Atmospheric Environment 96 (2014) 430–436

Contents lists available at ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

Characterization of atmospheric bioaerosols at 9 sites in Tijuana, Mexico

Lilia Hurtado [a], Guillermo Rodríguez [a,*], Jonathan López [a], J.E. Castillo [a], Luisa Molina [b], Miguel Zavala [b], Penelope J.E. Quintana [c]

[a] Facultad de Ciencias Químicas e Ingeniera, Universidad Autónoma de Baja California, Tijuana, B.C., Mexico
[b] Molina Center for Energy and the Environment, La Jolla, CA, USA
[c] Graduate School of Public Health, San Diego State University, San Diego, CA, USA

HIGHLIGHTS

- A highest microbial contamination level was 50,000 CFU/m^3.
- Gram positive bacteria were in higher concentration in all sites.
- Main bioaerosols potential sources In Tijuana are wastewater treatment discharges.
- Bioaerosols concentrations were highest in southeast Tijuana, Mexico.

ARTICLE INFO

Article history:
Received 3 August 2013
Received in revised form
3 July 2014
Accepted 4 July 2014
Available online 5 July 2014

Keywords:
Microorganisms airborne
Bioaerosols
Tijuana
Air quality

ABSTRACT

The atmosphere is not considered a habitat for microorganisms, but can exist in the atmosphere as bioaerosols. These microorganisms in the atmosphere have great environmental importance through their influence on physical processes such as ice nucleation and cloud droplet formation. Pathogenic airborne microorganisms may also have public health consequences. In this paper we analyze the microbial concentration in the air at three sites in Tijuana, Mexico border during the Cal-Mex 2010 air quality campaign and from nine sites over the following year. Samples were collected by impaction with the air analyzer Millipore M Air T, followed by incubation and counting as colony forming units (CFU) of viable colonies. Airborne microbial contamination average levels ranged from a low of 230 ± 130 CFU/m^3 in the coastal reference site to an average of 40,100 ± 21,689 CFU/m^3 in the Tijuana river valley. We found the highest microbial load in the summer and the lowest values in the winter. Potentially pathogenic bacteria were isolated from the samples, with *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Enterococcus faecalis* being most common. This work is the first evaluation of bioaerosols in Tijuana, Mexico.

1. Introduction

Air pollution in urban areas and cities is a known cause of respiratory disease (WHO, 2005). Particulate matter (PM_{10}, $PM_{2.5}$) is a commonly used indicator of air pollution (Rojas, 2005). An additional hazard of particulate pollution can be the associated microorganisms (Balasubramanian et al., 2003). Studies have shown that the bacteria responsible for respiratory diseases can be present in the air, as well as a significant number of opportunistic pathogens that can cause eye, skin and urinary tract infections (Cardona, 2003; Douwes et al., 2003; Perdomo, 2009; Toivola et al., 2002). The atmosphere has no native microbiota, but is a means for rapid dispersion of many types of microorganisms (Gregory, 1973). Wet or dry deposition has been considered as a mechanism for the entry of pathogens in land (Jones and Harrison, 2004) and aquatic systems (Kaushik and Balasubramanian, 2012). Although the lower troposphere has been considered hostile to microorganisms, some have been able to adapt to the atmosphere. Certain bacteria and their many metabolites affect atmospheric chemistry through physical processes such as ice nucleation and the formation of cloud droplets, and also can affect the global climate and the

* Corresponding author. Facultad de Ciencias Químicas e Ingeniera, Universidad Autónoma de Baja California, Calzada Universidad No. 14418, Parque Industrial Internacional, C.P. 22390, Tijuana, B.C., Mexico.
E-mail addresses: Jventura@uabc.edu.mx, jguillermorv@gmail.com (G. Rodríguez).

http://dx.doi.org/10.1016/j.atmosenv.2014.07.018
1352-2310/

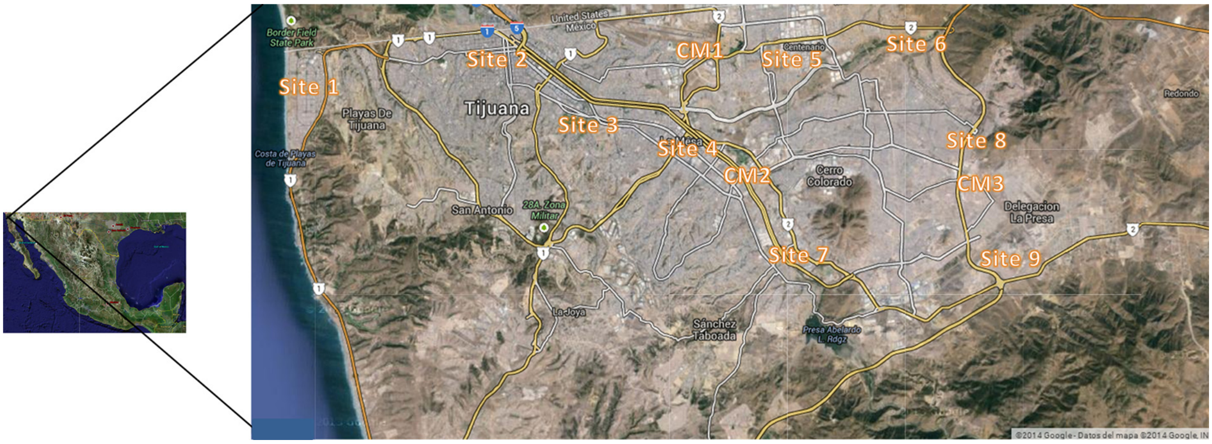

Fig. 1. Sampling sites in Tijuana, Mexico.

hydrological cycle (Bauer et al., 2003). Recent studies have focused on elucidating the mechanism through which atmospheric processes such as storms and hurricanes affect composition and function of microbial communities to improve dispersion models of microbial diseases and biogeography (De Leon et al., 2013). However, due to difficulties in sampling, tropospheric microbial communities remain poorly characterized.

Generally, the presence of microorganisms in urban air occurs as a result of anthropogenic activities, with main sources being agricultural production (Dungan and Leytem, 2009), biological wastewater treatment, and composting, reuse of solid waste, and landfills (Karra et al., 2007; Flores et al., 2007). Bioaerosols are particles suspended in the air with sizes ranging from 0.1 μm to 100 μm in diameter which contain bacteria, viruses, fungi and their metabolic products, as well as pollen, and even small insects and their waste (Urbano, 2011). Microorganism viability is influenced by factors such as water content, relative humidity temperature, oxygen levels and solar radiation (Dimmick, 1979; Pyankov et al., 2007). However, environmental factors (atmospheric turbulence, humidity and temperature) together with the physical properties of bioaerosols (size, shape and density) determine their aerodynamic performance which in turn dictates the time that the microorganisms remain suspended in the air before sedimentation (Griffin, 2007). Brodie et al. (2007) have reported a relationship between environmental conditions and bacterial dispersion, and climate change could potentially alter the microbial composition of the area, increasing the presence of certain pathogenic or allergenic components. The routes of human exposure to bioaerosols that have greatest relevance are inhalation, ingestion and skin contact, with inhalation thought to lead to the biggest health problems (Cardona, 2003). Risks to health not only directly affect the community exposed to bioaerosols at the point of origin but can affect other sectors of population further away through air transport, making it a potentially a serious public health problem (Gavidia et al., 2009; Montoya, 2004). The purpose of this study was to characterize the spatial distribution of viable microorganisms present in the air in various sites of the city of Tijuana over the course of more than a year. Some data collection coincided with the CAL-MEX air quality campaign of 2010 (Molina 2013).

Table 1
Selected places for air sampling in the city of Tijuana.

Site no.	Name	Main features	Geographic coordinates
CM1[a]	Library UABC	Scholar area	32°3150′N, 116°5744′W
CM2[a]	Morelos Park	Green area	32°5158′N, 116°9762′W
CM3[a]	Blvd 2000	Populated zone and livestock operations	32°2950′N, 116°5115′W
1	Tijuana Beach	Reference site	32°5328′N, 117°1235′W
2	Downtown	Population density, intense traffic	32°5379′N, 117°0373′W
3	Gastronomic District	Intense traffic and commercial area	32°5129′N, 117°0036′W
4	Tijuana river	River area	32°5158′N, 116°9762′W
5	Amistad Park	Residential and recreational green area	32°5331′N, 116°9442′W
6	Industrial zone	Intense road traffic and industrial area	32°5385′N, 116°9142′W
7	PTAR	Wastewater treatment	32°4660′N, 116°8462′W
8	Boulevard 2000	Populated zone and livestock operations	32°4571′N, 116°9076′W
9	Landfill	Solid waste and landfills	32°4923′N, 116°7898′W

[a] Sample site during Cal-Mex 2010 campaign. http://mce2.org/es/campanas/cal-mex-2010.

2. Methods

2.1. Measurement sites

Tijuana, Mexico, is located at 32°31′30″ north and 117° 04′31″ west, and is home to over 1,559,683 people. It is the sixth largest metropolitan area in Mexico covering an area of 1239 square kilometers, nestled among hills, canyons, ravines and streams. Tijuana has a dry Mediterranean climate, with mild, wet winters and warm, dry summers. Elevations vary from 0 m in Tijuana Beaches to 552 m in Cerro Colorado. The Tijuana River crosses the city for a length of 195 km. Due to migration and a floating population there are informal settlements on the river bank. According to the Ministry of Environmental Protection (SPA), it is estimated that these settlements generate a flow of 450 L per second of raw wastewater, which flows into the river. Consequently, the Tijuana River is considered among the 31 most polluted watersheds in the country (CNA 2012).

To analyze the bacterial microbiota suspended in the outdoor air of Tijuana, Mexico (Fig. 1), samples were collected from representative sites selected according to differential characteristics. General features of the sampling points are shown in Table 1. Sampling was performed in the period from May 31, 2010 to February 5, 2013.

2.2. Sample collection and meteorological data

At each of the sites, the sampler was mounted on a platform 1.5 m above ground level. Two separate samples were collected