



## Climate and Health Challenges Posed by Black Carbon: Proceedings of a Workshop-in Brief

### DETAILS

---

6 pages | 8.5 x 11 |  
ISBN 978-0-309-44985-4 | DOI: 10.17226/23648

### AUTHORS

---

Policy and Global Affairs; National Academies of Sciences,  
Engineering, and Medicine

BUY THIS BOOK

FIND RELATED TITLES

### Visit the National Academies Press at [NAP.edu](http://NAP.edu) and login or register to get:

---

- Access to free PDF downloads of thousands of scientific reports
- 10% off the price of print titles
- Email or social media notifications of new titles related to your interests
- Special offers and discounts



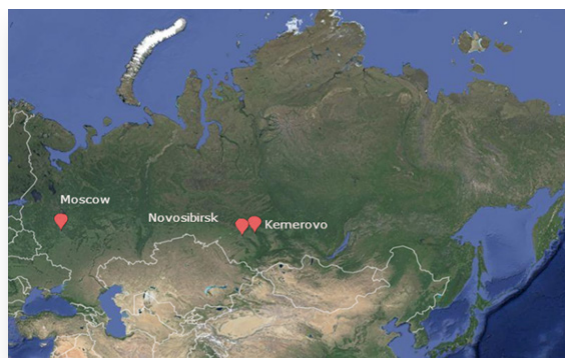
Distribution, posting, or copying of this PDF is strictly prohibited without written permission of the National Academies Press. (Request Permission) Unless otherwise indicated, all materials in this PDF are copyrighted by the National Academy of Sciences.

## CLIMATE AND HEALTH CHALLENGES POSED BY BLACK CARBON

### Proceedings of a Workshop—in Brief

In October 2012, the National Academies of Sciences, Engineering, and Medicine (referred to here as NAS) and the Russian Academy of Sciences (RAS) held a workshop in Moscow, Russia, on the Challenges of Black Carbon (BC). The workshop was carried out pursuant to the long-standing bilateral NAS-RAS Agreement on Cooperation in the Fields of Science, Engineering, and Medicine and attracted considerable interest among scientists and policy experts. More than 50 Russian and American scientists and specialists participated. The participants addressed many areas of scientific interest regarding BC dispersal, particularly in the northern latitudes, and called for continued cooperation between the academies on BC-related issues.<sup>1</sup>

In response to the enthusiasm expressed during the first workshop, NAS accepted an invitation from the Siberian Branch (SB) of the RAS to hold a second U.S.-Russian workshop on BC in Moscow and Kemerovo, Russia. This second workshop was held in April 2016 and included 29 technical presentations from individuals at 11 Russian and 8 U.S. institutions. The primary goals of the workshop were to learn about current research on BC and to identify opportunities for scientific and technical collaboration among experts in the United States and Russia. The first day of the workshop was held in Moscow and consisted of presentations from Russian and U.S. scientists conducting research on BC. The remainder of the workshop was held in Kemerovo, Siberia, the location of several scientific research institutes and relevant industries. Following the workshop, participants had an opportunity to tour laboratories in Novosibirsk, Siberia, engaged in research in analytical chemistry and material science.



### BLACK CARBON

J. Brigham-Grette, leader of the American delegation, provided an overview of the importance of BC as a contributor to climate change. The year 2015 was one of the warmest years on record within the warmest decade in recorded history. The principal driver of global warming—atmospheric concentrations of carbon dioxide—are now well above 400 parts per million for the first time since the mid-Pliocene era, 3 million years ago, when forests reached the coast of the Arctic Ocean, which was covered with little summer sea ice. Today, the winter sea ice in the Arctic is at an all-time low, and ice-free summers are predicted to occur 20 to 30 years in the future. Projections of sea level rise by the year 2100 as a result of melting ice in Antarctica alone exceed one meter.<sup>2</sup>

<sup>1</sup> Hansen, A.D.A., V.N. Kapustin and A.H. Polissar, 1991. "Measurements of Carbonaceous Aerosols in the Eastern Arctic," *Izvestiia AN SSSR Fiz. Atmos. Okeana*. 27, v. 6, pp. 614-618.

<sup>2</sup> DeConto, R. and Pollard D. 2016. Contribution of Antarctica to Past and Future Sea-Level Rise. *Nature*. 531, 591-597. doi: 10.1038/nature17145.

BC follows carbon dioxide as the second largest contributor to warming of the planet, Brigham-Grette explained. BC is a strong, light-absorbing type of carbonaceous material generated by the incomplete combustion of carbon-based fuels including biomass, timber, diesel fuel, and methane. It is often co-emitted with other gases and aerosols that commonly mix with atmospheric compounds that influence its radiative properties, its complex dispersal pathways, and its potential health effects. Brown carbon (BrC)—the fraction of organic carbonaceous material with enhanced ultraviolet light absorption that is often emitted in high quantities in biomass burning—is also of interest for its potential light-absorbing effects.

Z. Ismagilov, RAS workshop organizing committee chair and director of the Institute of Coal Chemistry and Material Science (SB RAS), summarized the primary sources of carbonaceous particulate emissions in Kemerovo Oblast, where the workshop was held. These include metallurgical industries (aluminum smelting, coke production, and pulverized coal production), thermal power plants, coal processing plants, diesel transportation, landfill waste combustion, and natural and man-made fires.

Workshop participants presented the results of original research as well as their analysis of the international and Russia-specific challenges posed by sources of BC, efforts to monitor BC emissions, and the health effects to people working directly with coal and to those living near sources of aerosol emissions. Presenters' remarks at the workshop have been selectively summarized below.

## SOURCES OF BLACK CARBON

Black Carbon has its largest radiative impacts in the atmosphere and through local changes in albedo, Brigham-Grette stated. Large inputs to the Arctic regions of climate forcing BC and co-emitted pollutants come most directly from gas flaring at the high latitudes and forest and grassland fires across mid- and high-latitude ecosystems. Meanwhile, the transportation sector is a major contributor in more urbanized areas.

Wildfires and agricultural burning are major sources of aerosols (BC and BrC) in the high latitudes. Research presented at the workshop pointed to strongly contrasting estimates of BC emissions from Russian forest fires. Wei Min Hao (U.S. Department of Agriculture, Forest Service) stated that estimates from the U.S. Forest Service, undertaken using biomass characterization data and satellite retrievals, suggest that Russia is responsible for 83 percent of the BC emissions from wildfires in Northern Eurasia. Estimates presented by A.A. Vinogradova (Institute of Atmospheric Physics, Moscow) and her colleagues were several times lower. The discrepancy may be the result of the use of Russian government statistics on burned area rather than satellite observations as the basis for estimating BC emissions. Some workshop participants noted that this illustrates the need for actual measurement data. E.S. Savelieva, (Institute of Monitoring of Climatic and Ecological Systems, Siberian Branch of the Russian Academy of Sciences) presented research suggesting that volcanic eruptions can act as a natural combustion furnace, lofting BC to high elevations in the atmosphere and causing additional sources of climate-changing emissions.

Given new legislation in the Russian Federation regarding air monitoring (2016), N.V. Zhuravleva (West-Siberia Test Center, Novokuznetsk) and her colleagues conducted research on the size of fine coal-powder particles used in several industrial processes such as steel mills, as well as proposed environmental improvements for the treatment of discharge water and aerosol emissions. She stated that understanding the composition of these BC sources will help in the measurement, monitoring, and reduction of their emission into the atmosphere. In particular, Zhuravleva and her colleagues determined that the use of laser granulometry methods can determine the particle size distribution in coal and sewage sludge, as well as particle size from mining and processing industries.

In his presentation, A.A. Lezhenin (Institute of Computation Mathematics and Mathematical Geophysics, Novosibirsk) outlined the major sources of BC emissions in the city of Krasnoyarsk, which include the city's heating stations, boiler-houses, and regional thermal companies. This work also documented the BC emissions from vehicles in the city. Diesel engines and their soot emissions were the focus of research presented by S.A. Yashnik. She stated that automobile emissions constituted 61.2 percent of total emissions in Novosibirsk in 2014, which prompted efforts to study methods of reducing soot from exhaust via catalytic converters on soot filters, improved quality of diesel fuel, the use of other fuel types, and improved diesel engines. S. Denisov presented similar findings of research conducted in Novouralsk, as well as improvements offered by a filter they developed, which includes a washcoat in combination

with other filter material. G. Hagler presented the findings of completed and on-going research conducted by the U.S. Environmental Protection Agency, focusing on BC and organic carbon emissions from vehicles in the United States. Although there is a need to continue focusing on these challenges, he said, BC emissions in the United States have been declining; and additional reductions are expected by 2030 due to controls on mobile diesel engines.

Since industrial processes are an integral part of modern economies, including those of the Russian Federation and the United States, into the foreseeable future, certain processes will continue to produce BC. However, there are means of mitigating the effects of those processes. O.A. Kokhanovskaya (Institute of Hydrocarbon Processing, Omsk) reported on the scientific and technical research of the Institute of Hydrocarbons Processing (SB RAS), which focuses on reducing the negative effects of oil refining, petrochemical production, and use of combustion engines. This work is currently operating at the pilot project level with an effort to identify opportunities for scale-up.

While industrial processes are frequently cited as primary sources of BC and BrC emissions, A. Kozlov's (Institute of Chemical Kinetics and Combustion, Novosibirsk) presentation outlined the importance of civil aviation engines as an additional source of emissions. In particular, high emissions of BrC occur during the idling of engines as well as while aircraft are in flight.

## **APPROACHES TO MONITORING BLACK CARBON**

During her presentation, G.V. Simonova asked two fundamental questions: 1) What type of aerosol should be monitored? and 2) What is the origin of pyrogenic carbon? Among the aerosol emissions monitored during her research were those from burning wood, peat, coal, and kerosene. She noted several methods of aerosol measurement, including optical and spectral methods, which she and her colleagues assessed from snow samples. Their work along these lines is continuing.

A.N. Popova's (Federal Research Center of Coal and Coal Chemistry, Kemerovo) presentation also outlined research applicable to understanding the effects of aerosol distribution of BC. Specifically, she and her colleagues are conducting research on x-ray powder diffraction to determine the structure of carbon materials. In a related area, A.A. Zvekov reported on research focused on calculating the absorption and scattering efficiency of BC particles on water.

Within Russia and in other northern maritime regions, measurements of BC are made from ships, aircraft, and ground-based stations on an occasional, individual-project basis. Few consistent long term measurement data sets of BC and co-emitted pollutants are available except from Tomsk (surface measurements and analysis from snow) and from Tiksi (ground-based measurements), as presented by N. Shonia.

A.V. Losev (Institute of Industrial Ecology Problems of the North, Apatity) presented the results of an analysis of BC emissions for the Kola Peninsula collected from 1960 to 2015, and now included in the Maccity Database. Specifically, he and his colleagues investigated the total amount of BC emitted, the distribution of BC sources, and general emissions trends as well as more local trends at the city level. From this analysis, they concluded that the greatest emissions occurred in 1980, the city of Murmansk contributed the greatest emissions on the Kola Peninsula, and those emissions at the city and regional level are primarily from residential sources.

During the workshop, V.S. Kozlov reported on the atmospheric and near-ground air layer measurements of the V.E. Zuev Institute of Atmospheric Optics (SB RAS) conducted in western Siberia, the Russian subarctic, and the city of Tomsk. He stated that the main goal of their research is to allow for assessments of the effects of the carbonaceous aerosol entering the Arctic on global climate and ecological changes as a result of long-range transportation.

Several institutes of the RAS, including the P.P. Shirshov Institute of Oceanology and the Oboukhov Institute of Atmospheric Physics, have been involved in efforts to monitor atmospheric BC distribution in the marine boundary layer over the Russian Arctic seas in the summer months. Results of monitoring cruises reported at the workshop by V. Shevchenko (Institute of Oceanography, Moscow), indicated that air masses originating in higher altitudes had lower concentrations of BC, whereas air masses arriving from industrially developed areas of Western Siberia, including areas of gas flaring, had considerably higher concentrations of BC. L. Geller's presentation, summarizing the 2015 Assessment by the Arctic Monitoring and Assessment Programme, similarly noted that per unit of emission, the Arctic

surface temperature is most sensitive to Russian flaring emissions primarily caused by BC deposited on snow. Additional research results were reported from the Aerosols of Siberia Project that was undertaken by the Voevodsky Institute of Chemical Kinetics and Combustion (SB, RAS) and the Shirshov Institute. In particular, S. A. Popova (Federal Research Center of Coal and Coal Chemistry, Kemerovo) stated that the project aimed to study the formation and transport of aerosols and reactive gas components in Western Siberia, to evaluate the influence of atmospheric aerosols on air and soil quality, to elucidate the effects of atmospheric aerosols on humans and animals, and to obtain quantitative data on the disposition of gas and aerosol emissions into the atmosphere in western Siberia.

Several workshop participants observed that long-term BC measurements will be critical to developing realistic emission inventories, estimating human exposure, and validating atmospheric transport models. A. Hansen and others noted that in addition to the lack of systematic long-term data collection across Russia, some of the research data sets are challenging to interpret due to the measurement methods used. A number of observational data sets presented by V. M. Kopienkin (A.M. Obukhov Institute of Atmospheric Physics, RAS), including ship-based measurements, may be confounded by nearby source emissions. The long integration time for filter samples (e.g., 8 hours) eliminates the ability to clearly separate ambient BC concentrations from nearby source contributions; and even within a short period of sampling, nearby exhaust may lead to findings that are not representative of the ambient Arctic environment. Hence real-time measurements could be beneficial for identifying aerosol types (BC vs. BrC)—if the monitor measures absorption at multiple wavelengths—and could permit the isolation of ambient versus source emission trends. There was recognition among many workshop participants of the need to employ current technologies and methodological approaches to provide the necessary data.

As a contribution to this effort, J. Ogren (University of Colorado) stated that the AErosol RObotic NETwork is a global federation of ground-based, remote sensing, and aerosol networks that measures sun and sky radiance at visible and near-IR wavelengths. As a result, surface measurements of equivalent BC provide an underutilized, independent data set for evaluating whether the AeroCom models systematically underestimate BC.

## HUMAN HEALTH EFFECTS OF BLACK CARBON

In addition to its climate effects, BC and its co-emitted pollutants are of significant concern to human health, both from outdoor air pollution exposure and from indoor environments. BC is commonly used as an indicator of proximate emissions impacts on local air quality, including indoor environments (residential heating and cooking) and areas near transportation emissions.

Research is ongoing into the health effects of industrial and engine emissions on the populations of the Kuzbass Siberian region surrounding Kemerovo, and other heavily industrialized territories of Russia. V. I. Minina (The Federal Research Center of Coal and Coal Chemistry, SB, RAS) presented findings indicating that coal miners studied had increased levels and variations of chromosome aberrations as a result of significant mutagenic exposure at industrial factories and in coal mines. New studies presented by V. Chashchin (Northwest State Medical University, St. Petersburg) suggested that extremely cold weather may fundamentally change the physiological absorption and impact of gas and particulate pollution in the human upper respiratory system, perhaps enhancing negative health effects. D. E. Zhabin (Siberian State University of Geosystems and Technologies, Novosibirsk) presented his group's research, which attempts to develop a low toxicity powder formulation and to develop and test a method for comprehensive evaluation of the effectiveness of fire-extinguishing powders for pulsed explosion-prevention systems in coal mines. These systems are designed to protect miners from explosions caused by a buildup of combustible substances. In a further effort to protect coal miners and other residents of the Kuzbass region, E. R. Khabibulina (West Siberia Test Center, Novokuznetsk) and her colleagues conducted research on the structure and toxicity of a variety of hydrocarbon molecules, including polycyclic aromatic hydrocarbons.

Several studies presented at the workshop looked at localized concentration gradients of pollutants co-emitted with BC, such as polycyclic aromatic hydrocarbons, and found significant differences at a neighborhood scale with downwind distance from a major roadway or industrial source. A.V. Shabaldin (Institute of Complex Issues of Cardiovascular Diseases, Kemerovo) and his colleagues studied the incidence of congenital heart disease among young children born in various neighborhoods in Kemerovo in an effort to determine the correlation between heart disease and BC-related emissions. O. Polikutina's (Institute for Complex Issues of Cardiovascular Diseases, Kemerovo) research

on the same correlation conducted among the 2.7 million people of the Kemerovo oblast concluded that there is a relationship between the incidence of hospital admissions for primary acute myocardial infarction and environmental pollution, particularly during the winter season. T.V. Yaroslavtseva (Institute of Hygiene of Rospotrebnadzor, Novosibirsk) and her colleagues conducted research on cancer morbidity rates among the population living along the highways in Novosibirsk, where high levels of hydrocarbon have been recorded. They found that the cancer morbidity rate for those living within 50-100 meters of a primary highway along which samples were taken was higher than those living farther away. Further, the risk of morbidity for males living downwind and within 50 meters of the highway was 1.5 times greater than for those living upwind within 50 meters.

Based on research on the carcinogenic and non-carcinogenic health risks of BC from various sources in Kemerovo. V.V. Turbinsky found that emissions from specific industrial sites can reach the upper limits of allowable carcinogenic risk rates, and the combination of general, low-level BC emissions with specific, high-level carcinogenic emissions may result in levels of carcinogens in excess of acceptable limits. T. Russell's (Georgia Institute of Technology) research similarly concluded that BC is often associated with increased toxicity, which is associated with reactive oxygen species generation; but health studies are not consistent on increased toxicity.

BC significantly and adversely affects human health through the inhalation of polluted air, the consumption of polluted water and/or food, and the skin's absorption of polluted air and water. Specifically, the inhalation of air polluted with coal dust affects coal miners, causing harmful particles to accumulate in the lungs. The leading cause of adverse health effects for non-coal miners is BC caused by internal-combustion engines, according to T. G. Tolstikova (N. N. Vorozhtsov Novosibirsk Institute of Organic Chemistry, SB, RAS) who presented her research at the workshop. J. Volkwein (U.S. National Institute for Occupational Safety and Health) admitted that atmospheric carbon reduction seems an enormous undertaking, and that it takes several elements to achieve noticeable changes such as the application of good science, committed and sound business practices, industry standards, local and global policies, and common sense. However, these changes need to start now and can draw upon the experiences of the coal mining sector.

In addition to other sources, methane releases remain a challenge; and opportunities exist to reduce atmospheric releases of methane. V. G. Smirnov (Kuzbass State Technical University, Kemerovo) presented research on the formation of pulverized coal at mine outbursts caused by methane hydrates, which leads to deaths and to the destruction of buildings and mining equipment. Given that methane and BC are released during such outbursts, Smirnov and his colleagues posit that clathrate compounds—methane gas hydrates—are present in coal beds; and this may contribute to sudden outbursts of coal and gas. S.N. Dubtsov (Institute of Chemical Kinetics and Combustion, Novosibirsk) and his colleagues conducted similar research. Analysis of several mine explosions since 2000 in Russia revealed insufficient understanding of the physio-chemical processes in coal pits. In order to correctly evaluate the risk of explosions in the mines, in-depth investigations are needed on how coal aerosols are formed and how this influences the combustion of air-methane-aerosol mixtures.

Additional potential negative health effects of BC were discussed by A. Glushkov (Federal Research Center of Coal and Coal Chemistry, Kemerovo) during his presentation on new approaches to immunodiagnosics and immunoprophylaxis of cancer. V. F. Raputa (Institute of Computational Mathematics and Mathematical Geophysics, Novosibirsk) and her colleagues conducted extensive experimental research and numerical analysis of organic carbon atmospheric transport processes in western Siberia, and found a link to research on related cancer rates. In Siberia, the snow cover is a fairly reliable indicator of atmospheric contamination by polycyclic aromatic hydrocarbons that can be used for operative detection of highly contaminated urban zones correlated with increased cancer risk.

## **OPPORTUNITIES FOR COLLABORATION**

Overall, measurement methodology and the ability to gain maximum information from observational data sets are potentially strong areas for international collaboration, as noted by several at the workshop. Further, many workshop participants stated that the scientific communities of Russia and the United States have the responsibility to work together to provide high-quality data to help guide decision makers on the formulation of meaningful evidence-based policies for emissions reductions. Russian and American participants agreed that future collaboration was essential and that joint contributions toward curbing fossil fuel emissions and mitigating its effects could be significant.

**Disclaimer:** This Proceedings of a Workshop—in Brief was prepared by Rita Guenther and Glenn Schweitzer as a factual record of what occurred at the meeting. The statements made are those of the authors or individual meeting participants and do not necessarily represent the views of all meeting participants, the planning committee, or the National Academies of Sciences, Engineering, and Medicine.

**Reviewers:** To ensure that it meets institutional standards for quality and objectivity, this Proceedings of a Workshop—in Brief was reviewed in draft form by **Julie Brigham-Grette**, University of Massachusetts at Amherst; **Michael Bergin**, Duke University; and **Nina Zaitseva**, Russian Academy of Sciences. The review comments and draft manuscript remain confidential to protect the integrity of the process.

**Planning Committee:** **Julie Brigham-Grette**, University of Massachusetts at Amherst; **Anthony Hansen**, Magee Scientific; and **Armistead Russell**, Georgia Institute of Technology. Staff: **Glenn Schweitzer**, Study Director; **Rita Guenther**, Program Officer; and **Gwynne Evans-Lomayeva**, Senior Program Assistant.

In collaboration with **Zinifer Ismagilov**, Institute of Coal Chemistry and Material Science, Kemerovo, and **Nina Zaitseva**, Russian Academy of Sciences.

**Sponsors:** This workshop was supported by the National Academies of Sciences, Engineering, and Medicine Thomas Lincoln Casey Fund.

For additional information regarding the meeting, visit: <http://sites.nationalacademies.org/PGA/dsc/BlackCarbon/index.htm>.

Map of meeting sites created by staff through the Google Maps application: <https://www.google.com/maps/>.

**Suggested citation:** National Academies of Sciences, Engineering, and Medicine. 2016. *Climate and Health Challenges Posed by Black Carbon: Proceedings of a Workshop—in Brief*. Washington, DC: The National Academies Press. doi: 10.17226/23648.

## POLICY AND GLOBAL AFFAIRS

*The National Academies of*  
SCIENCES • ENGINEERING • MEDICINE

The nation turns to the National Academies of Sciences, Engineering, and Medicine for independent, objective advice on issues that affect people's lives worldwide.

[www.national-academies.org](http://www.national-academies.org)

Copyright 2016 by the National Academy of Sciences. All rights reserved.