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Airborne bacteria and persistent organic pollutants associated with an intense Saharan dust event in the Central Mediterranean

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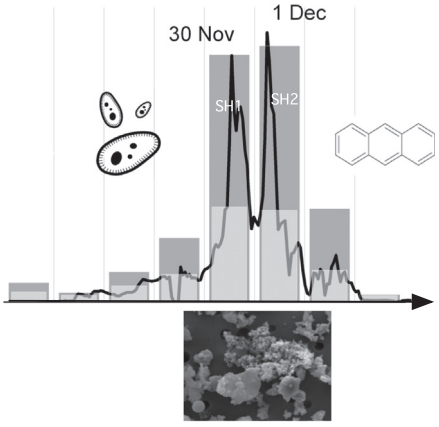
HIGHLIGHTS

- Airborne Saharan dust carries a highly diverse bacterial community as well as persistent organic pollutants;
- cultivable bacteria have the potential to be metabolically active and to resist to UV radiation;
- bacterial community and chemical speciation of Saharan dust are different from those associated to other air masses.

GRAPHICAL ABSTRACT



Bacteria, PAH and dust travel together in Saharan advection.

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ABSTRACT

In this paper, we present a comprehensive taxonomic survey of the bacterial community and accurate quantification of polycyclic aromatic hydrocarbons (PAHs) associated with an intense Saharan dust advection, which impacted Central Mediterranean area in the whole 2014–2015 period. This work is part of an intensive field campaign at the EMEP regional background site of Monte Martano (Central Italy), considered well representative of long-range transport in the Central Mediterranean area. 22 samples have been characterized in their provenance region and have been considered for the chemical and biological characterization. The event described in the present paper was exceptionally intense at the sampling site allowing a detailed evaluation of the dust load on a regional scale, an estimation of the impact of PAH based on the Toxic Equivalency Factor methodology and a thorough characterization of the airborne bacterial fraction performed by High Throughput Sequencing approach. Afterward, we cultured viable bacteria and evaluated several enzymatic activities and conducted UV survival tests. Principal findings include: (i) the striking evidence that, during the Saharan dust event, a highly diverse and abundant bacterial community was associated with PAH concentrations higher than the yearly mean; (ii) the tangible presence of cultivable microbes; (iii) the proof that the isolates recovered from Saharan dust had the potential to be metabolically active and that almost all of them were able to persist following UV radiation exposure. Comparisons of results for the present case study with mean values for the 2014–2015

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experimental campaign are presented. The bacterial community and chemical speciation associated with the Saharan dust advection were specific and very different from those associated with other air masses. The particular case of North-Western Atlantic, which represents one of the most typical advection route reaching the sampling site is discussed in detail.

1. Introduction

Bioaerosols and more specifically airborne bacteria have been receiving growing attention in recent years due to the increasing evidence of their role in the atmospheric environment (see, e.g., Smets et al., 2016; Fröhlich-Nowoisky et al., 2016). Airborne bacteria are usually associated with accumulation mode aerosols (Burrows et al., 2009), and therefore they can be transported in the atmosphere from source to receptor regions. Not surprisingly a relationship between the biodiversity of the airborne bacterial communities and the main characteristics of air masses has often been observed (Maron et al., 2006; Fierer et al., 2008; Franzetti et al., 2011; Gandolfi et al., 2013).

Particles emitted from deserts are supposed to participate significantly in long-range transport (LRT) due to their long residence times in the atmosphere. The arrival along Western American coasts of bioaerosols associated with a Saharan dust advection is known since a long time (Prospero et al., 2005; Kellogg and Griffin, 2006; Griffin, 2007). Most of the studies focused on microbial communities associated with desert dust were conducted on the culturable fraction (Kellogg and Griffin, 2006; Griffin, 2007).

The role of LRT in the global distribution of persistent pollutants, in particular in air masses of Saharan provenance, has also been pointed out (Rodríguez et al., 2011; Garrison et al., 2014). Stafoggia et al. (2016) recently demonstrated that, even if Saharan dust is classified as a natural aerosol, it affects human health as much as anthropogenic aerosol because of its high mass concentration. The dust mass may not be the only adverse factor, and both anthropogenic pollutants and bacteria present in an air mass can impact on the human health at the receptor site.

Recently increasing observations were reported on the effects of Saharan dust on the Mediterranean area (Polymenakou et al., 2008; Sánchez de la Campa et al., 2013; Katra et al., 2014; Rosselli et al., 2015; Mazar et al., 2016; Gat et al., 2017). The development of High-Throughput Sequencing (HTS) methods provided substantial support to the characterization of bacterial communities (Polymenakou et al., 2008; Katra et al., 2014; Rosselli et al., 2015; Mazar et al., 2016; Gat et al., 2017). A small number of papers reported the characterization of Saharan dust bioaerosols by combined cultivation and HTS-based methods (Sánchez de la Campa et al., 2013).

The present paper aims to provide a detailed chemical characterization, including PAH and *n*-alkane concentrations, and comprehensive taxonomic description of bacterial communities associated with a Saharan dust advection, which impacted on the Central Mediterranean area at the end of November 2014. It was the most significant event recorded in the 2012–2017 period at the EMEP background regional site of Monte Martano (MM, Central Italy), which had an influence on a large part of the Central Mediterranean and expanded over continental Europe.

The dust concentration during the event was exceptional for the site, and we attempted an estimate of the impact of the Saharan advection on the dust concentration at a regional scale. Second, we performed an extensive chemical analysis of the dust samples collected that allowed an estimate of the effect of PAH, based on the Toxic Equivalency Factor (TEF) methodology. Successively, we characterized the airborne bacterial communities by an HTS approach. Moreover, we were able to culture viable bacterial populations from the samples, and several enzymatic activities were evaluated to assess metabolic potentials. Finally, we conducted UV survival tests.

This research work is part of a long-term project aimed at characterizing in a systematic way bacterial diversity and chemical speciation as a function of air masses arriving at the MM site. We sampled and described an exhaustive number (22) of cases in the period 2014–2015. We will present a thorough discussion of the features of the entire dataset in a future publication and focused this paper on the major event of the observational period. In the present work, we will present comparisons with averaged values of the 2014–2015 period and with a sample obtained for a transport event arriving from North-Western Europe, one of the most frequent advection routes towards the sampling site.

2. Materials and methods

2.1. Sampling and sample processing

Monte Martano (MM) has been one of the observatory sites of the SDS-WAS (Sand and Dust Storm Advisory and Assessment System) network of WMO (http://sds-was.aemet.es) since 2013 and part of the EMEP (http://www.emep.int) network since 2017. This site experiences an entirely free horizon without any particular orographic obstacles in its proximity. Due to its intermediate elevation (1100 m asl) and low local background contamination, MM is well suited for catching LRT events including Saharan dust transports. The site is equipped with meteorological, gas and atmospheric aerosol monitoring instrumentation (Moroni et al., 2015; Petroselli et al., 2018). All the sampling inlets are installed on the roof of an air-conditioned cabin.

PM_{10} and $PM_{2.5}$ samples (quartz filters) are available daily at MM from a low volume dual channel sampler. Moreover, an Optical Particle Counter (OPC, FAI Instruments) with eight calibrated channels in the 270 nm–10 μm size range is run continuously at one-minute time resolution. We perform high volume sampling of PM_{10} at MM on a weekly base. Parallel to the above standard measurements, we conduct intensive sampling campaigns whenever we forecast a Saharan dust intrusion arriving at MM. The forecasts are provided by computational simulations generated every 4 h at the SDS-WAS computer center (DREAM8b model). Air mass origins are further characterized using a backward trajectory (BT) analysis. Calculations are performed using the HYSPLIT Trajectory Model (Draxler and Rolph, 2003) exploiting Global Data Assimilation System (GDAS, 1-degree resolution) meteorological fields. For the period of interest, BTs were computed every hour considering an endpoint located 1000 m asl.

During intensive campaigns, we performed additional PM_{10} samplings. In the present work, we focused on two complementary consecutive PM_{10} sampling events lasting 18 h each (SH1 and SH2 hereafter) conducted during the dust intrusion on November 30 and on December 1st, 2014, respectively. To this aim we used a high-volume sampler (TISH, TE6001) operated at a flux of 1440 L min^{-1} on quartz fiber filters (Whatman QMA 20.3 × 25.4 cm). The filters and the filter holding were sterilized before installation and kept inside a sterile double plastic bag for the transportation to and from the sampling site. The filters were subsequently cut into parts for chemical and biological analyses. A third HVS sample, used as a control, was associated with an air mass arriving from North-western Atlantic on December 12, 2014 (NW, in the following).