion and allows increased vertical dispersion. As already mentioned, the strong ground inversions which are associated with high pollutant levels at high latitudes are normally associated with light winds. Local factors preventing strong winds vary. Anticyclonic conditions are frequent in the Interior of Alaska, and Fairbanks is located in a sheltering arc of hills opening southward into the Tanana Valley. Anchorage is located just west of a sheltering mountain front. The result is that the observed winds during pollution episodes are normally locally generated and therefore light.

Local winds include those generated by cold air drainage, gravity waves, and local-scale eddies, and the interactions of these with regional winds (Benson and Weller, 1970, p. 59; Bowling and Benson, 1978, p. 62). From a practical point of view, a more useful division is into winds which produce a net flow through the city (thus removing pollutants) and winds which recirculate pollutants within the city (thus acting to enhance horizontal dispersion). In Fairbanks, the only Alaskan city in which studies have been made of locally generated winds, local drainage wind speeds are of the order of .5 m sec^{-1}, with values up to 1 m sec^{-1}

in well defined channels or on steep slopes. These winds continue through the city under moderate inversion conditions, but under severe inversions the hill slopes may be so much warmer than the valley bottom that the local slope winds may flow out over the dense, cold air mass in the lowest part of the ground inversion (Benson, 1974, p. 75). Winds measured in the downtown area when CO levels are high may be as low as 10 to 20 cm sec^{-1} (Bowling and Benson, 1978, p. 62). Gravity drainage winds down major valleys such as the Tanana, Matanuska and Susitna may reach speeds sufficient to break the ground inversion, as has been observed several times on satellite infrared images. Tanana Valley drainage winds at times extend northward far enough to affect the southern part of Fairbanks (including the Weather Service recording station located at the Airport). This situation does not, however, appear to remove pollutants from the downtown area--in fact it has been responsible for several severe (over 15 ppm CO) pollution episodes (Bowling, 1983, p. 63). One observation has also been made of a long-period (4 hour) seiche oscillation between Fairbanks and Eielson Air Force Base, 50 km away (Bowling and Benson, 1978, p. 62). This occurred with heavy ice fog and appeared to shift the fog (and the coldest air) back and forth between the two end points rather than actually removing polluted air.

Smaller gravity waves (periods 5-20 minutes) and stationary eddies (such as the one generated over the entire city by the Tanana drainage impinging on the ridge southwest of Fairbanks) produce major spatial and temporal variations in the surface wind field. These are probably responsible for a good deal of horizontal dispersion within the city, but have little or no effect in removing pollutants from the area.

Synoptic Situations Associated with High Latitude Air Pollution Episodes

In all of the high latitude air pollution cases examined so far, clear skies (or very high, cold clouds) and low wind speeds are critical factors. Ice fog in Fairbanks is known to be associated with northerly flow aloft and a surface anticyclone. High CO levels in Fairbanks have not been studied intensively from a synoptic point of view, but one situation well known locally is "chinook" flow. This is not a classical chinook, as the warm winds from the south over the Alaska Range are unable to penetrate the ground inversion, but it is associated with clear skies and temperatures aloft which may be above freezing, while surface temperatures remain below -20° C. Warm air advection just above the surface inversion has been a causative factor in several cases with alert (15 ppm) levels of CO. In Anchorage, the critical factors are high pressure to the north and low pressure well south in the Gulf of Alaska, leading to easterly surface geostrophic flow. The factors determining whether this situation will lead to strong surface winds or stagnation east of the Chugach Range are not well understood at this time (Bowling, 1983, p. 63).

Modeling

Modeling the air pollution situation at high latitudes is a severe problem. Well-tested standard models generally couple the horizontal and vertical dispersion in such a way that very poor vertical dispersion is associated with very little variability in wind direction. Ground inversions typically show the opposite relationship--Fairbanks winds at a point may vary over 180° or more within half an hour in extreme cases. Furthermore, standard models cannot handle the great spatial variation in winds seen in both Fairbanks and Anchorage. Nevertheless, regulatory agencies

require that standard models be used for environmental impact statements. This has led to environmental impact statements where modeling was carried out with 100 to 200m mixing heights, while (as mentioned above) 10m would be more appropriate. One model--ACOSP (Norton and Carlson 1976, p. 68, Carleton and Fox, 1976, p. 64, Carlson and Hok, 1980, p. 64)--has been developed for the Fairbanks CO problem, but it has not been adequately tested, in part because meteorological input data were not available. In this respect it is significant that ACOSP's best reproduction of observed CO levels was obtained using a 10m mixing height--exactly the height we have since recommended on the basis of tethered balloon measurements.

CO Forecasting

The Fairbanks North Star Borough produces a regular CO forecast during the air pollution season (October - March). This forecast is based on a modified persistance forecast (today's forecast maximum 8-hour CO level = yesterday's 8-hour maximum times the ratio of the most recent 8-hour level available to that for the same time the previous day) which is then adjusted to account for a dispersion forecast issued by the National Weather Service. The resulting forecast improves on persistance, but has rarely been successful in forecasting CO levels above 15 ppm. Provision of CO data to the Weather Service has improved the dispersion forecasts given to the Borough, but severe problems remain, especially in forecasts of surface winds in the downtown area (Bowling, 1983, p. 63).

Recommendations for Further Research

1. Probably the most pressing problem in the meteorology of high latitude air pollution is the verification, to standards that EPA will accept for environmental impact statements, of a dispersion model capable of handling high latitude meteorology. Two obvious candidates are ACOSP and a currently accepted Gaussian model with decoupled hori-

zontal and vertical dispersion. Verification would require several periods with good meteorological measurements (in-town soundings and/or tower measurements to at least 50 m, winds throughout the area) and either CO sources and concentrations or a tracer release. Fairbanks is the obvious site for initial verification, but once meteorological measurements are available from other areas (such as Anchorage) it might be possible to apply the model there as well.

2. Another area in which meteorological knowledge is seriously deficient is the variation of winds, temperatures, and lapse rates through the Anchorage area (needed for any detailed modeling there).
3. One problem for which no references were found for the bibliography is plume rise under stable conditions with significant winds and wind shears at some or all levels below the height to which the plume rises. The general problem involves both the fate of elevated plumes in interior Alaska and the behavior of plumes on the North Slope. In the Interior, a plume may rise through several layers with opposing wind directions before leveling off. Understanding of plume behavior is needed to evaluate the impact of such a plume on elevated terrain. On the North Slope, existing models may not be doing an adequate job of stimulating the rise of hot, high-volume plumes from short stacks, which may be associated with buildings on pilings. The combination of stability with high wind speed on the North Slope has scarcely been looked at.
4. Study of the synoptic situations most often responsible for high CO levels in Fairbanks. The goal here would be improvement of the existing CO forecasting scheme in Fairbanks.
5. The effect of wind shears on vertical dispersion. This is an extremely complicated micrometeorological problem which will be difficult and expensive to execute.

ICE FOG: A SPECIAL FORM OF COLD REGIONS AIR POLLUTION

The most startling, visible manifestation of urban winter pollution in the cold regions is ice fog. Although ice fog may occur in pristine areas, for example near hot springs, at very low temperatures, it is primarily an anthropogenic substance produced by the combustion of fuel in houses, power plants and automobiles. This combustion, whether of gasoline, fuel oil, coal, wood or other materials, produces water vapor which condenses into very small droplets and freezes at temperatures below about -30°C, on occasion reducing visibility in the city to as low as a few meters.

In combustion processes the primary exhaust products are H_2O and CO_2. As an example, consider an ideal combustion equation for gasoline:

	Molecular weight of fuels	Molecular weight ratios H_2O/fuel	Molecular weight ratios CO_2/fuel
$C_8H_{18} \xrightarrow[\text{excess } O_2]{\text{burned with}} 8\ CO_2 + 9\ H_2O$	114	1.42	3.08
		Avg 1.38	3.10

This type of equation has been used to calculate the amount of water released in burning various types of fuels (Benson, 1965, p. 74; 1970, p. 75). Although they yield order of magnitude values for the amounts of H_2O and CO_2 they are incorrect, especially at low temperatures and during "cold starts" of automobile engines. Cold starts produced large amounts of CO (Leonard, 1975, p. 144, 1977, p. 145), this fact and the presence of unburned hydrocarbons (Jenkins et al., 1975, p. 166), indicate that combustion is incomplete. The degree to which combustion is complete increases as the engine or burner warms up. The presence of high CO concentrations, the predominance of NO over NO_2, the lack of O_3 and the

fact that the water which comprises ice fog is basic (pH as high as 10) indicates a reducing atmosphere; this is an important aspect of low temperature air pollution, as already shown in a previous section.

Even with the above qualifications, it is clear that H_2O and CO_2 are the most abundant products of combustion. However, other sources than combustion roughly double the amount of H_2O added to the atmosphere. The largest of these other sources are the open water surfaces maintained by dumping of cooling waters from power plants (Benson, 1965, p. 74; 1970, p. 75; Ohtake, 1970, p. 92 and McFadden, 1976, p. 87). The rate of evaporation from warm water in cooling ponds is about 8 kg m^{-2} day^{-1}.

The Effect of Freezing on Fog Formation

When cooling occurs the air rapidly tends toward saturation (with respect to water). The cooling also stimulates increased input of water into the air from man-made sources. When the air is saturated, water vapor will be condensed in it as the temperature continues to decrease; at -35°C the rate of condensation will be 0.027 g m^{-3} $°C^{-1}$. Freezing of supercooled water droplets occurs at temperatures of about -35°C. This has the effect of reducing the saturation vapor density in the air because the vapor pressure must now be reckoned with respect to ice; at -35°C the difference between water vapor density relative to ice and water is 0.083 g m^{-3}. Thus, the effect of freezing of -35°C will force condensation of three times the amount of water forced by 1°C of cooling at -35°C.

The volume of air involved in the Fairbanks area is on the order of 2×10^9 m^3 so the freezing alone adds 160 metric tons of water to the air in a few hours as the cooling proceeds. For comparison, this is

about the same as the daily output of water vapor from the University of Alaska heating plant. Yet, this rapid addition is spread throughout the the entire area. The net result of rapid cooling, saturation of the air mass, freezing of droplets and continued - or accelerated - man-made input of water to the atmosphere, is an explosively rapid spread of thick ice fog at temperatures of -35° or below (Benson, 1965, p. 74; 1970, p. 75).

Mass Balance

The first attempt to estimate the mass balance of ice fog in the Fairbanks area was made by Benson (1965, p. 74; 1970, p. 75). The growth of Fairbanks since then has made it necessary to re-evaluate the mass balance. A preliminary attempt to do this during the winters of 1981-82 and 1982-83 indicated that the total rate of input of water to the Fairbanks air mass in winter is between 10,000 and 12,000 metric tons per day. Precipitation rates of ice fog particles have been measured to be as high as 80 g m^{-2} day^{-1} in the city center and 20 g m^{-2} day^{-1} in the outlying areas. If the core area is taken as 50 km^2 with an outer region of 100 km^2 and an outermost region of 100 km^2 we can calculate the total precipitation rate as follows:

Area km^2	Preciptation Rate g m^{-2} day^{-1}	Total Precipitation Rate(tons per day)
50	80	4000
100	50	5000
100	20	2000
	Total	11,000

Refinements are obviously in order because these values are based on very few measurements, but the agreement between total fallout and total input is close enough to indicate that we have the correct order of magnitudes (Benson, unpublished data).

The characteristics of ice fog are briefly summarized below:

Size Spectrum

The size spectrum of ice fog was studied intensively by Ohtake (1970, p. 92). He found that the mean diameter decreased with decreasing temperature, from 33 μm at -30°C to 3 μm at -47°C. The source of water vapor was also a factor, probably due in large part to the temperature of the exhaust gases. Automobile traffic produced the smallest crystals and was accompanied by high concentrations of crystals smaller than 2.5 μm.

Residence Time

To calculate residence time we need the average vertical component of the settling speed for a wide spectrum of particle sizes. This can be obtained by dividing the precipitation rate by the solid water content of the atmosphere. First estimates (Benson, unpublished data) yield a range of 0.1 to 1.0 cm sec^{-1} for the range of vertical falling speeds. When considering that the thickness of ice fog ranges from 10 to 150 m we obtain residence times ranging from 1 to 14 hours.

Optical Effects

The small crystals in ice fog are often nearly spherical and always irregular in shape. They lack the well defined plate or needle shape of crystals which form in a gradually cooling air mass. The small sizes and irregular shapes explain the complete lack of reflection and refraction features in ice fog - indeed, its optical characteristics are more like a water droplet fog than a display of ice crystals (Benson, 1970, p. 75; Bowing, 1970, p. 60).

Thermal Effects

The cooling and crystallization of 12000 tons of water vapor per

day will add energy to the air at a rate of about 3.4×10^{10} k J day^{-1}. This is on the order of 4×10^{8} watts or about 2 W m^{-2} in the Fairbanks area. An exceptionally strong heat island results over the city (see also p. 13) but the effects of ice fog are to reduce the heat island for reasons which are not yet fully understand. The total heat output in the Fairbanks area during winter was calculated to be 10 kW per person (Bowling and Benson, 1978, p. 62) or about 19 W m^{-2} (Benson, Bowling and Weller, 1983, p. 196).

Removal of other Pollutants by Precipitation of Ice Fog

The effect of precipitation in general is to clean the air. There is some question about the ability of small ice fog crystals to remove pollutant particles which are larger than the ice crystals. Ohtake is currently investigating this. There are two facets to the problem: first the adhesion of particles to ice crystals and second the adsorption of gases on the ice crystals. The specific surface area of ice crystals in ice fog is on the order of 10,000 to 20,000 cm^2 per gram of ice. It seems reasonable that this large surface area would interact with other materials, particulate and gaseous, in the air. Furthermore, the ice fog residue which precipitates on clean surfaces is very dirty. It contains 0.5 - 1% of matter other than ice, has a foul odor and basic pH values, up to pH = 10.

Recommendations for Further Research

The ice fog represents the visible part of a concentrated air pollution setting which requires further study. So far, attention to ice fog has concentrated on visibility aspects of the problem. Because it is visible, ice fog serves as a tracer that indicates the presence of

other exhaust products. It must be remembered that water is a highly reactive substance which has complex physical, chemical and thermal effects on other components of the air mass, all of which need to be better understood.

1. The mass balance of ice fog needs reassessment in light of the greatly increased population and fuel consumption of Fairbanks and other northern cities where ice fog occurs.
2. The residence time of ice fog particles needs to be investigated under a variety of different meteorological regimes.
3. The likely physical-chemical reactions between ice fog, supercooled water droplets and other pollutants present must be better known, for example, does ammonia and HCN from motor vehicles with catalysts produce the high pH values of ice fog? Do ice dogs contain cyanide in Fairbanks and how much? How do solvents from dry cleaning establishments react with ice fog etc?
4. The possible scavenging of pollutants by ice fog particles, including selective chemical and physical interactions needs further investigations.

ARCTIC HAZE: LONG-RANGE TRANSPORT OF INDUSTRAL POLLUTANTS

Except for isolated areas of air pollution centered on inhabited communities dotting the Arctic, it has always seemed reasonable to suppose that Arctic air masses must possess extraordinary chemical purity. It wasn't until the late 1950's and early 60's, however, that serious analytical air chemistry was begun in the Arctic, mainly by Professor Junge in Germany. The first measurements indicated, to no one's surprise, that Arctic air and snow were very clean, but by employing sensitive analytical methods chemists identified the presence of trace pollution preserved in the snows of remote areas like northern Greenland (Herron et al., 1977, p. 110). The contaminated ice extended to depths in the Greenland ice sheet corresponding to about the beginning of the industrial revolution. Thus, even though quantities were miniscule, traces of man's activity could be found preserved in the polar snows.

Most of the pioneering chemical work in the Arctic was carried out during summer expeditions, (e.g. Flyger, et al., 1976, p. 107), but with the wisdom of hindsight this was a mistake: in summer, the air is about as clean as one can find anywhere on the planet, but in winter the Arctic air becomes infiltrated with air pollution.

In the early to mid seventies for example, routine investigations near Barrow, Alaska indicated that fairly substantial quantities of aerosol were present in the lowest 1 or 2 kilometers of the atmosphere during the late winter and early spring months, (Rahn and Heidam, 1981, p. 125), a surprising finding since the mass loading of aerosols seemed to be greatest when winds came from the North! It was difficult to understand why the air appeared hazy when the number concentration of

suspended aerosols during haze episodes remained quite small, changing hardly at all from non-haze times. It is now realized that the ambiguity arose because the Arctic pollution aerosol has a size distribution differing from that encountered in urban situations: the Arctic aerosol does not have as many small particles (Shaw, 1983, p. 130).

Because the aerosol associated with Arctic air masses lowers visibility, the phenomenon is termed "Arctic Haze". It is believed to be synonymous with the unexplained haze reported by observers who flew on the U.S. Air Force Ptarmigan Weather Reconnaissance missions out of Alaska in the middle 1950's (see Mitchell, 1957, p. 116, for historical accounts and Raatz, 1983, p. 120, for a more recent analysis of the Ptarmigan data).

The chemistry of "Arctic Haze" was investigated in the mid-1970's in Alaska, and in the Scandinavian (Ottar, 1981, p. 116) and Canadian Arctic. Rahn (1981, p. 123) started a systematic program collecting air samples at Barrow, Alaska. The sensitive neutron activation method was used to determine the chemistry of the haze particles. It rapidly became apparent that the haze at Barrow had an anthropogenic "fingerprint" and could therefore be considered to be a form of air pollution. Similar findings were made in Canada and Scandinavia (Barrie et al., 1981, p. 102).

Efforts have been underway since the discovery of Arctic Haze to clarify the source regions and transport pathways of the pollution, but the work has been fraught with difficulty (Rahn and Shaw, 1982, p. 125). Speaking of Arctic Haze in Alaska, one can easily eliminate eastern Asia as a major source of Arctic aerosol: air from the Pacific pathway is the

cleanest observed due to the extensive storminess along the route. Likely source regions were suspected to be eastern North America and Europe (including the western USSR). Attempts to be more specific by constructing back trajectories along the direction of the winds were not entirely successful (Miller, 1981, p. 115), one reason being that trajectories calculated for the Arctic are less reliable than for other locations, and another being that small systematic errors pile up and limit what one can deduce about polluted air masses that have traveled for more than about three days.

Two significant advances in the origin and pathways of Arctic Haze were made in the early 1980's. Raatz (1983, p. 119) analyzed synoptic weather patterns occurring during and before episodes of Arctic Haze at Barrow. By using an iterative "closure" approach, he was able to demonstrate that most strong episodes of haze in the Alaskan Arctic are preceded by surges of northward flowing air over polluted areas in eastern North America, Europe and the Soviet Union. The pollution-laden air travels in characteristic large scale anticyclonic air circulation patterns.

Rahn (1979, p. 122 and Rahn and Lowenthal, 1984, p. 125) took another approach: they investigated chemical signatures in air samples collected in the Arctic. Characteristic signatures of certain trace elements present in Arctic Haze seem to relate to specific, albeit large, geographical regions in which the pollution aerosol was injected initially into the atmosphere. An example is the ratio of masses of pollution-derived manganese to vanadium (Rahn, 1981, p. 124). This ratio varies for pollution by-products in source regions in the eastern United States,

in Europe, Eastern Europe and the Soviet Union. Part of the reason for the variation in relative quantities of certain compounds pertains to the abundances of elements present in fuel which are burned. Another factor may be sociological in nature, reflecting variations in air pollution control strategies in the different countries, the relative amount of coal to oil burned, the number of automobiles per capita, etc. The central region of the Soviet Union, for instance, is a coal-based society with a heavy steel-processing industry, and apparently is bothered by considerable air pollution. The region is a heavy producer, relatively speaking, of submicron particles containing Mn, whereas the element vanadium is a common submicron aerosol found in effluents from industrial sources burning fuel oils. Since the United States is an oil-based society, the Mn/V ratio is larger in pollution by-products from the Soviet Union than it is from the United States. The example shows the principle on which characteristic chemical patterns can be used to deduce relative strengths and source regions of inflowing pollution to the Arctic.

Rahn and Raatz's deductions about the source regions for the Alaskan-sector Arctic Haze agree with each other rather well. Both investigators deduce that central Eurasia is the primary source region for Arctic Haze in Alaska during mid-winter, whereas European sources become more predominant in the spring. North American sources seem to be minor, contributing perhaps one-fifth of the Arctic Haze in Alaska (Shaw, 1982, p. 130, and Raatz and Shaw, 1984, p. 120). The same general picture seems to hold for the Canadian Arctic (Barrie et al., 1981, p. 102).

In spring, 1983, Arctic Haze was explored with airborne sensors on flights conducted by the United States, West Germany and Norway. One

U.S. experiment involved a WP-3D Orion research aircraft owned by the National Oceanic and Atmospheric Administration, which flew out of Anchorage, Thule and Bodø, Norway (Hileman, 1983, p. 110A). The flights were made during late March and early April, because the Arctic Haze is thickest at that time of year. A research aircraft owned by the University of Washington also conducted flights at about the same time of year out of Point Barrow, Alaska. Preliminary reports on some of the airborne experiments were presented and discussed at a meeting arranged by the Max Planck Institute in West Germany in September, 1983. An upcoming issue of Geophysical Research Letters will report on results of the U.S. airborne experiments.

Thus far, the effects of Arctic Haze on the environment are virtually unknown. Preliminary calculations imply that the haze absorbs a substantial amount of incoming solar radiation in the spring months, thereby causing heating of the atmosphere (Rosen et al., 1981, p. 126; Shaw and Stamnes, 1980, p. 128 and Heintzenberg, 1982, p. 109). But so far very few quantitative measurements have been made and little numerical modeling has been carried out to estimate the climatic impact of Arctic Haze.

It is expected that a great deal of new and important information pertaining to Arctic Haze will be reported at the Third Symposium on Arctic Air-Chemistry scheduled to be held at Toronto in May, 1984.

Recommendations for Further Research

The complex phenomenon of Arctic Haze is becoming of increasing importance because of the large potential impact it may have on climate and polar ecology. It is all the more urgent that the problem be put in correct scientific perspective because of the large geographic scales

involved and because we are speaking of a multinational, even multi-continental, sort of problem in which different countries are polluting each other's territory.

1. In the immediate future, there is a need for continued and even upgraded monitoring of the chemical composition of the haze at a variety of surface locations around the Arctic Basin. The chemical tracers should include elements that provide source-specific signatures (see the recent paper by Rahn and Lowenthal, 1984, p. 125) and possible source-specific organic gases.
2. There is a vital need to understand better than we do now the physics of gas-to-particle nucleation and, more generally speaking, the physics of aerosol and gas evolution in the well aged polluted Arctic air masses.
3. There is a need to know the relative amounts of light absorbed and scattered by Arctic Haze and its microphysical and macrophysical properties. These data are needed for numerical models to estimate the climatic influence of the haze.
4. Further work is desirable to assess the possible ecological effects caused by acidic precipitation in the Arctic.

AUTOMOBILE EMISSIONS AND THEIR CONTROL

Motor vehicle emissions are primary contributors of carbon monoxide, hydrocarbon and nitrogen oxides in urban areas. The high levels of carbon monoxide found in the two main urban areas of Alaska, Anchorage and Fairbanks, often exceed the National Ambient Air Quality Standards. They are almost exclusively due to motor vehicles operating during wintertime conditions of subfreezing temperatures and persistent ground based inversions (Hoyles, 1980, p. 141).

Since the inception of the Federal Motor Vehicle Control Program (FMVCP), auto manufacturers have been mandated to gradually reduce emissions 90% from a 1970 baseline. To verify these reductions, the Environmental Protection Agency performs a Federal Test Procedure (FTP) designed to simulate "typical" urban driving conditions on a dynamometer. Fuel economy is also measured. These tests are performed at 20-30°C (68-86°F). Researchers noted that emissions were greatest when the engine was at its lowest temperatures, i.e., the initial startup when choking action is typical (ADEC, 1979, p. 133).

Subsequently, studies done at temperatures lower than 20-30°C (68-86°F) showed even more dramatic increases in emissions at the startup and continuing until choking action diminished and steady state engine operating temperature was reached. Fuel economy also suffered (Austin et al., 1983, p. 134).

The State of Alaska has a particular interest in the "cold start phenomenon" because of its extended winters. Most low temperature tests were conducted at 20°F (~ -8°C), but the Alaska Department of Environmental Conservation undertook testing at 0°F (~ -18°C) in an attempt to be more representative of Alaskan conditions. Insignificant

incremental increases were noticed between 20°F and 0°F and the cost and effort of sustaining acceptable equipment operation and satisfactory vehicle response precluded further testing at 0°F. Therefore, all work done at 20°F is included in this section and is considered appropriate for arctic and subarctic conditions (Coutts, 1983, p. 138). Furthermore, in Fairbanks 35-40% of vehicle operators utilize engine preheaters at -10°F or lower temperatures, mitigating the cold start effect (Gilmore, 1978, p. 140).

As manufacturers introduced new emission control technology to reach statutory limits, researchers found that some devices performed better than others in reducing emissions at temperatures below 68-86°F. However, it is important to note that there is no requirement that emissions be reduced by 90% or any amount, outside of the FTP temperature range. Areas suffering from the effects of such lack of regulation are forced to examine other strategies that may reduce cold start CO emissions.

Methods such as alternate fuels, retrofit devices, preheaters and low temperature tune-ups were investigated in Alaska and elsewhere to determine their effectiveness. All show some potential, but only emission inspection and maintenance of vehicles is being pursued as a workable strategy by both Anchorage and Fairbanks. This should be considered as an addition to preheaters which are already in widespread use. Fuel injected vehicles generally have lower cold start emissions (Austin et al., 1983, p. 134).

The Environmental Protection Agency has developed numerous analytical tools to assist non-attainment areas (of pollution standards) in characterizing their future ambient CO levels due to auto emissions.

Both the data base and the computer model, Mobile 2.5, had to be modified for use in Alaska (Verelli and Moyer, 1982, p. 155). Data were culled from all of the subfreezing testing programs, to form a data set known as "low temperature emission factors", i.e., actual emissions measured from in-use vehicles in grams per mile. A modified version of the model, called AKMOBILE2.5, was developed that allowed use of local mileage accumulation rates, the disablement of certain temperature correction factors, and an internal restructuring of the model that allowed more accurate input of the emission factors (Austin et al., 1983, p. 134). AKMOBILE2.5 predicted that attainment of the 8 hour CO standard would not be reached by the year 2000 without control strategies over and above the Federal Motor Vehicle Control Program, such as inspection/maintenance and a check for tampering with emission control devices. This provided a significantly more realistic but bleaker prediction than the unmodified model.

Researchers also further refined the process by splitting the emission factors into stationary and mobile portions to represent emissions from a vehicle that is idling for long times while warming up, as is typical in Alaska, and emissions from the vehicle while in motion and warmed up. It was found that this modification was only significant when the typical commuter trip length was greater than approximately 3.5 miles (Hoyles, 1980, p. 141). Most trips in Fairbanks are not significantly in excess of that distance.

Recommendations for Further Research

1. Emission Control Devices

   The low temperature performance of future emissions control technology that may be under development is not known because the manufacturers

are not required to test prototypes (or production) vehicles at low temperatures and even if they did, they are not required to divulge the results. This hinders planning and prediction efforts. Existing devices need to be comprehensively examined to determine which devices malperform or perform less efficiently at low temperatures. Devices or procedures such as failed rubberized components, air pump bypass valves, and catalyst light-off time are examples.

2. Tune-up Deterioration Rates

   After a tune-up, emissions are reduced, then gradually over time, emissions increase until they reach or exceed the levels immediately before the tune-up. This is known as the deterioration rate and is measured by EPA on an annual basis. Only very limited measurements have been made of this effect under low temperature conditions. It is currently assumed that deterioration is unaffected by ambient temperature.

3. Diesels

   While low CO emitters, diesels emit particulates, nitrogen oxides, and unregulated pollutants such as formaldehydes and other aromatics. If diesel sales continue to increase, the effect on ambient air quality in Alaska needs to be assessed. The performance of diesel engines in arctic and sub-arctic climates also needs more documentation.

4. Alternate Fuels

   The emissions and fuel economy performance of gaseous fuels and alcohol fuels, other than gasohol, have not been adequately evaluated at low temperatures. More extensive studies need to be done, assessing the startability, driveability and ice fog production of vehicles using such fuels.

5. Tampering, Fuel Switching and Contamination

Anchorage and Fairbanks experience a rate of tampering with emission control systems and contamination of unleaded fuel and improper nozzles that exceeds the national average. It is suspected that misfueling rates are also higher. Tampering with emission controls and using leaded instead of unleaded fuel causes increases in emissions. It is not known if this effect is exacerbated at low temperatures.

6. Engine Size Effects

Although a data base exists now, analyses need to be done to determine the effects on the amount of cold start emissions by engine displacement. It is theorized that smaller size engines contribute less cold start emissions and that the trend in recent years towards smaller engines should have contributed to lower ambient CO levels.

Changes to the Clean Air Act and/or EPA Regulations

A statutory change is needed to set standards for motor vehicles at low temperatures in order to facilitate attainment of the ambient CO standard in Alaska. At the very least, the 3.4 g/mi standard should not be rescinded as proposed, since the standard forces the use of emission control technology that happens to also reduce low temperature emissions. Another approach to pursue would be an administrative one whereby EPA could allow manufacturers to make certain calibration changes that may also result in reduction at low temperatures without having to undergo extensive prototype testing and durability runs.

MONITORING COLD REGIONS AIR POLLUTION

Long-term monitoring of air pollution and its effects occurs at several locations north of 60°N. Routine monitoring of precipitation chemistry, for example, takes place at least at five locations in northern Canada and one location in Alaska (APCD, 1979, p. 161; NADP, 1983, p. 167; Shewchuck, 1983, p. 177A). Other studies add some additional precipitation data, e.g., Galloway et al., (1982, p. 171) for central Alaska. Most of the data from those stations show normal clean backgrounds. There is, however, some clear evidence for acid precipitation, the effects of which are not well understood at high latitudes.

Perhaps the largest number of articles pertaining to monitoring discuss the various trace elements derived from long range transport of particulate pollution (see Arctic Haze section, p. 25).

In monitoring urban air pollution one or more of seven chemical parameters are usually considered. Those parameters are, carbon monoxide, hydrocarbons, sulfur dioxide, particulates, nitrogen oxides, lead and ozone. Each of these parameters will be reviewed in the following paragraphs based on what is available in the literature on cold climates.

Carbon Monoxide. One of the largest bodies of literature on pollutants in cold regions deals with carbon monoxide in urban areas. There are two unique problems in cold regions which cause many (not all) urban areas to have frequent carbon monoxide violations. First is the frequent occurrence of stable inversions (see Meteorology section, p. 11). Second is that cold starts of automobile engines produce significantly higher CO levels than in more temperate latitudes. Federal regulations do not

mandate a low temperature standard (see Automobile Section, p. 31) for arctic and subarctic regions. Recent increased use of wood stoves also exacerbate the problem.

Areas such as the Prudhoe Bay oil fields also have inversions, but wind dispersion is so much greater that there is no indication of excessive carbon monoxide concentrations.

Hydrocarbons are not routinely monitored in northern urban areas since ozone standards are not exceeded. The few hydrocarbon tests in the past do not show any unusual concentrations. Non-methane hydrocarbons in the air of the Prudhoe Bay oil fields are also well below Class II limitations (Crow et al., 1981, p. 163).

Sulfur Dioxide does not appear to pose a problem in the urban areas of Alaska because of the relatively low sulfur content of coal used, and because the power plant emissions are usually above the steep inversions. One occasionally comes across titles of articles such as "High winter concentrations of SO_2..." for arctic and subarctic regions (Rahn et al., 1980, p. 175). The term "high" is relative, however, since the peak values ($\sim 5\ \mu g\ m^{-3}$ or ~ 0.002 ppm) are well below permissible levels. Part of the reason for finding these "high" values so far from sources is the significantly longer life time of species at low temperature and low light levels (e.g., Bottenhein and Strausz, 1980, p. 46, and Rahn et al., 1980, p. 175). The recent Canadian report by Shewchuck (1983, p. 177A) shows that less than one percent of SO_2 in Canada is generated in the Northern Arctic provinces.

Particulates Depending on one's point of view, particulate loading of the air in arctic and subarctic environments is either normal to astonishingly high. Within urban areas TSP (total suspended particulates)

loading of filters is normally very low. There are occasions where high values are encountered in the summer (at or above the secondary standard standard of 150 $\mu g\ m^{-3}$ in Alaska, but below the primary standard of 260 $\mu g\ m^{-3}$). The high values in summer are usually attributed to high winds picking up road and river bank dust. Recently, however, winter TSP, mainly fine particles, have been observed to be approaching the primary standard limit in Anchorage and Fairbanks, probably due to smoke from wood-burning stoves. The Mendenhall Valley in Juneau has exceeded primary standards, due entirely to woodsmoke (Cooper et al., 1983, p. 158) and Whitehorse has exceeded national guidelines (McCandless, 1982, p. 159).

Observations of particulate organic matter (POM) and graphitic carbon in remote arctic locations have shown that the loading of these materials is comparable to large metropolitan areas for some periods of the winter (Daisey et al., 1981, p. 104; Reichart and Reidy, 1980, p. 51). Usually, however, they are a factor of 3 to 10 lower.

Nitrogen Oxides are not found in substantial quantities in cold regions except during some periods of inversion trapping in urban areas, when they can exceed 1 ppm in any given hour (limit is 0.05 ppm) on an annual basis (Coutts, 1979, p. 163; Holty, 1973, p. 199). The unique aspect of nitrogen oxides in the cold regions is that the nitric oxide (NO) level equals and frequently exceeds the nitrogen dioxide (NO_2) concentration (Coutts, 1979, p. 163). This is due to the low photochemical activity and virtual absence of ozone within the city. There are no standards for NO and the only known test of its toxicity on mice was inconclusive.

Lead concentrations in urban environments have been decreasing in

the cold regions due to the shift towards unleaded gasoline. Some violations ($\geq 1.5\ \mu g\ m^{-3}$) occur irregularly during periods of strong inversion trapping (Winchester et al., 1967, p. 56; Gosink, 1983, p. 47). Its presence in aerosols in remote regions, along with other trace elements such as vanadium, is used as an indicator of long range transport of pollutants from lower latitudes. The argument about background concentrations of lead in the environment is not yet resolved (Patterson and Jaworowski et al., 1983, p. 50).

Ozone is one of several compounds used to indicate the occurrence of photochemical activity. No violations of the suggested 120 ppb limit have been reported in cold regions. However, summer highs approach this level. There are no concomitant hydrocarbon and NO_x data. Concentrations of O_3 in the Prudhoe Bay oil production area are slightly higher in winter than in summer (the winter high is only about half of the recommended limit) (Crow et al, 1981, p. 163). Winter ozone concentrations decrease to zero inside the pollution zone of urban areas (see comments in Chemistry section about photochemical activity, p. 7), but outside the urban area of Fairbanks they have been observed in the range of 60-80 ppb, probably due to stratospheric subsidence.

Gaps in the Technical Literature

Several large gaps, reflecting absence of information, are apparent. For example, there are no reports on any health monitoring activities to see if there are unique problems with air pollution in cold regions. A full suite of up-to-date pollution monitoring data for metropolitan and urban areas does not exist. No data are available for the vast Soviet sector of the arctic and subarctic regions.

While the number of reports on trace elements in air particulates in the Arctic is large, the number of elements covered is limited. Information about organic matter in the air in cold regions is also very limited. Acetate and formate data at least should become a part of the acid precipitation monitoring program. Maps of soils in Alaska showing their sensitivity to acid precipitation are not available as they are for a large portion of the lower 48 and recently for the Northwest Territories of Canada (Shewchuck, 1983, p. 177A).

Recommendations for Further Research

1. With regard to precipitation chemistry, trace element data for rain versus snow are needed. The information should also distinguish between wet and dry fallout and between soluble and insoluable forms of the elements.
2. Data on the size distribution, and composition of atmospheric pollutants (organic and inorganic compounds) in urban, rural and remote atmospheres are required.
3. The fate of elements and organics deposited on the surface needs to be known, and the quantity of organic matter re-emitted to the air in the same or modified form needs to be determined.
4. Deposition velocities on various surfaces, including plants, snow, ice and water etc., must be known.
5. The collection efficiency and best locations of wet and dry deposition collectors need to be determined. Furthermore, devices that will operate in cold environments need to be developed.
6. Oxidation rates (e.g., of NO and SO_2) under low light and low temperature conditions must be investigated.

SUMMARY OF RECOMMENDATIONS

Additional or new studies are required in the following areas, roughly listed under the various sub-headings in an order of priority which ranks the severity of present data and information gaps. This list is compiled regardless of the cost of the research involved or the relation of the recommended research to the missions of EPA or DOE in reducing pollution. Research priorities with such considerations in mind have been established only recently for EPA and DOE (States, 1983, see Preface).

Sources and Characteristics of Major Air Pollution Types

1. Full-year monitoring of the concentrations of the seven EPA priority pollutants in northern urban areas (pages 36-39).
2. Chemical composition of Arctic Haze (including source-specific chemical signatures).
3. Mass balance and physical-chemical characteristics of ice fog.

Chemical Processes and Conversions

1. Interactive processes between ice crystals, supercooled water droplets and other combustion products and pollutants.
   a) alkalinity of ice fog (ammonia, fly ash, acetate, formate)
   b) scavenging of pollutants such as PAH
2. Photochemistry at high latitude:
   a) ozone and PAN data for clean and dirty sites throughout the year
   b) data on hydroxy and peroxy free radicals
   c) oxidation rates (e.g., of NO and SO_2) under low light and low temperatures
3. Particulate matter:
   a) chemical fingerprinting (multivariate analysis) to determine sources.

b) rates of gas to particle nucleation (especially in dark atmospheres)

c) effects of selective partitioning on size ranges (relevant to respiration and health)

4. Precipitation chemistry:

a) rates and composition of wet and dry deposition (including snow and ice fog)

b) fate of materials deposited on surface (including re-emission of organic matter to atmosphere).

Dispersion and Transport of Pollutants

1. Dispersion model:

a) development and verification of a cold regions dispersion model.

b) data on winds, temperatures and lapse rates for input into model (particularly needed for Anchorage).

2. Vertical dispersion:

a) plume rise under stable conditions and effects of wind shears

b) scavenging efficiency of snow and ice fog

3. Meteorology of CO episodes:

synoptic situations responsible for such episodes.

4. Indoor air pollution:

transfer of pollution from the outside, trapping inside

Health and Other Effects

1. Eye and respiratory disease:

Statistical comparison between people in urban and rural areas

2. Acid precipitation:

   effects on arctic and subarctic ecosystems (including soil/vegetation susceptibilities)

3. Climate modification:

   effects of Arctic Haze on radiative transfer and climate

4. Carcinogenic factors:

   chemical and biological data of urban pollutants

5. Melt water pollution:

   chemical details of pollutants trapped in snow

Mitigative Measures and Controls

1. Automobile emissions and effectiveness of various control measures:
   a) emission control devices
   b) tune-up deterioration rates
   c) emissions from diesel engines
   d) use of alternate fuels
   e) effects of tampering and fuel switching
   f) effects of engine size
2. Wood smoke characteristics and control strategies

II. BIBLIOGRAPHY

Chemistry of Cold Regions Air Pollution

The references in this section include the following topics:

- Pollution species and concentrations present in cold regions
  - In the air
  - In snow
- Photochemical conversions
- Other chemical processes

Bottenheim, Jan W., and Otto P. Strausz, Gas-Phase Chemistry of Clean Air at 55° N Latitude, Environmental Science and Technology, Vol. 14, No. 6, pp. 709-718, June 1980.

ABSTRACT

This study was primarily undertaken in order to obtain insight into the clean air chemistry at northerly regions as a function of diurnal and seasonal variations, with potential future pollution effects in mind. Several assumptions had to be made due to lack of data required to define a standard model. Within this framework, diurnal and annual variations of NO_x and other N-containing species were discussed, and comparisons with polluted air chemistry were made. It was pointed out that the so-called photostationary state equation leads to a poor prediction of ozone in clean air, but the empirical rule implying high ozone levels when $NMHC/NO_x \sim 10$ should apply, provided hydrocarbon reactivity is taken into account. The model suggest that non(photo) chemical processes are largely responsible for background ozone levels in the winter, while NO_x levels must be at a level well below 1 ppb in the summer. The role of free-radical chemistry was also delineated, and it was shown that the effective HO radical mixing ratio is relatively invariant with the season, in contrast with the effective peroxy radical mixing ration. The effects of highly reactive natural hydrocarbons in summer were studied using trans-2-butene as a model compound. It was argued that early morning haze formation over wooded areas might well be due to radical-olefin reactions rather than O_3-olefin reactions. The chemistry of NH_3, H_2S, and SO_2 was also briefly discussed.

Duce, R. A., J. W. Winchester and T. W. VanNahl, Iodine, Bromide and Chlorine in Winter Aerosols and Snow from Barrow, Alaska, Tellus, V. 18, 238-248, 1966.

ABSTRACT

Iodine, bromine, and chlorine have been determined in atmospheric aerosols and in snow collected in Barrow, Alaska, during January, 1965, by means of neutron activation analysis. Aerosols collected using both an aircraft collector by impaction and a ground-based 1.0 micron Type EA Millipore filter collector show concentrations of Cl to be much more variable than either Br or I, and I/Br points cluster at 0.1-0.2 gI/gBr for the filter samples. Cl varies from less than 0.02 to 4 micrograms/Cl/cu m STP in the filter samples, and the aircraft concentrations agree with those taken by filter on the same days. Filter Br is 1-30 ngBr/cu m STP and I is 0.3-10 ngI/cu m STP, and the ratios I/Cl and Br/Cl increase sharply with decreasing Cl. Snow samples from the ground have Br/Cl somewhat greater than in sea water, although all halogen concentrations decrease with increasing distance from the sea up to 10 km. Assuming a mixture of undifferentiated sea salt and a more permanent atmospheric component, we estimate for the atmospheric component in the snow I/Br about 0.2. Sea water, sea ice, and related samples were analyzed, and I/Cl equals 0.000004 gI/gCl is normal for sea water, although Br/Cl equals 0.0038 gBr/gCl is a little high.

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Gosink, T. A., Trace Elements in the Aerosols Collected in Fairbanks and North Pole Alaska During 1980, Geophysical Institute Report, December 1981.

ABSTRACT

Most of the analyses presented in this report were done by means of proton induced x-ray emission (PIXE) a few samples (ice fog) were done by means of atomic absorption spectrophotometry.

Aside from the tables in the executive summary section the data is presented in three formats (see tabs). The first section presents the data in micrograms of the element per cubic meter of air as a function of time. The ice fog data is not included in any of these tables.

Gosink, T. A., A Report to the Fairbanks North Star Borough, Pollution Research Activities 1982-1983, Trace elements in the local aerosols and the identification of pollution sources, September 1983.

ABSTRACT

Measurements of the enrichment of several trace elements in Fairbanks and determination of a chemical signature of wood smoke against a background of other fuel pollutants.

Grosjean, Daniel and Barbara Wright, Carbonyls in Urban Fog, Ice Fog, Cloudwater and Rainwater, Accepted Atmospheric Environment, April 1983.

ABSTRACT

Formaldehyde, acetaldehyde, propanal, acetone + acrolein, n-butanal, 2-butanone, n-pentanal, n-hexanal and benzaldehyde have been identified in fog, ice fog, mist, cloudwater and rainwater samples collected at urban locations in California (Los Angeles) and Alaska (Fairbanks). Formaldehyde concentrations, up to ~2 mg L^{-1}, were highest in urban fog and ice fog samples. Concentrations of other carbonyls occasionally approached or exceeded that of formaldehyde. The results are briefly discussed in terms of scavenging of gas-phase atmospheric carbonyls.

MacKenzie, K.W. and R. E. Arnold, The seasonal and spatial distribution of two atmospheric pollutants around a sub-arctic city, Fairbanks North Star Borough Report No. 73-001, August 1973.

ABSTRACT

Around the city of Fairbanks, Alaska (UTMG 06-00465000-7190000, pop. 18,304) a condition of extremely stable air is produced during the winter months (November through March) by the effect of atmospheric temperature inversions, a ring of hills around three sides of the city area, and low wind speeds (avg. < Km per hour). Because this atmospheric stability inhibits the dispersal of man-made gaseous pollutants, and because men have concentrated a large number of motor vehicles (about 20,000) within the area, atmospheric concentrations of carbon monoxide are found in winter time Fairbanks as high and as persistent as those measured anywhere else in the United States.

Morachevsky, V. G., E. Golovina, A. Tsvetkova, The Conditions of Non-photochemical Smog Formation, Leningrad Hydrometeorological Institute. (undated short manuscript, translated by U. S. Dept. of Commerce)

ABSTRACT

The principal aim of my short report is to call attention to one of the possible meteorological aspects of the role of such active condensation nuclei as atmospheric organic pollution -+complicated hydrocarbons, surface active materials, SAM, and the products of their non-photochemical transformations in the atmosphere. We determine non-photochemical smog (NPCS) as fog in lower atmospheric layers, formed at relative humidities significantly below 100 %, which leads to decrease of visibility to values below 1 km. It means that NPCS differs greatly from PCS as well as common fog. Bulgarian academician Krystanov and later we in Leningrad Hydrometeorological Institute have considered the problem of capillaric activity of surface inactive particles (particles of dust). It was shown that such activity leads to formation of smog on coal particles when weight concentrations of these particles exceeds values $P_{min} = 0.1$ mg/m^3. Measuring weight concentration of pollutions in industrial cities we never observed such high concentrations. That is why we suggested that smogs in industrial regions may be related to the condensation activity of organic particles.

Patterson, C. C., and Jaworowski, Z. et al., Criticism of Flow of metals into the global atmosphere, and Reply. Geochem. et Cosmochim Acta, 47, 1163-1175, 1983.

ABSTRACT

There are serious disagreements (an order of magnitude) between various authors on the concentration of lead around the world, including glacier ice (some from Alaska and Spitsbergen). The latest round of arguments in print are to be found in these two references.

Peake, E. and H. S. Sandhu, The formation of ozone and peroxyacetyl nitrate (PAN) in the urban atmospheres of Alberta, Can. J. Chem. 61,000, 1983.

ABSTRACT

Atmospheric temperature inversions frequently trap pollutants in the urban atmospheres of Alberta leading to photochemical air pollution. Peroxyacetyl nitrate (PAN) was monitored, for the first time in Alberta, from November 1980 to August 1981 at the University of Calgary using electron capture gas chromatography. Measurements were made at one-half-hour intervals from July, 1981 to February, 1982 at a downtown location. Maximum PAN concentrations were recorded at the University and downtown sites on August 14 at 1400 h, 1981 and the values were 2.4 and 6.6 ppb, respectively. In each case the maximum PAN peak coincided with the afternoon peak in ozone concentrations, 79 ppb at the University and 59 ppb at the downtown site. Surprisingly, a high value of 2.3 ppb PAN was recorded at the University during January of 1981 giving rise to questions regarding the influence of low temperatures and solar radiation on the photochemical formation of PAN. Calculations employing a simple photochemical model for PAN and ozone formation have been carried out and comparisons made between the observed and the computed values.

Rasmussen, R. A., M. A. K. Khalik and S. D. Hoyt, Methane and Carbon Monoxide in Snow, Journal of the Air Pollution Control Association, Vol. 32, No. 2, February 1982.

ABSTRACT

Freshly fallen snow, gathered at Mt. Hood (Oregon), was found to contain a lot of carbon monoxide (CO) but no methane (CH_4). This result will be established in the paper and used to show that the atmospheric concentration of methane many hundreds of years ago was less than half what it is today.

Reichart, P., and Susan K. Reidy, Atmospheric Polycyclic Aromatic Hydrocarbons: An Aspect of Air Pollution in Fairbanks, Alaska, Arctic, Vol. 33, No. 2, p. 316-325, June 1980.

ABSTRACT

Quantitative analysis of atmospheric polycyclic aromatic hydrocarbons (PAH) in Fairbanks, Alaska revealed significant levels of representative components. A fairly constant PAH pattern was observed throughout the winter of 1976-77, and the absolute PAH level correlated with air stagnation. Consideration of relative levels of individual PAH components reveals vehicular emissions as the major source but also provides evidence for contributions from power plant emissions. Fairbanks' PAH levels approach those of major cities in more moderate climates, and this situation emphasizes the importance of air quality problems in development of the Arctic.

Schjoldager, J., B. Sivertsen and J. E. Hanssen, On the Occurrence of Photochemical Oxidants at High Latitudes, Atmospheric Environment, Vol. 12,. pp. 2461-2467, 1978.

ABSTRACT

Results from an ozone monitoring programme during the summers of 1975 and 1976 in the lower Telemark area (*ca.* 59°N) in Norway shows that elevated ozone concentrations (up to 120 ppb) occurred, mainly during prevailing high pressure situations. Wind trajectory analyses indicate that the elevated ozone concentrations in part seem to be generated from locally emitted precursors, and in part are associated with long range transport in north-western Europe.

Schjoldager, Jorgen, Observations of High Ozone Concentrations in Oslo, Norway, during the Summer of 1977, Atmospheric Environment, Vol. 13, pp. 1689-1696, June 1979.

ABSTRACT

Results from an ozone monitoring programme in Oslo (60°N) show that high ozone concentrations, up to 218 $\mu g\, m^{-3}$ (109 ppb) occurred, mainly during high-pressure situations. An assessment of the local meteorological conditions together with air trajectory analyses seems to indicate that the local and mesoscale formation and transport were more important than transport from distant sources.

Schjoldager, Jorgen, Ambient Ozone Measurements in Norway 1975-1979, Presented at the 73rd Annual Meeting of the Air Pollution Control Association, Montreal, Canada, June 22-27, 1980.

ABSTRACT

Ambient ozone measurements have been carried out in southern Norway (59-60°N) since 1975. During episodes in the summer months, with meteorological conditions conducive to oxidant formation, high concentrations of ozone (up to 200 ppb) have occurred. During the episodes, land/sea breeze often prevails for several days on the local scale. In some cases long range transport of oxidants and oxidant precursors from the major source areas in Great Britain and the European continent has probably occurred, while in other cases local and mesoscale formation and transport seem to dominate. Due to the variable climate at latitudes around 60°N, both the total number of episodes and the relative number of local/mesoscale and transport episodes can vary considerably from one year to the next. The highest ozone concentrations often occur during combined local/mesoscale or mesoscale/transport episodes. The precursor emissions from some stationary sources (e.g. the fertilizer industry) have decreased over the last years, but the total emissions of organics and oxides of nitrogen in southern Norway have increased steadily, and will probaly continue to do so over the next years.

Schjoldager, Jørgen, Harald Dovland, Peringe Grennfelt, Jørgen Saltbones, Photochemical Oxidants in North-western Europe 1976-79, A Pilot Project, Norwegian Institute for Air Research, P.O. Box 130, N-20001 Lillestrøm, Norway, April 1981.

ABSTRACT

This pilot project was undertaken as a result of various activities in Europe in the field of photochemical air pollution after 1970. Of special importance was the OECD "Ad hoc Group of Experts on Photochemical Oxidants and their Precursors in the Atmosphere", acting from 1973 to 1978. In 1978 the Norwegian Institute for Air research (NILU) hosted a planning conference on future research co-operation on long range transport of photochemical oxidants. The present study was the outgrowth of some of the recommendations from that conference. Economic support has been obtained from the National Swedish Environment Protection Board and the Norwegian Ministry of Environment.

Schjoldager, Jorgen, On the occurrence of photochemical air pollution at moderate and low temperatures, Presented at the 74th Annual Meeting of the Air Pollution Control Association, Philadelphia, Pennsylvania, June 21-26, 1981.

ABSTRACT

The ozone measurements carried out in Norway at 59-60°N latitude since 1975 generally confirm that high oxidant concentrations are experienced during stagnating anticyclonic weather situations with high temperature and low wind speed. However, ambient temperatures of 10-15°C do not seem to inhibit ozone generation. Two episodes with ozone concentrations of 80-95 ppb at temperatures around 10°C are discussed. In one case, long range transport from central and eastern continental Europe seemed to dominate, while the temperatures along the air trajectories were not exceeding 15°C. In the other case, local ozone production in stagnating air masses during the morning hours seemed to be the major cause, with an irradiation time of 4-6 hours at temperatures below 10°C.

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Sierra Research Report prepared for Fairbanks North Star Borough, Carbon Monoxide Air Quality Trends in Fairbanks, Alaska, September 1982.

ABSTRACT

An analysis of 8-hour average carbon monoxide concentrations at two locations in downtown Fairbanks shows two distinctly different trends: a consistent, gradual decrease in the seasonal average of daily maximum 8-hour concentrations; and a slight increase, followed by a decrease in later years, in the seasonal peak concentrations.

The trends were developed from data supplied by the Fairbanks North Star Borough for monitoring sites near the intersections of 2nd and Cushman and 4th and Lacey. Data were collected at the two sites for a total of ten years; however, the 2nd and Cushman site was shut down in 1978 while the 4th and Lacey site first began operations in 1976. In order to develop a long term air quality trend for Fairbanks, data from the two sites were combined using a least squares fit equation. Over 4,000 pairs of measurements from the 1976/77 and 1977/78 winter seasons were used to develop the equation.

Thomas, C. W., Atmospheric Natural Aerosols and Fallout Particulates During 1973 at Richland, Washington and Point Barrow, Alaska. In: Pacific Northwest Laboratory Annual Report for 1973 to the USAEC Division of Biomedical and Environmental Research, Part 3.

ABSTRACT

Measurements of atmospheric natural aerosols and fallout particles at Richland, Washington and Point Barrow, Alaska are reported. The concentration of radionuclides associated with weapons testing decreased two- to tenfold during 1973 at Richland, Washington, reflecting the lack of high-yield weapons testing during 1971 and 1972. The atmospheric radionuclide concentrations for the period 1971-1973 decreased with a residence half-time of 11 mo, similar to that measured from 1963-1966. The time variations in the atmospheric concentrations of Plutonium-238 and Plutonium-239 at Richland and Point Barrow since 1964 were typical of nuclear weapons-produced radionuclides, except for the increase in Pu-238 concentration from 1965 to 1968 resulting from the burnup of a nuclear generator at 46 km altitude in the southern hemisphere. The Pu-238 concentration showed seasonal variation typical of radionuclides of stratospheric origin. Richland air filter samples collected during 1973 and analyzed for trace elements showed concentrations of nickel, zinc, arsenic, bromine, molybdenum, and lead which were characteristic of large contributions from sources other than the earth s crust. The bromine-to-lead ratio (0.15) was about what would be expected from automobile exhaust.

Winchester, John W. and Robert A. Duce, Coherence of Iodine and Bromine in the Atmosphere of Hawaii, Alaska, and Massachusetts, Tellus 18 (2), p. 287-292, 1966.

ABSTRACT

Previously reported analyses of rain, snow, aerosols, and gas from Hawaii, Alaska, and Massachusetts, and new analyses of Antarctic and Alaska snow and ice, are compared. Both I and Br appear to be associated with aerosols of smaller particle sizes and longer residence times than Cl-rich aerosols. In most suites of samples there is a clustering at I/Br approximately 0.1-0.2, and Br/Cl exceeds the sea water ratio (3.4 x 0.001) several-fold. Aerosols collected over open sea water in Hawaii, however, show Br/Cl several-fold lower than in sea water. The latter particles are identified as "sea salt" aerosols whereas the Br-rich aerosols are smaller in size and may be basically different in composition. It is suggested that Br is "distilled" from the sea spray droplets, possibly by photochemical oxidation to Br2, and then "condensed" onto the smaller particles, possibly by participating in the oxidation of SO2 to sulfate. Iodine may engage in similar reactions, and the resulting I and Br-rich particles exhibit a world-wide constancy in I/Br. Precipitation analyses show a similar constancy in I/Br.

Winchester, John W., William H. Zoller, Robert A. Duce and Carl S. Benson, Lead and Halogens in Pollution Aerosols and Snow from Fairbanks, Alaska, Atmospheric Environment, Vol. 1, Pergamon Press, pp. 105-119, 1967.

Abstract—The composition of lead halide pollution aerosol particles was studied in the Fairbanks area during January and February 1965. At this time of year the sun is above the horizon for less than 4 hr and prolonged cold spells (surface air temperature below −40°C) are accompanied by strong (gradients of 20–30°C/100 m) surface inversions which severely restrict the dilution volume for air pollutants. Indeed, these inversions virtually decouple the dense surface air-layer from the overlying air. Accurate quantitative information on the total output of all pollution sources is available because of the isolated location of Fairbanks and the limited, measurable sources of fuel supply. Thus, Fairbanks is a model locality for studying the production, movement, and chemical reactions of air pollutants in what amounts to a simple two-layer atmosphere.

Lead was determined by inverse polarography in aerosol particles collected on Millipore filters. Measured values ranged from 6.0 μg of lead/m^3 of air in the city center, near the automobile traffic center, to 0.19 at the University of Alaska campus outside the city. These do not represent maximum values because pollutant-concentrating conditions were relatively mild during the sampling periods.

Halogens were determined by neutron activation analysis of material in the aerosols and in ground-lying snows, and two components were revealed, a pollution component derived from automotive ethyl fluid combustion and a low-level natural component. In the pollution aerosol component, the weight ratio chlorine/lead averages close to the ethyl fluid value of 0.34, but bromine/lead is up to four times less than the ethyl fluid value of 0.39. Bromide-chlorine of the pollution in the snows is only 15–30 per cent of the ethyl fluid value and exhibits the lower values further from the city center. These data support the interpretation that lead halide particles, formed initially by combustion of ethyl fluid in gasoline, suffer loss of bromine by oxidation and volatilization. The smaller particles, because of greater surface area per unit mass, may suffer the most extensive bromine loss and may migrate farthest from the city center by virtue of their long atmospheric residence time.

Meteorology of Cold Regions Air Pollution

The references in this section include the following topics:

Large-scale meteorological features conducive to pollution events
Temperature inversions
City heat islands
Local wind regimes
Pollution transport and dispersion models

Benson, C.S., and S.A. Bowling, The Sub-Arctic Urban Heat Island as Studied at Fairbanks, Alaska, Climate of the Arctic, Proceedings of 24th Alaska Science Conference, University of Alaska, 1975.

ABSTRACT

Changes in surface properties and addition of man-made heat combine to make cities generally warmer than their surroundings. This effect is known as the 'urban heat island.' The surface properties involved in the changes are: Albedo and thermal properties (building materials vs. soil), which affect response to solar radiation; moisture (vegetation or wet soil vs. pavement or, in desert climates, the reverse situation of dry land vs. irrigated areas), which affects latent heat exchange; surface roughness, which affects turbulent heat exchange due to wind action; and atmospheric clarity (smog vs. clear air), which affects the infrared energy exchange with the atmosphere. The arctic/sub-arctic heat island in winter is of considerable theoretical interest in that solar radiation is negligible and moisture contrast is cancelled by a uniform snow cover and dormant vegetation. Additionally, in the Fairbanks area wind speeds are generally very low, minimizing roughness effects. Thus the Fairbanks heat island provides a natural laboratory for the study of the interaction of added man-made heat and infrared (thermal) radiation in producing a heat island.

The Fairbanks winter heat island was studied prior to 1965 as part of the ice fog studies carried out at that time by one of us. Considerable changes in land use have taken place since that time. Furthermore, the effect of a heat island on pollutant dispersal has become a pressing theoretical and practical problem. Preliminary reconnaissance early in 1973 indicates that the heat island covers a larger area and is less sharply defined near its core than was previously the case. These changes parallel, and are probably related to, an increase in the area covered by ice fog. Even as early as 1962, however, the Weather Bureau (airport) temperature at 135 m was found to be consistently higher than the mean of the other flatland stations (one at 130 m and one at 140 m), and frequently higher than either. This suggests the possibility that the airport was actually within the Fairbanks heat island, or producing its own small heat island. On this basis, it will be necessary to extend the traverses beyond the areas studied so far to obtain good background temperatures.

Benson, Carl and Gunter Weller, A Study of Low-Level Winds in the Vicinity of Fairbanks, Alaska, Report to Earth Resources Company and Atlantic Richfield Company (ARCO), by Geophysical Institute, University of Alaska, 1970.

ABSTRACT

In order to more adequately understand the air pollution problems in Interior Alaska it is necessary to understand the characteristics of temperature inversions and air flow in the lowest air layers. In this paper we summarize a comparative study of inversions over Fairbanks and 10 other sub-arctic and arctic stations together with the results of measurements of low level winds during low temperatures in the Fairbanks area. Although surface inversions were present at all stations more than 50% of the time from November to April, only three of the eleven stations had inversion gradients equal or greater than those measured at Fairbanks.

In Fairbanks, in 10 years of records, surface inversions were present

(1) in more than 60% of <u>all</u> night time soundings, year round.

(2) in more than 80% of <u>day and night</u> soundings during December and January.

(3) in more than 80% of night time soundings for 5 months of the year.

Our study showed that during times of low temperature, low velocity, katabatic winds are generated on hillslopes by radiational cooling and gravitational forces. This results in a complex pattern of air flow from hills and valleys north, east and west of Fairbanks, with the general drainage wind moving West (down river) in the Tanana Valley. Winds veer over the city, as seen quite clearly in the orientation of smoke and vapor plumes from chimneys but velocities near the surface at 2 meter height are generally less than 0.5 m sec^{-1} (1 mph). Periodic oscillations such as internal gravity waves occur quite frequently in the inversion layer, and aid in the mixing of this layer. Strong winds, which could remove pollutants from the area when low temperatures occur, are almost entirely absent during those periods.

Bilello, Michael A., Survey of Arctic and Subarctic Temperature Inversions, Technical Report 161, U.S. Army Materiel Command, Cold Regions Research & Engineering Laboratory, Hanover, New Hampshire, October 1966.

ABSTRACT

A temperature inversion is defined meteorologically as a layer of air in which the temperature increases with altitude. As noted in the Glossary of Meteorology (1959), the principal characteristic of an inversion layer is its marked stability, which allows very little turbulent exchange to occur within it.

Bowling, Sue Ann, A study of synoptic-scale meteorological features associated with the occurrence of ice fog in Fairbanks, Alaska, Master of Science Thesis, University of Alaska, 1967.

ABSTRACT

A synoptic-scale investigation of Fairbanks ice fog indicates that two distinct types of ice fog may be recognized. A type I event occurs when a migratory, and generally rapidly intensifying, Siberian High moves eastward into Alaska. This migration is preceded by the formation of a 700 mb ridge in or slightly west of the Bering Strait, and by a junction in the low-level circulation of the Siberian High with that of a migratory Pacific High. In these events, Fairbanks temperatures aloft rise during the periods with clear skies when radiative cooling decreases the surface temperature. This behavior is attributed to advection of Pacific air combined with subsidence in the Siberian air. Type II events, rare but prolonged and extremely severe, occur when a Siberian High expands to cover northern Alaska after contact with a migratory Pacific High. The 700 mb pattern in this case generally has a High centered near the East Siberian Sea and a Low in southern Alaska.

Bowling, Sue Ann, Radiative cooling rates in the presence of ice crystal aerosols, Ph.D. Thesis, University of Alaska, 1970.

ABSTRACT

A method has been developed for computer calculation of radiative cooling rates within an ice fog (crystal radii 1 to 7 μ, number density 100 to 1000 crystals cm^{-3}) or an ice crystal display (also called diamond dust; crystal radii 25 to 500 μ, number density .01 to 1 crystals cm^{-3}). Mie scattering is assumed for the nearly spherical ice fog crystals, while diamond dust crystals, which are mainly flat plates, are considered black in the infrared. Elsasser's treatment is paralleled, with some modifications, for water vapor and carbon dioxide. The basic method is usable for almost any kind of cloud or fog, although the computer calculations become quite lengthy if both scattering and the dependence of the ice crystal parameters on wave number are considered.

Bowling, Sue Ann, Takeshi Ohtake and Carl S. Benson, Winter Pressure Systems and Ice Fog in Fairbanks, Alaska, Jour. of Applied Meteorology, Vol. 7, No. 6, December 1968.

ABSTRACT

The production of the low temperatures which are responsible for ice fog in inhabited areas of interior Alaska would appear to be a classic example of clear sky radiative cooling under nearly polar night conditions. However, examination of the meteorological conditions associated with 15 periods of dense ice fog at Fairbanks indicates that local radiative cooling is important only in producing the observed steep ground inversion. The most rapid decreases in temperature at heights >1 km occurred with cloud cover and cold air advection preceding the cold weather at the ground. The most common synoptic pattern (observed for the 12 shortest events) consisted of the migration of a small high from Siberia across Alaska. Rapid growth of the high was common, and the resulting subsidence was strong enough to counterbalance not only radiative cooling, but further cold air advection as well. This resulted in an observed warming aloft during all but the first 12–24 hr of the clear, cold weather observed at the ground. Three of the 15 events did not follow this pattern. Two long and very cold events were associated with warm highs in northeastern Siberia, continuous belts of moderately high pressure extending from Siberia across the Bering Strait into Alaska, and advection from Siberia and the Arctic Ocean. The remaining long but relatively mild event was associated with a warm high north of Alaska and advection from Canada and the Arctic Ocean.

Bowling, Sue Ann, Carl S. Benson and Wallace B. Murcray, Quasi-Equilibrium Temperature Differences between Radiating Ice Crystals and the Surrounding Air, Jour. of Applied Meteorology, Vol. 10, No. 5, October 1971.

ABSTRACT

A previous attempt to calculate the temperature gradient around a growing ice crystal in clear air started with the radiation budget of the crystal plus the assumption that the measured frost point temperature (about 2C below air temperature) represented the crystal temperature. When the conductivity equation for the air around the crystal is fully solved with the radiation budget as the boundary condition, however, it is found that less than 0.03C temperature difference can be sustained by radiative cooling of the crystals. The most probable explanation of the difference between the two approaches is that the humidity measurements are in error, and that the error has been generally recognized only at measured humidities in excess of 100%.

Bowling, S. A. and C. S. Benson, Study of the Subarctic Heat Island at Fairbanks, Alaska, Environmental Sciences Research Laboratory Report EPA-600/4-78-027, June 1978.

ABSTRACT

The heat island associated with the city of Fairbanks, Alaska was studied as a means of isolating the effects of self-heating and modified radiative transfer from other causes of heat islands. Minimal winter insolation virtually eliminated the effects of variable albedo and the daily temperature cycle; snow cover and dormant vegetation made differences in evapotranspiration unimportant, and very low wind speeds minimized the effect of surface roughness.

The observed steady-state heat island under clear skies and low wind speeds was around 10°C, with transient values reaching 14°C. This high value is probably due to the extremely steep ground inversions known to exist in Fairbanks, as the heat island intensity correlated well with the strength of the inversion between 2 and 60 meters elevation. The depth of the mixing layer was less than 90 meters, but the temperature structure at higher levels was disturbed, apparently by coherent lifting of the stable air. The mean surface wind field was extremely complex in both time and space, with strong vertical shears, horizontal eddies with scales from a few hundred meters to several kilometers, and seiche oscillations at several scales superimposed on gravity drainage. Speeds were generally too low for accurate measurement.

A self-heating term of 10KW person^{-1} in winter and 5KW person^{-1} in summer was derived from the fuel inventory carried out as part of the project. The winter value, applied in a simple model of a heat island over a conducting and radiating city, gave realistic heat island values with wind speeds under 1 m sec^{-1}.

Bowling, S.A., Meterological Factors Responsible for High CO Levels in Alaskan Cities, Geophysical Institute, University of Alaska, Fairbanks, Alaska, Report to EPA, 1983.

ABSTRACT

High winter carbon monoxide levels in Anchorage, as in Fairbanks, are due to intense nocturnal (ground-based) inversions persisting through the periods of maximum emissions and at times throughout the day. the problem is exacerbated by the large amounts of carbon monoxide emitted during cold starts at low temperatures. The Anchorage situation is unusual in that the nocturnal inversion develops most often with a substantial north-south pressure gradient and easterly geostrophic winds. The Chugach Range to the east sometimes produces a "wind shadow" effect in the city, and almost all the CO violations examined occurred in these conditions. There is evidence that inversions are significantly stronger, and dispersion conditions probably worse, near the mountain front than at the airport weather observation. CO forecasting in Anchorage would require close cooperation between the U. S. NOAA Weather Service and Municipality; improvement in communications between the Fairbanks North Star Borough and the Weather Service is also essential if the quality of the Fairbanks CO forecasts is to be improved. Measurements of mixing heights in Fairbanks suggest that a mixing height of 10 m be considered the maximum for worst case modeling of surface-source pollutants; values as low as 6 m were observed. As an interim measure, similar values are recommended for Anchorage.

Bowling, Sue Ann, Climatology of high-latitude air pollution, Submitted to J. of Clim. and Applied Meteorology, 1984.

ABSTRACT

High latitude communities frequently have severe air pollution problems. The usual situation is the release of moderate amounts of pollutants into an atmosphere with extremely poor dispersion. The poor dispersion is in turn a direct result of the high latitude radiation balance, which in winter is characterized by very short days and low solar elevation. The result is a ground-based nighttime inversion which continues through peak traffic hours (throughout the day in some places), coupled with a complete lack of photochemical reactions. If development in high latitudes is to proceed rationally, these meteorological conditions must be properly accounted for.

Carlson, R.F., and John Fox, An Atmospheric Carbon Monoxide Transport Model for Fairbanks, Alaska, Institute of Water Resources, University of Alaska, Fairbanks, Alaska 99701, Report No. IWR-75, June 1976.

ABSTRACT

A comprehensive computer model of atmospheric carbon monoxide transport has been developed for Fairbanks, Alaska. The model, based on a finite element method computational scheme, accepts input from specified vehicle traffic parameters including miles per day, number of cold starts, and total idle time. The carbon monoxide concentrations are calculated for specified time intervals at numerous points throughout the urban area. A test of the model against the data of January 22, 1975, indicates a good correspondence.

Extremely high carbon monoxide concentration were calculated at an unmeasured point down wind of the business district. The model should prove useful for a number of community needs including parking management, planning and zoning, episode strategy planning, and carbon monoxide forecasting.

(M)

Carlson, Robert F., and Charlotte Hok, Improvement of the Fairbanks Atmospheric Carbon Monoxide Transport Model -- A Program for Calibration, Verification and Implementation, Completion Report IWR 80-17, prepared for State of Alaska, Department of Transportation and Public Facilities, Division of Planning & Programming Research Section, October 1980.

ABSTRACT

In the early 70s, state, local and federal officials in Fairbanks, Alaska, became concerned with the rising incidence of high carbon monoxide episodes. Because of that concern, the Alaska Department of Highways (forerunner of the Department of Transportation and Public Facilities) and the Fairbanks North Star Borough requested that the Institute of Water Resources undertake a study to develop a computer model capability for understanding the transport of carbon monoxide and other pollutants within the Fairbanks airshed. The work was completed in June of 1976. Two publications (Carlson and Fox, 1976; Norton and Carlson, 1976) describe the initial development, documentation and implementation of the computer model. The model, ACOSP (Atmospheric Carbon monOxide Simulation Program), describes the two-dimensional behavior of pollutants in the atmosphere via solution of the convection-diffusion equation using the finite element method of numerical analysis.

Charlton, Robert B and Chan Park, Industrial Cloud, Fog, and Precipitation During Very Cold Weather in Edmonton, PNWIS-APCA, Edmonton, 1979.

ABSTRACT

The body of information in this paper is directed to engineers who are involved in the environmental aspects of northern development.

Fog, cloud, and precipitation caused by the petrochemical area of Edmonton, Alberta, were studied during the coldest days of two winters. Typical morning temperatures were between -25 and -40°C. The investigation included a comprehensive heat and vapor emission inventory, field studies of local and microscale cloud physics, and observations of cloud dispersal and precipitation formation. Results were compared with studies of residential Edmonton, oil sands plants, and power parks.

Emphasis was placed on the cloud microphysics of snow which falls from cooling tower plumes. Since this snow was nucleated by drift droplets its development was different than that of natural snowfall. Measured snowfall rates were found to be small compared with those reported during warmer weather when cooling tower emissions may trigger impending natural snowfall.

Holmgren, B., L. Spears, C. Wilson and C. Benson, Acoustic Soundings of the Fairbanks Temperature Inversions, Climate of the Arctic, Proceedings of the 24th Alaska Science Conference, University of Alaska, 1975.

ABSTRACT

In cooperation with the Wave Propagation Laboratory of NOAA in Boulder, Colorado, the Geophysical Institute of the University of Alaska is operating an acoustic sounder to study the dynamics of the formation and dissipation of the Fairbanks inversions. The acoustic sounder is generally operated in a monostatic mode, with receiving and transmitting antennas collocated. In the monostatic mode the recorded backscatter is supposedly due only to small-scale temperature fluctuations. The interpretation of the acoustic records is augmented by vertical profile measurements of wind and temperature using a captive-balloon-borne instrument package with telemetric link to the ground.

The Fairbanks inversions are quite complex, as indicated by the multi-layered structures of the acoustic records. There may be as many as 10–20 separate, quasi-horizontal backscatter bands within the height interval from the surface up to 500 m in situations with well-developed inversions. During these mutli-layered conditions the profile measurements using conventional wind and temperature sensors on a tethered balloon show a conspicuously strong temperature gradient in the lowest few tens of meters, and a wind speed at the 2 m level that is less than the starting speed of our anemometer ($\simeq$0.5 m s^{-1}). Above this extremely stable surface layer there is often a step-like build-up of the inversion; between layers of small temperature gradients, positive or negative, there are thin layers of sharp inversions. As for the winds aloft, one may typically recognize, in the lowest 500 m, two or more low-speed jets, often in diametrically opposed directions.

So far we have not been consistently able to relate the acoustic echo patterns to the simultaneously observed wind and temperature profiles. We are especially intrigued by the many thin backscattering bands which appear in layers of great stability, and which cannot be related either to marked wind shear or sharp temperature inversions. Although our present knowledge thus does not allow us to state unambiguously what is causing all the echo patterns, the acoustic soundings may still be used to deduce information on mesoscale processes in the boundary layer. Some examples of mesoscale processes that may be studied using acoustic records are: 1) the structure of surface inversions in connection with light or strong winds, 2) the formation of a convective or mixing layer below a capping inversion resulting from radiational heating of the surface, 3) the breakup of inversions due to increasing winds aloft and 4) the behavior of breaking waves associated with positive and negative wind shear. When used on a real time basis, the acoustic sounder should be a valuable tool for the local weather forecasts in Fairbanks, particularly for prediction of ice fog conditions.

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Hoyles, Michael R., A Study of Wind Patterns in Anchorage, Alaska that are Associated with Violations of the Carbon Monoxide Standards, January 1980.

ABSTRACT

Anchorage and Fairbanks are nonattainment areas for carbon monoxide and steps must be taken to insure that the National Ambient Air Quality Standards (NAAQS) for that pollutant be attained by 1987. The process to be followed involves a study of the problem, selection of reasonable control strategies, implementation of those strategies, and a monitoring of their success.

This report is part of that process. It is a study of the meteorological occurances coincident with violations of the carbon monoxide NAAQS. This is important for two reasons; to try and understand why the violations occur and to provide support and justifications for the assumptions used in the modeling of the problem.

Jayaweera, K., Comments on "Potential Relief from Extreme Urban Air Pollution", J. of Appl. Meteor., Vol. 12, No. 5, p. 887.

ABSTRACT

Half-page response to a paper by Ewing (1972). Heat generated by cities is unlikely to prevent inversions and air pollution.

Jayaweera, K., G. Wendler and T. Ohtake, Low cloud Cover and the Winter Temperature of Fairbanks, Climate of the Arctic, Proceedings of the 24th Alaska Science Conference, University of Alaska, 1975.

ABSTRACT

The paper will discuss the effects of low level cloud cover on the changes of the temperature of Fairbanks. Because Fairbanks is located in a valley in the interior of Alaska, the results presented in this paper may be applicable to similar locations in the Arctic land masses. The paper will be divided into three parts.

The first part will discuss the decrease of air temperature with time at various heights above Fairbanks, after clearing of the sky. Graphs showing the temperature at 2.5 cm, 1, 4, 8, 16 and 200 m at various times will be shown in order to illustrate the cooling at various levels and the formation of surface inversions. Energy balance computations will be presented which show that the radiation loss under clear skies is compensated mainly by sensible heat (62%) and soil heat flux (32%) while condensation contributes only a small 6%.

The second part of the paper will discuss the increase of the 1 m air temperature of Fairbanks when the sky is completely cloud covered after a clear period. Here only cases of low clouds (below 7000 ft, cloud base) and 100% cloud cover will be considered. The increase in surface temperature is plotted as a function of time with cloud base temperatures grouped in 5 C ranges varying from 0 to −25 C. The rate of increase of temperature will be compared with the expression of Brunt and the discrepancies discussed.

The final part of the paper will discuss the theory and experiments behind the generation of artificial clouds over an area under clear sky so as to inhibit radiative cooling. The results of the 1972/73 experiments showing the number of occasions suitable conditions existed for forming artificial clouds and the radiation effects of these clouds will be discussed. The small amounts of cloud cover that were produced during the experiments were not sufficient to obtain any significant change in the hemispherical radiation or the ground temperature but an indication of the radiative properties of these clouds were obtained using the Linke-Feussner actinometer with a 5° angle of view.

Norton, W.R., and R.F. Carlson, User's Guide for Atmospheric Carbon Monoxide Transport Model, Institute of Water Resources, University of Alaska, Fairbanks, Alaska, Report No. IWR-76, June 1976.

ABSTRACT

In the winter months of Fairbanks, Alaska, a highly stable air temperature inversion creates high levels of carbon monoxide (CO) concentrations. As an aid to understanding this problem, a CO transport computer model has been created which provides a useful tool when used in conjunction with other measurement and analytic studies of traffic, meteorology, emissions control, zoning, and parking management. The model is completely documented and illustrated with several examples. Named ACOSP (Atmospheric CO Simulation Program), it predicts expected CO concentrations within a specific geographic area for a defined set of CO sources. At the present time, the model is programmed to consider automobile emissions as the major CO source and may include estimates of stationary sources. The model is coded for computer solution in the FORTRAN programming language and uses the finite-element method of numerical solution of the basic convective-diffusion equations. Although it has a potential for real-time analysis and control, at the present time the model will be most valuable for investigating and understanding the physical processes which are responsible for high CO levels and for testing remedial control measures at high speed and low cost.

Reiter, Elmar R., Planetary-wave behavior and Arctic air pollution, Dept. of Atmos. Science, Colorado State University, Ft. Collins, Colorado, 1981.

ABSTRACT

An attempt was made to relate episodes of air pollution containing vanadium at Barrow, Alaska, to the behavior of planetary waves in middle and high latitudes. A stationarity index for planetary waves is defined as the ratio between amplitudes computed from monthly mean maps and the mean amplitudes computed on a daily basis and averaged over the same month, regardless of phase angle. Longitude-time sections of 500-mb height anomalies at various latitudes are related to vanadium pollution episodes at Barrow.

Rezek, John F. and Rick Jurick, Tracer Gas for Meteorological Analysis in the Fairbanks Basin, Final Report, State of Alaska, Department of Transportation and Public Facilities, May 1981.

ABSTRACT

The above EPA Maximum acceptable carbon monoxide (CO) level which often occurs during prolonged temperature inversions has been a major concern for the local governing agencies for several years. While progress has been made in reducing the problem from its source, understanding of CO disposition and dispersion has not significantly advanced due in part to the lack of good meteorological data. This study tested the use of sulfer hexafloride (SF_6) tracer gas to determine the wind field and mixing layer height. The results indicate a high probability of success for using SF_6 as the trace element in a comprehensive study toward that purpose.

Schmidt, Manfred and Peter Fabian, Relationships between Tropospheric Ozone Concentration and the General Weather Situation, Atmospheric Physics, Vol. 53, No. 1, February 1980.

ABSTRACT

The results of surface ozone records at five stations in the northern hemisphere (Tromsö, Norderney, Lindau/Harz, Zugspitze and Kairouan) are examined with respect to their dependence on wind directions and the general weather situation in Europe.

At Kairouan/Tunisia below average concentrations are connected with wind directions from the South, i. e. the interior of Africa and the Sahara desert. At Middle European stations, mixing ratios above the mean appear during periods of prevailing air streams from the North Atlantic Ocean and North Sea (with exception of Lindau, probably influenced by air pollution).

High ozone concentrations at Tromsö/Norway were found on the average when weather situations with high pressure regions over Northwest- and Northern Europe occured. These results probably point to a source of tropospheric ozone within these high pressure systems. A possible explanation is discussed.

Wendler, Gerd, Relation entre la concentration en oxyde de carbone et les conditions meteorologiques dans une communaute subarctique, J. Rech. Atmos, IX, No. 3, pp. 135-142, 1975.

ABSTRACT

An empirical formula was developped to describe the strength of the surface inversion for a subarctic community in Central Alaska. Besides the season and the time of the day, only cloudiness and wind speed were necessary to obtain good agreement (correlation factor 0.89). The « calculated » values of the inversion strength were correlated with the CO concentration. In spring and summer poor agreement was found, but in autumn and winter, when the highest and partly dangerous levels of CO were observed, the agreement was good (correlation factors around 0.8). Hence, by forecasting wind speed and cloudiness, the expected CO concentration can be estimated for Fairbanks in autumn and winter.

Wendler, Gerd and Philip Nicpon, Low-Level Temperature Inversions in Fairbanks, Central Alaska, Monthly Weather Review, Vol. 103, No. 1, pp. 34-44, January 1975.

ABSTRACT

Low-level inversions up to 200 m were investigated on a statistical basis for Fairbanks, Alaska, using hourly data for the year March 1967 to February 1968. Surface inversions were found to be present for more than 50% of the time. In winter (November to February) there is an inversion for more than 95% of the time; maximum values of the inversion strength were 20°C in 200 m altitude difference. In summer (June to August) inversions occur relatively seldom. For the rest of the year, inversions are normally established at night, but are destroyed by day.

The strength of the inversion was analyzed and shown graphically as a function of different independent meteorological parameters for the four seasons and annually. Although there are some differences depending on the season, the strength of the inversions was observed to increase with a) negative net radiation, b) decreasing cloudiness, and c) decreasing windspeed. Furthermore, during the winter a northerly wind direction, probably of orographic origin, was associated with stronger inversions. Such graphical data for a typical subarctic community should be useful in local forecasting and pollution control planning.

Special Forms of Cold Regions Air Pollution:

ICE FOG

The references in this section include the following topics:

Characteristics of ice fog
Sources of ice fog
Meteorological conditions and transport pathways
Effects of ice fog on pollution dispersion and scavenging of other pollutants
Radiative effects
Ice crystals and ice fog nuclei
Ice fog reduction and suppression.

AeResearch, Inc., Baseline Ice Fog Visibility Study, Report for Fairbanks North Star Borough, 1 Vol., 1975.

ABSTRACT

For many years the effects of ice fog on the community of Fairbanks, Alaska have been observed to worsen. Many studies have been made to help better understand the ice fog phenomenon. Probably the best known and most thorough investigation of ice fog was reported in 1965 by Benson. This assessment included a source inventory, determination of distribution, and estimation of density. More recent work has been devoted to particle formation and size distribution, atmospheric heat balance and low level air flow in the Fairbanks basin (Ohtake, Benson, Weller, Bowling, et. al.).

Armstrong, W.C., Effects of Thermal Discharges upon the Chena River, Institute of Water Resources, University of Alaska, Fairbanks, Alaska, Report No.: OWRR-B-020 Alaska(2); W73-14864, April 1973, 146 p.

ABSTRACT

The evaluation of several thermal discharges in Fairbanks, Alaska was carried out to determine their effects on the physical parameters of the Chena River, a typical sub-Arctic stream. In addition, the effectiveness of two discharge schemes at the main thermal source was compared. The use of a surface-spreading scheme at either source would result in a heat dissipation rate per unit area 2 to 10 times greater than use of a submerged jet. The amount of ice cover downstream from the discharges would be approximately 40% more using the submerged jet. The advantages of each discharge method are discussed and two alternative cooling methods are suggested.

Benson, Carl S., Ice Fog: Low Temperature Air Pollution in Fairbanks, Geophysical Institute Annual Report 1964-65, pp. 86-91.

ABSTRACT

General description of ice fog in Fairbanks, including water vapor sources and amounts of other combustion products.

Benson, Carl S., Ice Fog: Low Temperature Air Pollution, University of Alaska, Geophysical Institute, UAG R-173, 1965.

ABSTRACT

Stable pressure systems over interior Alaska sometimes produce prolonged, extreme (below -40°C) cold spells at the surface. The meteorological conditions responsible for two such cold spells are discussed in detail in Appendix A, where it is shown that the rate of radiative cooling of the air is enhanced by suspended ice crystals which are themselves a result of the initial cooling.

Radiation fogs formed during the onset of cold spells are generally of short duration because the air soon becomes desiccated. These fogs consist of supercooled water droplets until the air temperature goes below the "spontaneous freezing point" for water droplets (about -40°C); the fog then becomes an ice crystal fog, or simply "Ice Fog". During the cooling cycle water is gradually condensed out of the air until the droplets freeze. At this point there is a sharp, discontinuous decrease in the saturation vapor pressure of the air because it must be reckoned over ice rather than over water. The polluted air over Fairbanks allows droplets to begin freezing at the relatively high temperature of -35°C. Between -35 and -40°C the amount of water vapor condensed by freezing of supercooled water droplets is 3 to 5 times greater than the amount condensed by 1°C of cooling at these temperatures. This results in rapid and widespread formation of ice fog (Appendix B) which persists in the Fairbanks ara as long as the cold spell lasts. The persistence of Fairbanks ice fog depends on a continual source of moisture (4.1 x 10_6 Kg H_2O per day) from human activities within the fog.

Benson, Carl S., Ice Fog, Low Temperature Air Pollution, Research Report 121, Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire, 1970.

ABSTRACT

Stable pressure systems over interior Alaska sometimes produced prolonged, extreme (below -40°C) cold spells at the surface. The meteorological conditions responsible for two such cold spells are discussed in detail in Appendix A, where it is shown that the rate of radiative cooling of the air is enhanced by suspended ice crystals which are themselves a result of the initial cooling. Radiation fogs formed during the onset of cold spells are generally of short duration because the air soon becomes desiccated. These fogs consist of supercooled water droplets until the air temperature goes below the "spontaneous freezing point" for water droplets (about -40°C); the fog then becomes an ice crystal fog, or simply "ice fog." During the cooling cycle water is gradually condensed out of the air until the droplets freeze. At this point there is a sharp, discontinuous decrease in the saturation vapor pressure of the air because it must be reckoned over ice rather than over water. The polluted air over Fairbanks allows droplets to begin freezing at the relatively high temperature of -35°C. Between -35 and -40°C the amount of water vapor condensed by freezing of supercooled water droplets is 3 to 5 times greater than the amount condensed by 1°C of cooling at these temperatures. This results in rapid and widespread formations of ice fog (Appendix B) which persists in the Fairbanks area as long as the cold spell lasts. The persistence of Fairbanks ice fog depends on a continual source of moisture (4.1×10^9 kg H_2O per day) from human activities within the fog. Ice fog crystals are an order of magnitude smaller than diamond dust, or cirrus cloud crystals, which in turn are an order of magnitude smaller than common snow crystals (0.01, 0.1 and 1 to 5 mm respectively). The differences in size are shown to result from differences in cooling rates over five orders of magnitude. Most of the ice fog crystals have settling rates which are slower than the upward velocity of air over the city center. The upward air movement is caused by convection cells driven by the 6°C "heat island" over Fairbanks. This causes a reduced precipitation rate which permits the density of ice fog in the city center to be three times greater than that in the outlying areas. The inversions which occur during cold spells over Fairbanks begin at ground level and are among the strongest and most persistent in the world. They are three times stronger than those in the inversion layer over Los Angeles. Thus, the low-lying air over Fairbanks stagnates and becomes effectively decoupled from the atmosphere above, permitting high concentrations of all pollutants. The combustion of fuel oil, gasoline, and coal provides daily inputs of 4.1×10^9 kg CO_2; 8.6×10^3 kg SO_2; and 60, 46 and 20 kg of Pb, Br and Cl respectively, into a lens-like layer of air resting on the surface with a total volume less than 3×10^9 m^3. The air pollution over Fairbanks during cold spells is further worsened, because the mechanisms for cleaning the air are virtually eliminated while all activities which pollute the air are increased.

Benson, Carl S., and Sue Ann Bowling, Condensation of Exhaust Plumes from Jet Turbines Operating in Cold Air, Geophysical Institute Report, University of Alaska, 1978.

ABSTRACT

The proposed trans-Alaska oil pipeline involves 12 pumping stations. The pumps will be powered by gas turbine engines which use petroleum fuel. Since the exhaust plumes will be ejected upward into a very cold air mass, there are questions as to the amount of ice fog which will be produced at these sites. In order to estimate the seriousness of this problem, we have considered the interaction between an exhaust plume, with assumed properties, and a cold stratified air mass.

Bowling, Sue Ann, Carl S. Benson and Wallace B. Murcray, Quasi-Equilibrium Temperature Differences between Radiating Ice Crystals and the Surrounding Air, J. of Applied Meteorology, Vol. 10, No. 5, October 1971.

ABSTRACT

A previous attempt to calculate the temperature gradient around a growing ice crystal in clear air started with the radiation budget of the crystal plus the assumption that the measured frost point temperature (about 2C below air temperature) represented the crystal temperature. When the conductivity equation for the air around the crystal is fully solved with the radiation budget as the boundary condition, however, it is found that less than 0.03C temperature difference can be sustained by radiative cooling of the crystals. The most probable explanation of the difference between the two approaches is that the humidity measurements are in error, and that the error has been generally recognized only at measured humidities in excess of 100%.

Bowling, S.A., and Carl S. Benson, Report on the Probably Effects on Ice Fog of the Proposed Change from Electricity to Fossil Fuel for Heating the Airport Terminal Building, Geophysical Institute, University of Alaska, Fairbanks, Alaska 99701, January 1982.

We have used available climatic data to estimate the increase in ice fog which would result from each of the proposed heating plant plans. It appears that the incidence of ice fog dense enough to effectively close the airport would increase by 4 to 10% (7 to 14 hours per year) if the terminal and fire rescue heating system is switched to oil. Changing the fire rescue station only to oil would have about half that effect, and the Peger Road complex would have about one-tenth of the impact of the terminal/fire rescue plant. Use of coal rather than fuel oil would in each case give 12% more added ice fog than would occur with fuel oil.

The amount of water which would be released by the proposed oil-fired terminal plant is about 100 gm/sec (8.6 metric tons*/day) - comparable to about a hundred idling cars. This would roughly triple the water output from current and proposed stationary airport heating plants other than the terminal and fire rescue station.

Brown, Robena J., Ice Fog (A Bibliography with Abstracts), National Technical Information Service, Springfield, Virginia, November 1979, 73 p.

ABSTRACT

The bibliography includes citations relating to ice formation, modification, dispersal and forecasting. Problems of white outs and thermal pollution effects in arctic regions are discussed. (This updated bibliography contains 64 abstracts, 6 of which are new entries to the previous edition.)

Clark, John P., The Effect of Combustion Upon the Formation of Ice Fog in the Greater Fairbanks Area, EM 694, Arctic Engineering, Submitted to Dean Charle Sargent, Department of Civil Engineering, University of Alaska, January, 1963.

ABSTRACT

The scope of this report encompasses a study of the quantitative effects of the exhaust discharge of heat engines upon the formation of ice fog in the Fairbanks area. This study is based upon the total fuel (gasoline, aviation gasoline, Diesel fuel, fuel oil, and coal) sales to consumers in Fairbanks and the Fort Wainwright military base, from October 1961 to March 1962. The moisture discharge calculations are preceeded by a discussion summarizing the conditions necessary for the formation of ice fog.

Coutts, Harold J. and Ronald K. Turner, Research on control technology for ice fog from mobile sources, Arctic Environ. Res. Station, College, Alaska, EPA-600/3-78-055, May 1978, 90 p.

Automotive generated ice fog is a form of air pollution which results when exhaust water vapor freezes into minute particles that form a dense fog. This study on control techniques was conducted by the U.S. Environmental Protection Agency at ~~its Arctic Environmental Research Station~~ near Fairbanks, Alaska. The major control technique evaluated was the cooling of exhaust gases to below the dew point, thus, condensing water vapor into a liquid stream before final discharge. During the winter of 1974-1975, nine exhaust gas cooler-condensers were installed on local vehicles, and their water vapor removal performances were evaluated. Based upon these data, three cooler-condensers were fabricated, installed, and evaluated more intensely during the winter of 1975-1976. The sizing criteria developed the first winter were inadequate because ice film formation decreased heat transfer efficiency. Cooler-condensers must be designed to avoid or to accommodate condensate freezing. An ice fog mass emission reduction to 80% was attained with cooler-condensers on motor vehicles; however, the increase in visibility over roads was not proportional because of the many other ice fog sources. The overall impact of automotive ice fog control would be a visibility increase of at least 70% in areas where motor vehicles create 50% or more of the ice fog. Control of automobile-generated ice fog would also mean cleaner air, but perhaps more ice on the road. Cleaner air would result because sulfur oxides and lead compounds would be absorbed in the condensate.

Csanady, G.T., and T.M.L. Wigley, Ice Fog Clouds Formed by Vapour Emissions in Cold Climates such as the Upper MacKenzie Valley, University of Waterloo Research Institute,Task Force on Northern Oil Development Development Report No. 73-13.

The main conclusion of the report is that the formation of ice fog due to the combustion of hydrocarbons is, for all practical purposes, unavoidable in weather colder than about -40°C. At temperatures above -30°C, by contrast, little or no ice fog formation may be expected. The size of opaque ice fog clouds generated even by relatively small combustion sources is, for local conditions, relatively large; a single typical incinerator operating for two hours, may generate an opaque disk-like cloud of some 500 metres diameter. Therefore, landing-strips should be located at considerable distances from combustion sources and automobile traffic near airports should be minimized. On the other hand, large scale effects of such combustion generated clouds on weather, through influencing of the radiation balance, may be safely ignored.

The meteorological phenomenon chiefly responsible for the unfavourable behaviour of moisture released into the Arctic atmosphere is the occurrence of ground based inversions, with the consequent suppression of turbulence near ground level, and the very cold temperatures which develop under such circumstances. These physical processes all depend on the mechanics of the planetary boundary layer with downward heat flux, the properties of which are neither completely known nor very well understood. A study of planetary boundary layer behaviour in the Mackenzie valley would be a logical continuation of the present project. Such a study is likely to make an important contribution toward the opening up of the Canadian Arctic.

Gotaas, Yngvar and Carl S. Benson, The Effect of Suspended Ice Crystals and Radiative Cooling, J. of Applied Meteorology, Vol. 4, No. 4, 446-453, 1965.

ABSTRACT

Two periods of very low (below −40C) surface temperature at Fairbanks, Alaska, were studied in detail as part of ice fog investigations during the 1961–1962 winter. The observed cooling rates from the snow surface up to 3000 m were too large to be satisfactorily explained by advection and/or by radiative heat losses from the air and from the snow surface. The excess is shown to be due to radiation from ice crystals suspended in air.

The ice crystals, formed by overall cooling of the air, act as heat sinks. It is proposed that heat flows from the air to the crystals and is radiated away. This process results in strong temperature gradients in the air immediately adjacent to the crystals. It may also account for the fact that humidity measurements show less than saturation values during occurrences of ice fog, light snowfall, or "diamond dust" crystal displays. The air temperature values used in determining humidity pertain to ambient air between the ice crystals, whereas the air in contact with crystals has a lower temperature and is saturated with respect to ice.

Henmi, Teizi, Some Physical Phenomena Associated with Ice Fog, Masters Thesis, University of Alaska, College, 1969.

ABSTRACT

To measure the humidity under ice fog conditions in the vicinity of Fairbanks, Alaska, an air sampling method was used which consisted of extracting the water vapor by passing the air through a drying tube containing magnesium perchlorate. To measure the volume of sampled air, two glass bottles of 45 liters capacity were used, one containing kerosene and the other having kerosene drawn into it by means of electric pumps. The results show that water vapor pressure under ice fog conditions lies between ice and water saturation pressure.

Hicks, James R.; Motoi Kumai, Ice fog modification by use of helicopters, U. S. Cold Regions Research and Engineering Lab., Hanover, New Hampshire, Special Report 162, September 1971, 8 p.

ABSTRACT

The objects of the report are to increase the knowledge of the physical and optical properties of ice fog and to develop techniques for its dispersal. Two series of flight tests to determine the effects of CH-47 helicopter downwash on ice fog were conducted near Ft. Wainwright, Alaska, in January 1971. During the first series, clearings were produced which were large enough for helicopter operations. This series of tests was conducted when the ice fog was in a dissipating state. The second series of tests was conducted in a denser ice fog during its developing stage. The same flight procedures were used, but clearings were not produced.

Hoppe, Captain Eugene R., Ice Fog Conditions in the Alaskan Interior, Presented at the 203rd National Meeting of the American Meteorological Society at the University of Alaska, College, Alaska, June 1962.

ABSTRACT

Operation of jet aircraft by the Air Force at Eielson AFB.

Huffman, Paul Jacob, Size Distribution of Ice Fog Particles, Masters Thesis, University of Alaska, College, 1968.

ABSTRACT

This thesis presents the results of a theoretical and experimental investigation of the size distribution of ice fog particles in the vicinity of Fairbanks, Alaska.

The general theory of atmospheric ice crystal formation and growth is applied to ice fog and the predictions of this theory compared with the experimental results. General conclusions are drawn concerning the nature of the size distribution function.

A discussion of the scattering of electromagnetic radiation by ice fog particles is presented. The Trabert formula is used to estimate visual range and these values compared with the measured visual range.

Three different methods were used for collecting and photographing ice fog particles. A discussion is presented on the relative merits and disadvantages of each method.

The experimental problems encountered are discussed and procedures outlined which should prove useful in the future for this type of work.

Huffman, P.J.; Ohtake, T., Formation and Growth of Ice Fog Particles at Fairbanks, Alaska, Air Force Cambridge Research Labs, L. G. Hanscom Field, Mass., Report No.: AFCRL-71-0129, October 14, 1970, 10 p.

ABSTRACT

A mechanism is proposed for the formation of ice fog particles in the city and environs of Fairbanks, Alaska. Equations are developed for calculating the size distribution resulting from growth by deposition of water vapor. The equations are numerically solved with a computer for three major types of ice fog sources: (1) automobile exhaust, (2) exhaust from heating plants, and (3) open water. The size distribution produced by an individual source is determined by the cooling rate of water vapor injected into the environment. The cooling rate is a function of the source characteristics and the ambient temperature. The proposed mechanism adequately represents the observed size distribution if the cooling rate of the water vapor injected into the environment is not too large (source types 2 and 3). Because of the large cooling rate of water vapor injected into the atmosphere by source type 1, the size distribution from this source is not adequately represented by the model. In agreement with observations, the computational results predict a decrease in the size of ice fog particles with decreasing ambient temperature for source types 2 and 3.

Kumai, Motoi, A Study of Ice Fogs and Ice-Nuclei, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, N.H., June 1963.

ABSTRACT

This is a study of arctic whiteout, i.e., ice fog, supercooled fog and ice crystals in cold regions. Size and mass distribution, the rate of precipitation, and the concentration of ice-fog crystals were measured in Fairbanks, Alaska. Ice fog occurred at temperatures of -37C or lower only over the populated area included in the city of Fairbanks, Fairbanks International Airport, and Fort Wainwright in the Tanana Valley of Central Alaska.

Kumai, Motoi, A Study of Ice Fog and Ice-Fog Nuclei at Fairbanks, Alaska, Part 1, Army Cold Regions Research and Engineering Lab., Hanover, N.H., Report No.: RR-150; AD-451 667, August 1964, 33 p.

ABSTRACT

This study of arctic whiteout presents the results of condensation nuclei counts; identification of nuclei in fog, supercooled fog, and ice crystals; and the measurement of concentrations and liquid-water contents of icefog crystals. Ice fog occurred at temperatures of -37C or lower only over the populated area of Fairbanks. The crystals formed at -40C were predominantly spherical (2 to 15-mu in diam.), the remainder being hexagonal and columnar (5 to 30-mu diam.). It is suggested that spherical shapes were formed by the freezing of supercooled fog droplets, growing into hexagonal forms by sublimation of water vapor. Sintering of ice fog crystals was found even at a temperature of -40C in ice fog. The residues of ice-fog crystals, supercooled fog droplets and ice crystals were examined with an electron microscope and diffraction method to investigate their nucleation. The nuclei substances and their sizes differed from those of snow crystals on the Greenland Ice Cap and were mainly combustion by-products of 0.1 to 3-mu diameter.

Kumai, Motoi, Electron Microscope Study of Ice-Fog and Ice-Crystal Nuclei in Alaska, U.S. Army Cold Regiosn Research and Engineering Laboratory, N.H.

ABSTRACT

Ice fog particles, supercooled fog droplets and ice crystals which formed at temperatures between -10°C and -42°C were collected on electron microscope grids in the Fairbanks area, Alaska. After sublimation or evaporation, the remaining residues of these specimens were examined by the use of an electron microscope to investigate their nucleations. A solid particle of 0.1 μ to 3 μ diameter was observed in the residue of each ice fog particle, supercooled droplet and ice crystal which was examined. The nucleus substances were combustion particles, clay minerals and hygroscopic particles. The nuclei of ice fog particles which formed at about -40°C ranged from about 0.1 μ to 0.5 μ in diamteter. The nuclei of supercooled fog droplets formed at -10°C and ice crystals formed at -20°C to -25°C were found to be larger than those of ice fog particles and ranged from about 0.3 μ in diameter.

Shapes of ice fog particles formed at around -40°C were mainly spherical ice particles of 2 μ to 15 μ diameter, the remainder being hexagonal and columnar particles of 5 μ to 30 μ diameter. Sintering of ice fog particles, ice particles joined with a welding neck caused by collision of the particles in the atmosphere, was found in ice fog even at a temperature of -40°C.

Kumai, Motoi, and Harold W. O'Brien, Ice Fog Formation from the Cooling Pond at Eielson Air Force Base, Alaska, Technical Note, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire, Sept. 1964.

ABSTRACT

Richardson (1964) estimated the amount of water vapor available for ice fog formation at Eielson Air Force Base, Alaska, based on claculations of the water output be oxidation of fuel in power and heating plants, home heating appliances, internal combustion and jet engines and by evaporation from the cooling pond. He estimated that under the given conditions of air temperature, -34.4 C and water temperature, 7.2 C, the rate of production of water vapor form the cooling pond is 170,000 Kg/day.

Kumai, Motoi; Harold W. O'Brien, A Study of Ice Fog and Ice-Fog Nuclei at Fairbanks, Alaska, Part II, Cold Regions Research and Engineering Lab, Hanover, New Hampshire, Report No.: CRREL-RR-150, April 1965, 19 p.

ABSTRACT

Studies on ice fog and ice crystals have been conducted at Fairbanks, Alaska, since 1962. USA CRREL Research Report 150, Part I, presented the results of the first study, conducted during January and February 1962, which was concerned with the identification of nuclei of ice crystals, ice-fog crystals, and supercooled droplets; counts of condensation nuclei; and measurement of ice-fog concentrations and liquid water content. The second study of the series, conducted during January and February 1963, is the subject of this report. This investigation encompassed (1) a meteorological study of conditions favoring the occurrence and persistence of ice fog; (2) observations of ice-crystal formation with water vapor and hydrocarbon ice-forming nuclei provided by combustion products from a power plant chimney and an automobile exhaust; (3) design of a cascade impactor for use with a tethered blimp; (4) studies of the size relationship between ice-fog crystals and their nuclei; and (5) a comparison of size distributions between some seeding agents and natural ice-fog crystals, and their nuclei.

Kumai, Motoi, Micospherules in Snow and Ice-fog Crystals, Cold Regions Research and Engineering Lab, Hanover, New Hampshire, DA Task 1T061102B52A02, RR 245, March 1969, 10 p.

Electron diffraction techniques were used in an electron microscope examination of spherules found in snow crystals, ice-fog crystals, fallout particles, and fly ash. The central part of the residues of 1004 specimens of natural snow crystals from Greenland, the United States, and Japan were examined and 14 spherules 0.1 to 1.5 microns in radius were found among them. The residues of 658 artificial ice-fog crystals formed from water vapor in flue gases of coal-burning electric power plants at Fairbanks, Alaska, were also examined; nine spherules were found. Spherules similar to those found in ice-fog residues were found in furnace-produced fly ash fallout at Fairbanks, Alaska. The properties of spherules and the mean mass of snow crystals from Greenland are given. The electron microscope study indicated that less than 0.7% of the 1004 snow crystals contained spherules of possible extraterrestrial origin, and that snow crystals are formed mainly on clay mineral particles by heterogeneous nucleation.

Kumai, Motoi, Formation and Reduction of Ice Fog (Research rept.), Cold Regions Research and Engineering Lab, Hanover, N.H., Report No.: CRREL-RR-235, March 1969, 29 p.

ABSTRACT

During January and February of 1962, 1963 and 1964, Fairbanks, Alaska, and vicinity was the site of a series of studies dealing with ice fog and ice crystals. This report presents the results of an investigation of the amount and extent of air pollution and ice fog in the area with special emphasis on reducing ice fog by decreasing the water vapor being emitted into the atmosphere. The major sources of water vapor at the two military installations in the region, Fort Wainwright and Eielson AFB, are the heating and power plants and their associated cooling ponds. In the populated areas around Fairbanks, a high aerosol concentration of about 100,000 particles/cc exists, whereas in the uninhabited areas the concentration is extremely low (about 300 particles/cc). Much of the high concentration is due to the burning of coal for heat and power. Because the coal is of low grade it also emits about 350,000 kg of water vapor into the atmosphere on a day when the temperature is -40C. This water vapor condenses on the aerosols and produces ice fog. Anthracite or semi-bituminous coal would reduce the water vapor output to only 1/5 of the amount produced by the low grade coal. Water vapor from cooling ponds can be reduced by freezing the surfaces of the ponds.

Kumai, Motoi, Formation and reduction of ice fog, U. S. Cold Regions Research and Engineering Lab., Hanover, New Hampshire, Research Report 235, March 1969, 21 p.

ABSTRACT

Studies dealing with ice fog and ice crystals were conducted during January and February of 1962, 1963 and 1964 at Fairbanks, Alaska and vicinity. The results of an investigation of the amount and extent of air pollution and ice fog in the area are presented, with special emplasis on reducing ice fog by decreasing the water vapor being emitted into the atmosphere. The major sources of water vapor at two military installations in the region, are the heating and power plants and their associated cooling ponds. In the populated areas around Fairbanks, a high aerosol concentration of about 100,000 particles/cu cm exists, while in the uninhabited areas the concentration is extremely low (about 300 particles/cu cm. Much of the high concentration is due to the burning of coal for heat and power. Because the coal is of low grade, it also emits about 350,000 kg of water vapr into the atmosphere on a day when the termperature is -40 C. This water vapor condenses on the aerosols and produces ice fog. Anthracite or semi-bituminous coal would reduce the water vapor output to only one-fifth of the amount produced by the low grade coal. Water vapor from cooling ponds can be reduced by freezing the surfaces of the ponds.

Kumai, Motoi; Russell, Jack D., The Attenuation and Backscattering of Infrared Radiation by Ice Fog and Water Fog, (Research rept.), Cold Regions Research and Engineering Lab, Hanover, N.H., Report No.: CRREL-RR-264, April 1969, 14 p.

ABSTRACT

Ice-fog crystals consisting of many spherical particles, and some hexagonal plates and columns, were observed at ambient temperatures of about -40C in the Fairbanks, Alaska, area during mid-winter. The concentrations and the size distributions of the ice-fog crystals were measured. The attenuation and backscattering of infrared radiation by ice-fog crystals were computed for optical wavelengths of 2.2 microns, 2.7 microns, 4.5 microns, 5.75 microns, 9.7 microns and 10.9 microns using the Mie theory. The minimum attenuation coefficients and backscattering functions of ice fog were found to be at 9.7 microns wavelength in the observed wavelengths. Optical attenuation coefficients and volume backscattering functions of water fogs were also computed using the Mie theory. The minimum attenuation coefficients and backscattering functions of water fog were found to be at 10.9 microns wavelength in the region of 2.2 microns, 2.7 microns, 4.5 microns, 5.75 microns, 9.7 microns and 10.9 microns. Both the attenuation coefficients and backscattering functions of ice fog are within the same order of magnitude as water fog for equivalent fog concentrations and wavelengths.

Leonard, L.E.; Seifert, R.; Zarling J.; Johnson, R., Ice Fog Abatement and Pollution Reduction at a Subarctic Coal-Fired Heating Plant, University of Alaska, Fairbanks, Alaska, Report No.: EPA-600/3-81-020, February 1981, 75 p.

ABSTRACT

An experimental cooler-condenser system was constructed at the coal-fired heating and electric plant on the Fairbanks campus of the University of Alaska to evaluate its potential to reduce ice fog and other pollutant stack emissions in a subarctic environment. This experiment advanced the work began by Porteous and Wallis (1965) to a stage of field evaluation for a less than full scale system. Flue gas was diverted from the existing power plant stack through the experimental system for test purposes. A cold water spray was directed into the muzzle of the experimental stack counter-current to the direction of flue gas flow to cool the gas, condense combustion-produced water vapor and scrub the gas stream of potential pollutants before they were released to the atmosphere. Because of several factors, the system at this stage of development proved ineffective for its main function of ice fog reduction. Some of the problems could be prevented by changes in the design of the system and some remain inconclusive and not well understood. Results show that the scrubbing function was more successful. Environmental considerations such as process water treatment and disposal presented no major obstacles, however, the potential to recover waste from the system does not appear favorable.

McFadden, Terry T., Suppression of Ice Fog from Power Plant Cooling Ponds, Ph.D. Thesis, University of Alaska, Fairbanks, Alaska, 1974.

ABSTRACT

Ice fog generated at the Eielson AFB power plant cooling pond contributes heavily to the total ice fog problem on the base. Several methods for suppression were studied and two techniques were tested experimentally. Experiments were also conducted to determine the magnitude of the various modes of heat transfer within the pond's microclimate. Values of evaporative and radiative heat loss during ice fog are presented.

Ice cover is shown to be an effective ice fog suppression technique. Monomolecular films are also shown to be effective and offer some unique advantages, such as ease of application and low overall cost.

The heat normally lost to evaporation must be dissipated by other means during suppression. With the ice cover technique this is accomplished by melting the ice cover. During suppression with monomolecular films, the heat must be dissipated by increasing radiative and convective losses.

McFadden, Terry, Suppression of ice fog from cooling ponds, United States Cold Regions Research and Engineering Lab., Hanover New Hampshire, Report 76-43, November 1976, 78 p.

ABSTRACT

Ice fog generated at the Eielson AFB power plant cooling pond contributes heavily to the total ice fog problem on the base. Several methods of ice fog suppression were studied, and two techniques were tested experimentally. Experiments were also conducted to determine the magnitude of the various modes of heat transfer within the pond's microclimate. Values of evaporative and radiative heat loss during ice fog are presented. Ice cover is shown to be an effective ice fog suppression technique. Monomolecular films are also shown to be effective and offer some unique advantages, such as ease of application and low overall cost. The heat normally lost to evaporation must be dissipated by other means during suppression. With the ice cover technique, this is accomplished by melting the ice cover. During suppression with monomolecular films, the heat must be dissipated by increasing radiative and convective losses. The simplicity of application of monomolecular films, along with their lower cost, combine to make this technique attractive; however, the lower pond temperatures and increased suppression effectiveness weigh heavily in favor of the ice- cover technique. More exhaustive testing will provide a better understanding of the problems involved in the ice cover method of suppression.

McFadden, Terry T.; Charles M. Collins, Ice fog suppression using reinforced thin chemical films, U. S. Cold Regions Research and Engineering Lab., Hanover, New Hampshire, Report 78-26, November 1978, 27 p.

ABSTRACT

Ice fog suppression experiments on the Fort Wainwright Power Plant cooling pond were conducted during the winters of 1974-1976. Baseline information studies occupied a sizable portion of the available ice fog weather in 1974-1975. Hexadecanol was added to the pond and dramatically improved visibility by reducing fog generated from water vapor released by the pond at -14°C. Although this temperature was not low enough to create ice fog, the cold vapor fog created was equally as devastating to visibility in the vicinity of the pond. During the winter of 1975-1976, suppression tests were continued by using films of hexadecanol, mixes of hexadecanol and octadecanol, and ethylene glycol monobutyl ether (EGME). Suppression effectiveness at colder temperatures was studied, and limits to the techniques were probed. A reinforcing grid was constructed which prevented breakup of the film by wind and water currents. Lifetime tests indicated that EGME degrades more slowly than either hexadecanol or the hexadecanol-octadecanol mix. The films were found to be effective fog reducers at warmer temperatures, but still permitted 20-40% of normal evaporation to occur. The vapor thus produced was sufficient to create ice fog at lower temperatures, but this ice fog occurred less frequently and was more quickly dispersed than the thick fog that was present before application of the films.

McFadden, Terry T.; Collins, Charles M., Ice Fog Suppression Using Thin Chemical Films, Army Cold Regions Research and Engineering Lab., Fort Wainwright, Alaska, Alaskan Projects Office, Report No.: EPA/600/3-79/007, January 1979, 55 p.

ABSTRACT

Ice fog suppression experiments on the Fort Wainwright Power Plant cooling pond were conducted during the winters of 1974-76. Baseline information studies occupied a sizeable portion of the available ice fog weather in 1974-75. Hexadecanol was added to the pond and dramatically improved visibility by reducing fog generated from water vapor released by the pond at -14C. Although this temperature was not low enough to create ice fog, the cold vapor fog created was equally as devasting to visibility in the vicinity of the pond. During the winter of 1975-76, suppression tests were continued using films of hexadecanol, mixes of hexadecanol and octadecanol, and ethylene glycol monobutyl ether (EGME). Suppression effectiveness at colder temperatures was studied and limits to the techniques were probed. A reinforcing grid was constructed that prevented breakup of the film by wind and water currents. Lifetime tests indicated that EGME degrades much more slowly than either hexadecanol or the hexadecanol-octadecanol mix. All the films were found to be very effective fog reducers at warmer temperatures but still allowed 20% to 40% of normal evaporation to occur. The vapor thus produced was sufficient to create some ice fog at lower temperatures, but this ice fog occurred less frequently and was more quickly dispersed than the thick fog that was present before application of the films.

National Technical Information Service Report, Ice Fog. 1964-February, 1982 (Citations from the NTIS Data Base), National Technical Information Service, Springfield, Virginia, March 1982, 77 p.

ABSTRACT

The bibliography includes citations relating to ice formation, modification, dispersal and forecasting. Problems of white outs and thermal pollution effects in arctic regions are discussed. (This updated bibliography contains 67 citations, 2 of which are new entries to the previous edition.)

Nelson, William George, A Numerical Analysis of Ice Fog Produced by Automobiles, Oregon State University, Corvallis, Oregon, Thesis, 1973, 150 p.

ABSTRACT

A mathematical model was developed and programmed on a digital computer to predict the concentration and size distribution of ice fog particles produced from automobile exhaust in arctic conditions. The predicted mean diameter of the particles was 2.3 micron. The model was then used to compute the effects of exhaust compositon (water vapor and particulate content), exhaust gas temperature, and rate of exhaust gas cooling on particle size and number. Removal of soluble particles reduces ice particle size and increases particle concentration. Soluble particle nucleated ice particles dominate when conditions are such that high saturation ratios in exhaust gas are not quickly reached. The conditions are high initial exhaust gas temperature, high ambient air temperatures, low initial exhaust water vapor, and low exhaust gas velocities. Ice particles produced by an automobile operating with benzene as a fuel would have much larger mean diameters than those produced by gasoline- or methane-powered automobiles. Benzene would also produce fewer ice particles.

Nelson, W.G., Reduction of Ice Particle Production from Moist Plumes, University of Alaska-Anchorage, 3221 Providence Drive, Anchorage, Alaska 99504, 79-9.2.

ABSTRACT

It is generally conceded that the major effect of ice fog is the impairment of visibility. After a review of the physics of ice fog formation, the author, suggests methods to reduce the visibility reduction caused by various sources and, discusses several experimental attempts to reduce wet plume condensation and to increase the size and reduce the number of nucleated droplets within the plumes.

This discussion of the physics of ice fog formation includes modes of nucleation, growth, and freezing of droplets in wet plumes subjected to cold ambient air. The effect of ambient temperatures and various plume physical properties including temperature, water vapor content, plume-ambient air mixing rates, and plume outlet diameter and velocity are discussed.

The experimental attempts to reduce ice particle generation are compared to predictions based upon the author's work in modeling ice particle nucleation and growth in automobile exhaust plumes.

Ohtake, Takeshi, Alaska Ice Fog, (A progress report of ice fog research), Geophysical Institute, University of Alaska, Fairbanks, Alaska, Int'l Conf. on Low Temperature Sci., Sapporo, 105-118, 1966.

ABSTRACT

This study began in the fall of 1964 in the Fairbanks area of Alaska. It involves an inquiry into the sources and role of water vapor in the ice fog, investigation of the relative concentrations of ice-fog particles, ice nuclei and condensation nuclei, and examination of the characteristics of nuclei and crystals by electron microscopy. With the electron microscope it was found that most nuclei of ice crystals which developed from sublimation of water vapor were located at the center of the ice crystals. In contrast, ice-fog particles result from freezing of supercooled water droplets which form by condensation of water vapor from man-made sources of air pollution such as exhaust gases, open water surfaces on cooling pond, etc. The nuclei in these particles are not located in the center. Dense ice fog covering small areas originated from open water where the condensation nuclei concentration was much lower than in the downtown area, while thin but widespread ice fog was observed in the downtown area and along the highway. Dense ice fog was associated with large sources of moisture regardless of whether or not nuclei were abundant. The role of ice-forming nuclei and a preliminary consideration of synoptic conditions which cause ice fog is also discussed.

Ohtake, Takeshi, Freezing of Water Droplets and Ice Fog Phenomena, Proc. Intn. Conf. Cloud Phys., Toronto, 1968.

ABSTRACT

In arctic and subarctic continental cities, when the temperatures go down to about -30°C, a sort of fog appears. This is ice fog, which is composed primarily of ice crystals with some water droplets possibly mixed. Thuman and Robinson (1954a) reported that the crystal forms were mostly equant solid particles with rudimentary crystal faces which were termed "droxtals" and some hexagonal prisms. Our further observations confirmed their results, except that we found the size of the droxtals to be 3 to 10 microns rather than 13 to 19 microns as reported by them. Since the hexagonal ice crystals occur in low concentrations and do not seriously lower visibility compared with droxtals we will consider droxtals only. Thuman and Robinson postulated that the droxtals arise from the freezing of supercooled droplets. In order to form droxtals from direct freezing of supercooled water droplets, it is necessary for the droplets to freeze before they evaporate. The present paper inquires into the mechanism of formation of ice fog and attempts to present evidence for the freezing of droplets.

Ohtake, Takeshi and Paul J. Huffman, Visual Range in Ice Fog, J. of Appl. Meteor., Vol. 8, No. 4, 499-501, 1969.

ABSTRACT

This article presents the results of an experimental investigation into the relationship between visual range and the size distribution of ice fog particles at Fairbanks, Alaska. An empirical function is developed for the constant appearing in the Trabert formula. Use of this function gives visual ranges that agree with measured values for size distributions of different width.

Ohtake, Takeshi, Studies on Ice Fog, Final Report AP-00449 prepared for National Center for Air Pollution control, Public Health Service, Departhment of Health, Education and Welfare, UAG R-211, Geophysical Institute, University of Alaska, 1970.

ABSTRACT

In order to clarify the mechanism of ice-fog formation, various atmospheric factors in ice fogs such as size and concentration of ice-fog crystals, condensation nuclei and ice nuclei, amount of water vapor, temperature profile near the sources of ice fog, etc. were measured.

Nuclei of the ice-fog crystals were studied by use of an electron microscope and electron-diffraction. The examination showed that most nuclei of ice-fog crystals were combustion by-products and many individual crystals collected near open water did not have a nucleus, especially at temperatures below -40°C. Dust particles or particles from air pollution are not essential for formation of ice fog; they merely stimulate freezing of water droplets at higher temperatures than the spontaneous freezing temperature. The essential factor is to first form many water droplets in the atmosphere through condensation of water vapor.

Ohtake, Takeshi, Unusual Crystal in Ice Fog, J. Atmos. Sci., Vol. 27, No. 3, 509-511, 1970.

ABSTRACT

Photographs and drawings of unusual crystals observed in Fairbanks during ice fog.

Ohtake, Takeshi and Rudolf G. Suchannek, Electric Properties of Ice Fog Crystals, J. of Appl. Meteor., Vol. 9, No. 2, 289-293, 1970.

ABSTRACT

Electric properties of ice fog crystals were studied using uniform and nonuniform electric fields. It was observed that natural and artificial ice fog crystals had no significant net charge. An upper bound for the net charges was derived. The observations are discussed in relation to the induced dipole moment and Weyl's model of ice crystals.

Ohtake, Takeshi, Ice Fog and Its Nucleation Process, Proc. Conf. on Cloud Physisc, Amer. Meteo. Soc. Ft. Collins, Aug. 24-27, 1970, pp. 21-22, 1970.

ABSTRACT

Important role of air pollution to ice nucleation was studied in conjunction with ice fog formation. Nucleation of ice-fog crystals is due to both heterogeneous and homogeneous nucleations.

Ohtake, Takeshi, Studies on Ice Fog, Final Report AP-00449 for the Environmental Protection Agency, June 1970.

ABSTRACT

Nuclei of the ice fog crystals were studied by use of an electron microscope and electron-diffraction. The examination showed that most nuclei of ice-fog crystals were combustion by-products and many individual crystals collected near open water did not have a nucleus, especially at temperatures below -40°C. Dust particles or particles from air pollution are not essential for formation of ice fog; they merely stimulate freezing of water droplets at higher temperatures than the spontaneous freezing temperature. The essential factor is to first form many water droplets in the atmosphere through condensation of water vapor.

Ohtake, T. and K.O.L.F. Jayaweera, Ice Crystal Displays from Power Plants, Weather, 271-277, 1972.

ABSTRACT

Photographs of ice fog and ice crystal displays in Fairbanks.

Ohtake, Takeshi, X-ray Analyses of Nuclei in Individual Fog Droplets and Ice Crystals, Geophysical Institute, University of Alaska, Fairbanks, Alaska, Atmospheric Aerosols and Nuclei, Proc. 9th Int'l Conf. on Atmos. Aerosols, Condensation and Nuclei, Galway, Sept. 1977, (pp. 213-217, 1981).

ABSTRACT

Chemical elements of nuclei in cloud droplets and ice crystals were examined by X-ray energy spectrometry. All ice fog crystals collected in Fairbanks ice fog contained Sulfer. Ice fog crystals formed at temperatures higher than -32°C had substantial amount of Si and Al besides S.

Ohtake, T., and F.D. Eaton, Removal Processes of Aerosols in Ice Fog, Geophysical Institute, University of Alaska, Fairbanks, Alaska 99701, 1982.

ABSTRACT

Fairbanks, Alaska, is frequently covered by ice fog when the air temperature is lowered to -30°C or less. Although the ice fog is composed of minute ice crystals which result from freezing of condensed water droplets, it is formed usually in association with high emissions of air pollutants under a strong temperature inversion and gives an impression as being harmful to human health. Nucleation and diffusion of aerosols are considered to be major processes for removal in ice fog. In order to estimate the major process of removal of the aerosols by ice fog crystals, it has been necessary to acquire size spectra of the aerosols, which have never been available. Even though complete studies of ice fog crystals have been reported by Ohtake (1970), since the population of Fairbanks has increased with additional housing, vehicles, etc., the ice fog may have different characteristics than those found in the studies carried out 13 years ago. In this paper, preliminary results of this study, started in the winter of 1981, are reported.

Porteous, Andrew and Graham B. Wallis, A Contribution Towards the Reduction of Ice Fog Caused by Humid Stack Gases at Alaskan Power Stations, ATMOS ENVIR, 1970, Vol. 4, p. 21-33.

ABSTRACT

The intermittent occurrence of ice fog formed by the freezing of clouds at super-cooled water at 20-40 C at U. S. Air Bases in Fairbanks, Alaska causes severe visibility problems. At these temperatures, water vapor nucleates and freezes on grit particles to form minute ice crystals that have no appreciable settling velocity. The principle source of water vapor emissions at the bases are power station stack gases. Dehumidification of the flue gases was experimentally studied in a counter-current scrubbing apparatus to obtain optimum droplet size for both moisture and grit removal in a spray tower. In counter-current scrubbing, sprays of cold water are directed into hot gas flows, with the water droplets in effect forming an efficient counter-current heat exchanger.

Heat and mass transfer proceed simultaneously; the processes are rate controlled. Based on the experimental results, optimum droplet size for accomplishing both grid and moisture removal was determined to be about 1000 micrometer diameter. This permits initial flue gas velocities of 2.1 reciprocal msec which are low enough to eliminate the risk of particle entrainment.

Politte, Francis E., Minimum Ice Fog Visibility at Low Temperatures at Eielson AFB, Alaska, 1965.

ABSTRACT

Statistical relationship between surface temperature and minimum visibility in ice fog as an aid in forecasting runway visibility. (5 pages, typed).

Richardson, Gary L., Ice Fog Pollution at Eielson Air Force Base, Masters Thesis, University of Alaska, College, 1964.

ABSTRACT

A problem old to the world is just beginning in Alaska. This problem is the one of air pollution. London and Los Angeles are famous for their killing smogs, and most all of the cities of the world with any degree of industry are becoming increasingly bothered by this problem. Although Alaska is considered by most to be the last wilderness frontier, many are beginning to see great promise in the natural resources of the area. The effect of this will be to bring industry and more people into the area. Little study is required to convince one of the tremendous problems this is going to bring unless considerable prior planning is done. During a majority of the year combustion particles from industrial and domestic sources are emitted into the atmosphere and trapped by a low-level temperature inversion, thus not allowed to rise and dissipate. Smoke, fog, or ice crystal pollution will result, depending upon the temperature. The reason for this problem being so critical in Alaska is the fact that this inversion is present nearly nine months of the year, while Los Angeles and other cities at lower latitudes would be troubled for only relatively short periods of the year. It is for these reasons that planners for the population and industrial growth in Alaska should read this paper and evaluate for their use, the suggestions presented herein.

Sakurai, K.; T. Ohtake, On the condensation and ice nuclei contained in supercooled droplet and ice fog particle, Journal de Recherches Atmospheriques, Clermont-Ferrand, France, 13(4), October/December 1979, 291 p.

ABSTRACT

Ice fog particles are formed by the freezing of supercooled droplets in the cold regions such as Alaska, Asahikawa, and northern Canada. The authors examined the elements composed of condensation and ice nuclei by an X- ray energy spectrometer, combined with a scanning electron microscope. The nuclei in the supercooled droplet were composed of Si, P, S, and Cl. The nuclei in the ice fog particle were composed of Na, Al, Si, P, S, Cl, K, Ca, and Ti. These elements were found in ice crystals that were collected at the South Pole by Ohtake (1976) and at Barrow, Alaska, by Ohtake, Jayaweera, and Sakurai (1978). In order to confirm the condensation freezing process of the ice fog phenomena, new droplets were produced in a diffusion chamber on the nuclei that were contained in the supercooled droplets collected on a slide glass by a vapor method. The new droplets in a diffusion chamber were generated in traces of the original supercooled droplets. Then, the droplets were cooled in a cold chamber to examine the freezing temperature. Consequently, the new droplets were generated on the nuclei of .APPROX. .7% of the original droplets when the relative humidity in a diffusion chamber was 100%. These droplets froze at a temperature of .APPROX. .-25"C or lower.

Walker, Kerry E.; Brunner, Walter, Suppression of Ice Fog from the Fort Wainwright , Alaska, Cooling Pond, Cold Regions Research and Engineering Lab., Hanover, New Hampshire, Report No.: CRREL-SR-82-22, October 1982, 39 p.

ABSTRACT

Ice fog near the Ft. Wainwright cooling pond creates a visibility hazard. Observations show a substantial reduction in visibility along both private and public roadways in the path of the cooling pond's ice fog plume. This reduction in visibility increases as the ambient air temperature decreases. Visibility was less than 215 m (700 ft) on the Richardson Highway on the average of 8 days for each of the 3 data years. Data collected during the winters of 1979-80, 1980-81 and 1981-82 statistically show that use of a monomolecular film evaporation suppressant, hexadecanol (C16H33OH), on the pond to reduce ice fog is ineffective. There is an immediate need for a driver warning system when visibility is affected by the ice fog.

Weller, Gunter E., (Ed.) Ice Fog Studies in Alaska: A Survey of Past, Present and Proposed Research, Geophysical Institute Report UAG R-207, University of Alaska, March 1969.

ABSTRACT

Growing public interest in the practical problems posed by ice fog and air pollution in and around Fairbanks has drawn attention to the need for a 'state of the art' report on the subject. A number of members of our scientific staff have conducted investigations into various aspects of the ice fog phenomenon since 1961 and the activity has been increasing, both in scope and number of personnel involved. Besides the Geophysical Institute's work, important contributions have also been made by several other institutions. Partly with the object of keeping all participants mutually informed about each other's past, present and proposed activities, but also to summarize in a convenient form the present state of knowledge on the subject for the benefit of Federal, State and local authorities, the Institute decided to produce this report, edited by Dr. Gunter Weller.

Wendler, Gerd, Heat Balance Studies During an Ice-Fog Period in Fairbanks, Alaska, Monthly Weather Review, Vol. 97, No. 7, pp. 512-520, 1969.

ABSTRACT

Ice fog, which is in a way similar to a dense cirrostratus cloud near the surface, occurs in Fairbanks when the temperature drops below −35°C. The heat balance of two stations, one below the ice fog in the valley and the other one on Birch Hill above the ice fog, are compared for the longest cold spell in winter 1966/67. The valley station shows a relatively small radiative loss of 47 cal cm^{-2} day^{-1}, as the ice fog shelters the surface against a highly negative long-wave radiation balance. The energy for compensation of this loss comes mostly (25 cal cm^{-2} day^{-1}) out of the soil. On Birch Hill the radiative loss (124 cal cm^{-2} day^{-1}) is nearly three times larger, mostly due to the smaller amount of the incoming long-wave radiation, and here the sensible heat flux (102 cal cm^{-2} day^{-1}) provides most of the energy.

Willis, Graham B., A contribution towards the reduction of ice fog caused by humid stack gases at Alaskan power stations, Department of Mechanical Engineering, Glasgow University, Scotland Thayer School of Engineering, Dartmouth College, New Hampshire, January 1970.

ABSTRACT

Special Forms of Cold Regions Air Pollution:

ARCTIC HAZE

The references in this section include the following topics:

Possible sources of arctic haze
Long-distance transport and pathways
Composition and concentrations
Arctic haze monitoring network
Effects on climate.

Barrie, L. A., R. M. Hoff and S. M. Daggupaty, The influence of mid-latitude pollution sources on haze in the Canadian Arctic, Atmospheric Environment, Vol. 15, No. 8, 1981.

ABSTRACT

Air pollution released at mid-latitudes is reaching the North American Arctic during winter and early spring causing a reduction of visibility (Arctic haze). A three station network of aerosol monitors in the Canadian Arctic yields information on the pollen, trace element (Al, Mn, V, Pb, Cu, Ni, Zn) and major ion ($SO_4^=$, NO_3^-, Cl^-, H^+, NH_4^+, Na^+) content of weekly samples of suspended particulate matter as well as a continuous record of aerosol light scattering. Results for April 1979 to May 1980 at two locations, Mould Bay and Igloolik are reported. Arctic haze is widespread and undergoes a distinct annual cycle reaching a maximum in March–April. The cycling is caused mainly by annual variations in atmospheric scavenging rates of pollutants along their path from mid-latitudinal sources to northern regions. Elemental ratios of the metals Mn, Pb, Zn and Cu and of soot to nonsoil vanadium in Arctic aerosols are indicators of aerosol source region. Observed variations in these ratios coupled with results of analyses of air parcel trajectories and surface weather charts point to Siberia and North America as the predominant source of Arctic aerosols during December 1979 and January 1980, respectively. European sources were prevalent in early spring 1980. Aerosol light scattering (b_{scat}) and sulphate concentrations are linearly correlated. The slope of the regression line ($11\,g^{-1}\,m^2$) is higher than expected for pure sulphate aerosols. From this it is inferred that sulphates comprised about 30% of the total aerosol mass. Winter Arctic aerosols are acidic. It is estimated that in the absence of calcareous wind blown dust they acidify snow to a pH of 5–5.2 between February and April.

Bodhaine, B. A., J. M. Harris and G. A. Herbert, Aerosol light scattering and Condensation nucleai measurements at Barrow, Alaska, Atmospheric Environment, Vol. 15, No. 8, 1981.

ABSTRACT

N.O.A.A.'s Geophysical Monitoring for Climatic Change Program operates a background monitoring station at Barrow, Alaska. Continuous measurements of aerosols, gases, solar radiation and meteorological parameters are made in an effort to understand their possible long term effects on climate. The aerosol program consists of continuous measurements of integrated light scattering and condensation nuclei (CN) using a four wavelength nephelometer and an automatic CN counter.

Light scattering data show an annual cycle with a maximum above $10^{-5}\,m^{-1}$ in March and a minimum of about $10^{-6}\,m^{-1}$ in June. Condensation nuclei data show a semi-annual change with monthly mean concentration ranging between 500 and $40\,cm^{-3}$, maxima in March and August, and minima in June and September. Local aerosol sources have been identified by calculating CN concentration as a function of local wind direction and presenting the results on a 36 point wind rose. Local sources are clearly identified to the north, west and southwest of the observatory site and may be associated with local activities and population centers. A clean air sector may be defined on the wind rose, and pollution episodes may be defined in terms of short term variability of the CN concentration.

Large scale 10-day back trajectories have been analysed for Barrow and it is found that light scattering and condensation nuclei concentration are higher when trajectories originate north of the station than when trajectories originate south of the station. Anomalous trajectories from north of the station in August coincide with an anomalous peak in condensation nuclei.

Borys, Randolf D., and Kenneth A. Rahn, Long-range atmospheric transport of cloud-active aerosol to iceland, Atmospheric Environment, Vol. 15, No. 8, 1981.

ABSTRACT

During a study of cloud-condensation nuclei (CCN), condensation nuclei (CN) and various chemical constituents of the aerosol at Irafoss, Iceland, an episode of long-range transport of CCN and pollution aerosol from Eurasia was observed. This air was enriched in CCN by factors of 2–5 and in pollution aerosol by factors of 5–10 compared to near-background air from the west Atlantic and Arctic. CCN spectra of the aged European air were enhanced primarily in the largest particles, those active at the lowest supersaturations. The CCN appeared to be explained largely by nonmarine $SO_4^=$ and some yet-unidentified constituent of the aerosol, possibly organic matter. From these results, one may predict that anthropogenic CCN can be transported throughout the Arctic in a fashion similar to that already observed for $SO_4^=$.

Carlson, Toby N., Speculation of the movement of polluted air to the Arctic, Atmospheric Environment, Vol. 15, No. 8, 1981.

ABSTRACT

-Using arguments based on the idea that the motion of air parcels is adiabatic except for an adjustment for diabatic (radiational) cooling, we are led to the hypothesis that the arctic aerosol comes from regions north of the polar front, primarily over the Eurasian Continent during wintertime.

Cavanagh, Leonard A., Conrad F. Schadt and Elmer Robinson, Atmospheric Hydrocarbon and Carbon Monoxide Measurements at Point Barrow, Alaska, Environmental Science and Technology, Vol. 3, No. 3, pp. 251-257, March 1969.

ABSTRACT

The concentrations of low molecular weight hydrocarbons and carbon monoxide in uncontaminated Arctic air masses have been analyzed at Point Barrow, Alaska. Using gas chromatographic techniques, a variety of organic compounds were regularly observed in these air masses, and the folloiwng average concentrations were obtained: methane, 16 p.p.m.; butane, 0.06 p.p.b.; acetone, 1.0 p.p.b.; and n-butanol, 190 p.p.b. Carbon monoxide concentrations averaged about 90 p.p.b. Special investigations confirmed the unexpected presence of n-butanol in these samples. Sources of these organics are postulated.

Daisey, J. M., R. J. McCaffrey and R. A. Gallagher, Polycyclic aromatic hydrocarbons and total extractable particulate organic matter in the Actic Aerosol, Atmospheric Environment, Vol. 15, No. 8, 1981.

ABSTRACT

-Samples of total suspended particulate matter were collected in March and August 1979 at Barrow, Alaska, a remote site in the Arctic. Ambient concentrations of extractable particulate organic matter (POM), of polycyclic aromatic hydrocarbons (PAH) and of ^{210}Pb were determined. The samples were also examined by optical and scanning electron microscopy. Average concentrations of POM and PAH were similar to those reported for other remote sites in the northern hemisphere, but the concentrations were considerably higher in March than in August. The presence of fly ash in the samples collected during the March sampling period, as well as seasonal differences in the concentrations of the organic species and ^{210}Pb and in meteorology indicate that the principal source of POM and PAH was fossil fuel combustion in the mid-latitudes during the March sampling period.

Darby, Dennis A., Lloyd H. Burckle and David L. Clark, Airborne Dust on the Arctic Pack Ice, Its Composition and Fallout Rate, Earth Planet Sci. Lett., 24(2): 166-172, December 1974.

ABSTRACT

Dust collected from snow samples on the Arctic pack ice approximately 500 km north of Alaska indicated lower fallout rates than previously reported for Arctic stations 1400 km to the east (3.3 and 14 micrograms/sq cm/yr, respectively). Either the lower frequency of southerly (off-shore) near surface winds at the sample sites off Alaska or the unknown influx of dust with upper level air masses could account for the difference in dust fallout. The airborne dust contribution to Arctic deep-sea sediments north of Alaska, however, amounted to 1% or less. A consideration of the clay mineralogy and biogenous components of Arctic dust favors a global or distant source for most of the dust, especially the fraction smaller than 2 micron. No obvious industrial components were detected in the dust. (Author abstract)

Davidson, C. I., Liyang Chu, Thomas C. Grimm, Margaret A. Nasta and Margaret P. Qamoos, Wet and Dry Deposition of Trace Elements onto the Greenland Ice Sheet, Atmospheric Environment, Vol. 15, No. , 1981.

ABSTRACT

Trace element concentrations have been measured in the air and in fresh and older surface snow during the summers of 1978 and 1979 at Dye 3, south-central Greenland. These data have been used with other information in the literature to calculate a total (wet plus dry) deposition velocity on the order of $0.5 cm s^{-1}$ for trace element transport to the ice sheet on an annual basis. The data suggest that dry deposition contributes less than 25% of the total transport for elements with large enrichment factors. Crustal elements may be more significantly influenced by dry deposition.

Environmental Science and Technology Report, Arctic Haze, Vol. 27, No. 232A, June 1983.

ABSTRACT

Emphasis on Arctic-wide sampling network and institutions and individuals involved.

Flyger, H., N. Z. Heidam, K. Hansen, W. J. Megaw, E. G. Walther and A. W. Hogan, The background level of the summer tropospheric aerosol, sulphur dioxide and ozone over Greenland and the North Atlantic Ocean, J. Aerosol. Sci., Vol. 7, pp. 103-140, 1976.

ABSTRACT

A description is given of airborne measurements over Greenland and the surrounding seas of the concentration and size of Aitken nuclei and large nuclei, the concentration of cloud nuclei at a supersaturation of 1%, the concentration of ice nuclei activated at −20°C, the chemical nature of the tropospheric aerosol, the concentration of sulphur dioxide and ozone. The Aitken nuclei concentrations were generally log-normally distributed in the range of less than a 100 to 10^4 cm^{-3} with strong peaks of nuclei concentrations appearing in widely distributed thin layers superimposed on the background concentrations below 500 cm^{-3}. The geometric mean value was 960 cm^{-3}. The particle size distributions of the Aitken nuclei fluctuated widely, showing spectra of mono-, bi- and trimodal shapes. The particle size spectra are grouped by similarities in shape and their frequencies of occurrence are reported. The size spectra strongly indicate that formation of fresh nuclei by gas phase reactions is a common phenomenon in summer tropospheric air over Greenland and adjacent seas. The large nuclei concentrations were generally log-normally distributed in the region 0.3–300 cm^{-3} correlating in most cases with the Aitken nuclei concentrations. The geometric mean was 9 cm^{-3}. The size distribution of the large nuclei covers the range 0.3–3 μm dia. and follows a power law above 0.4 μm. Cloud nuclei concentrations are reported for the North Sea and the North Atlantic only, the concentrations were normally low, nearly 50% of the measured concentrations were below 12 cm^{-3}. Peak concentrations of up to 500 cm^{-3} were measured during a cold front passage. Ice nuclei concentrations were in the range of 0.01–0.1 l^{-1}. Samples taken for analysis of particulate sulphur compounds gave concentrations in the range $30–110 \cdot 10^{-9}$ g S m^{-3} over the nearby seas and $35–220 \cdot 10^{-9}$ g S m^{-3} over the ice cap. Measurements of sulphur dioxide gave concentrations in the range $50–725 \cdot 10^{-9}$ g SO_2 m^{-3} over the nearby sea areas and $60–1950 \cdot 10^{-9}$ g SO_2 m^{-3} in samples taken over the ice cap. A correlation coefficient between particulate sulphur and sulphur dioxide of 0.92 was found for samples taken over the sea areas, whereas a negative correlation between samples from the ice cap areas is dubious. Neutron activation analyses were performed for elements with a potential contribution from ground surface, volcanoes and anthropogenic activities. The volumes of the samples (50–100 m^3) were, however, too low to give reliable results.

The mean concentration of ozone measured over the ice cap was 34 ppb, higher with a 90% level of confidence than the mean concentration of 30 ppb, measured over the nearby seas. No correlation between ozone and altitude was found at a 95% level of significance.

Measurements of Aitken nuclei concentrations taken on the surface of the ice cap and showing only small variations around 150 cm^{-3}, were strikingly different from the airborne measurements.

Air mass trajectories, computed for selected events, show that the air sampled had within its recent history passed over Northern Canada, Greenland or the arctic seas.

Halter, Bradley C., and James T. Peterson, On the variability of atmospheric carbon dioxide concentration at Barrow, Alaska during summer, Atmospheric Environment, Vol. 15, No. 8, 1981.

ABSTRACT

Atmospheric carbon dioxide data obtained at Barrow, Alaska for the May–September period of [illegible] were studied to understand the causes of the day-to-day and within-day variations. Sixteen instances of [illegible]-h change in average CO_2 concentration of from 15 to 50% of the annual range (approx. 14 ppm) were ascertained. Within-day variations of up to 50% of the annual range were noted. The variations were found to be related to local and synoptic scale meteorology interacting with local and regional sources and sinks of CO_2. The results are consistent with an overall source of CO_2 in the tundra of the Alaskan North Slope and a significant sink for CO_2 in the ice-free areas of the seas bordering Alaska. The analysis provides an interpretation of the Barrow CO_2 record which can be used in the selection of representative data for studying large scale trends.

Heidam, Niels Z., On the Origin of the Arctic Aerosol: A Statistical Approach, Atmospheric Environment, Vol. 15, No. 8, pp. 1421-1427, 1981.

Abstract—Aerosol samples have been collected through two winter periods in Greenland. The particulates have been analysed for elemental composition, and the data subjected to factor analysis. It is found that 70–85% of the total variance can be explained in terms of three factors, which split the aerosol composition into three corresponding types: crustal, marine and anthropogenic. The temporal variation of the factors is calculated and related to the large-scale air movements of the period. It is shown that anthropogenic pollution in North Greenland in the winter may be caused by long-range aerosol transport over the North Pole.

Heintzenberg, Jost, Particle size distribution and optical properties of Arctic haze, Dept. of Met., Arrhenius Lab., University of Stockholm, Sweden, No. 32(3), June 1980, p. 251-260.

ABSTRACT

Simultaneous aerosol measurements with particle counters and a multiwavelength integrating nephelometer were made at Ny-Alesund, Svalbard (12"E, 79"N). The measured integral aerosol properties were used in an inversion procedure to derive a consistent model of the particle size distribution of Arctic haze. The obtained size distribution is compared with the global background aerosol size distribution. The light-scattering coefficients and the total suspended volume of particles were both found to be on the level of the global background.

Hileman, B., 1983. Arctic haze. Environmental Science and Technology, Vol. 17, No. 6, 232-236.

ABSTRACT

The results of airborne measurements of Arctic haze, collected from a NOAA WP-3-D Orion research aircraft on extended flights over the Arctic are reported. Continuous measurements were made of the sooty carbon component of the haze, radiation fluxes above, within and below haze and cloud layers, and other physical and chemical characteristics of the haze. The flights showed that the haze exists at all latitudes in the northern polar regions and extends continuously up to 10,000 ft., with discontinuous horizontal layers at greater heights.

Heintzenberg Jost and Steinar Larssen, SO_2 and SO_4 in the Arctic: Interpretation of observations at three Norwegian Arctic-subarctic stations, Tellus, 1983.

ABSTRACT

Three years of SO_2 and $SO_4^=$ measurements (1978–81) at three Norwegian Arctic-Subarctic stations (70, 74, and 79° N) have been related to air mass trajectories. The average decrease in non-marine $SO_4^=$-concentrations with increasing latitude was found to agree well with the latitude distribution of direct- or short-path return-flow frequency of trajectories from the Eurasian source area. As expected from its reactive, short-lived character average SO_2-concentrations decreased much more rapidly than the frequency of source trajectories when moving into the Arctic.

The seasonal variations in sulphur concentrations and source trajectories were less well correlated, best at the southernmost station. From the study of all individual pollution episodes (defined by ≥2 times average sulphur concentrations) we deduced that an increasing fraction of high sulphur levels could be ——xplained by long-path return flow, when moving deeper into the Arctic. On Spitsbergen 50% of all pollution episodes occurred during return-flow that had entered the Arctic between Novaja Zemlya and the Taymyr Peninsula.

Herron Michael, M., Chester C. Langway,. Jr., Herbert V. Weiss and James H. Cragin, Atmospheric trace metals and sulfate in the Greenland Ice Sheet, Geochimica et Cosmochimica Acta, Vol. 41, 1977.

ABSTRACT

Chemical analyses of surface snow and dated deep ice core samples from central Greenland suggest that Zn, Pb and sulfate are presently being deposited there at two to three times the natural rates. No recent increases in Cd or V concentrations were observed. Pre-1900 ice shows no measurable effect of the activities of man and represents a good natural aerosol baseline. High enrichment factors relative to average crustal material were observed for Zn, Pb, Cd and sulfate in all samples indicating a natural source other than continental dust is responsible. A high temperature process or vapor phase origin for these enriched elements, possibly volcanism, seems likely.

Heintzenberg, Jost, Chemical composition of Arctic haze at Ny-Alesund, Spitzenbergen, Sweden, No. 33(2), April 1981, 162-171.

ABSTRACT

Samples of Arctic haze particles were collected at Ny-Alesund, Spitsbergen (12°E, 79°N), during late winter 1979. The filter samples were analyzed wet chemically and by particle-induced X-ray emission (PIXE). The concentrations of 17 major ions and metals were determined and compared to previous results of Arctic and Antarctic research. Simultaneous measurements of the aerosol size distribution were used to check the consistency of the results. Both the chemical composition and the size distribution data support the hypothesis that the Arctic winter aerosol is heavily influenced by a well-aged continental aerosol originating in midlatitude anthropogenic source areas.

Heintzenberg, Jost, Size-Segregated Measurements of Particulate Elemental Carbon and Aerosol Light Absorption at Remote Arctic Locations, Atmospheric Environment, Vol. 16, No. 10, pp. 2461-2469, 1982.

ABSTRACT

Size-segregated aerosol samples were taken during 2 winter pollution periods and in clean summer air at different remote locations in the European Arctic > 74°N. By means of a newly developed integrating sphere photometer these filter samples have been analysed for aerosol light absorption coefficients and particulate elemental carbon (PEC). The relatively high PEC concentrations in winter confirm other findings about the Arctic winter atmosphere having an aged continental aerosol burden. In summer very low light absorption coefficients of $4.5 \times 10^{-6}\,m^{-1}$ were measured, similar to upper tropospheric background values. For the climatically important months of March–May the key optical aerosol properties (extinction coefficient, single scattering albedo and absorption to backscatter ratio) were determined. Based on the approach of J. M. Mitchell (1971, in *Man's Impact on Climate*. MIT Press, Cambridge, MA) the Arctic haze aerosol is found to contribute to atmospheric heating, even in the summer. A first PEC size distribution was determined in a clean polar summer air. The results show systematic variations in the PEC size distribution from urban to remote locations and seasonal variations in the sink region which may be exploited to quantify aerosol removal process in long distance transport studies.

Hoff, R. M., W. R. Leaitch, P. Fellin and L. A. Barrie, Mass Size Distributions of Chemical Constitutents of the Winter Arctic Aerosol, to be published J. Atmospheric Environment, 1983.

ABSTRACT

Two field experiments, one from November 24 - December 14, 1981 and the second from February 19-27, 1982, were conducted at Igloolik, Northwest Territories, Canada, to study the composition and mass size spectrum of arctic haze aerosol. In addition, measurements were made of sulphur dioxide and sulphate. Mass size distributions were obtained for Cl^-, NO_3^-, $SO_4^=$, Mg^{++}, Na^+, NH_4^+ and for elements Cl, Na, V, Mn, I, Br. The marine aerosol component at larger particle sizes is separated from the anthropogenic aerosol component at smaller particle sizes. Anthropogenic components (NH_4^+, $SO_4^=$, V, Mn) are found predominantly on sub-micrometre aerosols. Marine components (Cl^-, Na^+, Mg^{++}) are predominantly supermicrometre in size. Results for NO_3^- and Br indicate that a gas phase component or precursor may exist in the arctic. Different transport during periods of the February experiment indicates higher concentrations for the haze aerosols and SO_2 when the trajectories are from Asia. SO_2 was found in concentrations of 0.3 - 4.3 $\mu g/m^3$ and exceeded sulphate in mass. Possible explanations for the $SO_2/SO_4^=$ concentration ratio are given.

Isono, Kenji, Makoto Komabayasi, Takao Takeda, Toyoaki Tanaka, Kunimoto Iwai, Miyuki Fujiwara, Concentration and nature of ice nuclei in rim of the North Pacific Ocean, Tellus, XXIII, 1971.

ABSTRACT

Simultaneous collections of ice nuclei in the air were made with instruments of the same type at four sites in the rim of the North Pacific: College, Alaska; Blue Glacier, Washington; Mauna Loa, Hawaii; and Nagoya, Japan. Ice nuclei were collected on filter paper for counting of their number and also sheet meshes for examination with electron microscope.

During the period of the collection from the beginning of February through the beginning of March, 1968, three marked maxima of the concentrations of ice nuclei effective at $-15°C$ appeared at each of the sites except Mauna Loa. The peak values were the largest at Nagoya (5.3 nuclei/litre) followed by College (2.7 nuclei/litre) and Blue Glacier (1.3 nuclei/litre). At the Mauna Loa Observatory, no marked peak was observed. Neither a diurnal variation nor any other variations with a specific period have been detected. The result of identification of materials of ice nuclei collected at the four sites shows that clay and other mineral particles constitute the main part of the ice nuclei.

The results of the studies on the features of ice nucleus concentration, the trajectories of air masses and the examination of ice nuclei suggest that the ice nuclei detected originated from arid and semi-arid regions of the Asian Continent.

Jaenicke, Ruprecht, "Schmutzige" Luft uber den Polen [Polluted air over the poles.], Inst. fur Met., Johannes Gutenberg University, Postfach, Mainz, W. Germany, September 1, 1981.

ABSTRACT

During 3 mo on an icebreaker in the Arctic, the concentration of condensation nuclei in atmospheric air was measured. The results indicate regional air pollution from producers in the Arctic region. Air chemistry measurements of undisturbed natural conditions can be conducted only if influences from such local sources can be avoided. This has implication upon air chemistry measurements in the Antarctic, an area of recent German activities.

Jaenicke, R., and L. Schutz, Arctic aerosols in surface air, J. of the Hungarian Meteorological Service, Vol. 86, No. 2, 1982.

ABSTRACT

Arctic aerosols in surface air. During 3 months in summer 1980 measurements of the arctic surface aerosol were performed. The measurements of the condensation nuclei concentration permit the conclusion that true arctic air has concentrations below 100 cm^{-3}. Large portions of the European Arctic are polluted from sources within the Arctic itself. The aerosol size distribution shows lower values than expected for background aerosols. Under certain conditions, gas-to-particle conversion is not present and particles in the range 1 μm to 10 μm in radius have been removed from the aerosol.

Kerr, Richard, Global pollution: Is the Arctic haze actually industrial smog?, Science, Washington D.C., Report No. 205(4403), July 20, 1979, p. 290-293.

ABSTRACT

The possibility that the Arctic haze may contain particles derived from major pollutant courses in middle latitudes, and that these particles may have travelled distances exceeding 10,000 km, is discussed on the basis of studies of the Arctic Air-Sampling Network. Summer Arctic hazes are uncontaminated, whereas during winter the Arctic haze consists largely of droplets containing sulfate and organic matter with relatively small amounts of heavy metals, such as vanadium and manganese, found in urban-polluted air. Evidence for this is provided by an analysis of the proportions of the atmospheric content of sulfate at Point Barrow, Alaska, as compared with polluted urban air over middle latitudes. There is also evidence for the long-range transport of Saharan dust over the Atlantic to Barbados, of Gobi Desert dust from Mongolia over the Pacific, etc. Because of the small precipitation at Point Barrow in winter (10 cm/yr), the removal of pollutants by rain or snow would be slight. Data were obtained, suggesting Europe as a possible source of pollutants for the winter haze.

Kerr, Richard A., Pollution of the Arctic atmosphere confirmed, Science, Washington, D. C., No. 212(4498, May 29, 1981, 1013-1014.

ABSTRACT

New evidence has helped form a consensus that, during winter and spring, pollutants travel 5000 km and farther from industrial areas in Europe, Asia, and perhaps North America into the Arctic, producing a pervasive haze there. Part of the new evidence supporting Arctic air pollution comes from the air-sampling networks at Canada's Atmospheric Environment Service, Downsview, Ontario. Aerosols turned filters flannel gray and sooty black only during winter and spring, as happens at Barrow. Excess sulfate and vanadium are attributed to industrial sources in midlatitudes. Researchers now agree that Arctic air can become dirty during winter and spring because of an unusual combination of meteorological and geographical circumstances. Although it borders on fully one half of the Arctic and apparently makes a sizable contribution to the problem, the Soviet Union continues to limit cooperative studies to the natural aerosols of its southern deserts.

Lannefors, Hans, Jost Heintzenberg and Hans-Christen Hansson, A Comprehensive study of physical and chemical parameters of the Arctic summer aerosol; results from the Swedish expedition Ymer-80, Tellus, 35B, 40-54, 1983.

ABSTRACT

The Swedish icebreaker expedition *Ymer-80* exploring the Norwegian part of the Arctic during the summer of 1980 offered unique opportunities for a coordinated atmospheric research program. Chemical and physical properties of the Arctic aerosol were studied using different kinds of samplers and continuous monitors connected to a common air inlet. Local contamination such as emissions from the ship and its helicopters were avoided using a condensation nucleus counter to control the sampling. Emissions from Arctic settlements were found to contribute only condensation nuclei and to have no significant influence on the aerosol mass and chemical composition. Arctic summer grand average levels, especially those of possible anthropogenic components i.e. soot, non-marine S, Ni, Cu, Zn and Pb, were lower by one order of magnitude or more than late winter levels as found on Spitsbergen, but on the same level as summer values in Northern Greenland. Most of the components varied over 1 to 2 orders of magnitude during the expedition. Sampling periods mainly influenced by sea spray were characterized by high TSP and chlorine levels. A few cases, possibly influenced by long-range transport from the European continent, were characterized by high σ_{sp}, soot, sulphur and heavy metal concentrations. The Arctic background aerosol composition was found to be determined by the relative strength of active source and sink mechanisms in combination with the sampling time resolution.

Leighton, Henry, Influence of Arctic Haze on the Solar Radiation Budget, Atmospheric Environment, 1983.

ABSTRACT

Comparison of reported measurements of the change in the direct and total hemispheric solar irradiances at Barrow, Alaska between days with and without visible haze with values computed from aerosol models with different imaginary parts of the refractive index leads to the conclusion that the haze is only weakly absorbing. Using the value of the single scattering albedo deduced from the comparison the reduction in the effective local planetary albedo of the Arctic due to Arctic haze is estimated to be about 0.03.

Miller, John M., A five-year climatology of five-day back trajectories from Barrow, Alaska, Atmospheric Environment, Vol. 15, No. 8, 1981.

ABSTRACT

The Air Resources Laboratories' trajectory model was used to calculate five-day back trajectories from Barrow, Alaska for the period from February 1975 to January 1980. Using a 300–2000 m averaging layer, trajectories were produced four times a day over the five-year period. A simple typing scheme was designed to indicate both direction and distance of air transport. Analysis of the five-year period showed that most transport from distances beyond 2000 km takes place from November to March, with an anomalous peak in August. The direction of this transport is predominantly from the south, with a peak of over-the-pole flow during the month of March. Trajectory direction and speed vary significantly from year to year and season to season.

Mitchell, Jr., Murray, J., Visual Range in the Polar Regions with Particular Reference to the Alaskan Arctic, JATP, A Supplement, 1957.

ABSTRACT

The polar atmosphere often possesses a remarkably high optical transparency which can be attributed to very low dust and water-vapor contents. Below the tropopause, and especially in those regions which experience polar and Arctic frontal activity, however, extensive stratiform cloudiness usually develops. With a few notable exceptions, as when solid cloud masses have recently been sounded to heights of 39,000 ft (12,000 m) over the Arctic Ocean, cloud systems can usually be surmounted rather easily by propeller aircraft. Especially in the warmer months and near coastlines, mountains in the Arctic are submerged in heavy cloudiness.

Ottar, Brynjulf, The transfer of airborne pollutants to the Arctic region, Atmospheric Environment, Vol. 15, No. 8, 1981.

ABSTRACT

Chemical analysis of the Arctic aerosol has shown that considerable amounts of air pollutants are brought into the Arctic region in winter, particularly from sources in Europe and the eastern U.S.S.R. It is pointed out that mercury and chlorinated hydrocarbons, which after initial deposition can be re-emitted to the atmosphere by sublimation, must be subject to a systematic long term transfer from warmer to colder regions. For mercury natural emission may have resulted in an equilibrium between amounts deposited on the earth surface and ambient air concentrations. The heavier chlorinated hydrocarbons have probably not yet reached this stage. Continued large scale use of DDT and other chlorinated hydrocarbons may therefore lead to a long term increase of environmental concentrations, also in countries where restrictions on the use of these substances have led to a reduction of their concentrations in food and other biological materials. The Arctic is also the place where the first signs of a climatic change due to the increasing content of carbon dioxide and other pollutants in the atmosphere, may be detected. In order not to misinterpret any such symptoms, a detailed knowledge of the composition of the Arctic aerosol and its possible influence on the radiation balance is essential, and in view of the future oil exploitation activities in this region, the necessary investigations should not be delayed for too long.

Patterson, D. E., and R. B. Husar, A direct simulation of hemispherical transport of pollutants, Atmospheric Environment, Vol. 15, No. 8, 1981.

ABSTRACT

The seasonal fate of pollutant emissions from eastern North America, Europe and East Asia during 1974 is examined via 850 mbar forward trajectories of 20 days duration. Simple pure-decay kinetic scenarios are presented for atmospheric residence times of 5 and 10 days to illustrate the spatial extent of the continental plumes. The 20-day cutoff scenario is segregated by source region, indicating mean flow. The simulated potential impact at Barrow, Alaska indicates an annual pattern which resembles measured sulfate and haze patterns, with an anomalous August peak. Apparently European, and especially North American, plumes are unlikely to reach Barrow during May–September, but both appear to contribute to winter haze in the Arctic.

Patterson, E. M. and B. T. Marshall, Radiative Properties of the Arctic Aerosol, Atmospheric Environment, Vol. 16, No. 12, pp. 2967-2977, 1982.

ABSTRACT

Absorption coefficients of the Arctic aerosol have been measured by means of diffuse transmission techniques using filter samples collected at Barrow, Alaska. These measurements show a highly absorbing aerosol with an average winter absorption coefficient, σ_a, of $\approx 1.9 \times 10^{-6}\ m^{-1}$.

We have used these absorption measurements, concurrent aerosol composition measurements, and estimates of sizes and refractive indices for the individual aerosol components to model the radiative properties of the Arctic aerosol. Our results show good agreement between observed and modeled quantities and indicate that the Arctic aerosol has optical properties that are quite similar to those of an aged pollution-derived mid-latitude tropospheric aerosol.

Our results also indicate that particle growth with increasing relative humidity above the surface may cause the overall climatic impact of the Arctic aerosol to be different from that expected solely on the basis of measurements at the surface.

Peterson, James T., Dependence of CO. SUB 2., aerosol, and ozone concentrations on wind direction at Barrow, Alaska, during winter, Air Resources Lab., NOAA, Boulder, Colorado, Letter 7(5), May 1980, p. 349-352.

ABSTRACT

Measurements of CO.SUB 2., aerosol scattering, condensation nuclei, and ozone made continuously at the NOAA baseline observatory at Barrow, Alaska, were analyzed in conjunction with low-level trajectories of airflow arriving at Barrow during periods from Jan. to March 1977 and 1978. Ozone concentrations had no dependence upon wind direction, whereas CO.SUB 2. and aerosol values showed directional dependence; higher values occurred with airflow from the Arctic Basin than with that from the south. Aerosol analyses support the hypothesis that Arctic haze results from advection of aerosols to the Arctic from European or North American anthropogenic sources. CO.SUB 2. results suggest two possible sources for the higher concentrations: transfer from the ocean through annual sea ice to the Arctic atmosphere or advection from mid-latitude anthropogenic sources similar to that for the Arctic haze.

Raatz, Wolfgang E., Trends in cloudiness in the Arctic since 1920, Atmospheric Environment, Vol. 15, No. 8, 1981.

ABSTRACT

Long term (~ 50 year period) trends in cloudiness in terms of number of cloudy days per month at seven Arctic stations were investigated. Trends seem to be more pronounced in the Alaskan Arctic and Greenland, and less pronounced in the Norwegian Sea. There was no evidence found for monotonic increasing cloudiness which could have been related to a growing industrial activity.

Raatz, Wolfgang, E., On the Meteorological Characteristics of Polluted Air Masses at Barrow, Alaska, Submitted to Pure and Applied Geophysics, 1983.

ABSTRACT

Anthropogenic derived pollution episodes at Barrow, Alaska occur when air masses under anticyclonic influence emanate from the Arctic Basin. The high frequency of above-normal wind speeds and the only slightly above-normal pressures characteristic of these Arctic air masses suggest that pollutants are transported to Barrow along the periphery of the Arctic anticyclone within a zone of rapid transport.

Raatz, Wolfgang, E., Observations of "Arctic Haze" during the "Ptarmigan" Weather Reconnaissance Flights, 1948-1961, Submitted to Tellus, May 1983.

ABSTRACT

114 "Ptarmigan" weather reconnaissance flights over the Alaskan Arctic during 1948-1961 were analyzed for reports of "Arctic Haze" (~ 400 reports). Arctic Haze can reduce horizontal visibility significantly and is most frequently reported during late winter and spring but is also found during early winter and summer. Haze is reported everywhere within the Alaskan Arctic at altitudes between the surface and 6 km. Anticyclonic surface pressure conditions are characteristic of Arctic Haze; "clear skies" weather conditions were predominantly present with haze observations during the winter months, "cloudy skies" were predominantly present with haze observations during the summer months. We hypothesize that Arctic Haze has a dual character of origin: it is pollution-derived during winter and early spring, and desert dust-derived during late spring and summer.

Raatz, Wolfgang, E., Glenn E. Shaw, Long-Range Tropospheric Transport of Pollution Aerosols into the Alaskan Arctic, (in press: Climate and Applied Met., 1984).

ABSTRACT

A time series of chemical tracers in pollution-derived aerosols collected over a period of four years in the near-surface air at Barrow, Alaska was used to investigate tropospheric long-range transport of anthropogenic pollution form mid-latitudes into the Alaskan Arctic. This transport takes place when the mid-latitudinal and Arctic atmospheric circulations manifest quasi-persistent circulation patterns. Rapid transport of aerosols, on the order of 7-10 days, is dominated by quasi-stationary anticyclones and takes place along their peripheries where pressure gradients are relatively strong. The seasonal variation in concentration of the Arctic pollution-derived aerosol is explained by the seasonal variation in the occurrence and position of mid-latitude blocking anticyclones, of the Arctic anticyclone, and of the Asiatic anticyclone. The positions of the major anticyclonic centers are responsible for the fact that Soviet industrial sources contribute to the Arctic pollution-derived aerosol predominantly during winter, European sources during spring, and that North American and Far Eastern industrial sources contribute little to the Arctic pollution aerosols.

Rahn, Kenneth A., Randolf D. Borys and Glenn E. Shaw, The Asian Source of Arctic Haze Bands, Nature, Vol. 268, No. 5622, pp. 713-715, August 25, 1977.

ABSTRACT

'ARCTIC haze' refers to turbid layers of air which are found regularly over the pack ice north of Alaska during periods of clear weather[1]. These layers are diffuse, hundreds to thousands of kilometres wide, 1–3 km thick, and can occur as single or multiple bands of different heights at nearly any level in the troposphere. They are invisible from the ground, but may limit horizontal and slant visibility within a layer to as little as 3–8 km. Their colour is grey–blue in the antisolar direction and reddish–brown in the solar direction, suggesting that they are true aerosol rather than ice crystals.

Rahn, Kenneth A., Arctic Air-Sampling Network, Arctic Bulletin, Vol. 2, No. 14, 1978.

ABSTRACT

The Arctic Air-Sampling Network is now making its first attempts to describe the quality of the atmosphere in the Arctic. The data compiled by this series of sampling stations in several nations present a coordinated impression of arctic atmospheric chemistry. The international network hopes to develop a thorough picture of arctic atmospheric chemistry, which until recently has been only poorly characterized.

Rahn, Kenneth A., The Eurasian Sources of Arctic Aerosol, Norwegian Institute for Air Research, September 1979.

ABSTRACT

There is now considerable evidence that during winter the Arctic atmosphere contains surprisingly large amounts of submicron aerosol. High concentrations of sulfate, ^{210}Pb, and trace elements such as V and Mn suggest strongly that much of this aerosol is the product of aging of polluted air masses from midlatitudes, although some of it may be natural. The concentrations and compositions are similar for the aerosols of northern Norway, Bear Island, Spitsbergen, and Barrow (Alaska), suggesting a basic unity of the Arctic aerosol.

Rahn, Kenneth A., Elinar Joranger, Arne Semb and Thomas J. Conway, High winter concentrations of SO_2 in the Norwegian Arctic and transport from Eurasia, Nature, Vol. 287, No. 5785, October 1980.

ABSTRACT

Since July 1977, the Norwegian Institute for Air Research has been studying trace gases and aerosols in the atmosphere at Bear Island, an Arctic site located at 74° N and 19° E. Although Bear Island lies well north of the Arctic Circle, the warm Norwegian Sea gives it an annual mean temperature of −1.8 °C, considerably warmer than at many other Arctic locations (Barrow, Alaska, for example, is 350 km farther south but has an annual mean of −12.2 °C). In summer, Bear Island is surrounded by open water; in winter there is open sea to the south and west and pack ice to the north and east. Atmospheric samples are taken 20 m above mean sea level and 2 m above local ground: high-volume filters are taken three times a week and analysed for various elements by atomic absorption, neutron activation and wet chemistry; sulphate and sulphur dioxide are measured daily by a method similar to that of Johnson and Atkins[1], using low-volume (16 m^3) prefilters for sulphate and KOH-impregnated afterfilters for SO_2. The collection efficiency of this method for SO_2 has been tested extensively[2]. Results for the high-volume samples have been reported[3]; here we discuss the SO_2 data, which seem to indicate that during winter there is efficient transport from Eurasian midlatitudes, due at least in part to long atmospheric residence times in and around the Arctic.

Rahn, Kenneth A., Atmospheric riverine and oceanic sources of seven trace constituents to the Arctic Ocean, Atmospheric Environment, Vol. 15, No. 8, 1981.

ABSTRACT

The Arctic atmosphere contains surprisingly high concentrations of aerosol during the winter half-year, to the point that deposition to the Arctic Ocean becomes of interest. For lack of better information, we assume that wet deposition dominates dry deposition in the Arctic to the same degree as in midlatitudes. If so, most of the Arctic deposition should take place in winter, when anthropogenic contributions to the Arctic aerosol are the greatest. Thus, anthropogenic influences should be seen in Arctic deposition, but to a lesser extent than in the Arctic aerosol. Estimates of atmospheric deposition and riverine transport of seven trace species (Al, V, Mn, Cd, Pb, SO_4^{2-}, NO_3^-) to the Arctic Ocean suggest that riverine sources deposit more material than atmospheric sources, that riverine fluxes are often comparable to oceanic fluxes, and that atmospheric fluxes are usually much less than riverine or oceanic fluxes. Under certain circumstances, riverine Al, Mn, Cd and NO_3^- may significantly affect the oceanic concentrations. Atmospheric and riverine sources of SO_4^{2-} and V are both unimportant. Pb was the only element considered here whose atmospheric flux equals or exceeds the riverine and oceanic fluxes into and out of the Arctic basin; the atmosphere should thus have a major effect on Pb concentration in the Arctic Ocean.

Rahn, Kenneth A., The Arctic Air-Sampling Network in 1980, Atmospheric Environment, Vol. 15, No. 8, 1981.

ABSTRACT

Stations and participants in the Arctic air sampling network.

Rahn, Kenneth A., The Mn/V ratio as a tracer of large-scale sources of pollution aerosol for the arctic, Atmospheric Environment, Vol. 15, No. 8, 1981.

ABSTRACT

The ratio of noncrustal Mn/noncrustal V is five times greater for Eurasian aerosol than for eastern North American aerosol. When a decrease of this ratio during transport and aging is allowed for, the aerosol of the Norwegian Arctic in winter is seen to be compatible with a Eurasian source and incompatible with an eastern North American source. Winter aerosol of the North American Arctic seems to be affected by an additional source within Eurasia, with a still-higher Mn/V ratio. Chemical and meteorological evidence suggests that this latter source area is in the central U.S.S.R.

Rahn, Kenneth A., Relative importances of North America and Eurasia as sources of Arctic aerosol, Atmospheric Environment, Vol. 15, No. 8, 1981.

ABSTRACT

..... During winter, the Arctic atmosphere is filled with high concentrations of aerosol which is largely pollution-derived. This article reviews a series of meteorological, meteorological-chemical, observational, and compositional arguments in an attempt to determine which, if any, of the two most likely sources of Arctic aerosol, eastern North America and Eurasia, dominates. The majority, but not all, of the presently available evidence indicates that Eurasia is the more important source.

Rahn, Kenneth A., and Niels Z. Heidam, Progress in Arctic Air Chemistry, 1977-1980: A Comparison of the First and Second Symposia, Atmospheric Environment, Vol. 15, No. 8, 1981.

ABSTRACT

Introductory overview article on Arctic Haze in the volume of Atmospheric Environment dedicated to Arctic air chemistry.

Rahn, Kenneth A. and Glenn E. Shaw, Sources and Transport of Arctic Pollution Aerosol: A Chronicle of Six Years of ONR Research, Naval Research Reviews, Vol. XXXIV, No. Three, 1982.

ABSTRACT

The polar regions are universally considered to be desolate, remote regions whose air and water are still clean and pure. From the earliest explorers to modern travellers, all visitors to the polar regions attest to this view. After all, are not the poles literally the ends of the earth, far removed from the last traces of civilization's products?

Rahn, K. A., and Douglas H. Lowenthal, Elemental Tracers of Distant Regional Pollution Aerosols, Science, Vol. 223, 132-139, 1984.

ABSTRACT

A seven-element tracer system shows that regional pollution aerosols of both North America and Europe have characteristic signatures that can be followed into remote areas up to several thousand kilometers downwind. In aerosols of mixed origin, regional contributions to the tracer elements can be resolved by least-squares procedures. After transport of several hundred kilometers, secondary sulfate can also be apportioned satisfactorily. Regional elemental tracers thus offer a way to determine the sources of pollution aerosol in important areas such as the northeastern United States, Scandanavia, and the Arctic.

Reiter, Elmar R., Planetary-wave behavior and Arctic air pollution, Atmospheric Environment, Vol. 15, No. 8, 1981.

ABSTRACT

An attempt has been made to relate episodes of air pollution at Barrow, Alaska, containing vanadium, to the behavior of planetary waves in middle and high latitudes. A stationarity index for planetary waves is defined as the ratio between amplitudes computed from monthly mean maps and the mean amplitudes computed on a daily basis and averaged over the same month, irrespective of phase angle. Longitude-time sections of 500 mb height anomalies at various latitudes are related to vanadium pollution episodes at Barrow.

Rosen, H., T. Novakov and B. A. Bodhaine, Soot in the Arctic, Atmospheric Environment, Vol. 15, No. 8, 1981.

ABSTRACT

Substantial concentrations of graphitic carbon and its associated large optical absorption coefficient are observed in the Arctic. The graphitic content shows a dramatic increase from late fall to early spring, reaching levels that are comparable to those found in urban environments (i.e., the peak values in February are only about a factor of 10 less than the average levels found in New York City and a factor of three less than those found in Berkeley, California, and Denver, Colorado). If one ignores the possible contribution of natural burning processes which are expected to be small during this time of the year in the northern hemisphere, this graphitic component can be attributed directly to anthropogenic activity.

Shaw, Glenn E., Comparison of Arctic and Antarctic haze, Geophysical Institute, University of Alaska, Fairbanks, Alaska, September 1976.

ABSTRACT

Measurements made in 1976 in the American Arctic show substantial levels of haze: up to 20 times the amount found at the South Pole. From an aircraft, the haze usually appears to be concentrated in thin layers that sometimes can be seen as dark-colored bands against the sky near the horizon. Trajectory analysis suggests that, at times, industrial pollution from central Europe may be responsible for the haze layers found in the Arctic. It is also possible that the haze is caused by dust transported by winds from the Gobi Desert.

Shaw, Glenn E., Arctic haze, Geophysical Institute, University of Alaska, Fairbanks, Alaska, Report No. 33(5), October 1980, p. 219-221.

ABSTRACT

Arctic air can be, and has been, described as crystal clear-at least in summer. During the winter months the situation changes, and the northern, polar air fills with pervasive haze. Studies from aircraft show that the haze concentration increases upward from the ground, reaching a maximum at several thousand meters of altitude, then decreases above that. Sampling experiments indicate that Arctic haze is rich in elements associated with industrial pollution, such as vanadium and manganese. Researchers suspect that the source of the haze is Europe and, at times, northeastern U.S. Less frequently, the haze has been composed of particles of crustal material which apparently have come from the Gobi and other great Asian deserts.

Shaw, Glenn E. and Knut Stamnes, Arctic Haze: Perturbation of the Polar Radiation Budget, Annals of the New York Academy of Science, 338, 533-540, 1980.

ABSTRACT

Arctic haze refers to turbid air in the northern polar regions. It was first noticed and commented on in 1956 by Murray Mitchell, Jr.,[1] who more or less described it as being an amorphous haze extending from the northern Alaskan coasts to the highest polar latitudes. In the period 1971–75, Shaw and Wendler,[2] Shaw,[3] and Holmgren *et al.*[4] measured anomalously high values of optical extinction through the atmosphere at McCall Glacier in remote northeastern Alaska and at Point Barrow on the northern tip of Alaska. The high values of extinction (haze optical depth = 0.1–0.2 at 500 nm wavelength) were extremely puzzling, especially since the atmospheric optical extinction underwent a seasonal variation in the opposite direction from what one would expect: the values of optical extinction were large during the months March–April, when the oceans and surface are covered with ice and snow, but were smaller in summer. This behavior is distinctly anomalous, since turbidity at most locations is at its greatest in summer[5,6,7] and at its minimum in middle or late winter.

Shaw, Glenn E., Arctic Haze, Weatherwise, pp. 218-221, 1980.

ABSTRACT

Popular overview of the Arctic Haze problem.

Shaw, G. E., Eddy Diffusion Transport of Arctic Pollution from the Mid-Latitudes: A Preliminary Model, Atmospheric Environment, Vol. 15, No. 8, 1981.

ABSTRACT

Arctic haze, which here refers to aerosol particles of submicron size permeating the atmosphere of the northern polar regions, is a phenomenon showing strong and annually repeatable seasonal variations, with maxima in winter and early spring and minima in summer. This paper describes an eddy diffusion model which was constructed to understand that part of the haze (apparently its largest part) due to pollution sources at the mid-latitudes. The model is applied to the transport of emitted anthropogenic sulfur. The modeling has tentatively identified Arctic cloudiness amount as the controlling factor which gives rise to the tenfold seasonal changes of Arctic air pollution; it also has provided, within a factor of 2, the correct magnitude of the aerosol mass loading in the arctic regions and has allowed a rough estimate to be made of the possible impact on Arctic air quality as industrialization moves northward.

Future development of mining, petroleum extraction, smelting, refining, and manufacturing is expected to double every 15–20 years, and in another 50 years arctic haze may be serious enough to cause significant heating of the atmosphere of the northern polar regions.

Shaw, Glenn E., Atmospheric Turbidity in the Polar Regions, J. Applied Meteor. Vol. 21, No. 8, August 1982.

ABSTRACT

Analysis is presented of 800 measurements of atmospheric monochromatic aerosol optical depth made poleward of ~65° latitude. The atmosphere of the southern polar region appears to be uncontaminated but is charged with a background aerosol having a mean size of 0.1 μm radius, an almost constant mixing ratio throughout the troposphere, a sea level optical depth (λ = 500 nm) of ~0.025 and an inferred columnar mass loading of 4–15 $\times$ 10^{-7} g cm^{-2}.

At around the time of spring equinox the northern polar region (all longitudes) is invaded with Arctic Haze, an aerosol showing a strong anthropogenic chemical fingerprint. The optical depth anomaly introduced by this man-caused haze is $\tau_0 \approx 0.110$ and the associated columnar mass loading is ~1.5 $\times$ 10^{-6} g cm^{-2}. Turbidity measured seven decades ago at the solar observatory at Uppsala (60°N), suggests that Arctic optical depth has been rising at a rate of $d\tau/dt \approx 0.01 \pm 0.005$ per decade.

Shaw, G. E., Evidence for a central Eurasian source area of Arctic haze in Alaska, Nature, 299, 815-818, 1982.

ABSTRACT

During winter when the polar oceans are frozen, air masses entering Alaska from the Arctic are charged with suspended submicrometre particles whose chemical signatures show evidence of being derived from man-made sources of pollution[1-3]. Occasionally, the aerosol loading is large enough to reduce visibility and thus the phenomenon has come to be referred to as 'Arctic haze'. We report here three strong episodes of Arctic haze in Alaska which were examined during February–April 1982 and which were found to be possibly associated with air emissions in central Eurasia.

Shaw, Glenn E., On the Aerosol Particle Size Distribution Spectrum in Alaskan Air Mass Systems: Arctic Haze and Non-Haze Episodes, J. Atmos. Sciences, Vol. 40, pp. 1313-1320, 1983.

ABSTRACT

Aerosols in central Alaskan winter air mass systems were classified according to size by diffusive separation and light-scattering spectrometry. Particles entering central Alaska from the Pacific Marine environment had number concentrations ranging from 300 to 2000 cm^{-3} (geometric mean 685 cm^{-3}) and unimodal size spectra, with maximum in number concentration near 1×10^{-6} cm radius.

Air masses entering Alaska from the Eurasian Arctic possessed a factor of two smaller aerosol number concentrations than Pacific Marine systems (*e.g.*, 150–700 cm^{-3}; geometric mean 386 cm^{-3}) but contained a factor of two greater particle volume loading within the fine particle radius range $\sim 5 \times 10^{-7} < r < 1 \times 10^{-5}$ cm. The particles in Eurasian Arctic air masses were bimodally distributed, with maxima in the particle size spectra near $r = 3 \times 10^{-7}$ and 5×10^{-6} cm. Sulfur was the predominant element in all cases studied.

A particle depleted region was present in the size spectra obtained for Eurasian Arctic air masses. The deficiency of particles in the 10^{-6} cm radius range is interpreted as being the result of thermal coagulation taking place between sulfur-rich nuclei (produced at a rate of 10^{-20} to 10^{-18} g cm^{-3} s^{-1} and in sizes $r < 10^{-6}$ cm) and "large" ($r \sim 10^{-5}$ cm) imported primary particles. The primary particles are in the removal-resistant Greenfield Gap ($r \sim 10^{-5}$ cm) and seem to originate in the central Eurasian region.

Shaw, Glenn E., X-Ray Spectrometry of Polar Aerosols, Atmospheric Environment, Vol. 17, No. 2, pp. 329-339, 1983.

ABSTRACT

Aerosols sampled in the Alaskan and Norwegian Arctic and in Antarctica (western Antarctica and South Pole) were analyzed with scanning electron microscopy and energy-dispersive X-ray spectrometry. They were found to be predominantly submicron sulfur-rich particles. Large (1–3 μm) particles of crustal material (showing signatures of Al and Si and conchoidal fracturing) or sea salt particles (signatures of Na and Cl) were occasionally present and seemed to be coated with liquid or solid films of sulfur-rich compounds, possibly in the form of very small freshly-nucleated sulfates that had attached by coagulation. The sulfur coating may alter the cloud condensation nucleus spectrum.

The predominant X-ray peaks detected in the aerosol were from Na, Mg, Al, Si, S, Cl, K, Ca, Mn and Fe. Factor analysis of the correlation matrix of aerosol elemental composition suggested that it may not be valid to think of the polar aerosol as a simple mixture of primary marine and primary crustal components.

In the Arctic aerosol, Cu and Cl seem anomalous; their proximity on factor diagrams suggests there possibly may be a biogenic source of Cl, since such a source has been suggested for copper by Cattell and Scott (1978; *Science* 202, 429–430) and Duce *et al.* (1972; *Science* **176**, 161–163). At the South Pole, Cl and Si seem anomalous on the factor diagram; the anomaly possibly being caused by emissions from Erebus Volcano. Both Cl and Si were enriched in samples taken from the fuming vent at the summit of Mt. Erebus. The anomalous behavior of Cl, Si and Cu may not be significant, however, because of the limited number of experimental data.

Weschler, Charles J., Identification of selected organics in the Arctic aerosol, Atmospheric Environment, Vol. 15, No. 8, 1981.

ABSTRACT

GC/MS and pyrolysis/GC/MS techniques have been used to identify organics in aerosol samples collected at Barrow, Alaska. The major organics detected in the cyclohexane extracts included saturated aliphatic hydrocarbons, phthalate esters, and polydimethylsiloxanes (dimethyl silicones). The methylene chloride extracts contained primarily phthalate esters, while the major components of the acetone extract were phthalic anhydride and 4-methyl-3-pentene-2-one (both most likely artifacts), with lesser amounts of aliphatic acids.

Polydimethylsiloxanes have not been previously reported in airborne particulate matter (primarily because of analytical restrictions). These silicones are totally synthetic materials and, together with the general character of the organics detected in these samples, offer further evidence for the contribution of distant sources to the Arctic aerosol.

Automobile Emissions and Their Control

The references in this sections include the following topics:

- Effects of cold weather on automobile emissions
- Effects of automobile emissions on ambient CO concentrations
- Cold start and engine warm-up
- Reducing CO emissions through the use of:
  - Alternate fuels
  - Automobile inspection and maintenance
  - Retrofit pollution control devices
  - Preheaters
  - Other devices

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Alaska Department of Environmental Conservation Report, A Review of Carbon Monoxide Emissions from Motor Vehicles during Cold Temperature Operation, The Importance of Cold Start Emissions for Attainment of Ambient Air Quality Standards, March 1979.

ABSTRACT

1. Summarizes the available information regarding motor vehicle emissions caused by extreme cold start conditions.

2. Presents methods which are currently available to reduce such emissions.

3. Evaluates the extent to which emissions affect achievement of ambient air quality standards for carbon monoxide, particularly emphasizing Fairbanks and Anchorage, Alaska.

4. Recommends policies which need to be implemented to effectively control cold start emissions.

5. Outlines research needed to adequately quantify cold start emissions as they affect achievement of ambient air quality standards.

Ashby, H.A., R.C. Stahman, B.H. Eccleston, and R.W. Hurn, Vehicle Emissions--Summer to Winter, No. 741053, prepared for Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, Pennsylvania 15096, 1974.

ABSTRACT

A test program was conducted to study the effect of ambient conditions on exhaust emissions from a wide variety of automobiles. Twenty-six cars ranging from pre-control production cars to catalyst-equipped prototypes, including rotary, Diesel, and stratified charge cars, were tested at 20°, 50°, 75°, and 110° F.

Ambient temperatures above and below 75° F were found to have significant effects on exhaust emissions. The Diesel and stratified charge cars were affected less than production and catalyst-equipped cars by changes in ambient temperature.

The use of air conditioners at the 110° F test temperature led to increased emissions and fuel consumption. Hydrocarbon reactivity and aldehyde emissions were not affected by temperature and were lower from the catalyst cars at all temperatures.

Austin, T.C., G.S. Rubenstein, L.D. Verrelli, and T.E. Moyer, Light Duty Vehicle CO Emissions During Cold Weather, Sierra Research and Alaska Dept. of Environmental Conservation, SAE Technical Paper Series #831698, 1983.

ABSTRACT

However, the low temperature CO emissions of cars certified at 3.4 grams per mile CO are nearly 50% lower than vehicles certified to a standard of 15 grams per mile. Comparable levels of low temperature CO control may be possible with carburetors through the use of electric intake manifold heating grids. Unless new regulations provide an alternative mechanism for encouraging the use of such systems, the achievement of the ambient air quality standard for CO in areas which experience violations during cold weatheer may depend on the continued requirement for a 3.4 gram per mile standard.

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Bowditch, F. W., The Carbon Monoxide Issue in Alaska, Motor Vehicle Manufacturers Association, January 1982.

ABSTRACT

This paper was prepared by the Motor Vehicle Manufacturers Association of the United States, Inc. (MVMA), to outline what is known about carbon monoxide (CO) pollution in Alaska and to explore what might be required in terms of emission control to achieve the CO air quality standard (NAAQS). Data gaps and areas in which further information would be useful also are identified.

Carbon monoxide was selected for the study because it is the air pollutant of most concern to the people of Alaska. Other pollutants are of less concern. For example, ozone concentrations is Alaska are among the lowest in the Nation, and Alaska is in compliance with the nitrogen dioxide air quality standard. The carbon monoxide situation in Alaska is evaluated in this paper for center city as well as residential locations, using available air quality monitoring data. Future emission control requirements are appraised by means of air quality projections and evaluation of projection techniques.

Chang, T. Y., J. M. Norbeck and B. Weinstock, Ambient Temperature Effect on Urban CO Air Quality, Atmospheric Environment, Vol. 14, pp. 603-608, 1980.

ABSTRACT

Abstract – Changes in the ambient temperature cause changes in vehicle emissions mainly during the cold-start period of operation. The influence that this effect has on the seasonal variation of urban CO concentrations is examined by means of a simple air quality model. For fixed meteorological conditions, the model predicts that the atmospheric CO concentrations at a center city measuring location will increase by 5–15% for a decrease in temperature from 75° to 25°F when none of the vehicles in that vicinity are in the cold-start mode and will increase by 55–75% when all of the nearby vehicles are in the cold-start mode. An inverse variation of CO concentration with change in temperature is derived from a statistical analysis of CO data reported both for midtown Manhattan (1975–1977) and for downtown Los Angeles (1970–1975). The magnitude of the derived variation is small for both cities and corresponds to the case where none of the vehicles in the vicinity of the measuring site are in the cold-start mode. It therefore follows that the variation of CO vehicle emissions with temperature does not have an important effect on CO air quality at these two urban centers.

The highest CO concentrations are observed during the colder months in most American cities and the differences in meteorological conditions between winter and summer that might contribute to this are considered. Some significant factors are that, in the winter, multiday episodes of slowest dilution occur as well as nocturnal inversions of greater stability. From these considerations it is concluded that the meteorological factors play a significant role in the observation of high CO concentrations in urban areas during the colder months.

Chapman, C.C., 1984. Vehicle analysis program, 1983 results and overall history and results. Fairbanks North Star Borough, 60 pp.

ABSTRACT

This report summarizes the results of the eight years that the Vehicle Emissions Analysis Program (VEAP) has been run (1973, 1974 and 1978 to 1983). An analysis of the data, individually for 1983, and over the history of the program was made. Two major trends have been noted:

1) carbon monoxide and hydrocarbon emissions from the average light duty vehicle in the Fairbanks area have decreased with time, on the order of 45 to 70 per cent (by weight) from 1973 to 1983;

2) the number of vehicles in the Fairbanks area has increased at a rate of approximately 10 per cent per year since 1973.

Reasons for the decrease in carbon monoxide and hydrocarbons include: design changes in the gasoline engine (improved carburetion, smaller displacements, and increased combustion efficiency); addition of emission controls that both improve fuel/air mixtures and increase oxidation of combustion products.

In addition, a comparison of VEAP population samples was made with vehicle registration information, in order to illustrate the similarity of the samples to the overall Fairbanks area vehicle population. Proceeding from the assumption that VEAP samples are representative of the Fairbanks area vehicle population, failure rate curves were generated, based on carbon monoxide emitted at idle versus model year group, vehicle type and engine size.

This report deals almost exclusively with data, results and conclusions based on vehicles with warm engines being tested while unloaded. Any conclusion referencing cold engine and/or loaded engine conditions is made on a subjective basis.

Coutts, H. J., L. E. Leonard, K. W. MacKenzie Jr., Cold Regions Automotive Emissions, Dept. of Environmental Services, Fairbanks North Star Borough, Geophysical Institute, University of Alaska, Arctic Environmental Research Laboratory, U.S. Environmental Protection Agency, August 1973.

ABSTRACT

In Fairbanks, Alaska, during February and March 1973, the emissions of 631 vehicles wre analyzed at idle and adjustments were made to reduce CO and HC emitted. It was found that proper adjustment of in-use vehicles could result in approximately 34% reduction in CO and a 12% reduction in HC produced at idle. Emission levels of propane and gasoline and diesel fueled vehicles were measured and compared. Various pollution control devices are discussed and considered for cold weather use and conclusions are drawn. Ice Fog is considered as it relates to CO emission control.

Coutts, Harold J., Automotive Cold-Start Carbon Monoxide Emissions and Preheater Evaluation, Corvallis Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency.

ABSTRACT

Fairbanks and Anchorage, Alaska, experience high wintertime ambient levels of carbon monoxide (CO). Emissions from starting automobile engines in cold weather are thought to be a major source of CO. This research project developed a quantitative procedure for determining start-up CO emissions. The start-up emissions were measured as a function of soak time at several low ambient temperatures. The performance of engine preheaters in reducing the start-up CO at the various soak times and temperatures was estimated.

The data scatter was too great to draw any firm conclusions, however, the following general statements can be made.

The length of cold-soak time appeared to have a stronger effect upon cold-start CO emissions than did soak temperatures in the range of 0° to -30°C. Compared to no preheat, continuous preheat during an overnight cold-soak would reduce the cold-start CO emission by 20 to 90%.

This report was submitted in fulfillment of Interagency Agreement EPA-79-D-F0847 by Alaskan Projects Office-U.S. Army Cold Regions Research and Engineering Laboratory under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from October 1979 to March 1980; work was completed as of March 1980.

Coutts, H. J., The 1978 Fairbanks Voluntary Motor Vehicle Emission Inspection Program, Technical Report submitted to Fairbanks North Star Borough, 1979.

ABSTRACT

Fairbanks, Alaska has the distinction of suffering from air pollution although it is located in a relatively under populated and pristine state. The Fairbanks air pollution problem consists of three major components. They are carbon monoxide (CO) ice fog and particulates.

Mobile sources (cars and trucks) are major contributors of these and other pollutants. The other air pollutants are nitrogen oxides and lead (Pb) (1). Pb, a particulate, is the major particulate that is emitted from vehicles using leaded gasoline.

In Fairbanks CO and particulates (Pb and others) are the only pollutants exceding the U.S. EPA health effects standards. Time will take care of the Pb problem as leaded gasoline is slowly phased out.

Coutts, Harold J., Automotive Cold-Start Carbon Monoxide Emissions and Preheater Evaluation, Special Report 81-32, U.S. Environmental Protection Agency, U.S. Cold Regions Research and Engineering Laboratory, December 1981.

ABSTRACT

Fairbanks and Anchorage, Alaska, experience high wintertime ambient levels of carbon monoxide (CO). Emissions from starting automobile engines in cold weather are thought to be a major source of CO. A quantitative procedure for determining startup CO emissions was developed. The startup emissions were measured as a function of soak time at several low ambient temperatures. The performance of engine preheaters in reducing the startup CO at the various soak times and temperatures was estimated. The data scatter was too great to draw any firm conclusions; however, the length of cold-soak time appeared to have a stronger effect on cold-start CO emissions than did soak temperatures (0 to -30°C). Compared to no preheat, continuous preheat during an overnight cold soak can reduce the cold-start CO emissions by 20 to 90%.

Coutts, H. J., Low Temperature Automotive Emissions and Inspection and Maintenance Effectiveness, Final Report prepared for State of Alaska, Department of Environmental Conservation, August 1983.

ABSTRACT

The Anchorage and Fairbanks areas often experience wintertime ambient carbon monoxide levels that exceed the EPA Health Effects Standards. Previous research has indicated that the problem is mainly caused by exhaust emissions from automobile cold starts. This research was conducted without the use of costly emissions testing equipment specified by the Federal Test Procedures.

In the spring of 1981 the Alaska Department of Environmental Conservation obtained a Mobile Emissions Testing Facility from the EPA's Ann Arbor laboratories and modified it to operate at low temperatures. During the winter of 1981-82 14 light-duty, in-use vehicles were tested at 0°, 20°, 30° and 70°F using the Federal Test Procedure. Goals of the tests were 1) to determine the potential effectives of an Inspection and Maintenance program at low temperatures and 2) to obtain low temperature emission factors.

For the 11 vehicles in the I/M program, tuneups accomplished with the use of exhaust gas analyzers were found to be effective in reducing CO emissions at all test temperatures. In fact, for the vehicles tested, maintenance yielded about the same percentage CO reduction at 20-30°F as it did at 70°F. Maintenance was also shown to have a similar positive effect on fuel economy at 20-30°F as at 70°F. The data also confirmed previous research showing that low temperatures dramatically increase the cold-start CO emissions. The CO emitted during 20-30°F cold starts (the first 8.4 minutes of engine operation) average 11 to 20 times greater than that from cold start at 70°F. Continuous exhaust sampling during the 2-minute warmup periods at idle was conducted to establish choke curves for some of the vehicles. At the 30-50°F range the chokes did not completely open during the 2-minute warmup period.

Coutts, H.J., Low Temperature Automatic Emmissions and Inspection and Maintenance Effectiveness, U.S. Army Cold Regions Research and Engineering Laboratory, 72 Lyme Road, Hanover, New Hampshire 03755, Final Report, October 1983.

ABSTRACT

Fourteen late model vehicles were tested under a variety of conditions in order to determine the effect on carbon monoxide (CO) emissions and fuel economy of three factors:

(1) Extended idling times when vehicles are first started in the morning.
(2) Changes in ambient temperature from 0°F to 70°F.
(3) Tune-ups for vehicles which fail a warm idle emissions test, such as would be administered during an inspection and maintenance program.

The first two factors are believed to play a role in the carbon monoxide air quality problems experienced in Anchorage and Fairbanks, Alaska. The third factor is one potential approach for addressing the CO problem.

Coutts, H.J., 1983. Low temperature automotive emissions. Alaska Dept. of Environmental Conservation, Report No. AK-AP-83-1 Vol. 1 and Vol. 2. Winter 1981-1982.

ABSTRACT

Fourteen late model vehicles were tested under a variety of conditions in order to determine the effect on carbon monoxide (CO) emissions and fuel economy of three factors:

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The first two factors are believed to play a role in the carbon monoxide air quality problems experienced in Anchorage and Fairbanks, Alaska. The third factor is one potential approach for addressing the CO problem.

The results of the test program support the following main conclusions:

(1) For driving trips longer than about 3-1/2 miles, extended idling during warm-up does not affect trip average CO emission levels. For shorter trips, extended idle times could increase trip average CO emission levels beyond what they would be if the vehicles were started and immediately driven.

Contd.

(2) Extended idles associated with short trips (less than 3-1/2 miles) can reduce gas mileage by 10-25%. However, with average trips longer than about 7-1/2 miles, no significant fuel economy loss is associated with 2-6 minutes extending idling after a cold start.

(3) Carbon monoxide emissions and fuel consumption increase significantly, as ambient temperature decreases from 70°F to 0°F. The grams per mile increase in emissions appears to be about the same regardless of a vehicle's warm temperature emission level. Fuel consumption increases by up to 60% at cold temperatures during short trips. Most of the increase in emissions and fuel consumption occurs during the first 3-1/2 miles of driving after a cold start.

(4) Tune-ups for vehicles which fail a warm idle inspection test appear to achieve approximately the same percentage reduction in carbon monoxide emissions at cold temperatures as at warm temperatures. However, the sample of vehicles repaired was limited, and the extent of the repairs appears to have been broader than normally occurs in an inspection and maintenance program.

(5) Tune-ups result in greater increases in fuel economy at cold temperatures than at warm temperatures. Fuel economy improved by 6-16% at cold temperatures after repairs, but only by 1/2 to 3-1/2% at 70°F.

Coutts, H.J., and Peacock, J., An Evaluation of Automotive CO Emission Control Techniques at Low Temperatures, Coutts Engineering Limited, Esther, Alaska, and Technical Resources, Fairbanks, Alaska, Final Report, October 1983.

ABSTRACT

Tune-ups were found to be effective in reducing CO emission at 20F. However, the minimal tune-ups conducted during the second winter were not as effective as the complete tune-ups in the first winter's testing program. Only the second winter's program had medium duty trucks and tune-ups on these vehicles were not as effective as those on cars.

All retrofit devices did reduce the cold start CO emission. Compared to gasoline, gasohol was able to reduce the cold start CO, but it was not effective as the retrofit devices.

Eccleston, B.H., and R.W. Hurn, Ambient Temperature and Trip Length--Influence on Automotive Fuel Economy and Emissions, U.S. Dept. of Energy & Bartlesville Energy Research Center, Bartlesville, Oklahoma 74003, SAE Technical Paper Series 780613, 1978.

ABSTRACT

Experimental work was done to examine the interrelationships among automotive fuel economy, ambient temperature, cold-start trip length, and drive-train component temperatures of four 1977 vehicles. Fuel economy, exhaust emissions, and drive-train temperatures were measured at temperatures of 20, 45, 70, and 100° F using the 1975 Federal test procedure and the Environmental Protection Agency's highway fuel economy test. Results showed that vehicles used for short cold-start trips consume fuel at a much greater average rate than during long trips, and the effect is magnified with decreasing ambient temperature.

M

Frizzera, A., Vehicle Emission Analysis Program, for Environmental Services, Fairbanks North Star Borough, Fairbanks, Alaska, 1978.

ABSTRACT

Details of test program and results. The test of 1,242 vehicles showed that only 41% passed (specified CO and hydrocarbon levels).

M

Gilmore, Timothy M., Acceptability Survey for Cold Start Automobile Emissions Study, Report prepared for the Fairbanks North Star Borough, 1978.

ABSTRACT

The following report contains the results of a public opinion survey on automobile engine heating in the Fairbanks area. The primary purpose of the study was to determine the average person's auto usage habits: how often, at what temperature, for how long, where, and what type of engine heating devices are used. Questions were also framed to determine how often and in what places people start their automobiles in Fairbanks.

Hoyles, Michael R., An Empirical Approach to Modeling Low Temperature Carbon Monoxide Emissions, November 1980.

ABSTRACT

In Anchorage and Fairbanks, violations of the carbon monoxide (C) standards occur only in winter with the motor vehicle accounting for approximately 85% of the total emissions. Since CO emissions from this source are known to increase as ambient temperature decreases, it would follow that higher emissions are the main cause. There is reason, however, to doubt it's as simple as that. The increase in emissions with decreasing temperature simply cannot account for the overall increase in concentration. This anomaly may be due to erroneous emission factors, as yet unquantified meteorological effects or a combination.

Hoyles, M.R., and T.E. Moyer, The Facts of Cold Cold Temperature Effects on Carbon Monoxide Emissions from Vehicles, Alaska Division, American Association for the Advancement of Science, Fairbanks, Alaska, September 1979.

ABSTRACT

This paper is an up-to-date review and evaluation of research on the effects of cold temperatures on vehicle emissions, specifically concentrating on carbon monoxide. Although estimates of total CO emissions during a "typical" vehicle trip differ, all researchers agree that the percentage is consistantly very high. It is mainly during the first 4 to 8 minutes of operation after a cold start, when an engine is operated in choked condition, that the bulk of the CO emissions are produced. This predominance masks emissions from warmed vehicles in motion.

The significance of this effect is discussed in terms of shortcomings of both analytical planning tools and control stratagies for attainment of CO ambient standards. Ways to mitigate the effect will include discussion of alternate technology such as Honda CVCC engines, engine pre-heaters, tuneups, and establishment of cold weather standards and test criteria. This phenomenon not only affects Alaska but has national significance. Future research needs are also pointed out.

Hoyles, M.R., and T.E. Moyer, A Comparison of Emissions from Gasohol and Gasoline at Low Ambient Temperatures, State of Alaska Department of Environmental Conservation, June 1980.

ABSTRACT

The primary objective of this study was to determine the achievable reductions in carbon monoxide exhaust emissions through the use of gasohol, under cold start conditions. In addition, fuel consumption was compared between gasohol and gasoline.

M

Hoyles, Michael R. and Thomas E. Moyer, The Significance of Engine Warm-up time on Carbon Monoxide Emissions from Motor Vehicles, Presented at the PNWIS-APCA Conference, Spokane, Washington, November 1981.

ABSTRACT

The objective of this study is to illustrate the necessity and significance of modifying the methods used to model carbon monoxide (CO) emissions from motor vehicles. Low ambient temperatures in Alaskan cities dictate this revision, however, this methodology also applies to more temperate regions. Three test cases will be used for illustrative purposes. The effectiveness of some transportation control strategies in light of these modifications will also be discussed.

Koehler, D.E., Cold Temperature Emission Factors, Bartlesville Energy Center, U.S. Department of Energy, Bartlesville, Oklahoma, 1980.

ABSTRACT

The objectives of this study are to determine emission rates during the stationary and mobile modes of vehicle operation for different length idle periods prior to proceeding into the FTP, conducted at 20°F, then to develop, for modeling purposes, cold-start CO emission rates compatible with EPA Mobile 1 emission factor format. Ancillary objectives include fuel economy results, documentatio of choke behavior, and hydrocarbon (HC) and nitrogen oxides (NO_X) data collection.

Kailing, S. H., P.E., Evaluation of an Autotherm Energy Conservation System, Final Report for State of Alaska, Department of Transportation and Public Facilities, Division of Planning and Programming, Research Section, July 1982.

ABSTRACT

In early 1981, Department of Transportation and Public Facilities (DOTPF) was approached by Alaska Department of Environmental Conservation (ADEC) regarding evaluation of the AUTOTHERM Energy Conservation System because of its potential for reducing vehicle emissions and saving energy. ADEC had been in contact with representatives of AUTOTHERM, Inc. in Barrington, Illinois, and seven sample systems were supplied to DOTPF Research in Fairbanks for testing purposes.

Additional test systems went to ADEC in Juneau and the Alaska State Troopers in Anchorage. This report covers only those systems evaluated by DOTPF in Fairbanks.

Leonard, L. E., Cold Start Automotive Emissions in Fairbanks, Alaska. Interim Report prepared for State of Alaska Department of Highways and U. S. Department of Transportation, Federal Highway Administration, 1975.

ABSTRACT

Measurements of the cold start and warm-up emissions of more than one hundred in-use motor vehicles in the Fairbanks area were performed during the winter of 1974-75. It was found that, for densely populated areas of the city where large numbers of vehicles are started and allowed to warm up daily, the major portion of the carbon monoxide (CO) emitted to the ambient is produced during the cold start and warm-up phase of vehicle operation. In some areas the cold start CO contribution could be as much as 76% of the total. It was also found that none of the pollution control devices presently in common use were effective in reducing the cold start CO emissions. Thus, for the cold start phase of operation the older vehicles were not greater emitters of CO than were the newer vehicles. This investigation also shows that the most effective way of reducing cold start emissions on a per vehicle basis is to utilize smaller engine size, as evidenced by the significantly lower CO emissions produced during cold start by the foreign vehicles tested when compared to the American vehicles.

Leonard, L. E., Carbon Monoxide Emissions from Moving Vehicles in Fairbanks, Alaska Vol. 3, Prepared for State of Alaska Department of Highways in cooperation with U.S. Department of Transportation, Federal Highway Administration, UAG R-252, Geophysical Institute, University of Alaska, August 1977.

ABSTRACT

This report is the third and final volume in a series constituting the final report on a research project which has investigated carbon monoxide (CO) emissions from motor vehicles in Fairbanks, Alaska. This volume (Vol. 3) presents the findings of that part of the study dealing with vehicles operating in the moving mode. Two investigations were performed:

1. Driving cycles were developed which are representative of actual driving conditions in the urban area of Fairbanks. Development of two cycles was necessary to demonstrate the effect of traffic control strategies implemented during the summer of 1975. Therefore, the cycles presented here describe traffic conditions both before and after implementation of the new controls, with accompanying qualitative discussion of the effect on CO emissions. In an effort to retain consistency and ease comparison, the cycles developed here were modeled after the CVS-3 cycle used in the Federal Test Procedure.
2. CO emissions from in-use vehicles operating in the moving mode were measured in order to provide quantitative modal emission data for use in conjunction with the driving cycles. Quantitative emissions data for the steady-state mode of operation are presented; however, limitation in the response time of the CO analyzer used in testing precluded acquisition of reliable data for the transient (Acceleration and Deceleration) mode of operation.

Leonard, L. E., T. Scarborough and H. Black, Evaluation of automotive engine preheaters as a technique to control cold start carbon monoxide emissions, Scarborough & Associates, September 1978.

ABSTRACT

In an effort to gain a better understanding of the factors affecting ambient carbon monoxide (CO) pollution in the Fairbanks area, a research project was undertaken aimed at evaluating various techniques to control cold start CO emissions from automobiles. Testing was performed outdoors using in-use vehicles of various types and ages during the period of February through March, 1978 at Fairbanks, Alaska. The work was carried out in three phases:

I. Vehicle selection phase, where warm idle and cold start CO emissions were measured to gather baseline data.

II. Environmental phase, where data were gathered to define the parametric relationship of environmental factors (cold soak time and ambient temperature) affecting the mass of CO produced during cold start.

III. Evaluation phase, where four types of engine preheaters (electric immersion heaters, electric thermo-siphons, waste heat storage units, and automatic engine starters) were evaluated for their effectiveness as cold start CO emission control devices.

Marshall, W.F., B.H. Eccleston, Emissions at Off-Ambient Temperatures, Dept of Energy, Bartlesville, Oklahoma, SAE Technical Paper Series 800512, 1980.

ABSTRACT

Data on exhaust emissions were obtained from a group of 1970 model-year vehicles operating over a range of ambient temperatures. The work is providing a baseline against which current-production vehicles can be compared, thus enabling a more complete assessment of automotive emissions reduction achievements.

The vehicle fleet represented the 1970 model-year nationwide mix. The 25 cars were tested at 25°, 50°, 75°, and 100° F over the Environmental Protection Agency urban Federal test procedure, highway fuel economy test, and New York City driving cycles.

Both temperature and driving cycle were found to have significant effects on exhaust emissions. The conditions which yielded the greatest adverse effects on emissions were: 1) low temperature--urban driving cycle, and 2) high temperature--New York City driving cycle./ The data also indicate that the use of air conditioners causes increased emission levels.

McMullen, Vehicle Emission Analysis Program, Report for Fairbanks North Star Borough, 17 pp., AEIDC Reprint 00745. 1981. (M)

ABSTRACT

In 1981 the Fairbanks North Star Borough (Borough) operated its Vehicle Emissions Analysis Program (VEAP) as a continuing effort both to obtain data on in-service emissions of vehicles in Fairbanks, and to educate the public on the benefits of tuning for low emissions and fuel economy.

(M)

McMullen, K., Vehicle Emissions Analysis Program, Report for Fairbanks North Star Borough, 21 pp., AEIDC Reprint 00748, 1982.

ABSTRACT

In 1982 the Fairbanks North Star Borough (Borough) operated its Vehicle Emissions Analysis Program (VEAP) Sept. 7, thru Oct. 29, as a continuing effort both to obtain data on in-service emissions of vehicles in Fairbanks, and to educate the public on the benefits of tuning for low emissions and fuel economy.

M

Olle, Odsell, Influence of Ambient Temperature and Cold Start on Automobile Fuel Consumption, VTI RAPPORT, Natioonal Road & Traffic Research Institute, S-58101 Linköping, Sweden, 1981.

ABSTRACT

Ambient temperature has a significant influence on automobile fuel consumption, both with warmed-up car and during cold start. As a great percentage of all trips made by car covers less than 8-10 km, the cold start fuel consumption is of vital importance for the car owner. However, car manufacturers have during recent years concentrated on lowering the fuel consumption during standardized driving cycles, like CVS, HDC, and ECE. These cycles do not take into account cold start or driving at low temperatures, and therefore there is still a lot to be done in this field.

The report describes how ambient temperature affects fuel consumption with warmed-up car and during cold start. A formula is presented, that can be used for estimates of the fuel consumption as a function of ambient temperature and trip length after cold start. Finally some possibilities of reducing the cold start fuel consumption are presented.

M

Ostrouchov, Nicolas, Effect of Cold Weather on Motor Vehicle Emissions and Fuel Economy, Society of Automotive Engineers Technical Paper Series, 1978.

ABSTRACT

The effect of soaking temperature on exhaust emissions has been studied using a variety of automobiles representing three different emission control levels and testing them at ambients of 20°C down to -30°C(60°F to -22°F).

It was found that emissions of the three gaseous pollutants demonstrated a mild power relationship with ambient (soaking) temperatures. All regulated pollutants and fuel consumption were higher at -30°C than at 20°C: hydrocarbons (HC) - 3.5 to 9.2 times; carbon monoxide (CO) - 2.4 to 6.4 times; oxides of nitrogen (NO_x) - only 1.1 to 1.4 times; and fuel consumption 1.2 to 1.8 times higher. Analysis of the data has indicated that HC and CO emissions from the cold start phase of the Federal test were the most sensitive to soaking temperature. With NO_x emissions the soaking temperature sensitivity was fairly constant throughout the three phases of the Federal test.

The data also indicate that the temperature sensitivity of both fuel economy and, to a lesser extent, emissions is a function of inertia weight.

M

Ostrouchov, Nicolas, Effect of Cold Weather on Motor Vehicle Emissions and Fuel Consumption - II, SAE Technical Paper Series, 1979.

ABSTRACT

The effect of soaking temperature on exhaust emissions and fuel consumption was investigated using a variety of automobiles representing different emission control levels including diesel engine powered vehicles. Tests were performed at soaking and ambient temperatures of 20°C down to -20°C (68°F to -4°F).

It was found that emissions and fuel consumption are dependent on soaking temperature. Hydrocarbon and carbon monoxide emissions were higher at -20°C than at 20°C: hydrocarbon (HC), 1 to 4 times; carbon monoxide (CO), 1 over 3 times. The smallest increase of 1 to 1.04 time belonged to vehicles equipped with diesel engines. Nitrogen oxides (NO_x) emissions were higher or lower at -20°C than at 20°C depending on emission control technologies -0.75 to 1.11 times. Analysis of the data has indicated that HC and CO emissions from the cold start phase of the Federal test were the most sensitive to soaking temperature. With NO_x emissions the soaking temperature sensitivity was fairly constant throughout the three phases of the test.

It appears that temperature sensitivity of fuel consumption in vehicles equippped with diesel engines and lean burn gasoline engines is considerably lower in comparison to the vehicles equipped with other control technologies, and is higher at -20°C than at 20°C: for diesel engines and lean burn -1.15 times; for other vehicles -1.55 times. The data also indicate that the temperature sensitivity of fuel consumption is a function of inertia weight.

M

Ostrouchov, N., Vehicle Emissions and Fuel Consumption in Canadian Winter Temperatures, For Presentation at the 73rd Annual Meeting of the Air Pollution Control Association, Montreal, Quebec, June 1980.

ABSTRACT

Over the winter periods since 1972 Environment Canada engineers, in co-operation with vehicle manufacturers and the U.S. EPA, have investigated and reported on the effect of low temperature on motor vehicle emissions (CVS-CH) and fuel consumption for a variety of pre-control cars and cars with current and advanced emission control systems: 1972/73 - 5 cars, 1975/76 - 13 cars, 1978/79 - 9 cars. In 1979/80 studies continued including 3 new advanced technology cars and studies on the effect of using a block heater. The objectives of this paper are to summarize and discuss the most interesting results of the studies and to draw the important conclusions from the research to date.

(M)

Ostrouchov, N., and J. Polak, Automobile Emissions and Fuel Economy at Low Ambient Temperatures, Technology Development Report EPS 4-AP-78-1, Fisheries and Environment Canada, Environmental Protection Service, Air Pollution Control Directorate, August 1978.

ABSTRACT

In January 1975, the Emission Testing Laboratory of the Air Pollution Control Directorate, Environment Canada initiated a second program to investigate further the effect of cold ambient temperature on exhaust emissions and fuel consumption. The effect has been studied using a variety of automobiles representing three different emission control levels and testing them at ambients of 30°C down to -30°C.

It was found that emissions of the three gaseious pollutants demonstrated a mild power relationship with ambient (soaking) temperatures. All regulated pollutants and fuel consumption were higher at -30°C than at 20°C: hydrocarbons (HC) -3.5 to 9.2 times; carbon monoxide (CO) -2.4 to 6.4 times, oxides of nitrogen (NO_x) - only 1.1 to 1.4 times; and fuel consumption 1.2 to 1.8 times higher. Analysis of the data has indicated that HC and CO emissions from the cold start phase of the Federal test were the most sensitive to soaking temperature. With NO_x emissions the soaking temperature sensitivity was fairly constant throughout the three phases of the Federal test.

The data also indicate that the temperature sensitivity of both fuel economy and, to a lesser extent, emissions is a function of intertia weight.

Sierra Research, Automotive Retrofit Devices for Improving Cold Weather Emissions and Fuel Economy, Report prepared for U.S. Army Cold Regions Research & Engineering Laboratory, 1982.

ABSTRACT

There are several products which have the potential to reduce carbon monoxide (CO) emissions and fuel consumption in cold temperatures, and which have previously not been evaluated by the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL).

Monolithic replacement catalysts and the Dresser Economizer intake manifold gaskets are estimated to be capable of reducing CO emissions during low temperature driving conditions by approximately 25%. Although monolithic replacement catalysts will not effect fuel economy, the Economizer gaskets may improve fuel economy by 5% to 10%.

Greater CO control could probably be achieved through the use of two devices currently produced or under development for use in a limited number of new vehicles. These devices, start catalysts and electric intake manifold heaters, could be marketed as retrofit devices with minimal design changes. they offer the potential for reducing cold start CO emissions by more than 50%.

Two other products offer limited potential to provide CO and fuel consumption reductions at relatively low cost. One of these products is ARCO Graphite motor oil.

The other product that offers some potential for reducing low temperature CO emissions is a device for remotely adjusting spark timing.

Each of the six products discussed above is recommended for evaluation by CRREL.

Sierra Research, Memo Report: Estimated Emissions Benefits of Vehicle Inspection and Maintenance Programs in Alaska, July 1983.

ABSTRACT

The results of our analysis lead us to three major conclusions:

(1) At temperatures below 30°C., the proper identification and repair of the 25% of the Alaskan vehicle population with the highest idle CO emissions is estimated to reduce fleet average carbon monoxide emissions by 5-15% during the first year of an I/M program, depending on trip length. During the first few miles of driving after a cold start, the emissions reductions are only approximately one-third the levels associated with longer trips and a mixture of cold and hot starts.

(2) The emissions reductions due to I/M repairs are not affected by the length of time a vehicle is left idling after a cold start.

(3) A simple idle emissions test will identify many vehicles with high cold-start, cold temperature emissions. However, underhood inspections and functional checks are necessary to identify more cars with emission problems, and to guide mechanics in the proper repair of failed vehicles.

Sierra Research, Memo Report: The Potential for Reducing Cold Weather CO Emissions with Gasohol, March 1983.

ABSTRACT

Alcohol-gasoline blends, such as Gasohol, have demonstrated the ability to reduce cold weather CO emissions by about 15-20% during limited testing that has been performed. However, Gasohol degrades cold weather driveability and reduces the reliability and durability of many vehicles.

The driveability degradation may result in drivers using extended idle periods. This would offset the CO emissions benefit observed under laboratory tests during which vehicles were idled for an identical period of time with and without Gasohol. Also, since driveability problems often induce owners to seek repair and adjustment of their vehicles, the laboratory test benefits of Gasohol are likely to be further offset by the readjustment of chokes and idle air/fuel ratio that would be done in an attempt to correct driveability problems. The net "real world" effect of a switch to Gasohol is therefore difficult to forecast. It will likely be less than the benefit measured during laboratory tests.

(M)

Sierra Research, Proposed Emission Cutpoints for the Anchorage Inspection and Maintenance Program, prepared for Municipality of Anchorage, Department of Planning, June 1983.

ABSTRACT

Based on an analysis of data from existing Inspection and Maintenance (I/M) programs in other cities, cutpoints have been developed for possible use in an I/M program for the municipality of Anchorage. The proposed cutpoints have been designed to achieve a "stringency factor" of 30%. In other words, about 30% of the vehicles, those with the highest emissions, will initially fail an emission test under the cutpoints which have been proposed. If the emission reductions associated with the repair of failed vehicles last for more than one year, or if the presence of the I/M program induces vehicle owners to have more frequent tuneups, then the failure rate will be lower.

Spindt, R.S., and F. Peter Hutchins, The Effect of Ambient Temperature Variation on Emissions and Fuel Economy -- An Interim Report, SAE Technical Paper Series, 1979.

ABSTRACT

This paper summarizes the emission and fuel economy data obtained when ten dissimilar cars were run using the 75 Federal Test and the Highway Fuel Economy Test Procedures. The soak and test temperatures used for the modified standard procedures varied from 0 to 110°F.

The influence of the cars' air conditioners was also determined.

The purpose of the program was to determine how well the emission control equipment designed to be effective at normal FTP test temperatures would work at temperatures ranging between 0 to 110°F.

Stone, R.K. and B.H. Eccleston, Vehicle Emissions vs. Fuel Composition API-Bureau of Mines--Part II, Chevron Research Company, Richmond, California & U.S. Bureau of Mines, Bartlesville, Oklahoma, American Petroleum Reprint No. 41-69, 1969.

ABSTRACT

The API and the U.S. Bureau of Mines cooperatively have studied the influence of fuel volatility and front-end olefin on vehicular exhaust and fuel system emissions. Experimental work was done with sixteen 1966 and 1968 model vehicles among which there were broad differences in engine size, vehicle weight, and fuel systems. Six different gasolines were tested. Both exhaust and evaporative emissions, including hot soak losses, were measured in operating the vehicles on an all-weather chassis dynamometer to simulate city driving at four temperatures ranging from 20-95°F. Additional to the measurement of hydrocarbon concentration and composition, photochemical behavior of the emissions was studied using a laboratory photo-irradiation (smog) chamber.

Results showed that volatility reduction reduced both the quantitative total of exhaust and evaporative losses and the photochemical effect from these emissions. Replacing the olefin in the front end of the fuel with no change in volatility did not change the quantity of total hydrocarbon emissions but did reduce the photochemical effect of these emissions. The reduction in photochemical effect by olefin replacement was greater than the reduction from lowering fuel volatility to the lowest level considered in this study.

M

Taylor, G.W., Winter Testing of Automobile Idle Exhaust Emissions in Edmonton, Alberta, Surveillance Report EPS 5-AP-73-14, Environment Canada, Environmental Protection, September 1973.

ABSTRACT

The data presented in this report are the result of a six month automobile idle emission testing program carried out by the Alberta Motor Association under contract with Environment Canada. Tests were performed on over 3500 vehicles and emission distribution graphs were prepared from the results of 2300 of those tested.

A seven car control fleet was also operated to assess any influence that cold ambient temperatures might have on idle emission concentrations. The results indicated that because of fluctuations in the vehicles' state of tune and warm-up times, it was not possible to isolate any apparent effect of ambient temperature on idle emission levels. However, the engine temperature was postulated to be the primary idle emission-related parameter, with ambient temperature having only nominal influence. For this reason, it is recommended that any vehicle inspection program ensure that cars being tested are fully warmed up by setting minimum pre-test operating times.

The results produced are believed to give a reliable indication of the idle concentrations of emissions from cars in Alberta; however, because the sample was not wholly representative there may be slight biasing of the total vehicle population results towards lower emission levels.

The program further indicated that it is feasible to operate a mobile idle emission testing unit all year round without fear of inaccuracy of measurement or excessive program down time.

Turner, R.K., and H.J. Coutts, Fairbanks, Alaska Autmotive Retrofit Evaluation Study, U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, Arctic Environmental Research Station, College, Alaska 99701, Working Paper No. 29, CERL-004, December 1975.

ABSTRACT

During the winter of 1974-1975, automotive retrofit pollution control devices were installed on 18 domestic in-service automobiles to evaluate their winter performance for carbon monoxide emission reduction, driveability and fuel economy. The retrofit devices were (1) air bleed to intake manifold, (2) exhaust gas recirculation plus air bleed, and (3) catalytic converters. The emissions were measured at idle and at 2500 no-load rpm.

The air bleed devices initially functioned on 8 out of 11 installations. For the 8-month study, the overall carbon monoxide reduction was 44 percent. Fuel economy increased 2 to 3 percent. The exhaust gas recirculation plus air bleed devices were successful on 3 out of 4 installations. A 30 percent overall reduction in carbon monoxide was attained. Fuel economy increased about 1 percent. The average carbon monoxide reduction for catalytic converters was 62 percent. These devices worked on all four test vehicles. Fuel economy was not expected to be affected.

Conclusions indicate that, technically, the retrofits work, but the practicality of a mandatory retrofit program for the Fairbanks area is in question.

Verrelli, L.D. and T. E. Moyer, Cold Start Automobile Emission and Inspection/Maintenance Effectiveness, Department of Environmental Conservation, State of Alaska, Fairbanks, Alaska, Air Pollution Control Association, Pacific Northwest International Section, Vancouver, British Columbia, November 1982.

ABSTRACT

This paper is about cold climate automobile emissions, their causes, effects, remedies and difficulties in characterizing. Greatest emphasis is placed on discussing the effectiveness of inspection and maintenance on reducing emissions generated during a cold start, as determined in the Mobile Emission Test Facility (METFac), a unique automotive testing laboratory. Modifications made to the standard testing procedure are detailed as are modifications made to the test equipment itself for compatibility with the low test temperature and 29° F.

A brief discussion on the dynamics of cold starts will be included as background to previous cold temperature work that has led up to this program. How the data will be used is detailed, especially in the context of SIP submittals. Importantly, proposals for long term solutions are idealized as they pertain to the Clear Air Act Amendments and/or possible changes in EPA administrative practices. Plans for winter 1982-83 research are outlined to build on the data base and investigate alternative cold start control methods.

Voelz, F. L., Fairbanks Alaska - 1974 Motor Vehicle Emissions Inspection Results, Atlantic Richfield Company, June 1976.

ABSTRACT

During the period October 15 - November 9, 1974, the Environmental Services Department of Fairbanks, North Star Borough Alaska conducted a public vehicle exhaust emissions testing program. Tailpipe hydrocarbon (HC) and carbon monoxide (CO) emissions were measured for each vehicle inspected at no load engine speeds of idle and 2500 RPM. Approximately 500 vehicles participated in the program with 24% of those tested being imports. Testing was conducted in one shopping center parking lot located in the CBD.

Other Forms of Air Pollution

The references in this section include the following topics:

Wood smoke
Pollen
Dust

Anderson J.H., Aeropalynology Research in Alaska - Review and Outlook, Institute of Arctic Bioogy, University of Alaska, Fairbanks, Alaska, Paper presented at 34th Alaska Science Conference, Whitehorse, Yukon, 1983.

ABSTRACT

Results mostly from Juneau, Palmer, and Fairbanks are reviewed. Six pollen and spore calendars are presented showing the seasonal course of aeropalynological activity. Diurnal variations in airborne pollen and spores are illustrated. A prototype standard pollen calendar for birch in Fairbanks is presented. Data from four years of sampling in Fairbanks are comparatively analyzed to demonstrate significant year-to-year variations in six aeropalynological parameters.

Continuing research needs and possible directions and benefits are mentioned at several points, and plans for the 1984 sample season are outlined. Sampling will be extended to Whitehorse in 1984 even if only a minimal program can be sustained.

Chapple, T., Juneau Mendenhall Valley Carbon Monoxide Study, Alaska Department of Environmental Conservation, Project Summary Report, January 21, 1983 - March 14, 1983.

ABSTRACT

High particulate matter pollution from residential wood burning activities raised a concern for the potential existence of unhealthy exposures of carbon monoxide as generated by both residential and vehicular activities.

A study was designed and implemented whereby eight temporary monitoring sites (9 monitors) were established and operated for a selected 8-hour evening period of an eight week time span beginning mid-January 1983. Although exposures were found to be generally of low magnitude due to above normal temperatures and other controlling factors, two specific periods exhibited carbon monoxide concentrations to a maximum of 6.5 parts per million. Highest values were reported along major traffic corridors. However, corridor sites which were also subject to a significant residential impact component yielded the maximum values for the study period.

Residential impacts were found to be a major component and, for many areas, the controlling factor. Control strategies being implemented to reduce particulate emissions from residential wood burning devices should also be successful in maintaining carbon monoxide levels below the 9 part per million 8-hour ambient standard.

Cooper, J.A., and C.A. Frazier, Preliminary Source Apportionment of Winter Particulate Mass in Juneau, Alaska, Final Report, Vol. I, prepared for Alaska Department of Environmental Conservation, 3220 Hospital Drive, Juneau, Alaska 99811, June 13, 1983.

ABSTRACT

This study used chemical mass balance (CMB) receptor model methods to quantify the contribution of residential wood combustion (RWC) emissions to the Juneau-Mendenhall Valley. This method uses chemical fingerprints to identify each major source contributing to suspended particulate levels. The lead and bromine, for example, are commonly associated with the automotive exhaust fingerprint due to the combustion of leaded gasoline. On the other hand, aluminum, silicon, calcium, titanium, manganese, iron, etc. are associated with crustal sources such as road and windblown dust, while fine particle organic carbon, potassium, and zinc are associated with a RWC fingerprint.

The results from this study clearly show that RWC sources contributed between 100 and 230 $\mu g/m^3$ of fine particulate mass on cold, calm days and are responsible for between 40% and 90% of the TSP, depending mainly on the relative contribution of crustal dust sources such as road and parking lot dust. The dust contributions were much more variable ranging from less than detection limits to over 300 $\mu g/m^3$, depending mainly on ground conditions (dry, snow, or rain). RWC impacts were highest at the Floyd Dryden site and lowest at the Municipal Building site, while transportation source contributions were highest at the Super Bear site.

(M)

Joy, Richard and Pat Fisher, Ambient total suspended particulate (TSP) levels in the vicinity of a dirt track raceway, Fairbanks North Star Borough Environmental Services Department.

ABSTRACT

Ambient particulate levels have been monitored near a dirt track raceway. Weather conditions and track use are analyzed to determine the main parameters influencing dust generation.

M

Laroe, Steve, Fuel Wood Utilization in the Fairbanks North Star Borough, Interior Wood Cutters Association, 1982.

ABSTRACT

A total of 1148 questionnaires were sent in a random sample taken from a total available universe of 17,840. Responses were received from 641 of these samples, with 526 of those containing useable replies. From these 526 replies, the conclusions stated in this report were drawn. The standard deviation is 116.5 and the standard error for a significant (19 out of 20) conclusion is 3.78 percentage points. This figure means that each percentage stated in the report can vary ± 3.78 percentage points and still be within two standard deviations from the mean and have a 95% probability of being accurate.

McCandless, Robert G., Wood Smoke and Air Pollution at Whitehorse, Yukon Territory, 1981-1982. Environmental Protection Service, Regional Program Report 82-16, December 1982.

ABSTRACT

An ever-increasing number of homes in northern Canada rely on wood stoves for heating, alone or in combination with oil furnaces or electric heating. However, wintertime air conditions in the north are particularly stable and conducive to air pollution. The Environmental Protection Service, Yukon Branch, has responded to inquiries from the public by monitoring air conditions in a neighbourhood of Whitehorse. This report includes data from two winters' monitoring of total suspended particulate matter from Riverdale. On those days which had low temperatures in combination with calm or low wind conditions, levels of suspended particulate matter exceeded national guidelines. Also, measured levels of polycyclic aromatic hydrocarbons or PAH in that particulate matter at times exceeded those reported from monitoring surveys conducted in industrial cities. Since several of these compounds are known to have carcinogenic properties, these levels are of interest from an environmental health standpoint. This report recommends action by government to inform the public about possible health risks associated with air pollution from wood combustion, and preventative techniques available to reduce this air pollution.

NEA, Inc., Quantification of Impact of Residential Wood Combusion on Particulate Concentrations in Whitehorse, Y.T., Using Chemical Receptor Modelling Techniques, Final Report prepared for Dept. of Environment, Ottawa. (NEA, Inc., 10050 S.W. 5th Street, Suite 380, Beaverton, Orego, 97005, 1983.

ABSTRACT

Four high-volume TSP filters have been analyzed for their radio-carbon content and thirty dichotomous filters have been analyzed by x-ray flourescence. The resulting ambient elemental profiles were interpreted by chemical mass balance methods to determine the major sources responsible for the Riverdale (a suburb of Whitehorse, Y.T.) winter haze. On the average, 95% of the particulate material was in the fine particle fraction, i.e., less than 2.5 μm. The S, K, Br, and Pb were predominantly in the fine fraction while the only element consistently dominated by coarse particles was Ca.

The best estimate of the source contributions based on the current data are as follows:

Residential Wood Combustion	> 89.3% (109.08 $\mu g/m^3$)
Distillate Oil	< 9.3% (11.40 $\mu g/m^3$)
Transportation	1.1% (1.33 $\mu g/m^3$)
Road Dust	< 0.3% (< 0.36 $\mu g/m^3$)

SENES Consultants Ltd., Pollution from Woodstoves in Riverdale, Yukon Territory. 499 McNicoll, Ave., Willowdale, Ontarior, Canada, M2H 2CG, 1983.

ABSTRACT

This report presents data analysis and interpretation of the effect of wood stove emissions on air quality in Riverdale, Yukon during the 1982-1983 heating season. The variables assessed included Total Suspended Particulates (TSP), Total Polyaromatic Hydrocarbons (Total PAH), Individual PAH, Carbon Monoxide (C), Wind Speed, Sunshine, Vertical Potential Temperature Gradient ($\Delta T/\Delta Z$), and Temperature Range over 25 hours (Tmax-Tmin).

The use of wood as a heating fuel in Riverdale has been increasing since 1980. This has lead to increased emissions of fine particulates and polyaromatic hydrocarbons. Under poor dispersion conditions which are prevalent about half the time in Riverdale during the wood burning season, pollutant levels become elevated. As a result, concentrations of TSP and PAH in Riverdale are amongst the highest measured in Canada and the United States. Control measures such as switching to an alternate fuel or to more efficient wood-burning equipment could reduce pollutant concentrations to acceptable levels.

Air Pollution Monitoring Efforts

The references in this section include the following topics:

Pollution surveillance, monitoring and surveys in the cold regions
Air emission inventories
Air quality baseline studies

Air Pollution Control Directorate Report, National air pollution surveillance, annual summary for 1978, Environment Canada, Air Pollution Control Directorate, Ottawa, Canada, Report EPS 5-AP78-26, September 1979, 62 p.

ABSTRACT

Data on measured pollutants from a network of 63 stations in 54 cities across Canada from St. Johns, Newfoundland, to Vancouver and Victoria, B.C., and two stations in the Arctic (Whitehorse, Y.T., and Yellowknife, N.W.T.) are tabulated for each month of 1978 and for the year. The elements measured include SO.SUB 2., CO, NO.SUB 2., O.SUB 3., and COH (the soiling index); suspended particulates; lead; dustfall; sulfation rate; and a combination of SO.SUB 2. and suspended particulates. The methods of measuring or calculating parameter units used in tables and methods of data presentation are described in French and English in the introduction. Coordinates of stations and elements measured at each are tabulated, and the locations are shown on a map of Canada. The larger cities have many stations in various locations for urban pollution studies: 16 stations in Montreal; 14 in Toronto; 12 in Edmonton; 11 in Calgary; 10 in Winnipeg; seven in Vancouver; five each in Windsor, Halifax, and Quebec; etc. These urban sites sample most or all of the pollutants, whereas most of the smaller towns measure only SO.SUB 2., COH, suspended particulates, and lead. For most of the elements or indexes, the frequencies or percentages (centiles) from 10 to 99.9% and maximum values are tabulated for 2- and 24-hr periods, as well as the means and standard deviations for each month.

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Bennett, F. Lawrence, P.E., An Air Emission Inventory Computer Program, Final Report submitted to Fairbanks North Star Borough, Department of Environmental Services, December 1974.

ABSTRACT

This report describes a computer program that has been developed to assist the Fairbanks North Star Borough in cataloguing and summarizing air emissions data. The project was carried out under an agreement with the Borough dated July 22, 1974.

The report contains a short description of each of the two programs that were written, together with a summary of a preliminary analysis of point source air emissions data that were processed using one of the programs. The major portion of the report consists of a users' manual that will assist borough personnel in implementing the program.

CANSAP Data Summary, UDC:551.578.8, Environment Canada, Atmospheric Environment Service, 1981.

ABSTRACT

This publication contains the data for the year 1981. Beginning with these data, a new format for the presentation has been initiated. The data summary for the years 1977-1980 are available in this format and can be obtained from the Atmospheric Environment Service for a nominal charge. Commencing with the 1982 data, there will be an annual charge for the CANSAP data publications. Each year the publications will be two 6-month data summaries and an annual report. The annual report for 1981 is in preparation.

The precipitation chemistry data presented in this document were generated by the Canadian Network for Sampling Precipitation (CANSAP). The samples are collected over the period of a month using precipitation collectors that sample only precipitation and exclude dust and other types of dry fallout when precipitation is not occurring. Most of the sampling sites shown on the map are located at Atmospheric Environment Service Weather Observing Stations. The samples are analyzed by the Water Quality Branch Laboratory at the Canada Centre for Inland Waters in Burlington (Ontario). The data are archived in the National Water Quality Data Bank (NAQUADAT) and are published by the Air Quality and Inter-Environmental Research Branch of the Atmospheric Environment Service. Precipitation chemistry data from the stations in the WMO Regional Background Air Pollution Monitoring Network are also included since they are completely compatible with that from CANSAP.

Coutts, Harold J., A Study of Winter Air Pollutants at Fairbanks, Alaska, Corvallis Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Corvallis, Oregon 97330, September 1979.

ABSTRACT

It has been well documented for the past ten years that Fairbanks, Alaska has an air pollution problem with carbon monoxide (CO), particulates and ice fog, but there are other pollutants that have not been routinely monitored.

In addition, the theory has been raised that the low temperature and low insolation at this latitude may enhance conversion of precursory pollutants into their more toxic forms, e.g., nitric oxide into nitrogen dixide.

Consequently an air pollution monitoring program was initiated by the Arctic Environmental Research Station (AERS). Ambient monitoring was done throughout the winters of 76-77 and 77-78 at the old downtown Fairbanks Post Office and also on the AERS roof during the winter of 76-77. Indoor-outdoor monitoring was done at the new State Building during January 1979. Lead data obtained by the Fairbanks North Star Borough is also presented.

Pollutants measured during the first winter were nitric oxide (NO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), total suspended particulates (TSP), sulfate ($SO_4^=$), nitrate (NO_3), and lead (Pb). During the second winter, only the gaseous forms were measured. At the State Building NO, NO_2, and CO were measured.

High values, compared to those measured in the contiguous states, were found for NO and Pb. Most SO_2 levels were below the analyzer sensitivity of 0.004 ppm. The health effects of the measured levels of NO are not known, but Pb levels exceeded EPA standards. More monitoring for Pb is needed and, if the high concentrations are found to be area wide, then local authorities may want to consider restrictions on use of leaded gasoline during the winter months.

The garage under the new State Building with attendant air infiltration appeared to be responsible for higher indoor than outdoor CO levels. There was no evidence found that the natural environment hastened the transformation of NO and SO_2 to their more toxic forms.

Crow W., B. Lambeth, R. Evans, and Radian Staff, Air Quality & Meteorological Study at Prudhoe Bay, April 1, 1979 to March 31, 1980, Radian Corporation, 8501 Mo-Pac Blvd., P.O. Box 9948, Austin, Texas 78766, DCN #81-120-235-54, January 1981.

ABSTRACT

This report documents the results of a comprehensive one-year air quality and meteorological monitoring study conducted by Radian Corporation on behalf of the Prudhoe Bay Unit Operators. The purpose of the study was to obtain valid baseline air quality and meteorological data for Prudhoe Bay.

Elements of the monitoring program included network design, system fabrication, installation, operation, and data validation and reporting. In addition, an extensive quality assurance program was implemented to substantiate the validity of the data reported throughout the course of the program.

Fairbanks North Star Borough, Report No. 74-001, Particulate Snow Survey, March 1974.

ABSTRACT

The Environmental Services Department of the Fairbanks North Star Borough has completed a snow survey to determine the impact of MUS's power plant particulate emissions on the snow pack as dustfall in the residential area south of the plant. In addition to the immediate area surrounding MUS, snow samples were taken in other areas of the Fairbanks basin.

The snow pack in the Fairbanks area served as a dustfall collection filter as it contained the dustfall from the first snow fall in October 1973, until the samples were collected in March 1974, which covers a time span of near 160 days - a time during which power plant activity is at its maximum.

Each snow sample was carefully collected with a snow corer and sampled from the top of the snow pack to within 1/2" of the ground surface. These samples were analyzed for the amount of dustfall content, and the specific electrical conductance and pH of the snow melt.

Fairbanks North Star Borough Report, Carbon Monoxide Levels in Fairbanks, Alaska, Winter of 1977-78.

ABSTRACT

Ambient air quality sampling was begun in Fairbanks in 1969 by the Arctic Health Research Center. The results of this preliminary monitoring indicated that high carbon monoxide levels were occurring during the winter months. During the winter the Fairbanks area experiences severe temperature inversions, which result in a trapping of pollutants near the surface of the ground and in an absence of vertical dispersion of the pollutants. Due to the location of the hills surrounding the city and the absence of wind during the wintertime, there is very little horizontal dispersion as well. Therefore, the carbon monoxide, which in Fairbanks is generated almost totally by the automobile, just sits and builds up concentrations over town.

Gamara, K. E. and R. A. Nunes, Air Quality and Meteorological Baseline Study for Prudhoe Bay, Alaska, June 1974 - June 1975, Technical Report No. 217, Metronics Associates, Inc. January, 1976.

ABSTRACT

Environmental monitoring and sampling extended over a twelve-month period from 21 June 1974 to 21 June 1975 and encompassed acquisition of selected air quality and meteorological information. Specifically, the following parameters were either measured directly or derived indirectly from related parameters: wind speed, wind direction, ambient air temperature, total insolation, ultraviolet radiation, total hydrocarbons (THC), methane (CH_4), non-methane hydrocarbons, carbon monoxide (CO), sulfur dioxide (SO_2), hydrogen sulfide (H_2S), total sulfur (TS), nitric oxide (NO), nitrogen dioxide (NO_2), nitrogen oxides (NO_x), ozone (O_3), and total suspended particulates.

Gilmore, Timothy M., Thomas R. Hanna, Applicability of the Mass Concentration Standards for Particulate Matter in Alaska Areas, J. Air Pollut. Control Assoc., V. 25, p. 535-539, May 1975.

ABSTRACT

High particulate matter concentrations have been measured in several communities in Alaska using high volume air samplers. Because of these measurements, Anchorage and Fairbanks have been classified Priority 1 for particulate matter. A possible method for relating high volume air sampler data to ambient air particulate matter standards based on size distribution is presented. The results presented indicate that mass concentration data alone do not provide an index of possible health hazard in Alaska and probably other rural areas.

Gilmore, Timothy M., and Thomas R. Hanna, Regional Monitoring of Ambient Air Carbon Monoxide in Fairbanks, Alaska, J. Air Pollut. Control Assoc., Vol. 24, p. 1077-1079, November 1974.

ABSTRACT

A method employing the timed fill of Mylar bags was used to obtain average carbon monoxide concentration values for ten locations in the Fairbanks, Alaska, area. The method is shown to be accurate, reliable and inexpensive. The correlation coefficient between the bag sampling method and a continuous carbon monoxide analyzer was 0.945; correlation of carbon monoxide data from several locations to a reference in downtown Fairbanks showed a general decrease with distance from the reference analyzer.

Jenkins, T. F., R. P. Murrman and B. E. Brockett, Accumulation of Atmospheric Pollutants Near Fairbanks, Alaska, During Winter, Special Report 225, CRREL, Hanover, New Hampshire, April 1975.

ABSTRACT

Concentrations of hydrocarbons, carbon monoxide, carbon dioxide, condensation nuclei and nitric oxide were monitored near Fairbanks, Alaska, at a selected location not under the direct influence of a local pollution source. The measurements were made continuously over a period of weeks during January and February 1973, the period when atmospheric pollution would be expected to be most severe. Accumulation and dissipation of the pollutants was found to be related to atmospheric inversion conditions, wind speed and daily traffic patterns. Maximum hourly average concentrations of hydrocarbons, carbon monoxide, carbon dioxide and condensation nuclei were 9.7 ppm, 22.1 pp, 482 ppm and more than 10^4 N/cm^3 respectively. Comparative background levels are reported to be

Lafleur, R.J., E. P. Wintuschek, J. H. Emslie, Cold Weather Carbon Monoxide Survey at Whitehorse, Yukon Territory. Presented at 1976 Annual Meeting of the Pacific Northwest International Section; Air Pllution Control Association, Anchorage, Alaska, September 15-17, 1976. (Environment Canada, Environmental Protection Service, Room 225, Federal Building, White Horse, Y.T., Y1A 2B5) 1976.

ABSTRACT

An assessment of the winter-time carbon monoxide (CO) concentrations at ground level in the City of Whitehorse, Yukon Territory is presented herein. The measurements were carried out during the cold weather months over a three-year period (1974-76) utilizing a combination of continuous monitors togetheer with a network of integrating samplers. During cold weatheer months very stable atmospheric conditions, attendant intense inversion gradients, and limited ventilation within the valley setting of this city combine to result in CO concentrations that exceed the federal National Air Quality Objectives but only infrequently. During a twelve week measurement period in 1974, the Maximum Acceptable 8-hour average of the federal National Air Quality Objectives was exceeded on 6 separate days. The occurrence of maximum concentrations coincide with the previously mentioned stable atmospheric conditions together with low ambient temperatures when motorists allow continued idling of vehicles during daytime use. The data from this study substantiates earlier findings of work carried out at Fairbanks, Alaska having comparable meteorological conditions, although the pollution problem is not as severe as at the Alaska location. The bag sampling system was provent to be a reliable and inexpensive integrating method for field sampling of CO.

National Atmospheric Deposition Program, NADP Report: Precipitation Chemistry; First Quarter 1981. Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, Colorado, 169 pp. 1983.

ABSTRACT

Data on calcium, nitrate pH, sulfate and weekly precipitation for about 80 U.S. stations are presented. The only Alaskan station is at Denali (McKinley).

Norbeck, J. M., and T. Y. Chang, An Analysis of Ambient CO Concentrations in Alaska, Engineering and Research Staff, Research, Ford Motor Company, June 1982.

ABSTRACT

The Alaskan cities of Fairbanks (population: 25,600) and Anchorage (population: 205,000) have reported some of the highest ambient carbon monoxide (CO) concentrations in the United States. For example, the CO monitoring site at Benson and Spenard Sts. in Anchorage recorded the highest 8-hour average CO concentration in the United States in 1980 of 27.4 ppm. These high CO concentrations in Alaska occur only in winter. During other times of the year the ambient CO concentrations in Alaska are significantly lower than those observed in other cities in the United States that have comparable high values. Recent calculations by the Alaskan Department of Conservation (ADEC)[1], the Fairbanks North Star Borough (FNSB)[2], and the Municipality of Anchorage[3] have indicated that both Fairbanks and Anchorage will have difficulty meeting the primary National Ambient Air Quality Standard (NAAQS) for CO (9 ppm 2nd maximum 8-hr average CO concentration) by 1987 without the implementatin of other emission control programs (e.g., inspection maintenance, conversion to gasohol fuel, etc.). These calculations were done using a simplified total tonnage rollback model, which has been shown to underpredict the improvement expected in air quality (4), and EPA emission factors that were based on early estimates of future performance of emission control systems (MOBILE 2)[5]. The most recent EPA surveillance data[6] of in-use vehicles indicated that these initial estimates resulted in future year emission factors being too high.

Sierra Research, Carbon Monoxide Air Quality Trends in Fairbanks, Alaska, prepared for Fairbanks North Star Borough, September 9, 1982.

ABSTRACT

An analysis of 8-hour average carbon monozide concentrations at two locations in downtown Fairbanks shows two distinctly different trends: a consistent, gradual decrease in the seasonal average of daily maximum 8-hour concentrations; and a slight increase, followed by a decrease in later years, in the seasonal peak concentrations.

Schweiss, Jon W., Anchorage Carbon Monoxide Study, U.S. Environmental Protection Agency, Region 10, Printed Report, November 1983.

ABSTRACT

Typically, levels of ambient carbon monoxide (CO) vary widely among the four existing permanent monitoring sites distributed throughout the city of Anchorage. An ambient air sampling program was designed and implemented to clarify and define, if possible, the relationship of carbon monoxide (CO) levels reported from these permanent sites and levels occurring elsewhere in the city. Integrated bag sampling was conducted on weekdays at approximately 50 sites during the interval spanning November 22, 1982 and February 11, 1983. Samples collected from each site were analyzed by the non-dispersive infrared (NDIR) method. Comparisons were then made between data arising from the study sites and the four permanent monitoring sites. A comprehensive quality assurance program was developed and ordered to the study to ensure the collection of data that were of known and appropriate accuracy, precision, representativeness, comparability and completeness.

In largely fulfilling the purpose of the study, the primary conclusions arising from analysis of the study data were twofold: 1) The permanent monitoring network does not adequately characterize either the absolute magnitude of CO levels or the frequency of standards exceedances encountered at an array of locations elsewhere in the study area, and 2) The basic or immediate representativeness of each permanent monitoring site has been established.

TRW Systems Group, Redondo Beach, Califoria, Air Emission Inventory State of Alaska, Report No. TRW-18425.002, 77 p. August 1971.

ABSTRACT

The results of a statewide air emission inventory performed State of Alaska are presented. These results are intended to support the preparation of the State's air quality implementation plan. The data were obtained from a variety of sources including questionnaires returned from industrial, commercial and governmental organization. The calculation of emission of particulates, SO(x), CO, hydrocarbons and NO(x) from area sources and point sources representing emissions in excess of 5 tons per year, were performed. The report includes the following: description of the four air quality regions in Alaska; a summary and tabulation for each of the 5 pollutants for Anchorage, Fairbanks, and the air quality regions; data on fuel usage, fuel parameters, and refuse disposal rates and; a summary of the methodology used to identify emission sources.

Effects of Cold Regions Air Pollution

The references in this section include the following topics:

Health effects in the cold regions
Effects on biota
Acid rain
Other environmental consequences

Brydges, Thomas G. and Gary E. Glass, Memorandum of Intent on Transboundary Air Pollution, State of Knowledge Survey, Aquatic Impact Assessment, United States-Canada, Work Group I, Supplemental Document I, August 1981.

ABSTRACT

A state-of-the-knowledge survey was conducted to meet the requirements of the Phase I Work Plan of the U.S.-Canada Transboundary Air Pollution Agreement. Summary sheets calling for results of significant studies were sent to about 1,000 scientists and government department heads in the United States and Canada. Over 400 responses were received including 300 from principal investigators who returned one or more pertinent reports of significant findings.

The information obtained from the survey is reported here in four major sections: (1) catalogue of expertise and directory; (2) aquatic; (3) terrestrial; and (4) atmospheric. Each section includes a keyword and author index.

There are 784 abstracts, annotations, summaries, and progress reports that identify and assess physical and biological consequences possibly related to transboundary air pollution (including acid precipitation). This research information will be used to bring forward the most up-to-date findings to the decision makers of public policy and for the protection of the environment in North America.

Galloway, J. N., et al., The Composition of Precipitation in Remote Areas of the World, J. of Geophysical Research, Vol. 87, 8771-8786, 1982.

ABSTRACT

The Global Precipitation Chemistry Project Collects precipitation by event to determine composition and processes controlling it in five remote areas. Compositions (excluding seasalt) at St. Georges, Bermuda, and Poker Flat, Alaska, were primarily controlled by anthropogenic processes; compositions and acidities at San Carlos, Venezuela, Katherine, Australia, and Amsterdam Island were controlled by mixtures of natural or anthropogenic processes. Precipitation was acidic; average volume-weighted pH values were 4.8 for Bermuda; 5.0, Alaska; 4.9, Amsterdam Island; 4.8, Australia; 4.8, Venezuela. Acidities at Bermuda and Alaska were from long-range transport of sulfate aerosol; at Venezuela, Australia, and Amsterdam Island, from mixtures of weak organic and strong mineral acids, primarily H_2SO_4. Relative proportions of weak to strong acids were largest at Venezuela and lowest at Amsterdam Island. Weak and strong acids were from mixtures of natural and anthropogenic processes. Once contributions from human activities were removed, the lower limit of natural contributions was probably > pH 5.

Holtzman, Richard B., RA 226 and the Natural Airborne Nuclides PB 210, and PO 210 in Arctic Biota. In: Radiation Protection, Part 2, S.W. Synder (ed.)., New York, Pergamon Pressm p. 1087-1096, 1968.

ABSTRACT

In order to better determine the characteristics and effects on humans of arctic biota with high concentrations of lead (210) and Polonium (210), these nuclides, along with their long-lived predecessor, radium (226), were measured in lichens, in bone and muscle of caribou and other arctic animals, and in Eskimo placenta. The Ra (226) with concentrations 1/3 to 1/50 of the other nuclides, cannot be the direct source of the other nuclides. In caribou bone the Po (210) was in radioactive equilibrium with the Pb (210) and averaged about 11.7 PCi/g ash, twice the Pb (210) in reindeer bone. The Pb (210) content of muscle of both species was 10PCi/kg (wet). By contrast, the Po (210) content was much greater, about 200 PCi/kg. A definite seasonal decrease was noted in the lead in muscle during the second half of the year. Similar variations were indicated for Polonium in muscle and for lead in bone. The high levels in caribou are attributed to the high fallout levels of these nuclides in lichens, their winter forage, which contain (in dry weight) 6 PCi and 12 PCi Pb (210)/g. The other animals exhibited appreciably lower concentrations in bone and muscle. Wolf, which consumes large quantities of caribou, exhibited activities in bone of 1 PCi/g ash, about that observed in some Eskimo bone. The Po (210) content of wolf muscle was about the same as that of caribou, 200 PCi/kg, but the Pb (210) was only about 1 PCi/kg. Similar, but less dramatic, differences were observed in Eskimo placenta. Estimates of uptake show that Eskimos could acquire sufficient of the long-lived pb (210) to double the total skeletal radiation dose (rad) over that of Midwesterners. However, despite the high concentrations of Po (210) in meat, direct intake accounts for only a relatively small increase in total dose.

Joy, Richard W., Timothy Tilsworth, and Darrel D. Williams, Carbon Monoxide Exposure and Human Health, Institute of Water Resources Report No. 61, University of Alaska, February 1975.

ABSTRACT

A literature review of the effects of both chronic and acute exposure to carbon monoxide has been prepared. This was felt to be necessary in view of the fact that:

1. No comprehensive and up-to-date review of this subject exists, and

2. A controversy currently exists as to whether or not the carbon monoxide levels in the Fairbanks air are detrimental to human health, and whether or not the ambient air standards for carbon monoxide established by the U.S. Environmental Protection Agency (EPA) are appropriate.

199 abstracts of the literature reviewed are contained in the appendices of this paper. These abstracts are provided as a source of additional information for readers possessing a technical knowledge of the subject. A summary of the literature reviewed is presented herein.

Koerner, R. M. and D. Fisher, Acid Snow in the Canadian high Arctic, Nature, Vol. 295, 1982.

ABSTRACT

Increasing levels of acid sulphates in precipitation have recently been discovered in locations as far north as Barrow, Alaska and Bear Island (74° N and 19° E) in the Norwegian Sea[1–4]. The high sulphur concentrations are attributed to mid-latitude Eurasian sources[1]. We present here acid concentrations (each representing several years of snow accumulation) in ice from part of a 337-m surface-to-bedrock core on northern Ellesmere Island (81° N, 73° W) representing the past 5,000 yr and compare these with significantly higher acid concentrations in snow deposited over the past 25 yr at the same location showing seasonal variations in the concentrations which together constitute a significant trend of increasing acid levels over the past 25 yr.

Legrand, Michel R, Alberta J. Aristarain and Robert J. Delmas, Acid Titration of Polar Snow, Anal. Chem. 54, 1336-1339, 1982.

ABSTRACT

The acidity (or alkalinity) of polar precipitation is a parameter of great interest in the invesitgation of several global geochemical problems. This paper describes the contamination-free sampling and sample handling techniques used and a titration method suitable for determining the ultralow acidity levels of polar precipitation. Test experiments were performed to evaluate the accuracy (±0.2 μequiv L^{-1}) of the method in the 0–10 μequiv L^{-1} acidity and alkalinity ranges. These first acidity determinations of Antarctic snow and ancient ice samples illustrate the value of the developed procedure, which could be particularly useful for nearly neutral unbuffered natural water samples such as cloud and rain water collected in remote locations.

Norton, Stephen A., John J. Akielaszek, Terry A. Haines, Kenneth L. Stromborg, Jerry R. Longcore, Bedrock Geologic Control of Sensitivity of Aquatic Ecosystems in the United States to Acidic Deposition,

ABSTRACT

The effects of acidic precipitation on the chemistry of aquatic ecosystems are a function of different geologic conditions, hydrologic characterstics of the terrain (i.e., overland flow versus groundwater flow, soil porosity/permeability, residence time of water in the soil), distribution and amounts of precipitation through time, type of precipitation, thickness of soil, types of soils (residual, glacial [till, ice-contact stratified, etc.], aeolian, lacustrine, alluvial, etc.), age of soil, vegetation types, and changing land use. Recently acidified clear water lakes and streams generally occur only where precipitation pH is less than that predicted by CO_2-H_2O equilibria (pH 5.4-5.7, depending on temperature). Acidified lakes in Scandinavia, Scotland, and the Adirondack Mountains of New York occur only where precipitation pH is less than 4.7 (Wright et al., 1980). Charlson (1982) has suggested that natural emissions of S compounds may result in precipitation with a pH as low as 4.5, but only very locally.

Overrein, Lars, N., Hans Martin Seip and Arne Tollan, Acid precipitation effects on forest and fish, Final Report of the SNSF project 1972-1980, December 1980.

ABSTRACT

The Norwegian interdisciplinary research programme "Acid Precipitation – Effects on Forest and Fish" (The SNSF-project) was launched in 1972 in response to wide-spread concern, especially in Scandinavian countries, that acid precipitation was causing changes to the natural environment.

A major hypothesis has been that anthropogenic release of sulphur oxides and other pollutants may alter geobiochemical and biochemical cycles with consequences for the biota. The main research efforts were directed towards possible threats to forest and freshwater fish.

The final project report presented here is based on nearly 300 previously published SNSF-reports and publications in various international journals.

Ottar, B., Long Range Transport of Air Pollution and Acid Rain Formation, Norwegian Inst. Air Res., Lillestrom, Norway, 1980.

The increasing acidification of the precipitation in Europe was first pointed out in 1968 by Oden, who related this to the acidification observed in rivers and lakes in Scandinavia and the increasing use of fossil fuels with a high content of sulfur. It was shown that extensive exchange of air pollutants took place between the European countries, and in orographic precipitation areas frequently exposed to polluted air masses, excessive amounts of acid precipitation were observed. Later studies have shown that the air pollutants from Europe also find their way into the Arctic region, particularly in the winter. The main acid component of the precipitation is sulfuric acid with an addition of 20 to 50 percent of nitrate and ammonium ions on an equivalent basis. The sulfate content is largely explained by the sulfate in the aerosol phase. The content of nitrate and ammonium ions is explained by the uptake of gaseous nitric acid and ammonia from the atmosphere. Atmospheric dispersion is discussed in relation to the methods used to describe the chemical transformations and the dry and wet deposition processes.

Rahn, Kenneth A., Elinar Joranger, Arne Semb and Thomas J. Conway, High Winter Concentrations of SO_2 in the Norwegian Arctic and Transport from Eurasia, Nature, Vol. 287, No. 5785, pp. 824-826, October 1980.

ABSTRACT

Since July 1977, the Norwegian Institute for Air Research has been studying trace gases and aerosols in the atmosphere at Bear Island, an Arctic site located at 74° N and 19° E. Although Bear Island lies well north of the Arctic Circle, the warm Norwegian Sea gives it an annual mean temperature of −1.8 °C, considerably warmer than at many other Arctic locations (Barrow, Alaska, for example, is 350 km farther south but has an annual mean of −12.2 °C). In summer, Bear Island is surrounded by open water; in winter there is open sea to the south and west and pack ice to the north and east. Atmospheric samples are taken 20 m above mean sea level and 2 m above local ground: high-volume filters are taken three times a week and analysed for various elements by atomic absorption, neutron activation and wet chemistry; sulphate and sulphur dioxide are measured daily by a method similar to that of Johnson and Atkins[1], using low-volume (16 m^3) prefilters for sulphate and KOH-impregnated afterfilters for SO_2. The collection efficiency of this method for SO_2 has been tested extensively[2]. Results for the high-volume samples have been reported[3]; here we discuss the SO_2 data, which seem to indicate that during winter there is efficient transport from Eurasian midlatitudes, due at least in part to long atmospheric residence times in and around the Arctic.

Rancitelli, L. A., Trace Element Content of Alaskan Caribou and Lichen, In: Pacific Northwest Laboratory Annual Report for 1971 to the USAEC Division of Biology and Medicine, Vol. II: Physical Sciences, Part 2, Report BNWL-1651, May 1972.

ABSTRACT

To elucidate the mechanisms responsible for radionuclide transport through the Alaskan food chain, a study was conducted of 15 elements in lichen and caribou, including silver, arsenic, bromine, cobalt, chromium, cesium, iron, mercury, potassium, sodium, rubidium, antimony, scandium, selenium, and zinc. The measurements were made by instrumental neutron activation analysis using 200 mg aliquots of caribou liver, muscle and kidney tissue and lichen samples which were simultaneously analyzed for their radionuclide content. Preliminary results of the trace element analyses of caribou revealed some trace element patterns similar to those observed in marine and aquatic organisms. Trace element content data is given.

Schofield, Edmnd, Some Considerations on the Possible Effects of Local and Global Sources of Air Pollution on Lichens Grazed by Reindeer and Caribou, Alaska University, Fairbanks, Alaska, 1972, p. 90-94.

Considerable evidence shows that local sources of air pollution eliminate most lichens from the immediate vicinities of urban and industrialized areas in temperate regions. Pollutants such as sulfur dioxide appear to be transported hundred of kilometers from Britain and central Europe to Scandinavia. While there appear to be no reliable data or observations that link pollutants transported on a global scale to the deterioration of lichens there (primarily because the possibility has not been pursued), all of the ingredients necessary for lichen damage are present. Scattered comments and circumstantial evidence in the literature suggest that global pollution -- in addition to local pollution -- will adversely affect lichens grazed by reindeer and caribou. The accelerated industrialization of the Arctic makes this possibility of more than academic interest. The effects of SO2 on algal chlorophyll, osmotic effects on lichens, effects of temperature inversions and ice fogs on lichens, global versus local pollution, and possible consequences for reindeer and caribou in the Arctic are discussed.

Schofield, Edmund and Wayne L. Hamilton, Probable Damage to Tundra Biota Through Sulphur Dioxide Destruction of Lichens, Biol. Conserv., Report No. 2(4), July 1970, pp. 278-280.

Lichens, particularly the fruticose members of the genus Cladonia, are important components of many arctic ecosystems and form a principle component of the forage of indigenous caribou. The Nanamiut Eskimos, in turn, depend on the caribou for food, clothing, and other necessities. The lichens, particularly the caribou forage lichens, are extremely sensitive to sulfur dioxide. Atmospheric pollution from recent oilfield development in Arctic North America therefore seems likely to eliminate lichens from large areas. This threat is intensified by the climatic conditions on the Arctic Slope which make air pollution more serious there than in most other places. Probable future oilfield development in Greenland and the Soviet Union indicates that sulfur dioxide pollution will become an increasingly serious threat to remaining arctic ecosystems. Uncontrolled burning of crude oil, fuel oil, and natural gas should be avoided and adequate sulfur extraction facilities should be installed to protect these ecosystems.

Shaw, Roderick W. and Henning Rodhe, Non-photochemical Oxidation of SO_2 in Regionally Polluted Air During Winter, Report CM 53, Department of Meteorology, University of Stockholm, March 1981.

ABSTRACT

An examination of median concentrations of SO_2 and sulphate in air being transported from source regions in the United Kingdom and continental Europe to southern Scandinavia in the absence of precipitation indicated that even in wintertime there is an increase of sulphate with travel time. Comparisons of the observations with predictions by a simple transport model employing gas phase oxidation by OH and liquid phase oxidation by H_2O_2 indicated that an additional rate of oxidation of SO_2 of about twenty times that of OH and H_2O_2, is needed to explain the observations. For summertime conditions, with its higher concentrations of the photochemically produced OH and H_2O_2 molecules, the need for an additional oxidation mechanism was less evident.

Liquid phase oxidation by ozone was examined as a possible process in wintertime. It appears that this process could account for the estimated production of sulphate, if the pH of cloud water can be maintained above a lower limit which varies from 4.6 to 5.5 depending upon cloudiness, cloud water content and ambient ozone concentration. In view of some of the measurements reported in the literature of cloud water pH, the results from this study indicate that it is rather doubtful that ozone can be an effective enough oxidant for sulphur in wintertime. However, a more definite conclusion must await a more detailed examination of the meteorological and chemical aspects of the problem including field measurements of cloud liquid water content, chemical composition and modelling of the cycling of the air parcel in and out of clouds.

Shewchuk, S. R., An acid deposition perspective for the Northwest Territories, Dept. of Information, Government of the Northwest Territories, Yellowknife, NWT XIA 229 ($5.00/copy).

ABSTRACT

Acid deposition in the form of a wet and dry fallout from the atmosphere was reviewed for the Northwest Territories (NWT). Wet deposition at four sites in the Arctic is well documented. There is a great deal of variability in these data on a regional basis. Dry deposition is thought to be a significant atmospheric fallout mechanism in the NWT. Several studies of air pollution impacts have shown that air quality in the NWT is affected by long-range transport from continental sources. Most air pollutants impact on the Arctic in an episodic manner.

Due to lack of buffering elements, areas on the Precambrian Shield are highly sensitive to acid deposition. In general, most of the western portion of the District of Mackenzie has a low sensitivity to acid deposition. The possible impact of increased acid deposition on the Arctic Islands is not addressed due to lack of baseline data. This issue must receive increasing attention due to the extent and persistence of an Arctic haze atmospheric layer present in late winter and early spring.

Within terrestrial systems, sensitivities of higher plants to acid deposition are not well understood. It is generally believed that for low levels of acid input plant communities receive little impact. However, lichen communities which are present on extensive areas in the NWT are known to be highly sensitive to even low levels of air pollutants. Hence, the impact of increased heavy metal and acid loading on lichen communities is considered an important issue for this region.

Firm data is sparse for the Northwest Territories on aquatic system sensitivities; however, most of the freshwater lakes on the extensive Precambrian Shield are probably highly sensitive to acid deposition.

Whelpdale, D.M. and L.A. Barrie, Atmospheric monitoring network operations and results in Canada, Atmos. Environ. Serv., 4905 Dufferin St., Downsview, Ontario, Canada, M3H 5T4, Water Air Soil Pollution Vol. 18, No. 1, 2, 3, 1982, pp. 7-23.

Atmospheric monitoring activities in Canada relevant to the long-range transport of atmospheric pollutants and the "acid rain" problem are reviewed. Particular aspects examined are network objectives, station density and location, sampling protocol, and quality assurance. Results from a number of these networks are presented for the purpose of outlining the nature and extent of air and precipitation contamination by pollution released in eastern North America. Examples discussed include: the spatial distribution of acidic wet deposition, the temporal variation of acid-related substances in both air and precipitation, an episode of long-range transport, and the impact of acidic emissions on the Arctic atmosphere. Acidic wet deposition is greatest in Canada east of the Manitoba-Ontario border. In 1978, it ranged from 18 to 46 mmol H super(+) m super(-2) yr super(-1) in the southern half of eastern Canada, with maxima in southern Ontario and southwestern Quebec. Western Canada receives less acidity in precipitation, but areas of some concern are the Pacific Coast and to a lesser extent northern Alberta and Saskatchewan. Acidic emissions from mid-latitude sources which reach the Arctic in winter cause an increase in the acidity of snow from a pH of approximately 5.6 in the summer to values of 4.9 to 5.1 in January through March.

Wilson, Eedy,, Environmental Cause/Effect Phenomena Relating to Technological Development in the Canadian Arctic, National Research Council of Canada, Environmental Secretariat, Publication NRCC 13688, 136 p. April 1974.

ABSTRACT

The environmental cause/effect interrelationships observed as a consequence of man-mediated disruptions in Canadian Arctic regions are summarized. Sulfur dioxide pollution has destroyed vegetation in Southern Canada. Lichens are particularly vulnerable and have no defense mechanism against pollutants. In Fairbanks, ice fogs and stagnant air collect very high concentrations of pollutants, with the worst conditions arising from fossil fuel combustion and vehicle exhaust. In Yellowknife (Mackenzie) thermal inversions cause high local deposition of arsenic arising from smelter fumes. Concentrations are reported as high as 3 ppm. Fogs cause problems in the Edmonton (Alberta) air. Stable smoke clouds drifted north from a southern forest fire and reduced the solar radiation by 25%. Similar problems can occur with the plumes of industrial or thermoelectric stacks.

Control Measures and Plans

The references in this section include the following topics:

Impact analysis and impact statements
Clean air acts and laws
Air quality implementation plans
Alternative transportation control measures
Air quality demographic and attitudinal surveys

Aamot, Haldor W.C., Management of Power Plant Waste Heat in Cold Regions, Cold Regions Research Lab., New Hampshire, NTIS Report AD/A-003 217, December 1974, (195).

SPECIAL REPORT: THE BASIC POSSIBLE METHODS OF WASTE HEAT DISPOSAL AND AVAILABLE HEAT SINKS ARE DISCUSSED. ALTERNATIVES FOR WASTE HEAT UTILIZATION ARE DESCRIBED, AS WASTE HEAT IS A LARGE, FREE RESOURCE AND AS BETTER UTILIZATION REDUCES THE DISPOSAL PROBLEM. THE ECONOMIC FEASIBILITY OF THE PROMISING ALTERNATIVES FOR WASTE HEAT UTILIZATION ARE EVALUATED, AND THE BEST ALTERNATIVE IS CHOSEN FOR DETAILED ANALYSIS. A DESIGN FOR FAIRBANKS, ALSK., IS DESIGNED AND EVALUATED BASED ON THE MOST PROMISING CONCEPT. THE DESIGN OF A HEAT PUMP SYSTEM USING POWER PLANT COOLING WATER TO HEAT HOMES IN FAIRBANKS SHOWS THAT, COMPARED WITH OIL BURNING AND ELECTRIC RESISTANCE HEATING, WASTE HEAT DISPOSAL FROM THE PLANT IS REDUCED, AIR POLLUTION CONTROL IS IMPROVED, OVERALL ENERGY NEEDS ARE REDUCED, AND OPPORTUNITIES FOR FUEL SUBSTITUTION ARE INCREASED.

Air Pollution Control Directorate Report, Clean air act, annual report 1974-1975, Environment Canada, Air Pollution Control Directorate, Ottawa, Canada, May 1975, 39 p + 42 p.

ABSTRACT

Canada's federal and provincial efforts for FY 1975 (ending March 31, 1975); air quality objectives, inspection, protection, technical and advisory services, regulation of fuels, additives, and mobile sources; Atmospheric Environment Service work, and pertinent data for 1970-1975 concerning the control of pollution under the Clean Air Act of Nov. 1, 1971 are presented in detail with much tabular data. A map shows the Canadian National Air Pollution Surveillance network as of Sept. 1974; another map shows the 15 official WMO background air pollution stations in Canada, Alaska, northern U.S.A., and one station at sea-all parts of a global pollution network. The natural suspended particulate network includes equipment in commercial downtown core areas; that for SO.SUB 2. equipment, in 20 cities; for CO.SUB 2., in six, and for ozone, seven stations-all told, there are 432 instruments at 147 stations in 45 cities, and this includes 172 continuous gaseous pollutant monitors. Mobile stations and stratospheric chemistry studies are described. Considerable expansion of the network took place in 1974-1975.

Benson, Carl S., Role of Air Pollution in Arctic Planning and Development, Polar Record, Vol. 14, 783-790, 1969.

ABSTRACT

The role of air pollution in arctic planning and development is discussed. Low temperatures combined with strong surface inversions in wind-sheltered lowlands in the arctic areas produce exceptionally stable air masses which are easily polluted. Also the presence of the impermeable permafrost layer over much of the Arctic prevents the dispersal of man s waste products and facilitates pollution of water and land. Ice fog is low-temperature air pollution, occurring whenever cold air (minus 35 deg C or below) is calm and accompanied by a continuing source of water vapor. Sources of air pollution in Fairbanks, and the pollutant interaction with the atmosphere are reviewed. Conditions in Fairbanks are compared with those in Los Angeles for perspective. Water vapor is the greatest pollutant, contributing to the ice fog. Its sources are combustion products, power plant cooling waters, and commercial and domestic sources. Carbon dioxide, sulfur dioxide, lead in salts, and bromine and chlorine in salts are other pollutants found in the air. The future planning and development of communities in the Arctic regions must take into account the atmospheric environment in order to avoid the pollution problems of Fairbanks.

Department of Environmental Conservation, State of Alaska, Revisions to the State Air Quality Control Plan, Vol. II, Analysis of Problems, Control Actions, Vol. III, Appendices, January 1980.

ABSTRACT

The complete State of Alaska Air Quality Control Plan is contained in three volumes. The first volume is oriented towards informing the general public of the overall state air quality control policies and objectives, and includes a review of existing and projected air quality throughout the state. The second volume includes the specific details for (1) achieving ambient and emission standards where noncompliance exists, (2) identifying specific air monitoring objectives and details, and (3) ensuring compliance with regulations by emission point sources. The second volume also includes the full text of the revised air quality control regulations, along with the details of how the Department will develop and carry out a Prevention of Significant Deterioration program in those areas of the state with air quality cleaner than the Ambient Air Quality Control Standards. The third volume includes the appendicies to Volume II.

Egan, W.A., and M.C. Brewer, State of Alaska Air Quality Control Plan, State of Alaska Department of Environmental Conservation, Vol. 1, Plan, Vol. II, Appendix, April 1972.

ABSTRACT

The complete Plan is in two volumes, entitled PLAN and APPENDIX. Volume I, PLAN, is divided into six sections: Section I is INTRODUCTION. Section II is STATE AND LOCAL PROGRAMS, and provides a regional description of the State, resources existing and required for the program, a guideline for program development and a development schedule; Section III is AIR SURVEILLANCE, and describes the existing air quality data and sampling conducted thus far, in addition to a description of the projected air surveillance network and evaluations of control strategies. Section IV is CONTROL STRATEGIES, and presents an evaluation of known air quality problems for each region, and proposed control strategies for each region. Section V is AIR EPISODE PLANS, and presents the abatement measures expected to be carried out if and when air contaminant concentrations reach episode levels. Section VI is REFERENCES and presents the references specifically noted throughout the preceding sections.

Volume II, APPENDIX, provides supporting documentation to Volume I, PLAN, including emission inventory, Alaska Statutes, State and local program regulations, public hearing summary, resource information, permit forms, and control strategy calculations.

Environmental Protection Agency. Draft Environmental Impact Statement for the Energy Company of Alaska Topping Plant at North Pole, Alaska, EPA, Region X, 1200 Sixth Ave., Seattle, WA, 1976.

ABSTRACT

DEIS, including description of existing environmental and proposed project, likely impacts of proposed project and alternatives to the proposed action. The section on air quality impacts includes likely SO_2, NO_2 CO etc. emission rates.

Fairbanks North Star Borough Report No. 74-002, Air Quality Forecast Plan, February, 1974.

ABSTRACT

In order to keep up with the many requests for information, the Fairbanks North Star Borough Department of Environmental Services has initiated a forecast service which is available from November 1st to March 31st. This service will describe air quality conditions in general terms and will relay air stagnation information from the Fairbanks Weather Service Office.

Fairbanks North Star Borough, Department of Planning and Zoning, Fairbanks North Star Borough Parking Management Study, March 1977.

ABSTRACT

On July 27, 1972, the Environmental Protection Agency (EPA) informed the State of Alaska that it must submit a Transportation Control Plan to reduce carbon monoxide by February 15, 1973. When the state did not submit a plan, EPA published a proposed Transportation Control Plan for the Northern Alaska Intrastate Region on July 16, 1973. The area encompassed by the plan included the City of Fairbanks, the Fairbanks North Star Borough, and the Basin in the State of Alaska. Essentially, the plan contained provisions for: (1) anti-idling, (2) parking management, (3) inspection/maintenance, (4) air bleed retrofit, (5) traffic flow improvements, and (6) highway cut-offs.[3]

The purpose of the parking management element of the plan was twofold: (1) achieve the photochemical oxidant and/or carbon monoxide standards by reducing areawide growth in VMT, and (2) ensure that the automobile congestion generated by a parking area did not cause a violation of carbon monoxide standards. Specifically, it addressed a review of parking facilities with ten or more spaces, the provision for heated facilities or headbolt heaters, and review/permit procedures. The EPA's regulation was to be effective by August 15, 1973; the date was later postponed to January 1, 1975.[4]

Fairbanks North Star Borough, Fairbanks, Alaska, Air Quality Attainment Plan for the Fairbanks/North Pole area, February 1979.

ABSTRACT

This plan (1) defines the nature and extent of air quality problems in Fairbanks; (2) provides a listing of potential strategies that could be used. Includes detailed traffic data for Fairbanks and air emission inventories.

(M)

Fairbanks North Star Borough, Air Quality Attainment Plan, Volume 2, "A Decision-Making Guide", May 1982.

ABSTRACT

The urban area of the Fairbanks North Star Borough has been designated as being in nonattainment of the national ambient air quality standard for carbon monoxide. Federal law requires that all nonattainment areas be brought into compliance by December 31, 1987. Furthermore, the Clean Air Act specifies the method by which a suitable attainment plan must be prepared and adopted. This document, along with Volume 1 of the Borough's Air Quality Attainment Plan, has been prepared according to the guidelines shown in the Clean Air Act and to guidance documents written by the U.S. EPA.

This volume of the attainment plan contains a technical analysis of the potential air quality control measures and strategy packages. It is designed to provide local decision-makers with adequate information to allow them to select the most suitable package of control measures which will allow the Fairbanks area to achieve attainment by 1987. Because it is a purely technical document no public testimony has been used in its preparation. The information contained herein should be integrated by the decision-makers with subsequent public comments in the final selection of the appropriate strategy package.

Gallagher, James R., Analysis of alternative transportation control measures for Fairbanks, Alaska, March 1982.

ABSTRACT

This document presents separate task assignments to be incorporated into the Fairbanks North Star Borough's "Analysis of Alternative Transportation Control Measures for Fairbanks, Alaska." GCA has prepared these separate components based upon the information provided by the Borough from available reports, a parking survey conducted by the Borough, and draft versions of the final documents.

Gallagher, James R., Analysis of Alternative Transportation Control Measures for Fairbanks, Alaska, Final report prepared for Fairbanks North Star Borough, March 1982.

ABSTRACT

Details of bus use and resulting reduction in emissions, parking management and emission reductions, and emission control packages.

Gegen, E.W., Air Pollution Emissions and Control Technology: Arctic Mining, Canadian Environmental Protection Service, Canadian Air Pollution Control Directorate, Report 3-AP-76-4, November 1976.

SPECIAL REPORT: THE POTENTIAL FOR AIR POLLUTION FROM CANADIAN ARCTIC MINING OPERATIONS IS EVALUATED. ESTIMATED EMISSIONS FROM MINES OPERATING IN THE AREA DURING 1973 SERVE AS A BASIS FOR ESTABLISHING TYPE, SOURCE, AND MAGNITUDE OF EMISSIONS AND FOR DEFINING THE BEST PRACTICABLE TECHNOLOGY TO CONTROL SUCH EMISSIONS, SO THAT GUIDELINES REGULATING PRESENT AND FUTURE MINING OPERATIONS MAY BE PROMULGATED TO MINIMIZE THEIR IMPACT ON THE ARCTIC ENVIRONMENT. (6 DIAGRAMS, 1 MAP, 5 TABLES)

Hellenthal, Marc E., Anchorage Air Quality Demographic and Attitudinal Survey, prepared for State of Alaska Department of Environmental Conservation, January 1983.

ABSTRACT

This report is an analysis of a survey of Anchorage residents measuring their public attitudes toward and awareness of, air pollution. Research often involves estimating the characteristics of a designated population. Because of the costs of conducting a census of all items in a population and the adequacy of sample results, sample statistics were used to make statistical inferences concerning population parameters. Three hundred and eighty-six (386) Anchorage residents legally licensed to operate an automobile or truck (pickup) in the State of Alaska were interviewed between December 4th and 8th, 1982. Additionally, a four question addendum was fielded on December 11th. Interviewing was conducted by telephone on a random digit basis. All legally licensed Anchorage residents -- from Girdwood to the Knik River Bridge -- who are accessible by telephone, had an equal chance of being interviewed.

Hellenthal, Marc E., Fairbanks Air Quality Demographic and Attitudinal Survey, prepared for State of Alaska Department of Environmental Conservation, January 1983.

ABSTRACT

This report is an analysis of a survey of Fairbanks area-wide residents measuring their public attitudes toward and awareness of, air pollution. Research often involves estimating the characteristics of a designated population. Because of the costs of conducting a census of all items in a population and the adequacy of sample results, sample statistics were used to make statistical inferences concerning population parameters. Three hundred and ninety-five (395) Fairbanks North Star Borough residents legally licensed to operate an automobile or truck (pickup) in the State of Alaska were interviewed between December 4th and 8th, 1982. Additionally, a four question addendum was fielded on December 18th. Interviewing was conducted by telephone on a random digit basis. All legally licensed Fairbanks North Star Borough residents -- from Salcha to Ester -- who are accessible by telephone, had an equal chance of being interviewed.

(M)

Midurski, Theodore, Analysis of Alternative Transportation Control Measure for Fairbanks, Alaska, Final Report U. S. Environmental Protection Agency, Region 10, November 1979.

ABSTRACT

The Fairbanks North Star Borough has been declared a nonattainment area for carbon monoxide. The purpose of this study is to identify and analyze the economic, social and institutional impacts resulting from several potential CO control strategies. The strategies evaluated include: cold-start emission controls, gasohol, inspection/maintenance program, carpooling program, transit improvements, traffic flow improvements, parking management, idling ordinance, restricted delivery hours, and a national low temperature standard.

Moyer, T., State of Alaska Proposed Revisions to Air Quality Control Plan, State of Alaska Department of Environmental Conservation, Vol. I, December 1977.

ABSTRACT

The complete State of Alaska Air Quality Control Plan will be contained in two volumes. The first volume, a draft of which is the following proposed document, will be oriented towards informing the general public of the overall state air quality control policies and objectives, and will include a review of existing and projected air quality throughout the state. The second volume will include the more specific details for (1) achieving standards where noncompliance exists (both ambient and emission standards), (2) identifying specific air monitoring details and objectives, and (3) Insuring compliance with regulations by emission point sources. The second volume will also include the full text of the soon-to-be-revised air quality control regulations, along with the details of how the Department will develop and carry out a Prevention of Significant Deterioration program in those areas of the state with air quality cleaner than the Ambient Air Quality Control Standards.

Pollution Control Commission and Fairbanks North Star Borough, Report No. 73-002, Air Quality Improvement Plan, November 1973.

ABSTRACT

The subarctic continental climate imposes frequent surface inversions upon airsheds within the Fairbanks North Star Borough, such that in the absence of air circulation, all natural drainages within the Borough have similar stagnation potential. (Figure 1.1). Recognition of a deterioration of air quality in the Fairbanks area during this stagnation usually stems from the visible phenomenon, ice fog. Ice fog has plagued the Fairbanks community for many years. This phenomenon was first discussed as a cold weather air pollutant by Benson of the University of Alaska. Soon after Benson's exhaustive efforts to characterize ice fog were published in 1965 [1], air quality measurements were made by the National Air Surveillance Network (NASN) [2] and the Arctic Health Research Center [3].

Tigue, John E, and Larry K. Carpenter, Air Quality Impact Analysis of a Proposed North/South Runway at Anchorage International Airport, FAA, NTIS Report AD-A020, December 1975.

SPECIAL REPORT: THE POTENTIAL AIR QUALITY IMPACT OF A PROPOSED RUNWAY AT ANCHORAGE INT'L AIRPORT IS ASSESSED. AIR TRAFFIC CONDITIONS FOR 1978 ARE PROJECTED, AND THE AIRPORT VICINITY AIR POLLUTION MODEL IS USED TO CALCULATE THE AIRCRAFT IMPACT ON AIR QUALITY FOR CASES WITH AND WITHOUT THE PROPOSED RUNWAY. THE ADDITION OF THE PROPOSED RUNWAY DOES NOT SIGNIFICANTLY AFFECT THE AIRPORT VICINITY AIR QUALITY. AREAS OF CONCERN DO EXIST ON THE AIRPORT ITSELF, BUT THE IMPACT ON COMMUNITIES SURROUNDING THE AIRPORT IS MINIMAL.

TRW Systems Group, Redondo Beach, California, Air Quality Implementation Plan for the State of Alaska, Vol. I: Control Strategy, Report APTD-0926, December 1971.

ABSTRACT

The northern, south central, southeastern, and Cook Inlet intrastate air quality control regions of Alaska were analyzed according to topography, climatology, soil characteristics, and existing air quality. Regional growth and potential new population sources were projected for each of the four areas. Control strategies are proposed for sulfur and nitrogen oxides, particulates, and carbon monoxide. Suggested strategies include air monitoring studies, process and boiler emission limitations, a permit system to regulate construction and modification of new facilities, traffic control, fuel changes, and street paving and sweeping.

TRW Systems Group, Redondo Beach, California, Air Quality Implementation Plan for the State of Alaska, Vol. I: Control Stategy Appendices, Report APTD-0970, December 1971.

ABSTRACT

Supportive data and calculations for the control measures are presented. Appendices include: estimation of air quality caused by particulate emission in Anchorage; variations in particulate concentrations with wind, rain, and temperature; seasonal variations in particulate concentrations in Anchorage; description of Anchorage road surfaces; cost of paving and maintaining; estimation of air quality due to particulates and carbon monoxide in Fairbanks; motor vehicle emissions in Fairbanks; estimation of the reduction in carbon monoxide automobile emissions; emissions from fuel combustion; description of rejected control measures; estimate of carbon monoxide reduction due to automatic signal control; and estimates of ground level concentration of sulfur oxides, CO, and particulates.

TRW Systems Group, Redondo Beach, California, Air Quality Implementation Plan for the State of Alaska, Vol. II: Compliance Schedule, Report APTD-0950, December 1971.

ABSTRACT

Control measures for particulates include the requirement that all point sources apply reasonably available control technology to reduce emissions. All sources emitting from 5 to 100 tons/yr uncontrolled must register with the appropriate agency, and sources which emit 100 tons or more/yr must apply for a permit authority to construct, modify, or operate. All compliance schedules must be submitted on or before the prescribed date for submittal of the first semi-annual report. Also, a series of special studies will be conducted to facilitate solution of the particulate problem, including road surfacing and a planting program on all lands from which ground cover has been removed. The 50% rollback in carbon monoxide emissions in Fairbanks required by the National Ambient Air Quality Standards is expected to be met by the Federal Motor Vehicle Program, prohibition of unattended cars left idling, and completion of a bypass roadway.

TRW Systems Group, Redondo Beach, California, Air Quality Implementation Plan for the State of Alaska, Vol. III: Permit System, Report APTD-0971, December 1971.

ABSTRACT

Registration and permit requirements are detailed, including guidelines for minimum requirements for various types of process and fuel burning equipment. Also described are conditional permits to operate, exemptions, form and processing of permit applications, hearings, source surveillance, air quality control jurisdictions, and data management. State and local responsibilities are given.

TRW Systems Group, Redondo Beach, California, Air Quality Implementation Plan for the State of Alaska, Vol. III: Permit System Appendices, Report APTD-0972, December 1971.

ABSTRACT

The following terms are defined: stationary source, new source, modification, owner/operator, existing source, and air pollution control authority. Also included are the registration form and the form for the application for authority to construct and/or Permit to operate.

TRW Systems Group, Redondo Beach, California, Air Quality Implementation Plan for the State of Alaska, Vol. IV: Emergency Episode Plan, Report APTD-0973, December 1971.

ABSTRACT

The criteria for the three levels of air pollution episodes - alert, warning, and emergency - are described. The alert level marks the threshold at which selective control action is to be initiated. The warning level indicates a health hazard which requires the curtailment of certain industrial activities according to a prearranged schedule. The emergency level defines a threshold of air pollution which constitutes a substantially dangerous health hazard. The stages are specifically defined with respect to pollution levels of particulates, carbon monoxide, and sulfur dioxide. Also measures are established to alleviate the danger of each of these three pollutants at the three episode levels. Operational procedures including weather forecasting, air quality data acquisition, declaration of episode stages, episode action plan implementation, and source surveillance are detailed.

TRW Systems Group, Redondo Beach, California, Air Quality Implementation Plan for the State of Alaska, Vol. IV: Emergency Episode Plan Appendices, Report APTD--0974, December 1971.

ABSTRACT

Laws of Alaska are presented establishing the Department of Environmental Conservation, and defining its responsibilities, means, and policies. Under Title 46 are defined the laws of the state with regard to water, air, radiation, and pesticide pollution control. Article 7, Title 46 describes prohibited acts and penalties. A definition of terms is also included within the body of the laws. The second appendix lists weather stations in Alaska, detailing the nature and frequency of synoptic, hourly, upper wind, radiosonde, and ice reports from each station.

TRW Systems Group, Redondo Beach, California, Air Quality Implementation Plan for the State of Alaska, Vol. V: Surveillance System, Report APTD-0975, December 1971.

ABSTRACT

Existing air pollution data gathering programs are described separately for the Cook Inlet Air Quality Control Region, Fairbanks North Star Borough, and the remainder of the state. Minimum federal requirements for air quality surveillance in each of these areas is detailed, and a surveillance system to meet them is proposed. Sample collection techniques and methods of data handling and analysis which are to be consistent throughout the state are described. Also detailed are experimental methods for studying effects of automotive traffic on total suspended particles particle size distribution as a function of sampler elevation, and variation in dust fall with sampling elevation.

TRW Systems Group, Redondo Beach, California, Air Quality Implementation Plan for the State of Alaska, Vol. VI: Resources, Report APTD-0976, December 1971.

ABSTRACT

Areas of responsibility within the statewide air pollution control program are outlined, including management, engineering, enforcement, and technical services; and manpower and revenue needs for these tasks are estimated. Existing manpower and revenue resources from various state, local, and private agencies are surveyed; specific projections concerning required personnel and capital equipment are described. Taxation, permit fees, penalties, state assistance, and federal assistance are revenue sources.

General Summaries and Overviews

The references in this section include the following topics:

General summaries of air pollution and its associated problems in the cold regions, specifically Alaska.

M

Alaska Air Quality, 1981.

Unidentified manuscript discussing carbon monoxide, nitrogen, dioxide, acid rain and ozone levels in Alaska.

Benson, Carl, S. A. Bowling and G. Weller, Urban climates in Alaska, Environments, Vol. 15, No. 2, 1983.

ABSTRACT

Summary of the winter climate, meteorology, heat island, ice fog and air quality in Fairbanks, with some reference to Anchorage and Prudhoe Bay.

Benson, Carl S.; Kenneth R. Rizzo, Air pollution in Alaska, University of Alaska; National Weather Service Forecast Office, Fairbanks, Alaska, No. 33(5), October 1980, p. 211-215.

ABSTRACT

More than three-fourths of Alaska's population is clustered tightly around two urban centers: Anchorage and Fairbanks. Natural regenerative processes there are too sluggish to permit rapid recovery from man-made disturbances. In Fairbanks, impermeable permafrost complicates the disposal of human waste products. Especially in winter, the air over Fairbanks and many smaller Alaskan communities is exceptionally stable and prone to stagnation and, therefore, vulnerable to air pollution with even a relatively modest input of pollutants. The high potential for air pollution in Alaskan lowlands results from a combination of very low winds and strong temperature inversions, which are frequent and persistent in the colder months of the year. The inversions trap pollutants below them and prevent effective dilution of the pollutants by mixing with higher air layers. This type of low temperature air pollution occurs also in Whitehorse, Yukon Territory, and in the areas of increasing development of Canadian oil sands in northern Alberta. Another type of air pollution exists in the fjords of southeastern Alaska, such as at Glacier Bay National Monument. Air pollution has surfaced on the Arctic coast of Alaska with the petroleum development at Prudhoe Bay. One of the most striking examples of this is the exhaust plumes extending for 20 mi or more across the Arctic tundra and adjacent Arctic Ocean. These plumes can be seen on satellite photographs.

Bigler, S.G.; K. Mackenzie, R.A. Willis, Air pollution conditions in Fairbanks, Alaska, World Meteorological Organization, Geneva, WMO-No. 368, 1974, p. 188-195.

ABSTRACT

Meteorological conditions affecting air pollution in the Fairbanks, Alaska area are reviewed. Nighttime temperature inversions formed by radiational cooling of the land surface are present on most summer nights but are usually destroyed by the warm afternoon sun. Ice fog is a visible indicator of winter inversions when the temperature is colder than about -30 C. The ice fog results from the combination of water vapor and man-made pollution generated by combustion activities. Carbon monoxide concentrations in Fairbanks exceed National Ambient Air Quality Standards about 72% of the days during the November-March period. Particulate levels at downtown sites average 275 micrograms/cu m during the winter, and the geometric mean diameter of the particles is about 2.8 micron. The annual average airborne lead concentration for Fairbanks is 3.17 micrograms/cu m, ranking third highest in the United States.

Gosink, Thomas A. and Carl S. Benson, Aspects of Far Northern Air Pollution with Particular Reference to Fairbanks, Alaska, Geophysical Institute Report UAG R 291, University of Alaska, July 1982.

ABSTRACT

This report provides an insight into the principal meteorological factors influencing air pollution in Fairbanks, gives an up-to-date review of the principal components found in local air pollution, and identifies areas in which further research is necessary

Hickey, John L.S., The Air of Anchorage--Today and Tomorrow,Alaska Med., 9(i) March 1966, 8 p.

Air sampling results obtained in Anchorage since 1953 are discussed particularly in relation to possible corrective measures, while present knowledge obtained in other areas and how it might be applied for prevention of future pollution in this area are also considered. High particulate loadings were recorded for several months after the volcanic eruption of Mount Spurr, in July 1953, with a fairly rapid reduction in ash and fallout in the following years. Summer dust-suppressing measures and street paving are recommended. The slight seasonal difference in organic particulate indicates that the bulk of the organic load may be due to year-roun activities (industry, power generation, automobiles, incineration) rather than to heating. Pollution from vehicle exhausts may become a problem in Anchorage sooner than it might in a city of comparable size in a warmer climate because of the widespread practice of leaving engines idling during long periods in the winter. Use of electricity and gas in domestic and commercial heating systems causes much less air pollution than use of oil or coal. Control of open burning is recommended. Regardless of the degree to which Anchorage experiences ice fog, it is clear that its formation requires not only a low temperature but water vapor in th air and particulate nuclei. Particulate matter and pollutants in the air are presented tabularly.

Holty, Joseph G., Air Quality in a Subarctic Community Fairbanks, Alaska, Arctic, Journal of the Arctic Institute of North America, Vol. 26, No. 4, December 1973.

ABSTRACT. Expanding population centred around Fairbanks has brought concern that air pollution in the area may become intolerable. The atmosphere of the lower Chena River Valley is extremely stable during much of the year. Temperature inversions are believed to be among the steepest in the world. Inversions at —35°C. or below are characterized by a dense layer of "ice fog." This study found that pollution levels doubled or tripled during periods of extreme cold inversions. Some pollutants approached national urban averages, while total suspended matter and carbon monoxide averages exceeded ambient standards. Since air contaminants as well as ice fog increase with human habitation, the possibility of pollution reaching hazardous proportions in this subarctic community should be viewed with urgency.

Judkins, C.P. and J.C. Emerson, Air Pollution in the Cook Inlet Basin, ALASKA MED, No. 10(i), March 1968, p. 45-47.

The city of Anchorage and the surrounding area of the Cook Inlet Basin have a fairly high air pollution potential. According to the meteorological studies by the U.S. Weather Bureau, temperature inversions are common. In winter, ice fog is often formed. A warning is given that with an increase in air pollutant sources, the danger of serious air pollution incidents during the winter inversion periods will become more pronounced. While the air pollution problem today is minimal, steps have been taken to preserve fresh air. The Tri-Borough Air Resources Management District has been formed to encompass three boroughs with a total of 136,000 inhabitants in 39,800 sq. miles. The Greater Anchorage Area Borough has been authorized to apply for funds with which to perform research and studies necessary to the establishment of air pollution control standards. This development project will be directed by an engineer who will be assisted by a sanitarian and a chemist. The project is unique in that it will be conducted from a preventative rather than a corrective approach. Three to four years will be needed to define the existing air quality through sampling, to define the ventilation system of the Tri-Borough District, and then to define what emissions may be allowed or reduced.##

Kingsley, Kay, A Look at the Future of Hazardous Contamination of the Circumpolar Environment, Arch. Environ. Health, Vol. 17, p. 653-661, October 1968.

ABSTRACT

Current and potential contamination of the circumpolar environment by mining and mineral processing operations in reviewed in terms of biological, chemical, and radionuclide wastes. Biological wastes in the form of bacterial, viral, and zoonotic entities are capable of contaminating the permafrost, as evidenced by the recovery of viable bacteria present in permafrost. Chemical wastes, particularly arsenic compounds discharged into the air from mineral processing operations, pose a particular hazard in view of the arctic meteorological conditions which favor temperature inversion and low air movement. Arsenic water level increases of from 0.01-0.25 ppm are cited for industrial areas. Domestic preparations such as carbon tetrachloride and benzene also pose hazards under the poor ventilating conditions of arctic housing. Odorous emissions containing aldehydes and higher aliphatic alcohols are cited in connection with petrochemical operations. Sulfur dioxide is given off in appreciable quantities in gold ore roasting in the Arctic. Pesticides also contaminate the Arctic, owing to air spraying of insecticides to control the prolific summer insect population of the Arctic. Radionuclide wastes in the Arctic result from mining and smelting operations and meteorological distribution of wastes from other parts of the globe.

INDEX OF FIRST AUTHORS