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Characterization of particulate matter 2.5 in an urban tertiary care hospital in the Philippines

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ABSTRACT

This study characterized particulate matter 2.5 microns in the naturally ventilated Pediatric and Medicine wards and mechanically ventilated Central and Neonatal Intensive Care Units (CENICU and NICU) of an urban tertiary care hospital in the Philippines in terms of concentration, elemental composition, indoor/outdoor (I/O) ratios and enrichment factors. The samples were collected from October to December 2013 and from March to April 2014. Results showed that the average of $PM_{2.5}$ in the Pediatric (32.8 μgm^{-3} in October to December 2013 and 28.4 μgm^{-3} in March to April 2014) and Medicine Wards (30.0 μgm^{-3} in October to December 2013) exceeded the WHO guideline value of 25 μgm^{-3}. The I/O ratios suggest that outdoor air is the major source of $PM_{2.5}$ in all sites. Comparison of pollutant levels showed differences between the $PM_{2.5}$ concentrations in Pediatrics and NICU ($p < 0.0001$ in October to December 2013 and $p = 0.003$ in March to April 2014) and in Medicine and CENICU ($p = 0.002$ in October to December 2013 and $p = 0.037$ in March to April 2014). Moreover, outdoor $PM_{2.5}$ concentrations were higher than the measurements in NICU and CENICU ($p < 0.0001$). X-ray fluorescence analysis measured 15 elements, including manganese, iron, vanadium, lead and mercury, which are highly hazardous to health. Enrichment factor analysis showed that mercury, sulfur and bromine were highly enriched indicating significant contamination from anthropogenic sources. The researchers recommend the determination of these elements in soil within the area and other compartments and undertake a source apportionment study to ascertain the sources of these elements.

1. Introduction

The study of $PM_{2.5}$ is given attention because of its diverse chemical compositions. Particulate matter 2.5 can contain toxic inorganics such as metals Xinhua et al. [1]. found that vanadium (V), chromium (Cr), cadmium (Cd), nickel (Ni), copper (Cu), lead (Pb), zinc (Zn), arsenic (As), tin (Sn), and selenium (Se) were concentrated in the fine fraction or $PM_{2.5}$. Another study done by Jianjun et al. [2] showed increasing concentrations of V, manganese (Mn), Ni, Cu, Zn, Se and Cd with decreasing particulate aerodynamic diameter. The accumulation of metals in $PM_{2.5}$ is attributed to the availability of a larger surface area for the adsorption of these metals [3]. Previous studies have likewise shown that the aerosols can serve as carriers of pathogenic microorganisms, which results in an increase in the incidence of respiratory nosocomial infections [1] and [4].

Several studies done abroad have dealt with $PM_{2.5}$ in different indoor environments such as schools, offices, residential buildings

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and commercial buildings [5–7]. However, there are no available data of any study done regarding $PM_{2.5}$ and associated elements (AEs) in Philippine hospitals. This study was conducted to characterize $PM_{2.5}$ in terms of concentration elemental composition, indoor/outdoor ratios and enrichment factors. An urban tertiary care hospital was chosen because of the following reasons: i) it is situated within the 300–500 m radius of major thoroughfares thereby making the area vulnerable to the effects of traffic emissions including $PM_{2.5}$ and AEs; ii) many people, especially the lower middle class and the poor are serviced by the hospital; iii) and the persons at high risk and with heightened susceptibility to infections, respiratory distress and other related disorders are commonly found in the hospitals. Epidemiologic studies show that the groups most susceptible to the harmful effects of air pollution are young infants, the elderly and those with pre-existing cardiovascular and respiratory disease [8]. The workers who spend most of their time in the hospital are likewise exposed.

2. Materials and methods

2.1. Study site

The study site is the largest government tertiary care hospital in the country. It has a 1500 bed capacity for pay and indigent patients and 14 clinical departments. The $PM_{2.5}$ samples were taken from four wards, namely the Department of Pediatrics (Pedia) and Department of Medicine (Med) both in the ground floor, Central Intensive Care Unit (CENICU) in the second floor and Neonatal Intensive Care Unit (NICU) in the fourth floor. All of the study sites chosen are non-partitioned, multiple-bed hospital wards. The Departments of Pediatrics and Medicine are naturally ventilated whereas CENICU and NICU are mechanically ventilated areas. The key informant interviews and walk-through surveys done showed that the characteristics of the study sites vary in terms of size, bed capacity, type of ventilation system, level of human activities and occupancy (Table 1).

2.2. Sample collection and analysis

Sampling for $PM_{2.5}$ and AEs was done from October to December 2013 and from March to April 2014. The duration of eight weeks used as sample is based on other exposure studies where a one to two-week averaging time is deemed acceptable. Twenty four hour $PM_{2.5}$ samples were taken to consider possible diurnal variations in the levels of these contaminants. The outdoor sampler for $PM_{2.5}$ was placed on an elevated platform at a roof deck approximately 212 m from the study site. The Department of Environment and Natural Resources (DENR) has an air quality monitoring station near the study sites. The DENR refers to USEPA 40 CFR 60, Part 50, Appendix L for the applicable reference method for ambient $PM_{2.5}$ sampling (DENR, 2013) [9].

The mass concentration of $PM_{2.5}$ was determined by impactor-volumetric measurement wherein the samples are collected in filters at a specific flow rate and time. Air sampling made use of the Leland Legacy Sampler for $PM_{2.5}$. The sampler drew air into an inlet in the Harvard Impactor, which separated $PM_{2.5}$ from larger dust particles. The fine particulates were collected in polytetrafluoroethylene (PTFE) membrane filters with polymethylpentene support ring (diameter 47 mm, 2 μm porosity). Before sample collection, the filters were equilibrated for at least 24 h in a desiccating cabinet. These filters were weighed at an interval repeatedly until constant weights were achieved. The filters were placed in petri dishes coded with identification numbers. The indoor samplers were placed in the center of the study sites approximately 1.5 m above a horizontal plane and 1.0 m away from the walls to ensure that it is representative of the breathing zone of the building occupants. After sample collection, the filters were transferred to labeled petri dishes. These were equilibrated for at least 24 h at a mean temperature of 20–23 °C and 30 to 40 percent relative humidity (RH). The filters were analyzed gravimetrically using a microbalance that has a sensitivity of about ±1 μg. The filters were treated in a static charge neutralizer (Americium-241) to remove surface electrical charge which can affect the analysis. Mass concentration was computed using Eq. (A.3). Concentration data were not accepted if the elapsed time is less than 1080 min or 75% of the total sampling time.

After gravimetric analysis, the $PM_{2.5}$ samples were brought to the Harvard School of Public Health for analysis by X-ray Fluorescence spectrometry. This was done to determine the concentration of earth crust elements, such as: sodium (Na), aluminum (Al), potassium (K), magnesium (Mg), calcium (Ca), iron (Fe), titanium (Ti) and manganese (Mn). In addition, the anthropogenic tracers such as vanadium (V), chromium (Cr), cadmium (Cd), nickel (Ni), copper (Cu), lead (Pb), zinc (Zn), arsenic (As), tin (Sn), selenium (Se) and mercury (Hg) were quantified. The $PM_{2.5}$ filters were loaded into sample cups for automated quantitative analysis using the XRF spectrometer. The results of analysis included the concentration of the elements, uncertainty, peak counts per second (cps) and background cps.

2.3. Data analysis

Statistical analyses were performed using SPSS Statistics 20 and Microsoft Excel 2010. Descriptive statistics were computed to

Table 1
General description of the four study sites.

Study site	Location	Type of ventilation	Room size (m^3)	Bed capacity	Average number of occupants[a]	Average occupant density[b]	Activity level[c]	Wall and ceiling covering
Department of Pediatrics	Ground floor	Natural ventilation	1116.2	44	100	0.32	High[d]	Paint
Department of Medicine	Ground floor	Natural ventilation	1332.0	50	108	0.28	High[d]	Paint
Central Intensive Care Unit	Second floor	Centralized air conditioning system	1568.1	15	30	0.05	Low[e]	Paint
Neonatal Intensive Care Unit	Fourth floor	Centralized air conditioning system	924.4	45	63	0.18	Moderate[f]	Paint

[a] Patients, visitors and hospital staff.
[b] Number of occupants per square meter.
[c] Based on daily observations made by the researchers.
[d] The average occupancy is more than 80 and visitors stay in the area permanently/until the patient is discharged and move frequently.
[e] The average occupancy is 20 with minimal or no visitors and with low movement.
[f] The average occupancy is 40 and visitors do not stay in the area permanently and with moderate movement.