Science of the Total Environment 612 (2018) 957–965

Contents lists available at ScienceDirect

Science of the Total Environment

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

Investigating the impact of different sport trainings on particulate matter resuspension in a sport center using well-characterized reference instruments and a low-cost monitor

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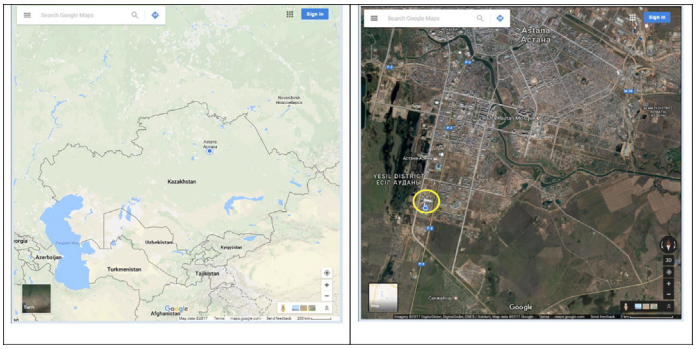
HIGHLIGHTS

- Sports with balls increase PM level.
- Number of attendees in training influences PM level.
- Dylos showed PM peaks but no correlation with Dusttrak $PM_{2.5}$ and coarse particle.
- Average PM concentrations were below WHO limit.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 12 June 2017
Received in revised form 11 August 2017
Accepted 11 August 2017
Available online xxxx

Keywords:
Particulate matter (PM)
Physical activity
Sport center
Exposure
Low-cost instruments

ABSTRACT

The present study investigated the exposure of teenagers, adults, and students to PM_1, $PM_{2.5}$, PM_4, PM_{10}, particle number concentration at two sport facilities of Nazarbayev University including Gymnastics Hall and Multi-purpose Hall. Measurements were conducted during variety of sport training sessions including soccer, basketball, volleyball, Mixed Martial Arts (MMA), boxing, table tennis, etc. A low-cost instrument, Dylos was employed to compare its performance against two TSI instruments. In overall, the Dylos showed acceptable peaks when the source of particle resuspension was present. However, no correlation was observed between Dylos data and Dusttrak fine and coarse particle data. The average $PM_{2.5}$ and PM_{10} concentrations were found to be below the WHO limits. The number of participants during the training sessions and sports involving balls including basketball, soccer and volleyball were the two factors responsible for the observed increased particle resuspension.

1. Introduction

Different studies showed the importance of evaluating and analyzing the indoor particulate matter (PM) concentrations as inhalation of particulate matter (PM) can cause a broad range of respiratory symptoms such as coughing, wheezing, asthma, lung cancer and cardiovascular diseases (Branis and Safranek, 2011). For every 10.0 μg/m^3 rise in total mass concentration of inhalable particles (PM_{10}) in the air, an increase about 1% in cardiovascular mortality on a day-to-day basis was reported (Rouledge and Ayers, 2006). Most people spend 90% of their time in indoor environments including home, academic buildings, shopping

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http://dx.doi.org/10.1016/j.scitotenv.2017.08.107
0048-9697/

malls, cars, work places, sport center, etc. (Massey et al., 2012). Hence, it is important to identify the indoor PM sources and evaluate and control indoor PM concentration (Halios and Helmis, 2007).Typical sources of indoor particulate matter include but are not limited to cooking (Amouei Torkmahalleh et al., 2017, 2017, 2017; Gorjinezhad et al., 2017; Buonanno et al., 2009; Buonanno et al., 2011), candle burnings, use of fireplaces, use of unvented space heaters or kerosene heaters, hairdryer, ironing, toasting, cigarette smoking (Wallace and Ott, 2011; Environmental protection agency, 2016), three-dimensional (3D) printers (Stabile et al., 2016), laser printers (Scungio et al., 2017) and particle resuspension (Qian et al., 2014).

Sport centers were also considered as an important indoor environment concerning air quality. While sport activities are beneficial for our health and general well-being, activities, in a polluted environment may not be productive and recommended. The concentration of indoor PM in sport facilities may exceed the limit recommended by World Health Organization (WHO). Thus, a clean indoor environment in a gym is essential. It is reported that individuals may be under risks by practicing in a polluted environment due to inhalation using mouth, which cannot filtrate large particles, and the increased air flow velocity causing PM to be inhaled deeper into the respiratory tract (Carlise and Sharp, 2001). Therefore, it is crucial to study the PM concentrations in sport centers, where particle resuspension may occur due to physical exercises.

Branis and Safranek (2011) examined PM concentrations in indoor and outdoor environments in Prague (Czech Republic). They reported high concentration of coarse particles ($PM_{10-2.5}$) up to 70.6 μg/m^3 in school gyms. The average daily PM mass concentration in a gymnasium at the University of Leon, Spain was measured to be 440 μg/m^3 when magnesia alba was used in the gym (Alves et al., 2014). However, none of the discussed studies investigated the impact of different sport activities on the PM resuspension. To our knowledge, no monitoring programs for indoor air quality assessment were done in Kazakhstan. Such studies help us to better understand the exposure level of the people attending sport center.

The main objective of this study was to evaluate indoor PM concentrations in a sport center in Astana Kazakhstan. A sport center located in Nazarbayev University (NU) in Astana which includes a variety of indoor environment with a reasonable number of participants was selected. This sport center also includes participants with a broad range of age including kids to adults. The second objective of this study was to compare different sport activities for particle resuspension. Finally, this study aims to compare the performance of two low-cost monitors with commercial TSI monitors.

2. Materials and methods

2.1. Monitoring location

Two sport facilities including a Gymnastic Hall and a Multifunctional Hall at the sport center of Nazarbayev University, located in Astana, Kazakhstan were chosen to carry out an indoor air quality monitoring campaign. Indoor air pollutants including PM_1, $PM_{2.5}$, PM_4, PM_{10}, total PM and particle number concentration were investigated. The sport center is in the south part of the campus where is close to Turan street. Behind the multifunctional room, some construction was taking place to build a new sport center complex. Fig. 1 shows the location of the sport center.

Activities in the sport center usually started at 8:00 am. In the mornings and afternoons Gymnasium hall usually was occupied by few students to individually practice, while in the evenings, there were several sport training sessions including Table Tennis, Parthowa (an Iranian Martial Sport), Boxing, Mixed Martial Art (MMA), Judo, Aikido, and Gymnastics for group of students with scheduled hours for three sessions per week. The evening training sessions were conducted from 18:00 pm to 22:00 pm. Some of the trainings were conducted simultaneously. The time table for the training sessions (Table 1S) is found in the Supplementary Materials section of this article.

In the Multifunctional hall, training activities were repeated for three days per week. In the mornings and afternoons, there were training in volleyball, basketball and football for kids and teenagers. In the evenings, there were training sessions for NU students. The Multifunctional hall and the Gymnastic hall were connected through the reception desk and entrance zone. Each hall was separated from the entrance zone using a normally closed door. In the second floor of the sport center, there was a weight lifting room and multiple dancing rooms. Although different rooms and hall in the sport center were separated using interior doors, the sport center shared one ceiling for the whole center which connected the indoor air for the entire center. Therefore, the pollutants generated in one of the halls or rooms could transport to other halls

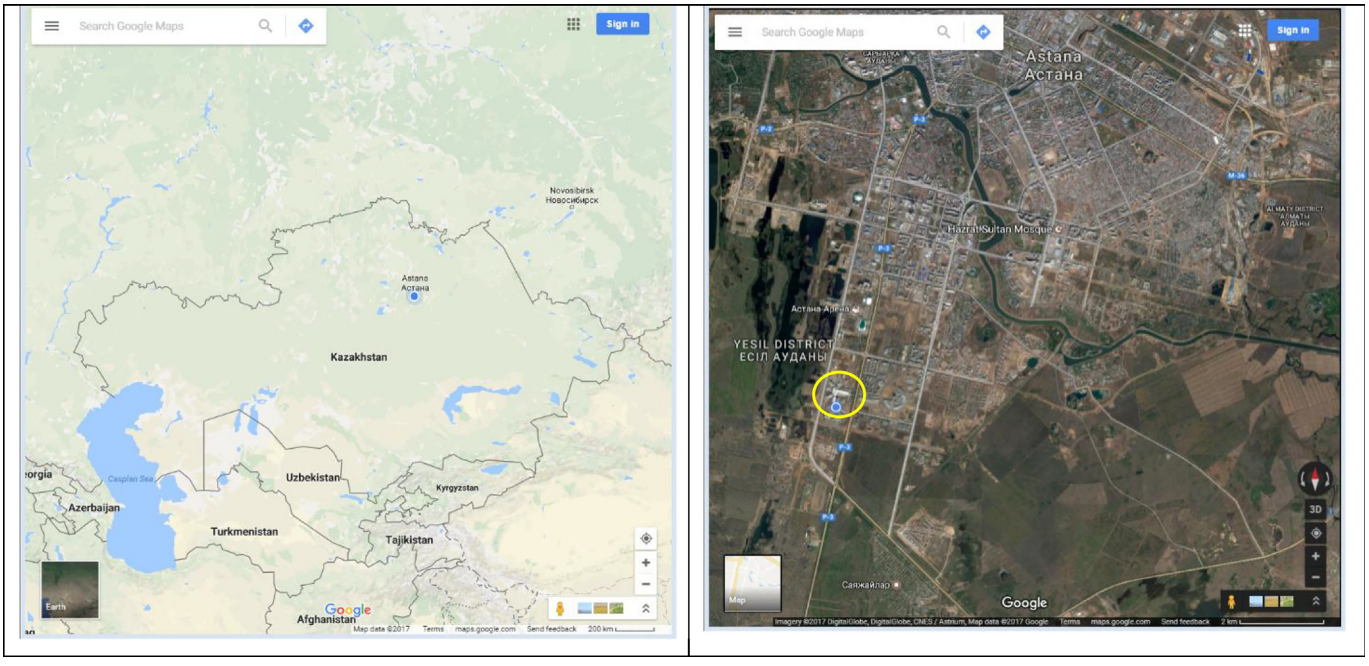

Fig. 1. Location of NU Sport Center where monitoring was carried out.