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Investigation of Indoor Air Quality in a Hospital: A Case Study from Şanlıurfa, Turkey

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Abstract

Most people spent more than %80 of their time indoors. In Turkey, hospitals are prominent governmental places. Its importance becomes from more visits than others. An investigation about the interior air quality across the polyclinics of one of the most visited hospital of Şanlıurfa, Turkey, was conducted in this study. Indoor air quality in terms of PM, CO, CO_2, temperature and relative humidity was investigated. The performed measurements were revealed that the levels of $PM_{2.5}$ and PM_{10} in surgery, urology, neurology, heart surgeon and eye diseases polyclinic were higher than the threshold limits in international standards set by WHO and ASHAE. CO_2, a surrogate for indoor pollutants emitted by humans. In this research, CO_2 was found to be under the standards in radiology, tomography, X-ray, orthopedics polyclinics and emergency services. Conversely, it was measured above the standards across the other polyclinics. Temperature and relative humidity were found unsuitable; CO was found to meet the standards. The significantly high rates were considered as a result of inadequate ventilation, lack of proper cleaning, low ceiling and crowd of patients. The old age of the building could create risk of dust particles, CO_2, temperature, humidity in the hospital for the health of the staff and patients visiting the polyclinics.

Keywords

Indoor Air Quality, Particulate Matter (PM), Carbon Dioxide (CO_2), Hospital, Human Health, Şanlıurfa

Bir Hastanede İç Hava Kalitesinin Araştırılması: Şanlıurfa’dan Örnek Bir Çalışma

Özet

Çoğu insan zamanlarının %80’ninden fazlasını iç ortamlarda geçirmektedir. Hastaneler, Türkiye'de önemli bir kamusal alandır. İnsanların hastanelere diğer kamusal alanlardan çok daha fazla gitmesi hastaneleri önemli bir kurum haline getirmektedir. Bu çalışmada, Türkiye’nin Şanlıurfa ilinde en çok hasta bakan hastanenin polikliniklerinde iç hava kalitesi araştırılmıştır. İç hava kalitesini belirleyen partikül madde (PM), CO, CO_2, sıcaklık ve bağıl nem iç hava kalitesini belirleyen parametreler olarak değerlendirilmiştir. Ölçülen değerler WHO, ASHAE gibi uluslararası standartlarla karşılaştırıldığında $PM_{2.5}$ ve PM_{10} konsantrasyonun her ikisinin de yüksek değerlerde olduğu poliklinikler sırasıyla genel cerrahi, üroloji, nöroloji, kalp servisi ve göz hastalıkları olarak belirlenmiştir. CO_2 insanlar tarafından solunum yoluyla yayılan bir iç hava kirleticisidir. Bu araştırmada CO_2 seviyesinin radyoloji, tomografi, röntgen, ortopedi polikliniği ve acil serviste ASHAE standartlarının altında olduğu bulunmuşken diğer polikliniklerde standartın üstünde ölçülmüştür. Sıcaklık ve bağıl nem değerleri tüm polikliniklerde standartlara uygun olmadığı, CO değerinin tüm polikliniklerde düşük olup standartları sağlamakta olduğu saptanmıştır. Yetersiz havalandırma, eksik temizlik, alçak tavan ve hasta sayısındaki fazlalık polikliniklerde standartların üzerinde değerlere sebep olan ana etmenler arasında olduğu düşünülmektedir. Eski yapılı hastanelerde, toz partikülleri, CO_2, sıcaklık ve bağıl nem polikliniklerde çalışanların ve hastaların sağlığı için risk oluşturabileceği saptanmıştır.

Anahtar Sözcükler

İç Hava Kalitesi, Partikül Madde (PM), Karbondioksit (CO_2), Hastane, İnsan Sağlığı, Şanlıurfa

1. Introduction

Recent studies revealed that people spend more time indoors rather than outdoors (Yang 2017) and the indoor concentrations of pollutants have already exceeded those of outdoors due to the presence of strong emission sources and lack of ventilation (Jovanović et al. 2014). Thus, the poor indoor air quality (IAQ) poses a heavy threat to human health (Shy et al. 2015; Ciuzas et al. 2016; Chang et al. 2017).

Supplying medical care and nursing care to the people in need is the basic responsibility of a hospital. Hospitals posses different medical opportunities and services and are composed from different units including inpatient wards, operating theatres, intensive care units (ICUs), outpatient departments (OPDs), pharmacies, radiology departments, laboratories, etc. The operation and the routine of the services differ one from another.

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There are 3 major categories of the dwellers of a hospital: patients, medical personnel and visitors. In the way of the health condition and sensitivity to aerial chemicals and microbes, personal groups differ from each other. Hospitals are different from other profitable or manufacturing constructions in terms of the variety of opportunities and dwellers. The air contamination happening in closed areas has turned into a common issue in terms of avoiding the patients' and medical staffs exposing hospital acquired infections and occupational diseases. The environmental insufficiencies of closed areas are related to particular constructional matters, ventilating systems, air-conditioning percentage, as well as attitude of people (Leung and Chan 2006). Contamination happening in closed areas may bring into oxidative stress (Lu et al. 2007a; Lu et al. 2007b) including epidemic hospital-acquired infections (i.e) throat, irritability, tiredness, dizziness, and other symptoms (Lu et al. 2015). The management of IAQ is instrumental in avoiding the patients' and medical staff 's exposing hospital acquired infections specially those immunosuppressed and immunocompromised patients, who are remarkably sensitive to negative influences of different aerial chemicals and microbes. Inadequate hospital IAQ can bring into epidemics such as sick hospital syndrome (SHS), migraine, tiredness, eye and skin scratchiness and other signs. Most importantly, controlling hospital IAQ incorrectly can bring into hospital acquired infections (nosocomial) and occupational diseases (Lu et al. 2016). In IAQ, the most important polluters are PM, CO, CO_2, temperature and relative humidity for the creation of the comfortable environment.

Scientists have been investigating the PM because of the negative impacts of it on people's well-being. It has been revealed in numerous researches that the inhalable particles and respiratory and cardiovascular diseases were connected to each other (Araújo et al. 2011; Kim et al. 2015). As PM_{10} and $PM_{2.5}$ tend to endamage respiratory health by means of wide influence on the respiratory tree, scientists have highly focused on them. Furthermore, Riediker et al. (2004) have shown that mortems due to lung cancer and cardiopulmonary disease were associated to them. Thus, PM are one of the most important factors contributing to poor IAQ (Li et al. 2017).

Structure of PM is composed of solid particles and fluid dribs. Those components are found hanged in atmospheric environment in different magnitudes and structures from diverse derivations. Classical approaches categorize context of particles according to their magnitude as PM_{10}, $PM_{5.0}$, $PM_{2.5}$, $PM_{1.0}$, and $PM_{0.5}$ which are formed by the condensation of inhalable particles tinier than 10, 5, 2.5, 1, 0.5 µm in turn. According to their sizes, particles above 10 µm are named as coarse particles and the ones tinier than 2.5 µm are named as fine particles (Vilcekova et al. 2017).

In respiratory tract diseases, the particle size of dust is of great importance. In the respiratory tract which functions as a gate for the entrance into the flesh, storage space and target organ, there are the nasopharynx, the tracheobronchial and pulmonary zones as depicted in Figure 1 (McClellan 2000; Morman and Plumlee 2013). The air inhaled by the lungs is transmitted to the digestive system and the stomach. It is reported in this study that alveoli occlude with dust particles triggers many diseases including death.

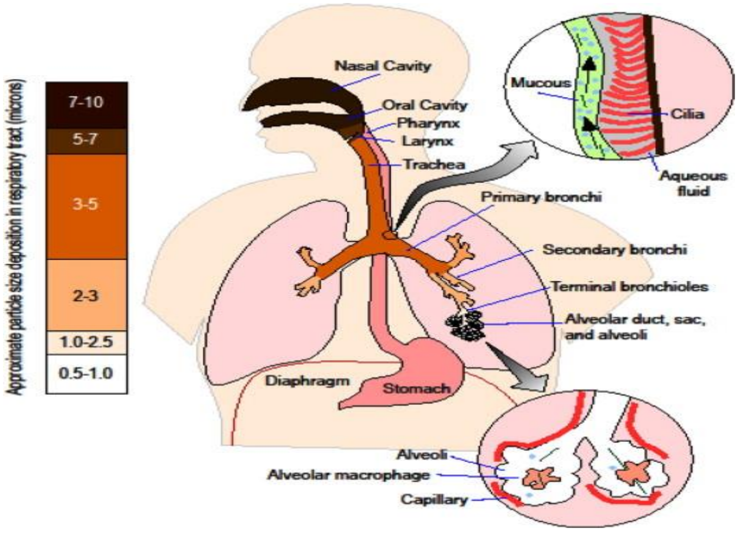


Figure 1: Simplified diagram of the human respiratory system. The approximate particle size deposition that may occur in each section is color coded and identified in the legend (Modified from McClellan 2000; Morman and Plumlee 2013)

The impacts of inhalable PM to the health are properly certified. Health risks are due to exposure over both short period such as hours and days and long period such as months and years. Upon exposure to inhalable PM, people experience respiratory and cardiovascular morbidness, that is, worsening of asthma, respiratory signs and the increasing hospitalization frequency. Moreover, increase of death rate due to lung cancer and cardiovascular and respiratory illnesses is highly correlated with the inhalable PM exposure. Each 10 $\mu g/m^3$ increase in $PM_{2.5}$ levels results in 6-13 % increase in cardiopulmonary death upun long-time exposure (Beelen et al. 2008; Pope III et al. 2002).

CO_2 is a surrogate for indoor pollutants emitted by humans and correlates well with human metabolic activity. Humans are the main source of indoor carbon dioxide. According to the crowd of the hospital environment, the CO_2 level may change. The CO_2 emission causes health problems for the patients thus making it a must for further academic research on IAQ.

Carbon monoxide (CO) is a gas without color and odor also it is a component of exhaust gases caused by incomplete combustion. In cities, the major source of CO is cars. Avoiding CO emissions is quite important for the IAQ because of its toxical impact. Chamseddine and El-Fadel (2015) has pointed out that main source of indoor CO in hospitals is from the outdoor intrusion.

There are three reasons that indoor air quality in a hospital evaluated in this study. First of all, hospitals are receiving the maximum number of guests as compared to other public places. Accordingly, the IAQ in hospitals affect the people considerably. Secondly, it has been shown in the epidemiological studies that the hospital-acquired respiratory system infection (HARSI) is associated with the indoor aerosols. Therefore, PM_{10} and $PM_{2.5}$ are the main carriers for the transport of these viruses within the hospitals. Thirdly, the studies demonstrating the impact of IAQ in hospitals are very limited for Turkey. The sources and loads of PM are yet poorly known. To our best knowledge, the data generated in this study will be the first one for our country.

This research was conducted in the vicinity of Şanlıurfa at the most populated Mehmet Akif Inan Training and Research Hospital. Its location as the hospital that serves the most patients in Şanlıurfa makes it a prominent place for research. Thus, the IAQ was measured across waiting rooms in 20 different polyclinics in terms of CO, CO_2, PM_{10} and $PM_{2.5}$ as well as meteorological parameters including temperature and relative humidity. The results were compared with World Health Organization (WHO) and American Society of Heating and Air-Conditioning Engineers (ASHAE) standards.

2. Materials and Methods

2.1. Presentation of Workspace and Measurement Methods

Situated in the North of Iraq and Syria, West of Iran; Şanlıurfa is the 7th largest metropolis in Turkey. The Mehmet Akif İnan Training and Research Hospital serves 3500 patients daily in its 49500 m^2 complex in general surgery, urology, neurology, eye diseases, pediatrics, heart surgeon,brain surgeon, chest diseases, cardiology, internal medicine, endocrine, physiotherapy, radiological, tomography, X-Ray, orthopedics, emergency polyclinic waiting rooms were chosen for the research. The location of the city and hospital was depicted in Figure 2. The building was finished in 2004 and started to serve the people of Şanlıurfa since then. Although the building was renovated from time to time, it did not have a good reparation. The hospital floor has a ceiling height as low as 2.5 m.

Owing to the hot summer periods of the region, the surveyed hospital is climatized by split type-air conditioners or central air conditioners all day. Smoking is strictly forbidden and frequent house-cleanings are done during the day.

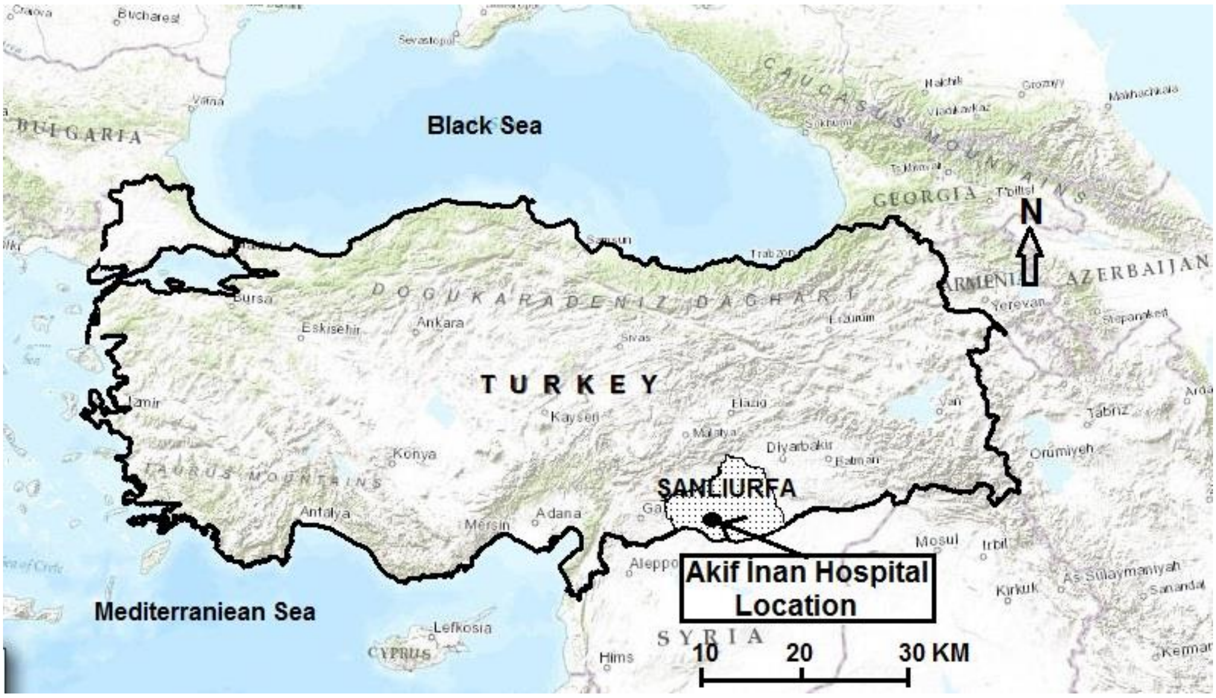


Figure 2: Location of the city and hospital

2.2. Methodology

This study was performed in the waiting rooms of 17 different polyclinic (general surgery, urology, neurology, eye diseases,pediatrics, heart surgeon,brain surgeon, chest diseases, cardiology, internal medicine, endocrine, physiotherapy, radiological, tomography, X-Ray, orthopedics, emergency) of the Mehmet Akif Training Research Hospital, which is known as the one of the most visited hospital of Şanlıurfa. PM10, PM2.5, temperature and relative humidity were measured by Termo Scientific pDR 1500 personal DataRam device during the period of August-December 2017 with 15-minute sampling periods for each parameter. In addition, CO and CO_2 levels in the hospital was detected by the Kanomax 2221 device, which is able to measure CO_2 concentration in the range of 0-5000 ppm with an accuracy of ± 1 ppm.

3. Results and Discussion

The summary statistics of the measured levels of $PM_{2.5}$, PM_{10}, CO and CO_2 in each of the polyclinics were provided in Table 1. The mean $PM_{2.5}$ concentrations ranged from 9.65 μg/m^3 for X-ray polyclinic to 45.7 μg/m^3 for neurology polyclinic. Maximum and minimum mean PM_{10} levels were measured 18.55 and 84.48 μg/m^3, respectively, for pathological and neurology polyclinics, respectively. The maximum CO level was recorded in chest diseases polyclinic as 2.5 ppm while that for CO_2 was measured in cardiology with a value of 2653 ppm.

Table 1: $PM_{2.5}$ and PM_{10} concentrations in polyclinics

	$PM_{2.5}$ (μg/m^3)			PM_{10} (μg/m^3)			CO (ppm)	CO_2 (ppm)
Polyclinic	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Mean**	**Mean**
General Surgery	40.54	32.71	26.66	67.72	51.71	40.65	1.4	1080
Urology	45.04	42.71	39.81	75.72	69.03	63.12	1.5	1707
Neurology	66.99	45.7	33.75	95.88	84.48	73.81	1.7	1319
Eye Diseases	28.39	26.8	25.82	60.2	55.49	48.67	1.7	1923
Pediatry	26.65	25.5	24.33	51.79	43.58	37.42	1.5	2156
Heart Surgeon	30.89	25.05	24.33	50.79	55.49	37.4	1.7	2253
Brain Surgeon	26.05	25	24.03	51.89	44.58	38.42	1.9	2363
Chest Diseases	18.66	16.96	16.25	36.67	28.05	24.53	2.5	2652
Cardiology	14.84	13.55	12.78	43.22	36.03	31.98	1.9	2653
Internal Medicine	16.18	13.68	11.74	33.23	24.65	21.81	1.9	1323
Endocrine	22.65	18.78	15.09	39.17	35.59	32.14	1.6	1179
Physiotheraphy	21.2	20.33	19.2	52.47	42.36	36.17	1.4	1293
Padiological	10.12	9.45	8.77	22.26	18.55	16.66	1.6	690
Tomography	10.18	9.5	8.9	22.3	18.7	16.7	1.4	836
X-ray	10.02	9.65	8.87	22.36	18.85	16.76	1.6	897
Orthopedics	29.1	23.86	15.37	45.85	36.61	29.85	1.6	995
Emergeny	37.51	19.79	9.12	34.03	27.39	16.14	1.2	669

3.1. PM_{10} and $PM_{2.5}$ Levels

In a hospital environment, PM_{10} and $PM_{2.5}$ have importance for the IAQ. These environments are open to the public. The PM_{10} and $PM_{2.5}$ levels, which were conducted across the hospital polyclinics, are shown on the Table 1. It can be deduced from Table 1 that the measured PM_{10} and $PM_{2.5}$ levels varies widely from polyclinic to polyclinic. The polyclinics that are well above the WHO standards for $PM_{2.5}$ and PM_{10} are the general surgery, urology, neurology, heart surgeon, emergency, orthopedics, pediatry, brain surgeon and eye diseases as tabulated in Table 1. The reason for the high $PM_{2.5}$ concentrations in these clinics is due to the large number of patients waiting, lack of adequate ventilation and the lack of cleanliness. In addition, according to the studies conducted in the literature, people walking indoors have been found to be able to influence the level of PM in the air (Zhang et al. 2008; Jung et al. 2015). Hence, the elevated PM levels in these polyclinic could be attributed to movement of people. The $PM_{2.5}$ and PM_{10} levels were found to be lower in outpatient clinics, radiology, tomography and X-ray than WHO threshold limit of 25 $\mu g/m^3$. The reason for the low values in these polyclinics is that the number of waiting patients is low due to the patients arriving by appointment in advance, intensive ventilation, and more attention is paid to cleanliness of the polyclinics.

The correlation between PM_{10} and $PM_{2.5}$ was also investigated in this study and the correlation coefficient was found to be as high as 0.903 (Figure 3). Significantly high correlation between $PM_{2.5}$ and PM_{10} was attributed to human activities inside the hospital. The presence of elevated $PM_{2.5}$ inside the hospitals as a result of human activities was also found by Wang et al. (2006). A test was conducted to determine whether human activities had a significant effect on measured $PM_{2.5}$ levels or not. It was designed to find out whether there were significant differences in indoor particulate concentrations between weekdays and weekends in a section, where outpatients were present. Once the measured weekday and weekend $PM_{2.5}$ levels were compared, the average rate of weekday samples was significantly higher than the weekend samples, which confirmed that the level of the interior space particle during the week is significantly affected by indoor human activity, resulting in resuspension of the particles. During one of the week day, many people walked frequently from inside and outside of the hospital; which may have caused the PM accumulated on the floor surfaces to be resuspended, thereby causing the concentration of $PM_{2.5}$ in the regions to increase. On the contrary, there was little or no activity during the weekend, and lower $PM_{2.5}$ concentration was recorded.

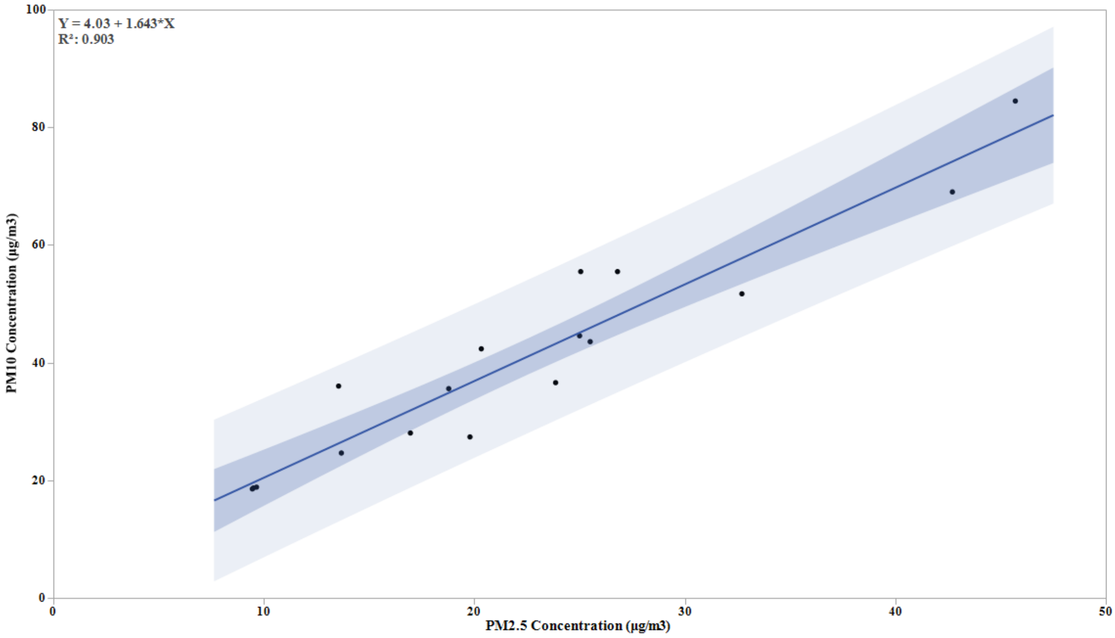


Figure 3: Relationship between PM_{10} and $PM_{2.5}$ in indoor environments

Studies those have been done in outer parts show that emissions in closed places or particles infiltrated from outside by means of air-conditioning, windows or constructional fractures impact PM levels inside the building (Chen and Zhao 2011; Halios et al. 2013). Likewise, the measurements of PM_{10} and $PM_{2.5}$ were performed inside and outside of the hospital within the same day. It has been found out that corresponding outside concentrations were 65 and 40 $\mu g/m^3$, respectively, which exceeded the threshold limit values set by WHO (Figure 4). It can also be deducted from Figure 5 that outside $PM_{2.5}$ levels slightly higher than corresponding value measured inside, which can be explained by the traffic around the hospital. On the other hand, measured PM_{10} levels were almost similar both inside and outside.

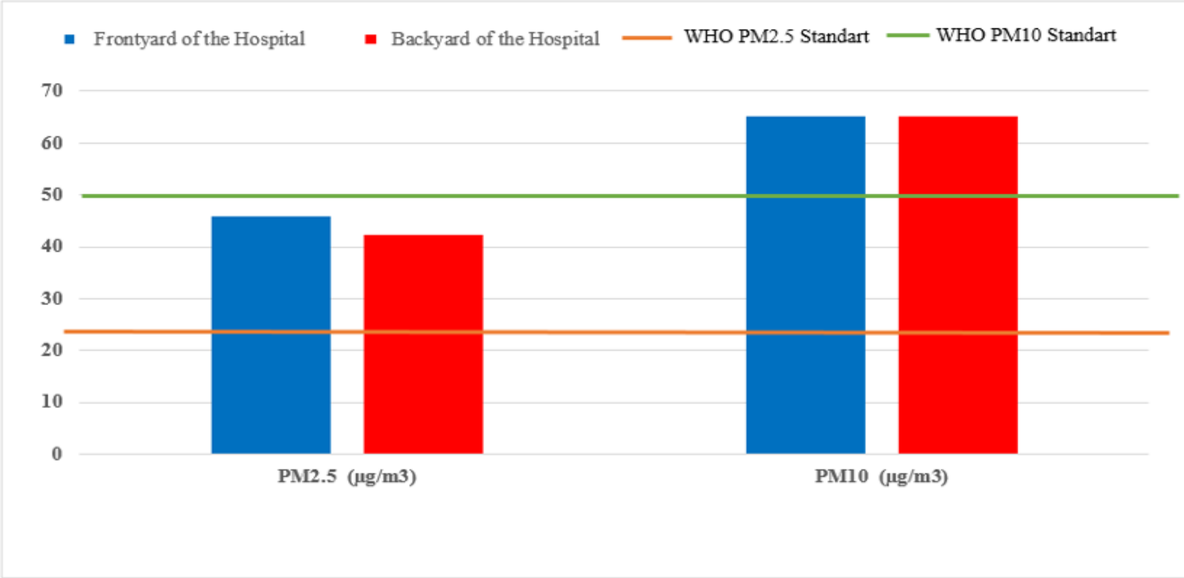


Figure 4: Comparisons of PM $_{2.5}$ and PM_{10} outdoor air concentrations with standards

3.2. CO and CO_2

Other important parameters in indoor environments for human health are CO_2 and CO. Human inhales these gases through the respiratory tract. Elevated concentrations of these gases can cause many illnesses, poisonings and even deaths. In this study, measurements were made in the same 17 polyclinic waiting rooms of the hospital. Carbon dioxide (CO_2) is a surrogate for indoor pollutants emitted by humans and correlates well with human metabolic activity, in other words, humans are the main source of indoor CO_2. Carbon dioxide is a constituent of exhaled breath and is an indicator of the adequacy of outdoor air ventilation relative to indoor occupant density and metabolic activity.The level of CO_2 is therefore often used to assess the efficiency of ventilation (Seppänen et al. 1999). According to the WHO and EPA standards, indoor CO_2 levels should not exceed 1000 ppm to ensure satisfactory comfort (Bruce et al. 2002; WHO 2000; Jung et al. 2015).

In this study, the CO_2 value was found to be below the critical and standard value of 1000 ppm in radiology, tomography, X-ray, orthopedics, and emergency services, and was measured to be quite high in other outpatient clinics Figure 5 (a). According to the research of the National Institute for Occupational Safety and Health (NIOSH) indoor air concentrations of CO_2 that exceed 1000 ppm are a marker suggesting inadequate ventilation. For this reason, it became clear that there is a serious ventilation problem in polyclinics with high CO_2 rates in the hospital.

CO has been thought as a procurator for civic air contamination in variety of countries over the years, besides being located in the horizontal range to highways is modificated as exposing the air contamination (Stephen 1997; Oliver et al. 1998). In Athens, nearly all of the entire CO transmissions are identified with mobile sources (Chaloulakou et al. 2003). It is not possible to find an interior resource transmitting CO into the hospital (i.e) unvented kerosene and gas-room-heaters, leaky flues and furnaces, gas-water-heaters, log burners or gas-stoves, log fires and petrol-driven kit (Erdoğan et al. 2010). In this study, CO rates were measured below the standard rates of 3 ppm Figure 5 (b). It may be due to the fact that it is far from vehicle parking area and the hospital uses fuel oil for heating.

3.3. Temperature and relative humidity in hospital environment

The most significant factors of thermal comfort are internal heat and moisture. There are particular heat and proportional moisture ratio needed for people to be at ease corporeally. Humid and hot weather above the standards are disturbing for humans. In low humidity, dryness occurs in nose and mouth, and it is needed to drink water frequently due to rapid loss of water in the body. The comfort zones are defined according to temperature and relative humidity for summer and winter, because temperature and humidity cannot be dissociated from each other. Figure 6 (a) represents the comfort zones in accordance with heat and proportional moisture (Doğan 2002; ASHRAE 2001). While external temperature in summertime mainly affects the selection of internal heat, the intention aimed and the character of the environment in wintertime are taken into consideration when deciding the interior heat design. It is suggested that internal heat be betwixt 15 and 26°C and the internal proportional moisture be betwixt 30 % and 70 % for varied environments (ASHRAE 2001; Recknagel-Sprenger 2003; Işık and Çibuk 2015).

As the research demonstrates on Figure 6 (b), the indoor air temperature of the hospital is high in all polyclinics whereas the relative humidity is very low. These conditions are in the concerning category for the patients. Under these circumstances, it may trigger further increase in illnesses among the patients. In old buildings, especially because of the ceiling height (> 2m), it is thought that the relationship between temperature and relative humidity in the lack of ventilation is affected and does not meet the standards.The reason for this is that the ventilation is inadequate because of the large number of people waiting in polyclinics.

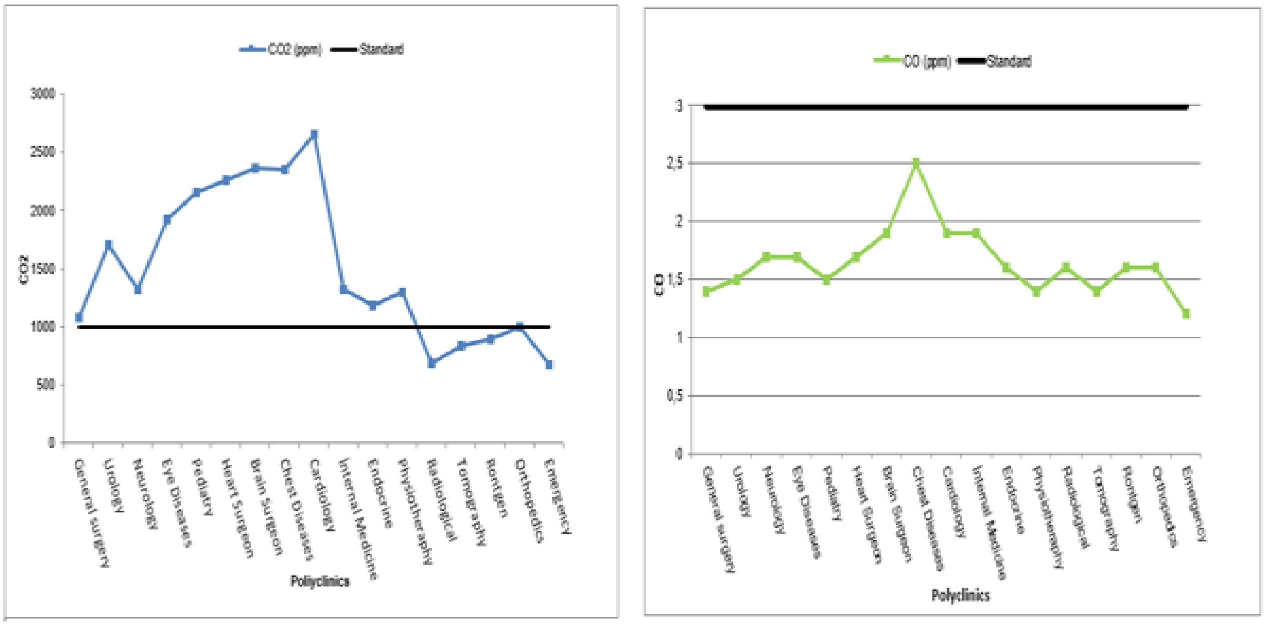
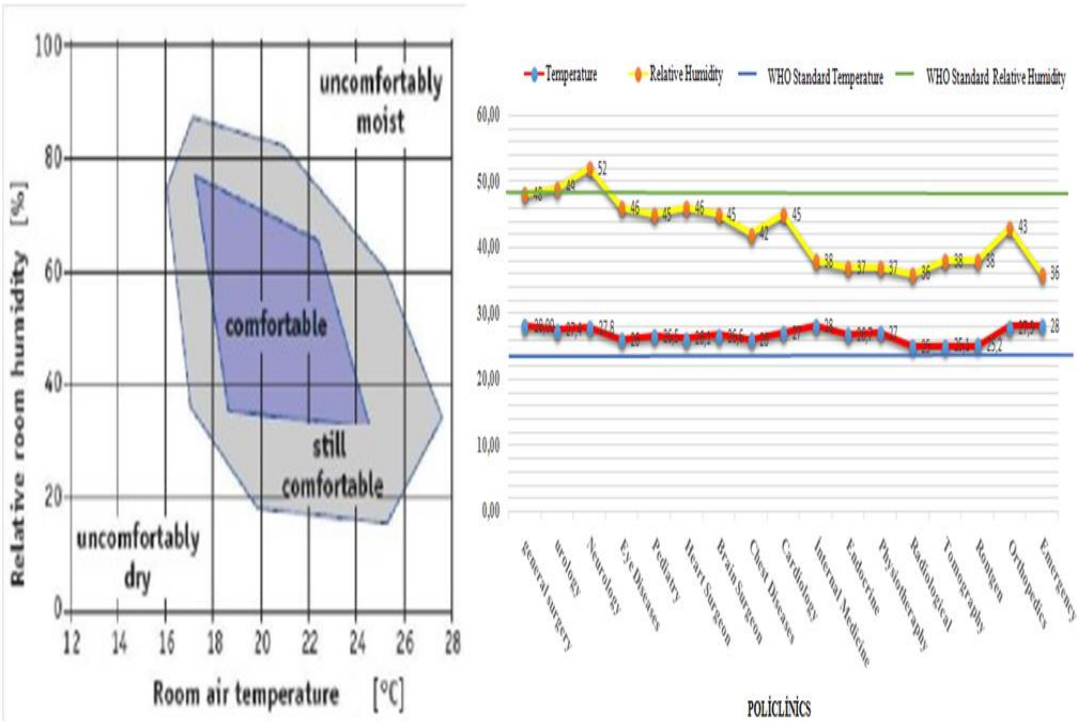


Figure 5: (a) Measured CO_2 Concentrations in Polyclinic (b) Measured CO Concentrations in Polyclinics



(a) (b)

Figure 6: (a) Thermic comfort zone determined by air temperature and relative humidity (Doğan 2002)
(b) Comparison of temperature and relative humidity measured in the hospital with WHO standards

4. Conclusions

In many countries, there are standards controlling the maximum permissible limits for pollutants related to IAQ. These standards are constantly updated and reduced to more sensitive rates for human health. IAQ is rather very important in all public areas considering that people regularly visit public spaces for services needed. The low air quality of these places causes the spread of many epidemic diseases, causing daily complaints such as headache, nausea and psychological depression. Since the hospital building we examined is a well aged public building, the rates in PM_{10}, $PM_{2.5}$, CO_2, temperature and relative humidity have exceeded the maximum standard rates in many polyclinics. The results show that the bad IAQ may affect the patients and working personnel negatively due to high concentrations of people, lack of necessary sanitation and insufficiency of ventilation. In order to overcome this challenge, routine measurements of IAQ in public buildings should be made a legal requirement. Old public buildings should be periodically repaired and taken care of while the state of the building must be improved. Ventilation is essential for IAQ, thus it is necessary to do regular maintenance and establish legal compliance standards.

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