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Assessment Of Indoor Particulate Matter In Hospital Environment A Case Study In China

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ABSTRACT:- The assessment of the air quality of indoor environment where people usually spend extended time periods, especially for sensitive population groups such as patients during their hospitalization, is of major importance. Ensuring a safe level of air quality in these indoor environment serves as an amelioration factor for human health not only for the often habitués of those indoors places, but also for the working personnel that spend more than 90% of their time indoors. In that aspect the concentration of coarse (PM10) and fine (PM2.5) particulate matter was measured in two Hospital with six different unit (OPD, Doctors room, Infusion room, patients room, ICU and Outside) with different spatial and trespassing characteristics, of the ABC Hospital and XYZ Hospital in People Republic of China (PRC) The measurements were conducted with the application of a portable aerosol monitoring equipment (TSI DustTrak CW-HAT200 and Grimm HAT200).

The results indicated that the 24-h average concentrations were above the indicative limits proposed by the World Health Organization (WHO) (50 and 25 μg m-3 for PM10 and PM2.5 respectively). Relatively elevated instant concentration levels were also recorded during specific activities and in conjunction with the temporal variation of the observed concentration levels raised questions regarding the side effects of poor indoor air quality.
Keywords:- *Indoor Environmental Quality, particulate matter, Indoor air quality.*

I. INTRODUCTION

1.1 Indoor Environmental Quality

There is an increasing need for controlling indoor Environmental quality (IEQ) in hospital operating room and it's environment, as this has led to increase in the sick acquiring respiratory illnesses and loss in productivity because hospitals and health care buildings are among the most complex indoor facilities with numerous different end uses of indoor spaces and functions. In particular, the most demanding independent indoor zones are hospital operating theaters that comprise operating rooms or surgical operating theatres, their interconnecting hallways and ancillary work areas. Indoor environmental quality (IEQ) in operating rooms (ORs), and its surrounding needs thermal, visual and acoustical comfort in this environment, and its surroundings, affects the works and patients conditions as well as the safety and health of the medical personnel who work in these environments. Heating, ventilating and air-conditioning (HVAC) installations are the most effective control indoor air quality and aseptic conditions which secure healthy, safe and suitable indoor thermal comfort condition (i.e. temperature, humidity, air quality and airflow) conditions for surgeons, medical staff and patients need a very good and healthy indoor environmental quality (IEQ) for good health.

II. METHODOLOGY

2.1 Description of the Study Area (Pm2.5, Pm10)

2.1.1 Particulate Matter Effect on Hospital Indoor Environment

The assessment of air quality of indoor environment where people usually spend extended time, especially for sensitive population groups such as patients during their hospitalization, is of major importance. Ensuring a safe level of air quality in these indoor environments serves as an amelioration factor for human health not only for the comfort ability of those indoors places, but also for the working personnel that spend more than 90% of their time indoors. In that aspect, the concentration of coarse (PM10) and fine (PM2.5) particulate matter was measured in two hospitals. Indoor environmental quality for hospital indoor has been testing and survey in ABC Hospital. This hospital was founded in 1927, initially named "Hankou city hospital." In May 1949, it was renamed as ABC Hospital, and in 1985 the Wuhan municipal people's Government named it "traditional Chinese and Western medicine hospital in Wuhan". It is a hospital set for healthcare, research and teaching Hospital. Now, it is the country's largest tertiary hospitals of traditional Chinese and Western medicine and affiliated to Tongji Medical College, Huazhong University of science and subsidiary Hubei College of traditional Chinese medicine and Western medicine. The Hospitals has a total area of 175 acres, at Li Ji bei road, and its headquarter is located in Qiaokou District, Wuhan City, Jian Han Sai Yuan area, panlong district, Wuchang. It has Hanyang skin diseases and skin disease specialist outpatient clinics with specialist clinics and preparation Center. The hospitals have prepared beds of 3000 and 1700 beds is now being used. The annual out patient volume is 2.156 million passenger trips, annual in patients is 62,000 visitors, yearly operation is 16,000 times, the occupancy rate is 108.7%, the business income of 1.23 billion Yuan, and total assets of 1.85 billion Yuan. And the second hospital was the XYZ Hospital.

Table 1 General Characteristics Of The Sampling In The Hospital

Hospitals	Location	Area (m^2)	Bed occupancy during sampling	Total capacity in beds	Windows area (m^2)
ABC Hospital	OPD	40x60	350	450	NONE
	Infusion room	20x40	150	300	NONE
	Doctor's room	8x12	6	6	NONE
	Patient room	4x6	4	6	NONE
	Outside	-	-	-	-
XYZ Hospital	ICU	12x18	12	45	1.2x1

2.2 Sampling Devices

Sampling devices were used for conducting the measurements, in order to ensure the comprehensiveness of the study. A CW-HAT200 Handheld Air Tester was used as technology devices to determine particulates concentration in real time (in µg/m-3). The sampling device that was used is Grimm particle Model CW-HAT200 (GRIMM). GRIMM is a small portable unit used for continuous measurements of particle. An internal volume controlled pump draws the ambient air and analyzed the rate of PM2.5 and PM10.

Table 2 Prevailing Weather Conditions During The Measurement Period

DATE	AVG. TEMP. °C	AVG. HUMIDITY %
29/03/15	21.67	65.78
30/03/15	23.35	73.47

2.3 Sampling Area

Sampling campaign was performed at the ABC Hospital in the People's Republic of China. The hospital was built in 1927 and is located in the city Centre of Wuhan. Sampling was carried out in these areas as follows OPD, Infusion room, Doctor's room and Patient room. In the second Hospital, the sampling area was in the ICU department of the XYZ Hospital. More specifically, the sampling was conducted in two hospitals in Wuhan and six units located in these hospitals. The general characteristics of the units are presented in Table 3 and 4.

III. RESULTS AND DISCUSSION

Table 3 shows the air quality distribution in various units or sampling locations at the ABC Hospital and XYZ Hospital. During the surveillance period in the ABC Hospital, the particulate matter of PM2.5 at the OPD, Infusion room, Doctor's room, patient room and outside ranged from 68µg/m3-148µg/m3, 70µg/m3-88.85µg/m3, 68µg/m3-149µg/m3, 71µg/m3-108.50µg/m3, 79µg/m3-219µg/m3 respectively. The Pm10 particulate matter in the sampling locations at OPD, Infusion room, Doctor's room, patient room and outside ranged from 139µg/m3-332µg/m3, 139µg/m3-243µg/m3, 212.30µg/m3-317µg/m3, 149µg/m3-49µg/m3 and 156µg/m3-279µg/m3 respectively. At the XYZ Hospital, PM2.5 range from 56µg/m3-96µg/m3 in the ICU (Table 3). The average levels obtained for the sampling locations has exceeded the Indoor Air Quality (IAQ) level (PM2.5, and PM10 averaged over 24 hours) recommended by the WHO (Table 3). It was observed during sampling period that the central air-conditioning in the OPD, doctor's room and infusion room were not working or functioning properly and the air purification was very poor. The central air-conditioning system needs check-up and proper maintenance. The ABC Hospital is the biggest hospital in the central part of Wuhan and Hubei province the population of and visitors and patient that visit this hospital is very much. Over 800 people were recorded around the OPD, infusion room and doctor's room therefore there is the need for proper ventilation and indoor environmental quality in these areas. High efficiency particulate filters need to be installed at the point of air discharge into the room.

Room pressurization is mainly provided to ensure that untreated air does not pass from dirtier adjacent areas into the clean room. The clean room is positively pressurized with respect to these dirtier areas. This is done by extracting less air from the room than is supplied to it, this application is for the betterment of indoor environmental quality or better yield is the primary reason for investing in a clean room environmental space. When properly ventilated, hospitals and other healthcare facilities complex serve as environments which provides comfort for patients provided hazardous emissions are properly controlled. However, patients may serve as source of microbial contaminant in hospital environment thereby distributing pathogens to the hospital staff and fellow patients as well as visitors. The primary role of hospitalization and medical procedures are intend towards cure of diseases, but if not properly manage they can sometimes introduce pathogenic microorganisms into the body and environment hence initiate a nosocomial infection (NI). During the sampling period in the XYZ Hospital, the split type Air Conditioning was not working and also windows where left open where twelve patient out of 45 bed and five nurses were on duty. The average concentrations of PM10 and PM2.5 exceeded the WHO guidelines (Tang et al. 2009; Wan et al. 2011).

Table 3 Concentration Levels Measured In The Hospitals (CONCENTRATIONS IN $\mu/^{M-3}$)

Hospital	Location	Particulate matter	Max	Min	Average	Median
ABC Hospital	OPD	PM2.5	148	68	103.06	105
		PM10	332	139	218.82	217.50
	Infusion room	PM2.5	88.85	70	88.85	86
		PM10	243	139	188	189.52
	Doctor's room	PM2.5	149	68	101.65	104.50
		PM10	317	144	212.30	213.50
	Patient room	PM2.5	108.50	71	108.50	100
		PM10	495	149	224.23	200.50
	Outside	PM2.5	219	79	102.33	105
		PM10	279	156	203.17	194
XYZ Hospital	ICU	PM2.5	96	56	74.3	73.5
WHO guidelines*: PM10						20/50
WHO guidelines*:PM2.5						10/25

PM2.5 and PM10 samples did not met the World Health Organization IAQ guideline for 24-hour mean level of 50µg/m3 and 25µg/m3 respectively. The hourly variations in particulate matter concentration are shown in Figures 1-6 for both hospitals. A significant hour variation in PM10 and PM2.5 levels were found in the infusion room and the patient's room. This suggests that proper ventilation is needed in these rooms. Proper ventilation remains the primary objective for securing a safe and healthy indoor environment in order to preserve indoor air quality (e.g. reduce bacteria, viruses, and particulate matter concentration to acceptable levels and remove anesthetics gases and odors). This provides optimum and comfortable working conditions for the occupants to facilitate their demanding work during patient visit to hospital. Although special requirements and pressure relationships may determine different minimum ventilation rates, it is commonly recommended to use Air changes per hour (ACH). The systems usually require 100% outdoor air. Some national regulations and guidelines allow for a limited recirculation under favorable outdoor conditions and for certain types of surgeries.

Air should be delivered from the ceiling and exhausted or returned from at least two locations near the floor. Supply diffusers should be unidirectional, while high-induction ceiling or sidewall diffusers should be avoided. The air velocity must be maintained at low levels (an average velocity at diffusers of 0.127–0.178 m/s) to avoid annoying drafts and more important to eliminate turbulence that will cause air mixing and the dispersion of bacteria and airborne particles. Fluctuations in air velocity and poor air circulation will create drafts or pockets of still air. Occupants sense this kind of disturbances indicating that the air distribution is unsatisfactory, even if the average air velocity is within acceptable limits. The primary air supply should provide a unidirectional airflow, from the top downwards, to maintain laminar airflow pattern, especially over the patient and surgical team (Wan etal 2011). Additional air supply diffusers may be required to provide additional indoor air quality in patient and doctors room which ventilation to meet the loads and satisfy indoor thermal comfort conditions. Indoor air quality can improve considerably by using scavenging equipment to recover proper indoor environmental quality.

The ventilation system should operate continuously, during patient visit and even when the other rooms are not being used, but possibly at a reduced ventilation rate, in order to maintain continuous aseptic indoor conditions and stand-by indoor environmental quality. During this investigation, the OPD, Infusion room, doctor's room as well as the patient room, the ventilation system was evaluated by the personnel on a seasonal basis and air flow was poor. This resulted in high particulate concentration of PM2.5 and PM10 (Table 3). The air distribution was characterized as annoying (e.g. due to strong drafts or poor air circulation) and satisfactory. Winter appears to be the most problematic period. Proper design and operation of the ventilation system results in an average 72% personnel satisfaction. On the other hand, inappropriate ventilation systems average 45.3% personnel satisfaction, as a result of poor operation and maintenance (e.g. frequent system breakdowns), bad design (e.g. poorly sized and located inlet and outlet openings in the hospital environment) and unbalanced system.

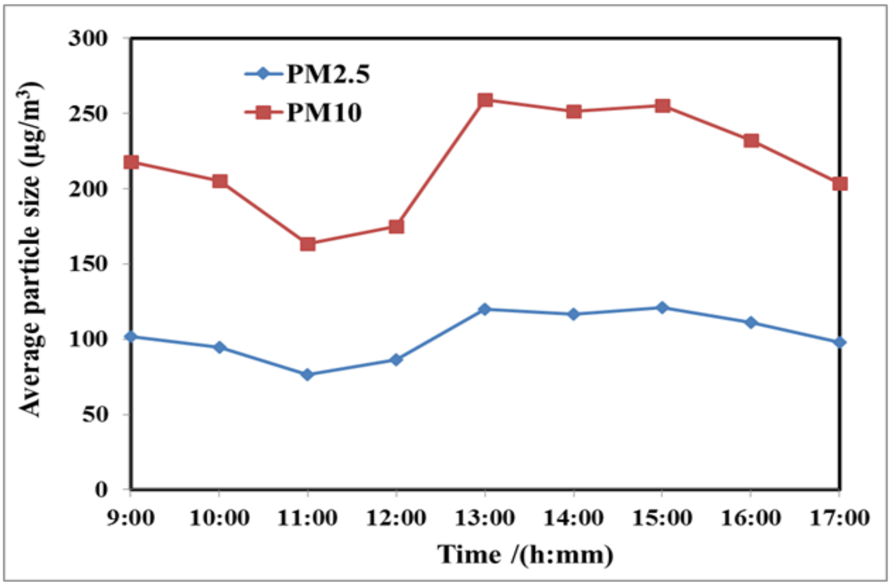

Figure 1. Time variation in average PM10 and PM2.5 particle concentration level in OPD.

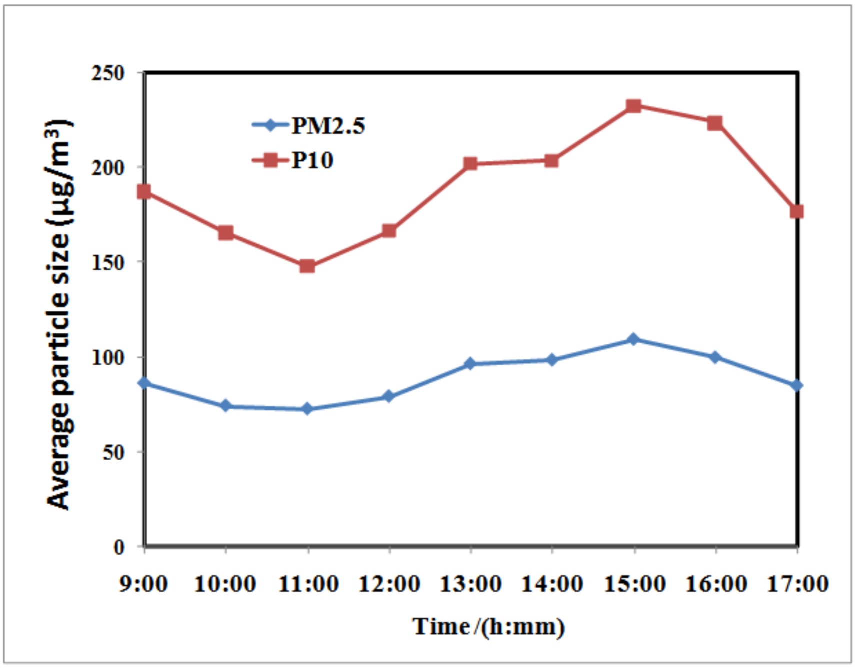

Figure 2. Time variation in average PM10 and PM2.5 particle concentration level in infusion room.

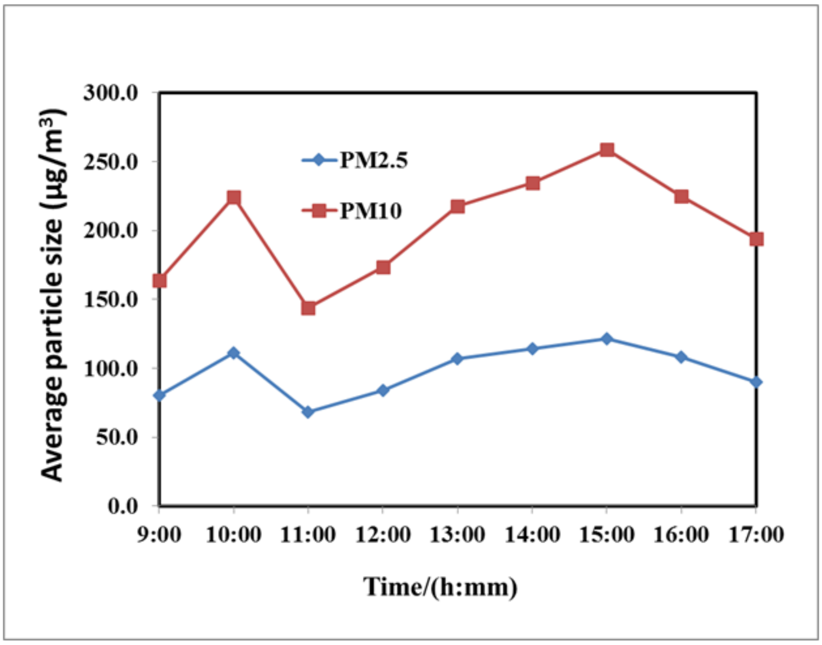

Figure 3. Time variation in average PM10 and PM2.5 particle concentration level in Doctor's room.

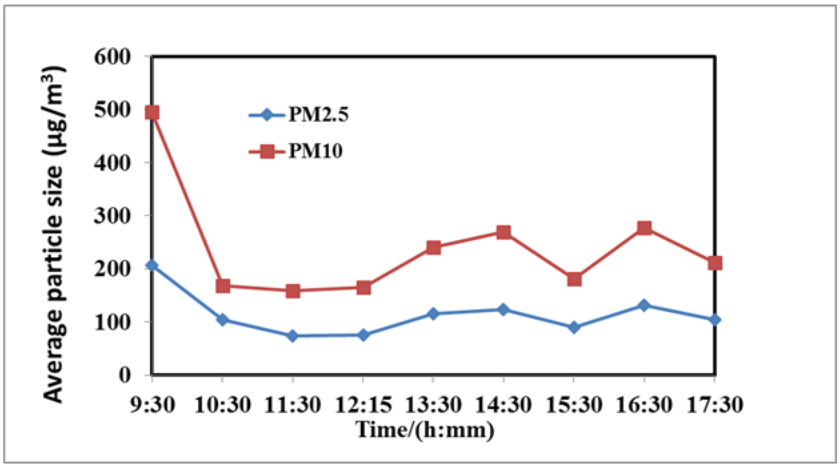

Figure 4. Time variation in average PM10 and PM2.5 particle concentration level in patient room

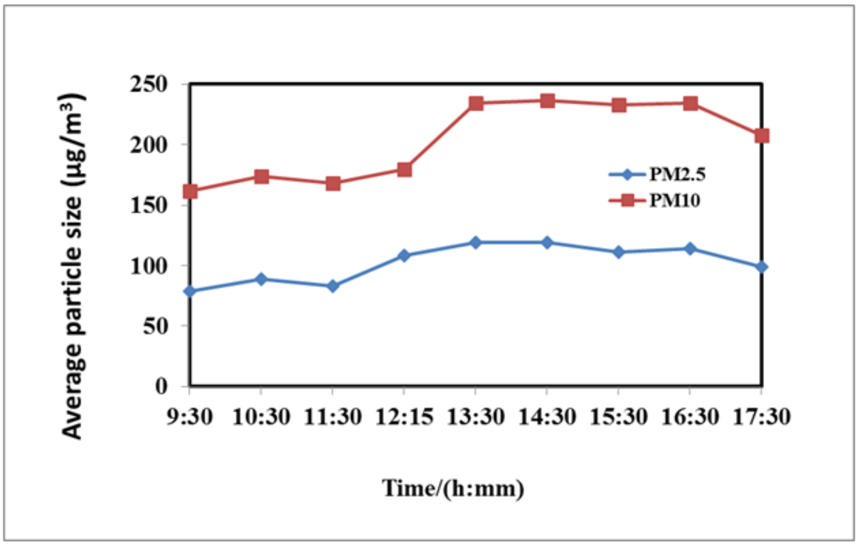

Figure 5. Time variation in average PM10 and PM2.5 particle concentration level in outside.

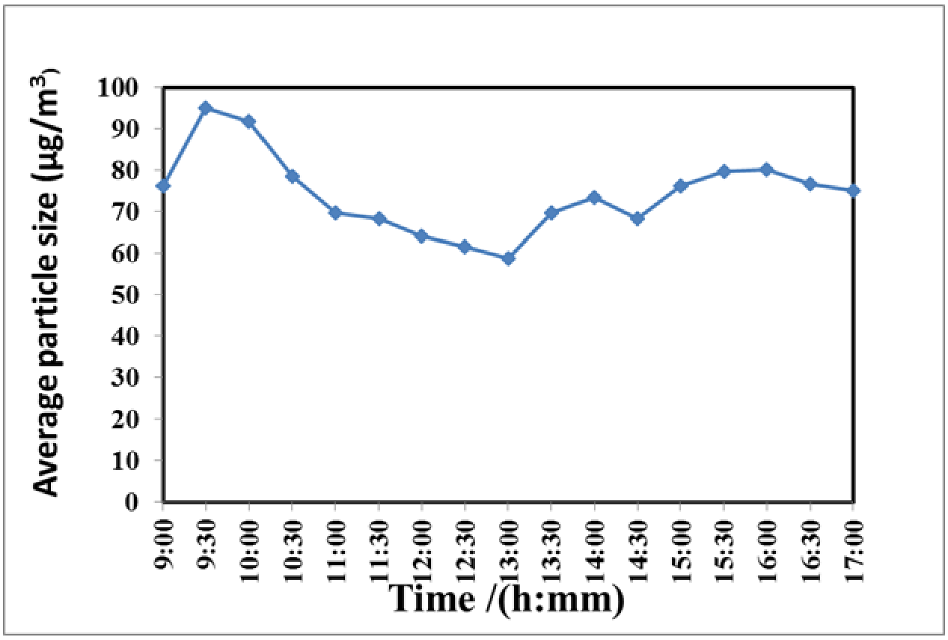

Figure 6. Time variation in average PM10 and PM2.5 particle concentration level in ICU at XYZ Hospital

3.1 Temperature

The indoor air temperature in hospitals must be maintained within recommended ranges (20-24oC), according to international regulations and standards, to ensure acceptable conditions. Use of lower or higher temperature is acceptable when patients' comfort and/or medical conditions require this kind of conditions. The indoor air temperature must be uniform within the space. In this study, temperature level range from 19°C to 26°C which is not too high above the acceptable level. The Hospital indoor environment may have a different perception of prevailing indoor conditions due to different levels of activity and even work stations within the hospital indoor environment. These are in agreement with other studies where preferable thermal comfort conditions were reported for hospital indoor environment in the range of 23–24oC (Dascalaki eatl 2009). During this investigation, the perceived indoor temperature was documented by the personnel on a seasonal basis (Table 2). The prevailing indoor temperature was characterized as high, low, satisfactory, and non-uniform. Summer appears to be the most problematic period, which is due to the poor Heating Ventilation and Air-conditioning (HVAC) cooling performance. Overall, problems encountered with the ventilation and air circulation inside the hospital environment, are also confirmed by the high percentage of personnel declaring non-uniform indoor conditions, throughout the investigation period. Unsatisfactory indoor air temperature and spatial variations are mostly due to malfunctions of the air handling units (AHUs) that do not deliver the air at the desirable conditions, or as a result of blocked ventilation air supply and exhaust. Access to controls for setting the desirable indoor temperature is essential for meeting the occupants' comfort requirements.

Provided that the AHU serving the various site has the appropriate heating/cooling capacity, doctors and authorized medical staff should be able to directly set the desirable physical parameters that are most appropriate for each procedure and prevailing conditions. Poor control of indoor environmental conditions is not only inconvenient but is psychologically unacceptable because the occupants do not feel that they have a role in controlling their surroundings. As a result this may lead to complaints.

3.1.1 Humility

Air humidity must be maintained at acceptable levels. High humidity levels favor the growth and transfer of bacteria that can easily become airborne on water molecules, and cause thermal discomfort. Low humidity levels favor blood coagulation, and may cause problems associated with static electricity on medical equipment and surfaces, and even pose a fire hazard. The recommended levels of indoor relative humidity are 30–60%, according to international regulations and standards. During this investigation, the perceived indoor humidity was documented by the personnel on a seasonal basis (Table 3) in all the two hospitals. The prevailing humidity was characterized as high, low, and satisfactory. Winter appears to be the most problematic period. For the hospitals, the RH ranged from 35% to 89.9% in ABC Hospital and 28% to 99 (Table 2).

This implies that the humidifier in the AHU do not provide personnel thermal satisfaction averaged on daily basis. The average humidity satisfaction was 60%, but there was no noticeable distinction based on whether the AHUs were equipped with a humidifier or not (averaging 73% and 65.78%, respectively). Prevailing humidity is most satisfactory for other personnel and health works (averaging 68.8%). The time and variation in average temperature and relative humidity at the hospitals is shown in Figures 7 and 8. It was observed there was slight increase in temperature and relative humidity after 12.15 pm. This indicates that there was a rise in temperature after this period.

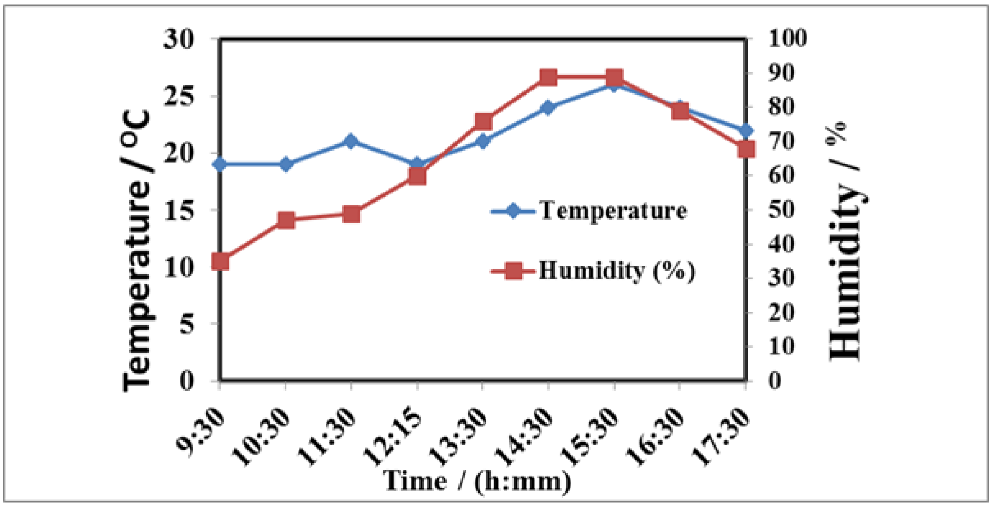

Figure 7. Time variation of average temperature and relative humidity level in the atmosphere in the ABC Hospital.

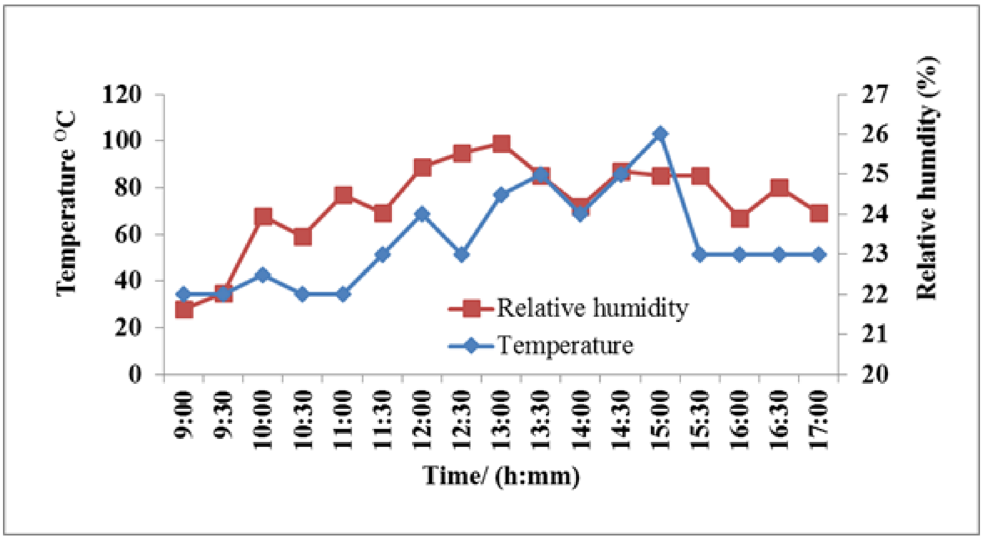

Figure 8. Time variation of average temperature and relative humidity level in the Atmosphere in the ICU of XYZ.

IV. CONCLUSIONS AND FINAL RECOMMENDATION ON (PM2.5, PM10)

4.1 Conclusions

Indoor air quality in terms of particulate matter was determined in two hospitals and six units in Wuhan. The measurements were conducted with the application of portable CW-HAT200 Handheld Air monitoring equipment (TSI DustTrak Particle Matter Monitor CW-HAT200 and Grimm HAT200). The results indicated that the indoor air quality in terms of average concentration of PM10 and PM2.5 were very high and exceeded the World Health Organization guidelines (i.e. 50µg $/m^3$ for PM10 and 25 µg/ m^3 for PM2.5). The results indicated that a long-term campaign would be of great importance, since high concentration levels of particulate matter were recorded in both hospitals. Improper ventilation, temperature and humidity seem to have a negative impact on the particulate matter concentration levels. Management need to strategies for proper indoor environment technique in order to successfully control IEQ in hospitals. Therefore, in order to efficiently reduce the PM concentrations at hospitals, joint efforts of technical, healthcare and administrative staff are necessary.

4.2 Executive Summary

Indoor air quality (IAQ) is a very complicated subject involving issues related to indoor environmental, and related to people living in indoor occupational and environmental for hygiene, health personal and patients in IEQ, this has been developed at more and more Hospital environment around the world, especially in developed countries, but it is relatively slow and late in developing countries. This paper overviewed the sources and effects of indoor particulate matter (PM). Indoor PM is generated both outdoors and indoors, with a great variety of ratios in concentration. Some outdoor PM can enter indoor via ventilation and cracks on structure, while most indoor PM is generated inside the indoor environments. Indoor sources of airborne PM include indoor combustion processes, abrasion of surfaces, equipment operation, furnishings, human activities, and aerosol consumer products such as personal care, pest control, and clearing, growth, and chemical reaction among indoor pollutants. In livestock buildings, particulate matter is almost entirely organic and originates from feed, skin and feathers or feather debris, bedding and dried faeces; fungal spores originate from damp feed or bedding. There are great variations of the PM mass concentration. For indoor environments without significant indoor sources is always less than one but still varies extensively. In Hospital indoor environments, both smoke and particle contributes significantly to the indoor repairable suspended particulates matter level. Indoor activities have substantial influence on ratio of PM level; the effect is more significant in public places where it is crowded and the ventilation rate is not enough. In Health buildings, the dust concentrations vary significantly since patient and visitor spend more time in this environment, PM2.5, PM10 ratios are based on mass concentrations and some point samples, Real time investigation on particulate matter ratio using multiple sampling technology has been done.

Indoor PM, especially that smaller than 10 □ m, adversely affects human by causing lung dysfunctions, acute respiratory infections or even death, and carrying other pollutants. Particulate matter can also cause irritation and dryness of the eyes and nose and allergenic responses. It also acts as transport vehicles for gaseous pollutants, viruses and bacteria, infectious disease, and odors. PM in livestock buildings has significant effects on the health and comfort of both animals and human. Particulate matter (PM) is the term used to describe condensed phase (solid or liquid) particles suspended in the atmosphere. Their potential for causing health problems is directly linked to the size of the particles. A growing body of research has pointed towards the smaller particles, in particular PM less than 2.5 μm in diameter (PM2.5), as a metric more closely associated with adverse health effects than other metrics such as PM10 (particles with a diameter less than 10 μm).

4.3 Further Recommendation

I will further recommend that a study need to be carry out at the hospital site to determining the Volatile Organic Compound (VOC) level in the ABC Hospital Environment to ensure TVOC at the site, A further study also need to be look at the various department like theater, ICU, and recovery for particulate matter (PM2.5, PM10) concentration in the Hospital site to ensure proper and safe working environment. Microorganisms need to look at to ensure perfect surgical site of surgical site infection (SSI), with possible mechanisms pathogenic contaminates. The growth of air bone microbial contamination which is very stringent to ensure freedom from microbial contamination in the Hospital Environment site, the study recommendation that the Heat Ventilation and Air- Conditioning (HVAC) system need to be service on regular basses to ensure indoor environmental quality.

HEPA filter should be replaced in due time for effective and air flow for proper indoor environmental quality.

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