**Air Pollution in Antarctic and Artic Environment due to Anthropogenic Activities and Orographic Effects**

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**Abstract:** Air pollution is a man-made environmental-related problem and has importance globally among all environmental issues. It is defined as an atmospheric situation in which several components are present at high concentrations above their ambient level and produce a quantifiable effect on vegetation, animals, or people. Air pollution and its control are a universal problem and have become a matter of great concern for us in recent years. However, monitoring and measurement of the concentration of air pollutants are most difficult in comparison to monitoring other elements in the environment. Air pollutants are transported to Antarctica and Arctic by the different mechanisms such as long-range atmospheric transport or Grasshopper effects and via anthropogenic activities. After reaching the continents they settle down and remain as such for a long-time due to their persistent nature. They can distress the environment and animals of Antarctica and the Arctic. Generally, dangerous chemicals may pose a risk of health effects, whereas toxic pollutants focus on one physiological response.

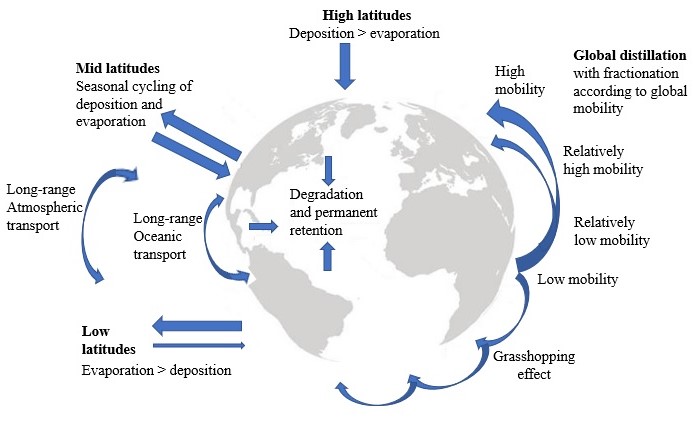
**Keywords:** Antarctica; Arctic; Air Pollution; Environment

1. **Introduction:** Air pollution is the pollution of air or can be well-defined as the presence of pollutants in the atmosphere for a specific duration. It may exist as solid particles, gases, and liquid drops. It is the main cause of the thinning of the ozone (O3) layer in the atmosphere above Antarctica and leading to climate change. Now, these pollutants are moved to Antarctica and the Arctic via different mechanisms. Both continents arepristine and located on the poles of the Earth. They are covered with ice. Antarctica (82.8628° S, 135.0000° E) is located in the South pole and is uninhabited by humans while the Arctic (76.2506° N, 100.1140° W) is located in the North pole and has humans as one of its inhabitants. They are the highest, driest, and coldest region on the earth. They are a sensitive indicator of global change. The polar ice cap holds a record of past atmospheres of tens or even hundreds of thousands of years and allows the study of the changes in the Earth.

Air pollution originates in one country, but its impact may be felt in other countries which are nearby that country. First time, it was documented in the 13th century in London. The Clean Air Act (1963) established national standards for air quality. These are of two types, primary standards (PS) and secondary standards (SS). PS set the limits of pollutants to protect the health of the community, children, and asthmatic patients. While SS sets the limits of pollutants to protect against reduced visibility, buildings, crops, and vegetation. The EC introduced an air quality standard in Europe in 1980 for the measurement of SO2 and suspended particulates.

USEPA has set NAAQS for the pollutants like nitrogen oxide (NOx), ozone (O3), carbon monoxide (CO), sulphur dioxide (SO2), lead (Pb), and particulate matter under the Clean Air Act Amendments of 1970 (CAAA70). These six pollutants are called criteria pollutants. Grifin (2007) categorized air pollutants into criteria and non-criteria pollutants. Those pollutants whose numerical concentration limit has been established as the dividing mark between poor air quality or acceptable air quality, are known as criteria pollutants, while those pollutants which are designated as toxic by legislation, are known as non-criteria pollutants. SO2, O3, NOx, benzene, Pb, PM10, and CO are criteria pollutants.

Due to anthropogenic activities, and natural phenomenon like wind-blown dust particles, the air quality of the polar regions has deteriorated. Pesticides like DDT, Endosulfan, etc. have been reported in Antarctica (Bhardwaj et al. 2019 & 2020) and the occurrence of these pollutants supports the aerial transport of these contaminants in the polar region. Hao et al. (2019) have reported that OCPs, PCBs, and PBDEs in the air samples, collected from the Fildes Peninsula, West Antarctica. After travelling a long distance by wind or other factors, these pollutants can be stored in the ice/snow. Bhardwaj et al. (2018) have presented the “Grasshopper” mechanism for the transportation of these pollutants from one continent to another continent. Lebedev et al. (2015) described the “Cold Finger” phenomenon, and in this phenomenon, the chemicals are transported from a warmer area to a colder area (high mountains and Polar Regions).



**Figure: Global Transport Processes of Pollutants (Grasshopper Effect)**

Arnold et al. (2016) reported that air pollution affects the polar environments, societies, and climate through the different various sources. These sources may be local and remote. Shindell and Faluvegi (2009) stated that the changes in the air contaminants affect the radiation balance and contribute to polar climate warming. Mercury (Hg) and POPs are the major toxic contaminants in the Arctic (Sharma et al. 2013). Simpson et al. (2007) and Abbatt et al. (2012) reported the presence of halogens in snow, sea-ice, aerosols, and seawater in the Arctic continent and stated that it causes the depletion of ozone during spring and summer.

Warneke et al. (2010) reported that harmful gases are released from the open fires near the Arctic. Due to anthropogenic activities such as shipping, petrochemical extraction, and processing, there is the existence of nitrogen in the snow/sea ice (Grannas et al. 2007; Bartels-Rausch et al. 2014). The black carbon was found on the surface of snow and atmosphere near the Russian Station in the Arctic continent, and it was due to the flaring of additional natural gas throughout oil extraction (Stohl et al. 2013).

1. **Sources of Air Pollution:** Emissions are the major cause of air pollution while other causes are transportation engines, burning of solid waste, power, and heat generation. Faulty or diesel-run vehicles, brick kilns, dust from roads & construction sites, and toxic fumes from industries contribute to air pollution. Industries like cement, thermal power plants, steel, mines, refineries, petro-chemicals, and urbanization are the foremost factors responsible for air pollution. As per the study of Friedrich & Reis (2013), air pollutants mainly arise from the combustion process. The use of wood could be a noteworthy source of PAHs and other absorbing or non-absorbing particles. The polar regions (Antarctica & Arctic) are the receiver of air pollutants from various sources. The resident sources of air pollution are already influencing the atmospheric composition (Marelle et al. 2016). The local discharge of air pollutants is increasing due to the increased number of populations, mining activities, urbanization, and infrastructure development (Andrew 2014).

VOCs, which include hydrocarbons (HCs), halocarbons, and oxygenates, are directly released from various sources. These sources may be anthropogenic as well as natural sources. They can contribute to the expansion of secondary pollutants (SPs) with different efficiencies. Hydrocarbons (ethane & ethyne) and higher aliphatic hydrocarbons (toluene, benzene, and xylenes) are emitted from vehicles which depend on fuel. Benzene is released in high concentrations (1-50 µg/L in ambient air). NO, and NO2 together called NOx, are released from anthropogenic sources such as stationary sources, i.e. power generation (21 %), and mobile sources, i.e. transport (44 %). Both are known as nitrogen oxides. They have atmospheric lifetimes of approximately five days. After that, they converted into nitric acid and falls with rain. However, NO2 is a precursor of tropospheric ozone while NO does not affect ozone.

1. **Health Effects Due to Air Pollution:** Air pollution can be injurious to human health. The presence of toxic chemicals in the air badly impacts humans, agriculture, climate, vegetation, and animal life. It can damage the property and environment. Due to an increase of PM10 and PM2.5, people lose lung function and suffer from chronic respiratory and cardiovascular diseases. NO2 also causes respiratory infection. Carbon monoxide (CO) reduces the delivery of oxygen (O2) into the human body, and creates a severe headache, and decreased visual perception. Ingested lead (approximately 75 %) is deposited in the bones and tissues causing brain and kidney damage. Due to air pollution, the growing nervous system of young children is particularly vulnerable. Air pollution has long been known to have a hostile effect on human beings, plants, livestock, and the aquatic ecosystem through acid rain. In the untreated state, benzene has unwanted ecotoxicological properties and is known as a human carcinogen. Often the quantity of the released pollutants has been relatively high in a certain area, so the harmful effects due to the pollutants are more noticeable.
2. **Conclusions and Recommendations:** Antarctica and Arctic continents are the coldest and most preserved places on Earth.In some areas, water has been sealed from air and light in continental ice sheets for perhaps millions of years. So, these continents act as a global library for humans for the understanding of preserved ancient data. Over the last few decades, the environment of these continents is now changing due to several anthropogenic activities such as mining, exploration, overfishing, construction, and the introduction of invasive species. These anthropogenic activities trigger the potential dangers which affect climate change. Air pollution negatively affects the health of humans and other wildlife animals and may lead to death. It is a major concern for the countries which are working to improve the air quality. The monitoring of air pollution is carried out by various analytical methods and different measurement instruments. These apparatuses have different specificities and sensitivities. Monitoring plays a serious role in the safety of the environment and is the main component of all happenings to the management. It is a very significant source of data.
3. Regular monitoring of the air pollution near the polar regions is necessary for maintaining the pristine land of Antarctica and the Arctic.
4. Emission of CO, NO2, and HCs should be measured by catalytic converters.
5. More strategies for controlling air pollution should be made which will be based on the continuous monitoring of air quality data.
6. **Abbreviation:**

EC = European Commission

USEPA = United States Environmental Protection Agency

NAAQS = National Ambient Air Quality Standards

OCPs = Organochlorine Pesticides

PCBs = Polychlorinated Biphenyls

PBDEs = Polybrominated Diphenyl Ethers

POPs = Persistent Organic Pollutants

PAHs = Polycyclic Aromatic Hydrocarbons

VOCs = Volatile Organic Pollutants

NO2 = Nitrogen Dioxide

NO = Nitrogen Oxide

CO = Carbon monoxide

O2 = Oxygen

1. **References:**

Abbatt, J. P. D., Thomas, J. L., Abrahamsson, K., Boxe, C., Granfors, A., Jones, A. E., King, M.D., Saiz-Lopez, A., Shepson, P.B., Sodeau, J., Toohey, D.W., Toubin, C., von Glasow, R., Wren, S.N., Yang, X. (2012). Halogen activation via interactions with environmental ice and snow in the polar lower troposphere and other regions. Atmospheric Chemistry and Physics, 12(14), 6237-6271.

Arnold, S. R., Law, K. S., Brock, C. A., Thomas, J. L., Starkweather, S. M., von Salzen, K., Stohl, A., Sharma, S., Lund, M.T., Flanner, M.G., [Petäjä](javascript:;), T., Tanimoto, H., Gamble, J., Dibb, J.E., Melamed, M., Johnson, N., Fidel, M., Tynkkynen, V.P., Baklanov, A., Eckhardt, S., Monks, S.S., Browse, J., Bozem, H (2016) Arctic air pollution: Challenges and opportunities for the next decade. Elementa: Science of the Anthropocene, 4.

Bartels-Rausch, T., Jacobi, H. W., Kahan, T. F., Thomas, J. L., Thomson, E. S., Abbatt, J. P. D., Ammann, M., Blackford, J.R., Bluhm, H., Boxe, C., Domine, F., Frey, M.M., Gladich, I., Guzman, M.I., Heger, D., Huthwelker, T., Klan, P., Kuhs, W.F., Kuo, M.H., Maus, S., Moussa, S.G., McNeill, V.F., Newberg, J.T., Petterson, J.B.C., Roeselove, M., Sodeau, J. R. (2014). A review of air–ice chemical and physical interactions (AICI): liquids, quasi-liquids, and solids in snow. Atmospheric chemistry and physics, 14(3), 1587-1633.

Bhardwaj, L., Chauhan, A., Ranjan, A., & Jindal, T. (2018). Persistent organic pollutants in biotic and abiotic components of Antarctic pristine environment. Earth Systems and Environment, 2(1), 35-54.

Bhardwaj, L. K., & Jindal, T. (2020). Persistent organic pollutants in lakes of Grovnes Peninsula at Larsemann Hill area, East Antarctica. Earth Systems and Environment, 4(2), 349-358.

Bhardwaj, L., Sharma, S., Ranjan, A., & Jindal, T. (2019). Persistent organic pollutants in lakes of Broknes peninsula at Larsemann Hills area, East Antarctica. Ecotoxicology, 28(5), 589-596.

Friedrich, R., & Reis, S. (Eds.). (2013). Emissions of air pollutants: measurements, calculations and uncertainties. Springer Science & Business Media.

Grannas, A. M., Jones, A. E., Dibb, J., Ammann, M., Anastasio, C., Beine, H. J., Bergin, M., Bottenheim, J., Boxe, C.S., Carver, G., Chen, G., Crawford, J.H., Domine, F., Frey, M.M., Guzman, M.I., Heard, D.E., Helmig, D., Hoffmann, M.R., Honrath, R.E., Huey, L.G., Hutterli, M., Jacobi, H.W., Klan, P., Lefer, B., McConnell, J., Plane, J., Sander, R., Savarino, J., Shepson, P.B., Simpson, W.R., Sodeau, J.R., von Glasow, R., Weller, R., Wolff, E.W., Zhu, T. (2007). An overview of snow photochemistry: evidence, mechanisms and impacts. Atmospheric chemistry and physics, 7(16), 4329-4373.

Griffin, R. D. (2007). Principles of air quality management, Boca Raton, FL: CRC.

Hao, Y., Li, Y., Han, X., Wang, T., Yang, R., Wang, P., Xiao, K., Li, W., Lu, H., Fu, J., Wang, Y., Shi, J., Zhang, Q., Jiang, G. (2019). Air monitoring of polychlorinated biphenyls, polybrominated diphenyl ethers and organochlorine pesticides in West Antarctica during 2011–2017: Concentrations, temporal trends and potential sources. Environmental Pollution, 249, 381-389.

Lebedev, A. T., Mazur, D. M., Polyakova, O. V., & Hänninen, O. (2015). Snow samples as markers of air pollution in mass spectrometry analysis. In Environmental Indicators (pp. 515-541). Springer, Dordrecht.

Marelle, L., Thomas, J. L., Raut, J. C., Law, K. S., Jalkanen, J. P., Johansson, L., Roiger, A., Schlager, H., Kim, J., Reiter, A., Weinzierl, B. (2016). Air quality and radiative impacts of Arctic shipping emissions in the summertime in northern Norway: from the local to the regional scale. Atmospheric Chemistry and Physics, 16(4), 2359-2379.

Sharma, S., Ishizawa, M., Chan, D., Lavoué, D., Andrews, E., Eleftheriadis, K., & Maksyutov, S. (2013). 16‐year simulation of Arctic black carbon: Transport, source contribution, and sensitivity analysis on deposition. Journal of Geophysical Research: Atmospheres, 118(2), 943-964.

Shindell, D., & Faluvegi, G. (2009). Climate response to regional radiative forcing during the twentieth century. Nature Geoscience, 2(4), 294-300.

Simpson, W. R., Glasow, R. V., Riedel, K., Anderson, P., Ariya, P., Bottenheim, J., Burrows, J., Carpenter, L.J., FrieB, U., Goodsite, M.E., Heard, D., Hutterli, M., Jacobi, H.W., Kaleschke, L., Neff, B., Plane, J., Platt, U., Richter, A., Roscoe, H., Sander, R., Shepson, P., Sodeau, J., Steffen, A., Wangner, T., Wolff, E. (2007). Halogens and their role in polar boundary-layer ozone depletion. Atmospheric Chemistry and Physics, 7(16), 4375-4418.

Stohl, A., Klimont, Z., Eckhardt, S., Kupiainen, K., Shevchenko, V. P., Kopeikin, V. M., & Novigatsky, A. N. (2013). Black carbon in the Arctic: the underestimated role of gas flaring and residential combustion emissions. Atmospheric Chemistry and Physics, 13(17), 8833-8855.

Warneke, C., Froyd, K. D., Brioude, J., Bahreini, R., Brock, C. A., Cozic, J., de Gouw, J.A., Fahey, D.W., Ferrare, R., Holloway, J.S., Middlebrook, A.M., Miller, L., Montzka, S., Schwarz, J.P., Sodemann, H., Spackman, J.R., Stohl, A. (2010). An important contribution to springtime Arctic aerosol from biomass burning in Russia. Geophysical Research Letters, 37(1).