DUST-STORM Call 2022

DUST-STORM research initiative: program information

Title:
Inhalable airborne desert DUST: A comprehensive Study On physical micro-structure, chemical composition and Respiratory toxicity of fine Mineral and anthropogenic dust

Acronym:
DUST-STORM

Preamble:
A joint interdisciplinary initiative of the University of Rostock (Analytical Chemistry, Prof. Zimmermann), the University of Potsdam (Institute of Physics and Astronomy, Prof. Föhlisch), the Free University of Berlin (Experimental Physics, Prof. Lips), SESAME (Synchrotron-light for Experimental Science and Applications in the Middle East, Scientific Director SESAME Prof. Andrea Lausi) in Jordan and Jordan Universities in the field of aerosol and health research is proposed. The research topic is: Inhalable airborne desert DUST: A comprehensive STudy On physical micro-structure, chemical composition and Respiratory toxicity of fine Mineral and anthropogenic dust, leading to the acronym: **DUST-STORM.** The idea for the **DUST-STORM** project was created during a scientific delegation travel of German scientists organized by the Helmholtz Association of Germany (HGF) to Jordan (i.e. to SESAME and Universities) and is thematically linked to the Helmholtz International Lab. aeroHEALTH (www.aeohealth.eu). The **DUST-STORM** initiative wants to train young Jordan scientists (MSc level) in the framework of interrelated PhD-projects in Germany and to establish and deepen cooperation's between the German partners, SESAME and Jordan Universities in the field of aerosol and health. The SESAME Institute will become the link between the researchers from the German and Jordan Universities in this interdisciplinary research programme and will serve as a condensation nucleus for further joint research efforts.

Scientific Motivation and Regional Implication for Jordan:
Inhalable Atmospheric mineral dust is linked to an increased morbidity and mortality due to cardiovascular and respiratory effects (Renzi et al. 2018). Associated diseases include e.g. asthma, tracheitis, pneumonia, allergic rhinitis, silicosis and stroke (Goudie 2014). Additionally, immuno-suppressive effects have been observed and an increased risk of allergic symptoms was ascertained (Keil et al. 2018, Kanatani et al. 2016). Moreover, crystalline silica is classified as a probable carcinogen, with inflammation-driven secondary genotoxicity discussed as a principal mechanism (Borm et al. 2011). However, open questions remain concerning the basic causes of these effects, i.e. whether apart from particle size or the rough chemical composition parameters such as morphology, crystalline structure, oxidation state, surface properties, free-radical content or surface-bound organic or biological molecules are involved. In particular mineral fine dust and anthropogenic particles such as soot from wood combustion or traffic emission and their possible agglomerates are important in this context. Dust storm events and anthropogenic emissions in the Middle East, and particularly also in Jordan, cause air pollution episodes which are constituting serious health issues and thus are an important topic in the country.

Project Goals and Work Plan:
The essential goal of the collaborative **DUST-STORM** effort is to characterize the inhalable dust fraction in Jordan and to better understand the mechanisms and causes of adverse health effects caused by episodes with high contributions of fine desert dust to the atmospheric particulate matter (PM). The partners' complementary expertise to collect dust particles, determine their relative toxicity in lung cell models, identify reactive oxygen and radical species, analyze and quantify organic components as well as determine the structural and electronic properties for the mineral dust grains down to the atomic level is utilized in **DUST-STORM**. The sampling of the fine particulate matter during normal and different air pollution events is performed in Jordan (e.g. at Universities or the SESAME campus). This includes further analyses of the samples, such as elemental composition, recording of the atmospheric data and meteorological- as well as satellite-data analysis (i.e. back-trajectory calculation). Under the guidance of the University of Potsdam and in cooperation with the Helmholtz-Zentrum Berlin (HZB), the structural and electronic properties of the collected dust samples will be elucidated by synchrotron radiation analysis at BESSY II in Berlin. In cooperation with the SESAME in Jordan, structural characterization is performed at the powder diffraction (XRD) and extended X-ray absorption fine structure (EXAFS) beamlines of SESAME. With small-angle X-ray scattering (SAXS und ASAXS) the outer and possible inner nanostructure of different pure and loaded dust particles and their aggregates will be determined at BESSY II. The electronic structure, i.e. the oxidation state is determined at BESSY II using near-edge X-ray absorption fine structure (NEXAFS), photoelectron spectroscopy (PES), and X-ray emission (XES). These electronic structure probes are currently only available at BESSY II but in the framework of the ongoing construction of the Helmholtz soft X-ray spectroscopy beam line at SESAME, these capabilities will become available at SESAME soon. With this effort, we will provide direct atomic level insight to dry dust and dust particles and compare for select systems to the aqueous colloidal suspension. University of Rostock will contribute by chemical and biological analyses of collected dust samples. Beyond morphology- and structure-mediated biological effects, mineral dust can serve as a carrier of harmful organic substances (e.g. polycyclic aromatic hydrocarbons, PAH) or carbonaceous fractions (e.g. soot). Such known airtoxic components can be transferred to mineral dust via agglomeration with other particle types or by condensation on the particle surface during atmospheric transport and aging. Such mixed aerosols supposedly induce different biological lung effects compared to pure mineral dust, organic aerosol components or soot. Therefore, the aerosols will be characterized with respect to their organic content and elemental composition. State-of-the-art thermal analysis techniques hyphenated with laser ionization mass spectrometry, comprehensive gas chromatographic methods and high resolution mass spectrometry approaches will be applied to identify toxic organic compounds and perform source apportionment of the anthropogenic component. In cooperation with the Helmholtz Zentrum München, the biological effects of the dust samples are determined. Health effect analysis of the particles will be based on exposure of lung cell models (submersed culture) to the dust particles followed by cytotoxic and genotoxic analyses as well as the measurement of selected pro-inflammatory cytokines. For distinction between direct and secondary genotoxicity a co-culture model of lung epithelial cells and fibroblasts or endothelial cells will be applied. At HZB and Freie Universität Berlin (FUB), the concentration and nature of stable free radicals will be determined by electron spin resonance spectroscopy (ESR). A sampling scheme to collect air PM samples using spin-trap components will be developed and set up and introduced in the sampling campaigns in Jordan. The proposed **DUST-STORM** research project will work in close

collaboration with the existing Helmholtz International Lab AeroHealth, in which Helmholtz-Zentrum München, Rostock University, University of Eastern Finland and Forschungszentrum Jülich work together with the Weizmann Institute of Science in Israel. The overarching goal of aeroHEALTH is to comprehensively investigate the physico-chemical properties as well as the biological and health effects of aged aerosols and ambient particles. The investigation of toxicological effects of secondary organic aerosols and desert dust constitutes a bigger part of this effort. With this newly proposed **DUST-STORM** collaboration, in addition to that scientists from the bio-community, who define toxicity using cell models, will come into contact with the physical chemistry tools of atomic level structural and electronic structure characterization. This will increase the insight into the leading terms regarding structure, electronic state and surface properties of mineral dust toxicity. Dust preparation and toxicity response standardization will be supported by the German and Israeli aeroHEALTH partners. Atomic level structural characterization is ideally performed by combining the current capabilities of SESAME (XRD and EXAFS in Jordan), with electronic and nanostructure characterization capabilities (NEXAFS, PES, XES, SAXS, ASAX) at BESSY II. Since these capabilities are being built up in the new soft X-ray beamline at SESAME, **DUST-STORM** will launch a long-term endeavor by educating Jordan scientists supporting the current and future utilization of the SESAME infrastructure in Jordan. For steering and developing the cooperation within the **DUST-STORM** initiative, biannual status and coordination meetings will be held alternating in Germany and Jordan. The partner institutes in Germany supply staff personnel for supervision of the project-performing PhD-students as well as consumables. Excellent PhD students from the Jordan side, who shall be educated and perform **DUST-STORM** related project-work in Germany, are supported to prepare competitive proposals for DAAD scholarships. After publishing first joint publications it is anticipated to prepare bi-national science foundation proposals. The actual project work coordination between partners will be performed via frequent web-meetings. Seminar lectures of experts will be web-transmitted for the PhD-students, and staff scientists involved in **DUST-STORM** to support the training and education.

Expected Results:

In the framework of this project, we will elucidate the key drivers within structural and electronic properties of mineral dust particles as well as within the chemical variety of organic adsorbates, which contribute to the toxicity of both collected and standard dust particles. The scientific approach comprises the comparison of locally collected airborne mineral dusts (particulate matter PM10), desert dust samples, standard dusts (Arizona Test Dust), NIST urban dust, and soot. Electronic structure, chemical properties and biological effects will be investigated. Dust particles will be heated in thermal analysis-mass spectrometry instruments to elucidate the role of organic compounds, which are evaporated and analyzed. Subsequently, the mineral cores, free from organic matter and will be analyzed again with regard to their structure and toxicology. Comparison of the particles' biological effects before and after removal of organics will help to understand their health relevance in such mixed aerosols. Atomic level characterization on structure (XRD), local coordination and electronic structure of valence, in particular, frontier orbitals from NEXAFS, PES and XES helps to relate to the biological effects. For selected systems also the complement of aqueous colloidal suspension will be considered. Both experimental and computational synchrotron x-ray analytics are combined for highly active and inactive models. Since photochemical activation based on long-lived excited states and radical formation might play an important role, the timing capabilities of BESSY II will also be employed. SAXS will allow to quantify the nanostructured surfaces of different types of dusts with and without urban loadings. This nanosensitive scattering method opens up chances to describe a nanosized inner structure of dust particles, if such one is existing. Quantitative elemental analyses will round off the aerosol characterization. Submersed exposure of human pulmonary epithelial cells (A549) and other relevant cell models, including disease-oriented co-culture models, to the collected aerosol particles will reveal their typical effect strengths via analysis of cytotoxic, inflammatory and genotoxic responses. Dose response relations will be investigated for the different endpoints. It will be deciphered, which aerosol compositions and properties lead to direct or inflammation-dependent secondary mechanisms of genotoxicity. These experiments will be performed before and after thermal removal of organics from the dust particles. The joint analysis of all results will lead to a better understanding of the relative contribution of different components.