ISSN: 0067-2904

Assessment of Ambient Air Quality in Neonatal Incubators at Selected Sites of Baghdad Hospitals

Hind J. Al Obaidi*, Nada A. R. F. Al Easawi
Department of Biology, College of Science, University of Baghdad, Baghdad, Iraq

Received: 2/8/2022 Accepted: 19/10/2022 Published: 30/8/2023

Abstract

An infant incubator in the neonatal intensive care unit (NICU) is a medical instrument of care that provides oxygen, warmth and moisture to a newborn baby. Due to environmental conditions affecting the infants foster babies may experience discomfort and pain at some point. Thus, this study aimed to assess ambient air quality in neonatal incubators to improve the environmental quality of neonatal intensive care units and safety. Air pollutants concentrations consisting of particulate matter ($pm_{2.5}$, pm_{10}), hydrocarbons (HOCH), volatile organic compounds (VOC), air quality index (AQI), humidity and temperature, were measured at four selected Baghdad hospitals (Al-Karkh and Rusafa) . The results showed that the increase in relative humidity (RH%) measured in all baby incubators and in all locations during the summer and winter seasons contributed to an increase in polluting gases emission inside the incubators, which was the highest measurement that gave significant difference for the incubator.

The highest recorded measurement with significant difference for $pm_{2.5}$ was 73.78 ± 0.096 in site2 in winter, pm_{10} was 106.73 ± 0.05 in site1 in winter, HCHO was 0.148 ± 0.005 in site3 in winter, VOC was 673 ± 0.005mg/m3 in site2 in winter, AQIwas 177.25 ± 0.5 in site2 in winter, RH% was 53.887 in the site3 during the winter and temperature was 32.25°C in site3 in summer. It can be concluded that there is a relationship between relative humidity and temperature that affectedthe gases concentrations as it showed variations in gases and particle matters concentrations which affected the air quality inside the neonatal incubatorsthat in turn affected the health of the neonates, especially increased severity of asthma attacks and low Intelligence quotient (IQ) in children in the future.

Keywords: neonatal incubator, intensive care unit, air quality index, temperature and RH%.

تقييم جودة الهواء المحيط في حاضنات الأطفال حديثي الولادة في مواقع مختارة من مستشفيات بغداد

هند جبار العبيدي *، ندى عبدالرحمن فليح العيساوي
قسم علوم الحياة، كلية العلوم، جامعة بغداد ، بغداد، العراق

الخلاصة

حاضنة الرضع في وحدة العناية المركزة لحديثي الولادة (NICU) هي أداة طبية للرعاية توفر الأوكسجين والدفء والرطوبة للطفل حديث الولادة. قد يعاني رضيع الحاضنة في وقت ما من عدم الراحة والألم وقديرجع ذلك إلى الظروف البيئية التي تؤثر على الرضع. وبالتالي ، تهدف هذه الدراسة إلى تقييم جودة الهواء المحيط

*Email: hind81jabbar@gmail.com

في حاضنات الأطفال حديثي الولادة لتحسين الجودة البيئية لوحدات العناية المركزة لحديثي الولادة وسلامة حديثي الولادة. قمنا بحساب تركيزات ملوثات الهواء في أربعة مواقع مختارة من مستشفيات بغداد (الكرخ والرصافة) لقياس ملوثات الهواء التي تتكون من الجسيمات ($pm_{2.5}$، pm_{10}) ، الهيدروكربونات (HOCH) ، المركبات العضوية المتطايرة (VOC) ، مؤشر جودة الهواء (AQI)،الرطوبة ودرجة الحرارة. أظهرت النتائج أن الزيادة في الرطوبة النسبية (RH٪) المقاسة في جميع حاضنات الأطفال وفي جميع المواقع خلال فصلي الصيف والشتاء ساهمت في زيادة انبعاث الغازات الملوثة داخل الحاضنة ، وهو أعلى قياس يعطي فرقاً معنوياً بالنسبة للحاضنة.، كان أعلى قياس يعطي فرقًا معنويًا لـ $pm_{2.5}$ هو 73.78 ± 0.096 في الموقع 2 في الشتاء ، pm_{10} كان 106.73 ± 0.05 في الموقع 1 في الشتاء ، HCHO كان 0.148 ± 0.005 في الموقع 3 في الشتاء ، VOC كان 673 ± 0.005 مجم \ م 3 في الموقع 2 في الشتاء ، كان مؤشر جودة الهواء 177.25 ± 0.5 في الموقع 2 في الشتاء ، وكانت نسبة الرطوبة النسبية 53.887 في الموقع 3 خلال الشتاء وكانت درجة الحرارة 32.25 في الموقع 3 في الصيف.في الختام ، كانت هناك علاقة بين الرطوبة النسبية ودرجة الحرارة التي تؤثر على تراكيز الغازات ، حيث أظهرت اختلافات في تركيزات الغازات والجسيمات ، مما يؤثر على جودة الهواء داخل حاضنات الأطفال حديثي الولادة ، مما يؤثر بدوره على صحة الأطفال حديثي الولادة، وخاصة زيادة شدة نوبات الربو عند الولدان وانخفاض معدل الذكاء عند الأطفال في المستقبل.

1. Introduction

A biomedical equipment known as an infant incubator gives newborns the warmth, humidity and oxygen required in a regulated environment and provides special environment for high risk babies till they adapt themselves to standard nursery or home conditions [1]. Premature infants in neonatal intensive care units (NICUs) have underdeveloped immune systems, making them susceptible to adverse health consequences from air pollutants exposure [2]. Any agent that alters the natural properties of the atmosphere, be it a chemical, physical or biological one, constitutes air pollution [3]. Indoor air quality (IAQ) in neonatal wards may affect both the health of employees and the treatment of neonates [4]. The world health organization (WHO)refers to indoor air pollution as being the biggest environmental health risk that has been linked with many adverse maternal and neonatal outcomes. Indoor air quality (IAQ) is an indicator for assessing air quality by evaluating the concentrations of pollutants in the indoor environment that directly affect air quality like NO_2, HCHO, O_3, CO, CO_2, PM2.5 and volatile organic compoundsemitted from different sources such as paint, furniture, office equipment, trash, exhaled breath and/or sweating [5]. Numerous illnesses such as necrotizing enterocolitis (NEC), bronchopulmonary dysplasia (BPD) and late-onset newborn sepsis have been examined using fecal VOCs as biomarkers (LONS) [6]. Neurodevelopment results have shown that high $PM_{2.5}$ exposure causes reduced head circumference and significantly effects the motor skill and social emotional development [7]. The exposure to PMs can lower the Intelligence quotient IQ of a child which is indicative of its capacity to cause fetal neuro-developmental delay [8]. $PM_{2.5}$ has also been associated with reduced fetal growth and rapid postnatal growth as well as increased risk of pre-eclampsia. After a day with high particle levels, premature deaths from breathing these particles can happen immediately or one to two months later. Even low levels of particles can be deadly [9]. The humidity in the outdoor somehow influences the indoor [4]. Both high and low relative humidity (RH%) can be uncomfortable. Low air humidity in winters affects comfort and health, thus increasing respiratory problems [10]. In a study for indoor air of neonatal intensive care units were monitored in real time to detect deviations from target parameters quickly. Infants have very low thermal regulation and temperature regulation which is one of the most important factors which affect the preterm [11]. The feeble body is incapable of coping with the thermal loss. This necessitates placing the neonates body in a moist and heated environment. Hence, one of the most important factors that must be maintained with minimal variation is temperature [12].

2. Materials and Methods

2.1.The Field of Study

The field of study was performed at four pediatric hospitals in Baghdad, two each in AL-Karkh and AL-Rusafa. The samples were collected in tow season summer (June and July (and winter (December and January (for each pediatric neonatal hospitalist intensive care unit (NICU).Wards of neonatal were measured in these pediatric hospitals. The first hospital in AL-Karkhhas had three NICU wards and each ward had 8 incubators. The dimension of each ward was 6m * 8m * 3m with 144m3 volume and moderate ventilation conditions. The incubators in the first site of study were not at all in use. Some wards, however, had all incubators in use with infants and their relatives (mother, aunt and grandmother) septic and other incubators in two NICU rooms were not in use. The second site of study in AL Karkh had one NICU ward with dimensions of the NICU room being 8m * 16m* 3 m with 348m volume and moderate ventilation conditions. It had all 10 incubators in use but there were no relatives (mother, aunt and grandmother) aseptic by the nursing staff took care of neonates.

The first pediatric hospital in Al-Rusafa had four NICU wards with each having 8 incubators and the dimensions of each ward in the pediatric hospital came down to being 10m * 8m * 3m with 240m^3 volume with moderate ventilation conditions. The readings for parameters used in this study (particulate matter (pm$_{2.5}$, pm$_{10}$), hydrocarbons (HOCH), volatile organic compounds (VOC), air quality index (AQI), humidity and temperature)were measured and recorded for all study sites.

2.2.Air Samples Measurement Devices

Digital devices designed by Temtop in California and assembled in China were fixed at five points in each of the study sites.The values readings were replicated five times for each point and the concentrations gave readings in part per million units (ppm) and mg/m3.

2.3.Statistical Analysis

The Statistical Package for the Social Sciences SPSS version 25 (Armonk, NY: IBM Corp.) and GraphPad Prism version 8.0.0 (San Diego, California USA) were used to perform the statistical analysis. The parameters were given as percentage frequencies, and significant differences between frequencies were assessed by Pearson-Chi-square test or two-tailed Fisher exact probability (*p*). T-test and ANOVA probability were used to compare continuous variables (normally distributed) and to assess significant differences between means (Asterisk indicates significant differences $p< 0.05$). Moreover, the Pearson bivariate correlation was employed to understand the correlation between certain parameters.

3. Results and Discussion

3.1. MeanLevels of Environmental Gases.

As shown in Table 1, the results of particulates matter **PM$_{2.5}$** that were measured in neonatal incubators in NICU reported the highest values in site2 in winters (73.78 ± 0.096) and the lowest value of 45.57 ± 24.9 was recorded in site4 in summer.The statistical analysis showed a significant relationship for all sites during the winter and summer seasons, as well as the it was significant for each site during the two seasons at level of probability *p*-value<**0.**01.

Table 1: Mean levels of environmental markers stratified according to summer and winter among fourneonatal incubators site.

Season	Environmental markers mean ± Std. Deviation among incubators

		Site 1	**Site 2**	**Site 3**	**Site 4**	***p*-value**
$PM_{2.5}$/ ppm	Winter	69.18 ± 0.096	73.78 ± 0.096	66.88 ± 0.05	65.83 ± 0.05	<**0.01**
	Summer	60.2 ± 0.22	60.38 ± 0.19	61.4 ± 0.6	45.57 ± 24.9	<**0.01**
	p-value	< **0.01**	< **0.01**	< **0.01**	< **0.01**	
PM_{10}/ ppm	Winter	106.73 ± 0.05	100.43 ± 0.05	99.13 ± 0.05	106.33 ± 0.05	<**0.01**
	Summer	93.1 ± 0.08	92.9 ± 1.0	94.03 ± 0.32	90.43 ± 0.29	<**0.01**
	p-value	< **0.001**	< **0.01**	< **0.01**	< **0.01**	
HCHO mg/m3	Winter	0.143± 0.005	0.105 ± 0.01	0.148 ± 0.005	0.128 ± 0.005	<**0.01**
	Summer	0.038 ± 0.005	0.018 ± 0.01	0.025 ± 0.005	0.043 ± 0.046	> 0.05
	p-value	< **0.001**	< **0.001**	< **0.001**	< **0.001**	
TVOC mg/m3	Winter	0.593 ± 0.005	0.673 ± 0.005	0.643 ± 0.005	0.663 ± 0.005	<**0.01**
	Summer	0.04 ± 0.008	0.06 ± 0.006	0.043 ± 0.005	0.025 ± 0.01	<**0.01**
	p-value	< **0.001**	< **0.001**	< **0.001**	< **0.001**	
AQI	Winter	156.75 ± 0.5	177.25 ± 0.5	168.25 ± 0.5	155.25± 0.5	<**0.01**
	Summer	151.25 ± 0.96	167 ± 0.00	165.25 ± 0.96	151.25 ± 1,89	<**0.01**
	p-value	< **0.05**	< **0.05**	< **0.05**	< **0.05**	

PM: HCHO: TVOC: AQI: ; *p*: ANOVA test and T-test probability.

The results of this study for PM2.5 concentrations in neonatal incubators agree with those of a study by Lomboy et al. which took place from October to December 2013 in an urban tertiary care hospital in the Philippines for the characterization of particulate matter 2.5 in NICU. The results were very significant at a level of p = 0.001 which were more than the 25 gm-3 WHO recommended threshold. However, our results disagree with this study during March to April 2014 in which PM2.5 was recorded at 28.4 µgm-3. The reason for this increase in PM2.5 concentrations in our study results showed that indoor PM2.5 was mainly derived from outdoor sources[13.[

Particulate matter PM10 showed highest result with 106.73 ± 0.05 in site1 in winter, with the lowest result being 90.43 ± 0.29 in site4 in summer. The statistical analysis showed high significance in the first site at level of probability p-value<0.001 during summer and winter seasons, and significant relationship in the second, third and fourth sites during summer and winter seasons at level of probability p-value<0.01 for each site. Current study results conflicted with the results of the study by Dusan et al.[14] which showed that the time-averaged PM10 mass concentrations were generally low, not exceeding 5 µg/m3 (mean ± standard deviation = 2.9 ± 0.8 µg/m3). Their research attributed it to efficient particle filtration, effective building hygiene protocols and relatively low occupancy. The results of the current study for PM2.5 & PM10 agree with those of Chamseddine et al. [15] where their cited data revealed that the observed PM2.5 & PM10 concentrations were 2 to 3 times higher than the advised levels in a number of locations. These regions may have such high levels of PM2.5 & PM10 throughout the summer due to the high occupancy rate, human activity and occurrence of regional dust storms [16.[

Among the gases measured in the incubators, hydrocarbons **(HCHO)** showed high values with0.148 ± 0.005 in site3 in winter and the lowest values being 0.018 ± 0.01 in site 2 in summer, and the statistical analysis showed significant relationship in all sites in winter at level of probability *p*-value<0.01 and significant relationship in all sites in summer at level of probability *p*-value< 0.05.According to this study, the high relative humidity contributed to an increase in hydrocarbons emission as Prazad *et al.* [13] mentioned that two non-target hydrocarbon compounds, 2-heptanone and n-butyl acetate were found when compared to ambient room air samples, the amounts inside the incubators were higher. The concentration of these chemicals was further raised by a rise in temperature with the addition of humidity. Formaldehyde (TVOC) is one of the gases that were measured in incubators in neonatal intensive care units which showed high values of (673 ± 0.005) in site2 in winter and the lowest values being(0.025 ± 0.01) in site4 in summer. The statistical analysis showed significant relationship in all sites in two season at level of probability *p*-value < 0.01 and showed highsignificance for each sites during the summer and winter seasons at level of probability *p*-value< 0.001**.** As mentioned previously, the current study agreed with another research concerning the results of $\mathbf{PM_{2.5}}$ & $\mathbf{PM_{10}}$, also agreed with them in the result of TVOC in both warm and cold weathers tha interior TVOC concentrations were higher than outdoor concentrations, The main causes of these levels included the regular use of air fresheners and floor cleaners, which are known sources of TVOC [14] [15].

For evaluating the concentrations of above pollutants in the incubator of NICU,Air Quality Index (IAQ) is an indicator that was used for assessing indoor air quality. The results of IAQ from Table 1 shows high value of 177.25 ± 0.5 in site2 in winter and the lowest value being151.25 ± 0.96 in site1 in summer and the statistical analysis show significant relationship for all sites in summer and winter at level of probability *p*-value<0.01and also show significant relationship for each sites in two season at level of probability *p*-value<0.05. Limiting and eliminating particles from the outer environment while also minimizing interior PM sources is the greatest way to improve indoor air quality [16], [17], [18]. For this purpose, central air conditioning and mechanical ventilation systems are properly constructed, maintainedwith enough filtration are useful [19], [20], [21]

3.2. *Measurement of Temperature and Humidity among NeonateIncubators.*

Figure 1 shows the relationship between relative humidity (RH%) and temperature that were measured in neonatal incubators at all sites and for summer and winter seasons is inverse, as when the RH% increases, the temperature decreases, so the relative humidity is inversely proportional to the temperature for the summer and winter seasons for all sites. The highest RH% level was 53.887 insite3 during the winter and the lowest level was 21.25 in the site 4 during summer. The statistical analysis showed a high significance value of RH% at level *p-value*< 0.001.

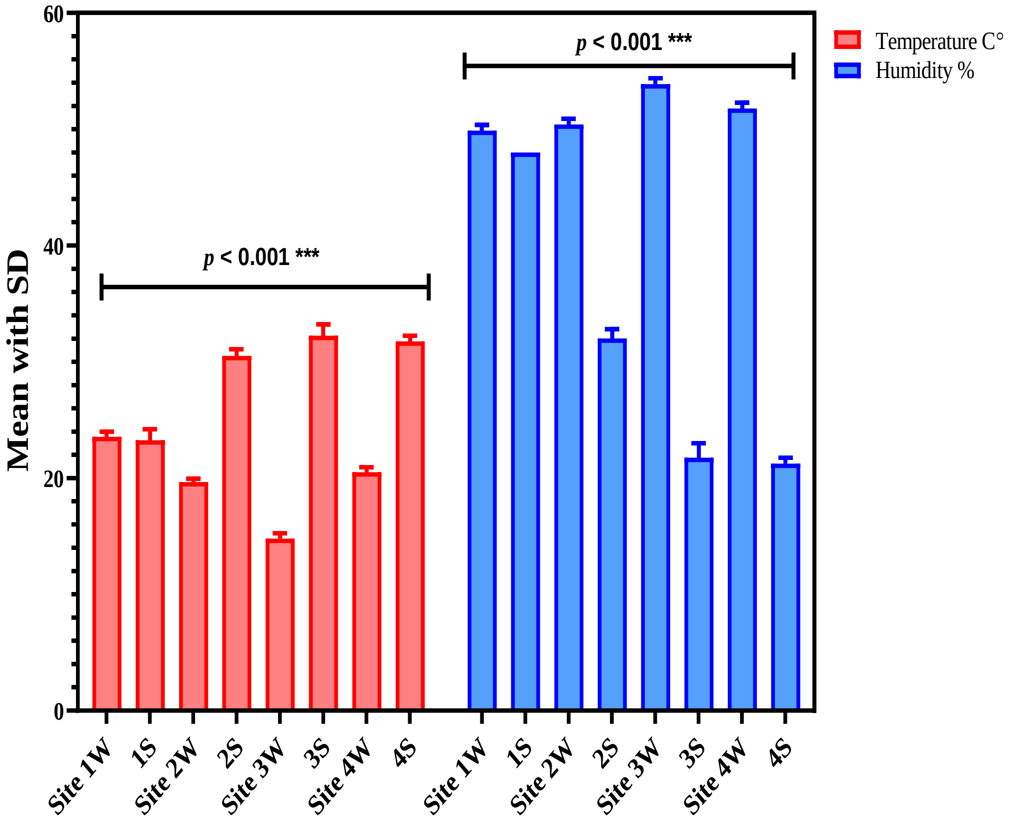

Figure 1: Mean of temperature and humidity among neonats' incubators during winter (W) summer (S) season. *P:* one-way ANOVA test probability.

The highest level of temperature was 32.25°C in site3 in summer, while the lowest level was 14.25°C in site3 in winter. The statistical analysis for temperature showed high significance value of temperature at level *p-value*< 0.001. The primary health effects of high humidity are caused by the growth and spread of biotic agents, although humidity interactions with non-biotic pollutants, such as formaldehyde, may also cause adverse effects [22]. Humidity sensor should provide its level in the incubator in terms of relative humidity (%RH) in the range of 0-100% RH [23]. Few investigations have shown that the bodyweight and insensible water loss are inversely proportional. If the humidity in the shell environment is not at a healthy level, it may have a harmful impact on the patient. Too little humidity can cause infants to evaporate moisture and heat, while too much humidity makes it more likely that bacteria and germs will be present. It is advantageous to regulate or at least keep track of humidity [24].

3.3. *The Relationship of Temperature and Relative Humidity with $PM_{2.5}$, PM_{10}, HCHO, TVOC and AQI.*

Figure 2 shows the results of positive relationship between the **gases** and relative humidity (RH%) for all sites during winter and summer seasons, as well as the positive relationship between humidity and **gases** for each site during the two seasons. From Figure 2A, the Pearson's correlation (r_p) results of $\mathbf{r_p}$= 0.54 show a correlation between the increase of RH% with the increase of $\mathbf{PM_{2.5}}$, and the statistical analysis shows significant proportionality of RH% with the particles $\mathbf{PM_{2.5}}$ at a level of probability *p-value*< 0.01. Also, RH% showed positive relationship with the increase of $\mathbf{PM_{10}}$ and good correlation with it as represented in Pearson's correlation (r_p) at $\mathbf{r_p}$=o.73, statistical analysis show highly significant proportionality of RH% with the particles $\mathbf{PM_{10}}$ at level of probability *p-value*< 0.001 as shown in Figure 2A for all sites during winter and summer seasons, as well as for each site during the two seasons. The current study disagrees with the investigation conducted by Fromme *et al*. and . [24] and Bouwstra [25] in winter where they found a significant negative correlation between relative humidity and real-time monitoring $PM_{2.5}$ concentration(r=-0.32, p<0.05). Our investigation however agrees with this study's results in summer where they found significant positive correlation in summer (r=0.24,p<0.05).

While the increase of RH% is positively related to the increase in gas concentrations, there is a weak correlation between the increase of RH% and the increase of AQI as shown in $\mathbf{r_p}$=0.149 and the statistical analysis showed no significant proportionality of increase in RH% with increase of AQI at level of probability p=0.42, as shown in Figure 2B for all sites during winter and summer seasons, as well as for each site during the two seasons.

In contrast to the weak correlation of RH% with AQI, the increase of RH% had positive relationship with the increase of HCHO and TVOC gases as shown in Figure 2C. There is a strong correlation between the increase of RH% and increase of HCHO gas as shown in $\mathbf{r_p}$= 0.76 and the statistical analysis showed highly significant proportionality of RH% with HCHO at level of probability *p-value*< 0.0001 for all sites during winter and summer seasons.
Also, the increase of RH% had positive relationship with increase in TVOC gas as shown in Figure 2D that there is a strong correlation between the increase of RH% and TVOC gas as shown in $\mathbf{r_p}$=0.81 and the statistical analysis showed a highly significant proportionality of RH% with TVOC at level of probability *p-value*<0.0001 for all sites during winter and summer seasons. Many studies have mentioned that the emission profile of polar VOCs from building materials may alter markedly due to increase in RH [25], [26], [27], [28].

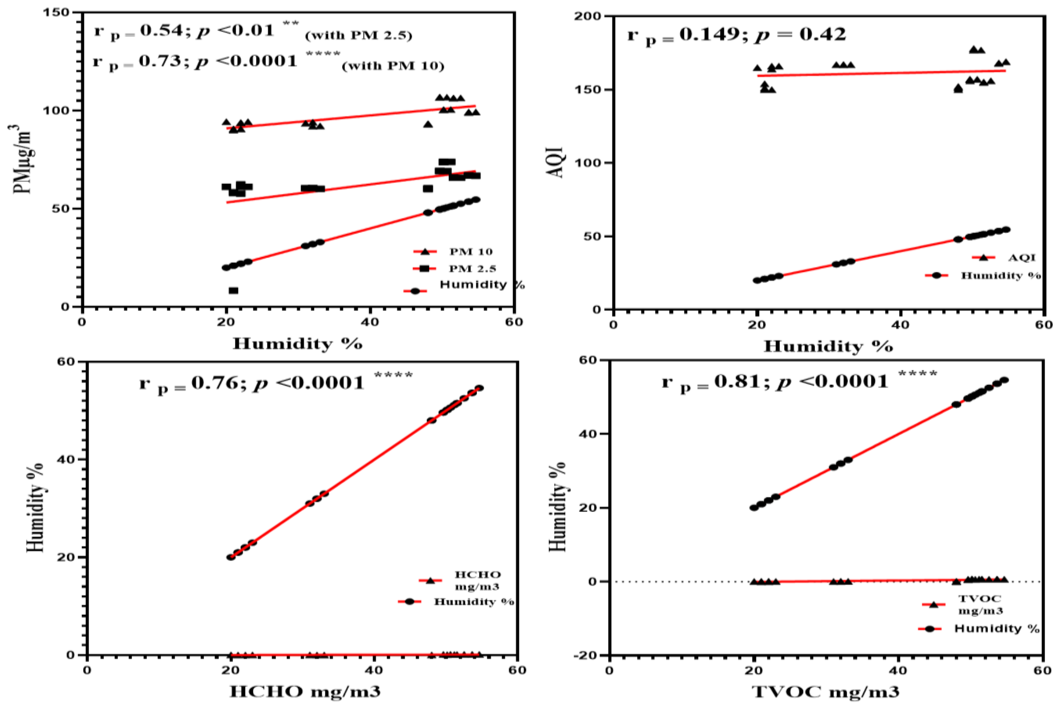

Figure 2: Pearson correlation coefficient (r_P) between the gases and RH%for all sites during the winter and summer seasons.Figure 2A is Pearson correlation coefficient between PM_{10} &$PM_{2.5}$ and RH%,2BPearson correlation coefficient between RH% and AQI, 2C is Pearson correlation coefficient between RH% and HCHO and2 D is Pearson correlation coefficient between RH% andTVOC.

In contrast to RH%, the increase in temperature is inversely related to the increase in all gases as shown in Figure 3A. There is inverse proportion for Pearson correlation coefficient between PM_{10} & $PM_{2.5}$ and temperature. Where the $\mathbf{r_p}$= -0.47 for temperature with $PM_{2.5}$ and the statistical analysis shows inverse significant proportionality between the increase of temperature and increase of $PM_{2.5}$ at *p-value*<0.01 and the same for PM_{10} with temperature are shown in Figure 3A. Three is inverse proportion for Pearson correlation coefficient between PM_{10} and temperature at $\mathbf{r_p}$= -0.54 and the statistical analysis shows inverse significant proportionality between the increase of temperature and increase of PM_{10} at *p-value*<0.001 for all sites during winter and summer seasons. Studies have also shown that there was no significant correlation between indoor temperature and indoor particle concentration [29]. These results are mainly due to the difference in geographical, climatic and architectural types of the measurements [30].

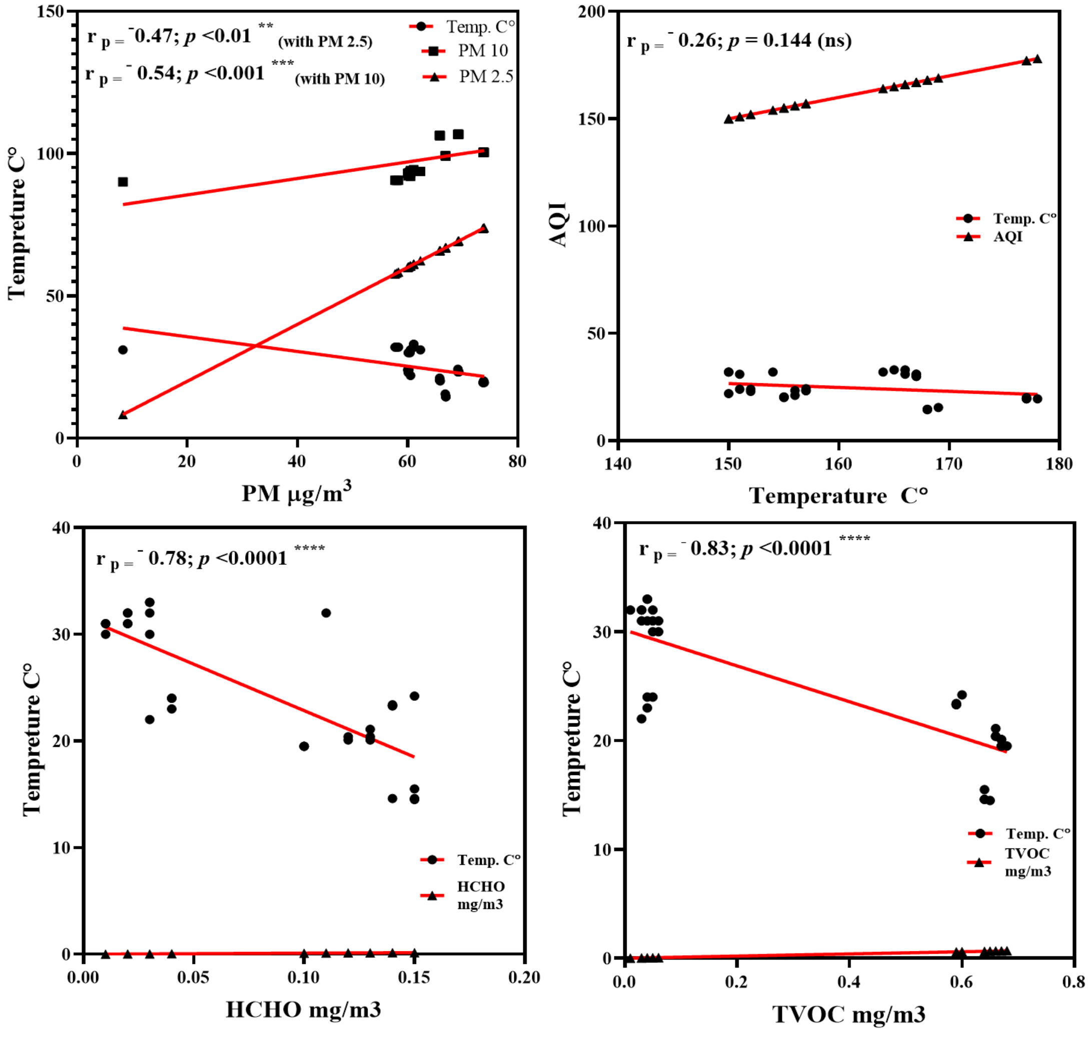

Figure 3: shows the Pearson correlation coefficient (r_p) between the gases and temperature for all sites during the winter and summer seasons.Figure A is Pearson correlation coefficient between PM_{10} &$PM_{2.5}$ and temperature, Pearson correlation coefficient between temperature and AQI, C is Pearson correlation coefficient between temperature and HCHO and D is Pearson correlation coefficient between temperature and TVOC.

While there is inverse correlation between the increase of temperature and gases concentrations, there is a weak inverse correlation between the increase of temperature and AQI as shown in rp= -0.26, and the statistical analysis shows no significant proportionality between temperature and AQI at level of probability p=0.144 as shown in Figure 3B for all sites during winter and summer. The increase of temperature had inverse relationship with the increase of HCHO and TVOC gases as shown in Figure 3C that there is a strong inverse correlation between the increase of temperature and increase of HCHO gas as shown in rp= -0.78 and the statistical analysis shows highly inverse significance proportionality of temperature with HCHO at level of probability p-value< 0.0001 for all sites during winter and summer seasons. Also, the increase of temperature had inverse relationship with the increase of TVOC gas as shown in Figure 3D. There is a strong inverse correlation between the increase of temperature and increase of TVOC gas as shown in rp=-0.83 and the statistical analysis shows highly inverse significance proportionality of temperature with TVOC at level of probability p-value< 0.0001 for all sites during winter and summer seasons.The hospital administration's efforts to lower the temperature and pay attention to the heating, ventilation, and air conditioning systems which are necessary to maintain good indoor air quality and is also an important non-pharmacological strategy in the prevention of hospital-acquired infections, may be the cause of the decrease in temperature and its inverse relationship with polluted gases [35],[36],[37]. The high percentage of polluted gases could be due to the incinerators that hospitals use to dispose of waste, as well as from the electricity generators located near the hospital buildings, as well as due to the large emission of vehicles smoke, since these hospitals are inside the capital, Baghdad [38], [39] ,[40], [41.[

References

[1] D. Ahmed, L. Ali, "Nurse's Skills Regarding Care of Preterm Infants in Neonatal Intensive Care Unit," Jazan, *Neonatal and Pediatric Medicine*. KSA.,vol.5,pp.1-7, 2019.

[2] D. Licina, et al., "Concentrations and Sources of Airborne Particles in a Neonatal Intensive Care Unit ," *PLOS ONE*. May 2016,doi:10.1371/journal.pone.0154991.

[3] World Health Organization(WHO)," Air pollution," 2022. Available: https://www.who.int/health topics/air-pollution#tab=tab_1.

[4] Y. Aljeesh, "Assessment of Indoor Air Quality in Neonatal Intensive Care Units in Government Hospitals in Gaza Strip, Palestine," Public Health Research, vol. 6(1),pp. 24-30, 2016, doi: 10.5923/j.phr.

[5]A.Barthwal and K.Rastogi, "AQCI: an iot based air quality and thermal comfort model using fuzzy inference," *International Conference on Advanced Networks and Telecommunications Systems* (ANTS), no. Institute of Electrical and Electronics Engineers: Piscataway, NJ, USA., 2019,doi: https://ieeexplore.ieee.org/document/9118026.

[6] C. Course, "Volatile organic compounds as disease predictors in newborn infants: a systematic review," *Journal of Breath Research*,vol. 15, no. 2, 2021,doi:10.1088/1752-7163/abe283.

[7] C.Kao, "Infants' Neurodevelopmental Effects of PM2.5 and Persistent Organohalogen Pollutants Exposure in Southern Taiwan," Aerosol Air Qual,vol.19,pp.2793-2803,2019,doi: 10.4209/aaqr.2019.10.0550.

[8] C.T. Loftus, "Prenatal air pollution and childhood IQ: Preliminary evidence of effect modification by folate. Environ," vol. 176,pp 108505, 2019, doi: 10.1016/j.envers2019.05.036.

[9] United States of environmental protection agency U.S.(EPA), " Air Quality Criteria for Particulate Matter," 2004, doi: cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=87903.

[10] L.G. Berglund, " Comfort and humidity ," American Society for Heating, *Refrigerating and Air conditioning Engineers Journal*,pp. 35-41, 2002.Available: https://www.scribd.com/document/507330151/Comfort-and-Humidity.

[11] A.J.Lyon, M.E.Pikaara, P.Badgera and N.Mclntosh "Temperature Control in Very Low Birthweight Infants During First Five Days of Life," Archives of Disease in Childhood Fetal and Neonatal Edition, vol. 76, no.1,pp.47–50, 1996, Available: http://dx.doi.org/10.1136/fn.76.1.F47.

[12] H. Bansa,L. Mathew and A. Gupta, "Controlling of Temperature and Humidity for an Infant Incubator Using Microcontroller," *Nternational Journal of Advanced Research in Electrical*, Electronics and Instrumentation Engineering, vol.4, no. 6,pp.4975- 4982, 2015, doi: 10.15662/ijareeie.2015.0406012.

[13] M.F.C. Lomboy, "Characterization of particulate matter 2.5 in an urban tertiary care hospital in the Philippines,Building and Environment," vol.92,pp.432-439,2015, doi: https://doi.org/10.1016/j.buildenv.05.018.

[14] L. Dusan, et al., "Concentrations and Sources of Airborne Particles in a Neonatal Intensive Care Unit," 2016. Available: https://doi.org/10.1371/journal.pone.0154991.

[15] A. Chamseddine,"Seasonal variation of air quality in hospitals with indoor–outdoor correlations,Building and Environment," vol.148, pp.689-700, 2018. Available: https://doi.org/10.1016/j.buildenv.2018.11.034.(https://www.sciencedirect.com/science/article/pii/S0360132318307297.

[16] N. Kubilay,et al., "An illustration of the transport and deposition of mineral dust onto the eastern Mediterranean," Atmospheric Environment, vol. 34 ,no. 8,pp.1293-1303, 2000. Available: https://doi.org/10.1016/S1352-2310.

[17] P. Prazad,D.R.Cortes,B.L.Puppala,R.Donovan,S.Kumar and A.Gulati, "Airborne concentrations of volatile organic compounds in neonatal incubators," *Journal of Perinatology*, vol. 28,pp. 534-540 , 2008. Available:https://doi.org/10.1038/jp.2008.75.

[18] M.S. Erdogan, et al., "Total volatile organic compounds (TVOC), carbon monoxide (CO), carbon dioxide (CO2) concentrations in the hospital building of a medical faculty in Istanbul, " Turkey, Nobel Medicus., vol. 6 ,pp.66–72, 2010.

[19] H.X. Lu, et al., "Carbonyl compounds and BTEX in the special rooms of hospital in Guangzhou, China," *Journal of Hazardous Materials,* vol.178(1-3),pp. 673–679, 2010,doi: 10.1016/j.jhazmat.2010.01.138

[20] P.S. Nimlyat and M.Z. Kandar, "Appraisal of indoor environmental quality (IEQ) in healthcare facilities: A literature review, Sustainable Cities and Society," vol. 15,pp. 61–68 , 2015,doi: 10.1016/j.scs.2015.04.002.

[21] C. C. Jung,P.C.Wu, C.H.Tseng and H.J.Su,"Indoor air quality varies with ventilation types and working areas in hospitals, Building and Environment," vol.85,pp.190-195, 2015, doi:10.1016/j.buildenv.2014.11.026.

[22] S.A. Abdul-Wahab, et al., "A review of standards and guidelines set by international bodies for the parameters of indoor air quality, " vol. 6,pp. 751-767, 2015,doi: 10.5094/APR.2015.084.

[23] S.R. Agrawal, et al., "Effect of an air cleaner with electrostatic filter on the removal of airborne house dust mite allergens, " *Yonsei Medical Journal*, vol. 51,pp. 918–923, 2010,doi: 10.3349/ymj.2010.51.6.918.

[24] P.Hye-Kyung,C.Kia-Chung,T.Afua,H.Lynn and N.Kari, "Effectiveness of air purifier on health outcomes and indoor particles in homes of children with allergic diseases in Fresno, " *Journal of Asthma* , vol. 54,no. (4) ,pp.341-346, 2016,doi: 10.1080/02770903.2016.1218011.

[25] A. Baughman and E.Arens "Indoor humidity and human health - Part I: Literature review of health effects of humidity-influenced indoor pollutants," vol. 102,pp. 193-211, 1996.

[26] A.Gupta and H. Mittal, " Design and Development of anInfant Incubatorfor ControllingMultiple Parameters," *International Journal of Emerging Trends in Electrical and Electronics* , vol.11, p. 205,2012, Available: https://www.researchgate.net/publication/324562895.

[27] H. Fromme, and et al.,"Particulate matter in the indoor air of classrooms e exploratory results from Munich and surrounding area," vol. 41, pp. 854-866, 2007, doi:10.1016/j.atmosenv.2006.08.053.

[28] S. Bouwstra, W. Chen, L. Feijs and S. B. Oetomo, "Smart JacketDesign for Neonatal Monitoring with Wearable Sensors," *Proceedings of the Sixth IEEE International Workshop onWearable and Implantable Body Sensor Networks*,Washington, pp.162-167, 2009, doi: 10.1109/BSN.2009.40.

[29] J.O. Fechter,F.Englund and A.Lundin, "Association between temperature, relative humidity and concentration of volatile organic compounds from wooden furniture in a model room, " *Wood Material Science & Engineering*, vol. 1,no.2, pp.69-75, 2006, doi: 10.1080/17480270600900551.

[30] J. Xiong, et al., " Influence of humidity on the initial emittable concentration of formaldehyde and hexaldehyde in building materials: experimental observation and correlation," pp.1-9, 2016,doi: 10.1038/srep23388

[31] P. Markowicz and L. Larsson, "Influence of relative humidity on VOC concentrations in indoor air," *Environmental Science and Pollution Research*, vol.22,pp. 5772-5779, 2015, doi:10.1007/s11356-014-3678-x

[32] L. Glass, “Preterm Infant Incubator Humidity Levels. Advances in Neonatal Care,” vol.21, pp. 297–307,2020, doi: 10.1097/ANC.0000000000000791.

[33] M. Branis, P. Rezácová and M. Domasová “The effect of outdoor air and indoor human activity on mass concentrations of PM10, PM2. 5, and PM1 in a classroom,” vol. 99,pp. 143-149, 2005.

[34] Y.Lv,H. Wang, S. Wei, L. Zhang and Q.Zaho, “The Correlation between Indoor and Outdoor Particulate Matter of Different Building Types in Daqing, China,” vol. 205, pp.360-367,2017,Available:https://doi.org/10.1016/j.proeng.2017.10.002,(https://www.sciencedirect.com /science/article/pii/S1877705817345514).

[35] H. Fromme et al., “Particulate matter in the indoor air of classrooms e exploratory results from Munich and surrounding area,” vol. 41,pp. 854-866,2007, doi:10.1016/j.atmosenv.2006.08.053.

[36] L.T.Curtis,“Prevention of hospital-acquired infections: review of non-pharmacological interventions, ” *J Hosp Infect*,vol.69,pp .204–219,2008, doi:10.1016/j.jhin.2008.03.018.

[37] S. Saran et al.,“Heating, ventilation and air conditioning (HVAC) in intensive care unit ” *Crit Care*,pp.1-11,2020, doi:10.1186/s13054-020-02907-5.

[38] R.Oleniacz,“ Impact of a large medical waste incinerator on air quality,” *J.Environmental Studies*,vol.2,pp.176-182,2010, Available: https://www.researchgate.net/publication/270571406.

[39] M.M.Hassan, et al.,“Pattern of medical waste management: existing scenario in Dhaka City, Bangladesh,”*BMC Public Health*,pp1-10,2008,doi:10.1186/1471-2458-8-36,https:// doi.org/10.1186/1471-2458-8-36.

[40] N. Rott, “Study Finds Wildfire Smoke More Harmful To Humans Than Pollution From Cars,”2021,Available:https://www.npr.org/sections/health.