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Authors: Bani Mfarrej, Manar Fawzi, Qafisheh, Nida Ali, and Bahloul, Moez Mohamed

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Manar Fawzi Bani Mfarrej[1], Nida Ali Qafisheh[1] and Moez Mohamed Bahloul[2]

[1]Environmental Health & Safety Program, Abu Dhabi University, Abu Dhabi, UAE. [2]Laboratoire des Sciences de l'Environnement et Développement Durable (LASED), LR18ES32, University of Sfax, Sfax, Tunisia.

ABSTRACT: The maintenance of a good indoor air quality (IAQ) has been revealed highly required for ensuring comfort and respectable health conditions for home's residents. Nowadays, the main causes of the homes air quality degradation have been stated to be originated from both indoor and outdoor sources such as gases and/or particles, where their health impacts have been showed to be more hazardous under inadequate ventilation, high temperatures, and high humidity. In the light of the above, investigation of IAQ inside homes seems to be highly recommended. Accordingly, the current research has been aimed to investigate the IAQ in 12 houses located in different parts from Abu Dhabi in United Arab Emirates (UAE) through a regular monitoring of total suspended particles (TSPs), carbon monoxide (CO), carbon dioxide (CO_2), formaldehyde (CH_2O), and volatile organic compound (VOC) concentrations and some meteorological parameters such as humidity and temperature in side door, kitchen, and bathroom of each selected house. Compared with international standards and with other measured concentrations exhibited in diverse studies around the world, recorded concentrations in different compartments of selected houses have been lower than detection limits and standard values in the case of VOCs and in the case of CO, respectively, indicating that no health risk originates from such pollutants, especially for residents without sensitive problems. On the contrary, registered CH_2O and CO_2 concentration levels have largely exceeded standard values alerting residents about the potential impact of cooking, fuel combustion, hot water boilers, air conditioning systems, smoking and may be using electronic cigarettes (vaping) while keeping windows and doors closed, causing a bad aeration. In the case of TSP, recorded concentrations have never exceeded 100 µg/m³ in all compartments of 40% of selected houses. However, in the case of houses "3" and "5," recorded concentrations have been higher than those recorded in houses from Slovakia, indicating the significant impact of outdoor activities in UAE around these houses and to the non-negligible effect of dust event originating from Saharan advection.

KEYWORDS: Air pollution, indoor air quality (IAQ), total suspended particles (TSPs), carbon monoxide (CO), carbon dioxide (CO_2), formaldehyde (CH_2O), volatile organic compounds (VOC)

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CORRESPONDING AUTHOR: Manar Fawzi Bani Mfarrej, Environmental Health & Safety Program, Abu Dhabi University, P.O. Box 59911, Abu Dhabi, UAE.
Email: manar_mfarrej@yahoo.com

Introduction

The United Arab Emirates (UAE) is characterized by a desert climate marked by hot summers and warm winters with a less than 120 mm average annual rainfall. UAE is, occasionally, submitted to violent dust storms which could severely reducing visibility. On the contrary, there is serious pollution in the UAE mainly caused by exploitation of the natural resources, rapid population growth, and high traffic density.[1,2] While there are measures being taken by the UAE government to improve air quality, pressures from both natural and man-made factors are still significant. Natural factors such as sand storms, minerals from coastal areas, and naturally air born dust make it easy for the air to be polluted with particulate matter. Man-made contributors to the air pollution are vehicles, as the biggest contributor to emissions, followed by heavy manufacturing industries, and then the rise in energy and water consumption. Such characteristics require from citizens minimizing direct exposure to the extreme weather issues (high temperatures, dust events, etc) and pollution sources. Therefore, citizens are indebted to spend most of their time in indoor areas.[2,42]

In these terms, studies have revealed that people spend most of their time indoor. Indeed, Americans spend 87% of their time (in average) indoors.[3] Residents of the UAE spend 80% to 95% of their time indoors to escape high temperatures.[4] Hence, safe indoor air quality (IAQ) seems to be indispensable for an individual's well-being. It is well known that being indoor does not mean being totally safe. Previous studies have revealed that indoor areas could be a receptor of a mix of outdoor pollutants mainly originating from vehicular traffic and industrial activities. These pollutants enter indoor environments by infiltration and/or through natural and mechanical ventilation system. Indoor pollutants could be originate, basically, from human activity in indoor environments (burning fuels, cooking, coal wood, smoking, painting, and candles), and from building and constructing materials, furniture, and various types of indoor equipment (central heating and cooling systems, humidification devices, moisture processes, electronic equipment, and products for household cleaning)[5-8] (Reynolds et al., 2001).

Table 1. Selected guidelines for air contaminants of indoor origin in the United States.

CONTAMINANT	CONCENTRATION	EXPOSURE TIME
Carbon dioxide	4.5 g/m	Continuous
Chlordane-o	5 μg/m^3	Continuous
Ozone-o	120 μg/m^3	Continuous
Radon	0.01 working level (WL)	Annual level
Formaldehyde-o	120 μg/m^3	Continuous

Source: National Research Council.[12]

The effect of these factors is that the level of chemical compounds in the indoor environment is much higher than in ambient (atmospheric) air.[7,9] According to the United Nations, there are more than 3.5 million premature deaths every year due to household air pollution.[10]

Hence, the main objective of this study is to collect data of indoor air pollution in the country, to learn more about residential IAQ in AD Emirate, and what can be done to either help bring these numbers down or eliminate the air pollutants to the best of our ability.

Literature Review

Regarding the long exposure time of a human to diverse types of indoor areas/enclosed spaces (especially in domestic areas), a bulk of research have been done to synthesize accurate analytical information on IAQ (defined by the type and the amount of the chemical compounds present in it) as well as to highlight its impact on human health.

Indoor air pollution standard in United States

Governments are coming up with regulations to reduce the discharged amounts of contaminants into the environment. They declared rules and environmental policies to protect the environment. Air enforcement regulates emissions of air pollution under the Clean Air Act.[11,43] There is a regulatory indoor standard for nonoccupational air in the United States only for ozone. In the past few decades, standards for indoor air have been defined, for serving as guidelines to state, federal, or local government agencies, in terms of formaldehyde, carbon monoxide, chlorine, radon, and other chemical substances considered as pollutants.[12] Table 1 shows selected guidelines for Air Contaminants of Indoor Origin in the United States.

According to literature, some chemical compounds present in indoor environments and have a significant impact on its air quality as well as on the health and the well-being of occupants are polycyclic aromatic hydrocarbons benzene, toluene, ethylbenzene, and xylene compounds as representatives of the volatile organic compounds (VOCs) in addition to formaldehyde and acetaldehyde[13] and terpenes, for example, α-pinene, 3-carene, or d-limonene (Curci et al. 2009; Król et al. 2014). Harmful chemical compounds in the indoor environments such as benzene and formaldehyde, classified by experts from the International Agency for Research on Cancer (IARC) as group 1 carcinogens, have been measured in research conducted in this field. The maximum allowable/permissible concentrations or amounts of harmful chemical species in indoor environment have been well defined by appropriate legal regulations for some species and still required advanced research for others.[14]

Indoor air pollutants

Indoor air quality could be affected by the presence of diverse pollutants including (1) gases such as carbon monoxide, ozone, radon; (2) VOCs; (3) particulate matter with different aerodynamic diameter (PM10, PM2.5, PM1, etc), total suspended particles (TSPs), and fibers; (4) organic and inorganic contaminants; (5) biological particles such as bacteria, fungi, pollen; and (6) asbestos which has been used in a variety of building construction materials for insulation, as fire-retardant and in other consumer products. Research shows that asbestos fibers can cause major breathing problems and cancer[6,7,8,14-19,39].

Based on their appearance, their usual concentration levels, and their sources, indoor pollutants could cause harmful health risks including cancer, effects on the cardiovascular, gastro-intestinal, immune, nervous, and respiratory systems. In addition, these pollutants have effects on reproduction, skin and mucous membranes in the eyes, nose, and throat.[20]

IAQ in the UAE

Most residents of the UAE spend most of their time indoors because of the high temperatures that limit their outside activities duration. Hence, it seems to be highly recommended to guarantee clean, safe, healthy, and well-ventilated buildings. Such conditions require regulations of IAQ to ensure the best conditions of life for residents.[21]

The assessment of IAQ in the UAE has been done in 2014 through measuring, during 8-hour work shift, of indoor air pollutants, mainly gases and particulate matter sampled from 628 homes from the 7 emirates (Abu Dhabi, Dubai, Sharjah, Ajman, Fujairah, Ras al-Khaimah, and Umm al-Quwain). Obtained results mainly revealed low indoor concentrations of gaseous pollutants carbon monoxide (CO), formaldehyde (HCHO), hydrogen sulfide (H_2S), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2). Results also showed that carbon monoxide (CO) concentrations have been the highest in urban areas than the rural areas, contrary to recorded particulate matter concentrations, which were higher in rural areas compared with those measured in urban ones.[22,40]

Hazard assessment of UAE incense smoke

A hazard assessment on the use of incense in UAE was done in December 2012 to inspect the consumption of incense inside homes. Incense consuming is a social practice in the UAE and used in 94% of Emirati families to add fragrance to clothing and the home in general. Incense burning depends on the usage of charcoal and burning emanates aromatic smoke throughout the house. Emissions from burning incense have 2 categories; particulate matter and gas phase. They are emitted at the same time creating a complex mixture. Researchers did an experiment on 2 Bakhoor and 2 Oud, one with full piece of charcoal and the other one was cut in half charcoal; each type was burned in 2 different days. Concentrations of pollutants were monitored up to 180 minutes after burning. The research showed that particulate matter decayed at a fast rate. HCHO concentrations found to be at steady high rate for 2 hours after burning but SO_2 was not detected from burning Bakhoor or Oud.[23]

Deaths and medical visits attributable to environmental pollution in the UAE

According to a research conducted in the UAE by MacDonald Gibson et al.,[24] the main cause of death is outdoor air pollution, followed by the indoor one. Considering indoor air pollution, such research has highlighted that indoor poisons such as environmental tobacco smoke causes cardiovascular illness and lung cancer frequently leading to death. Moreover, it has been revealed that presence of mold and formaldehyde causes asthma for teenagers and adults, as well as it has been identified that radon causes lung tumors[36,41].

Materials and Methods

In this research, a standardized methodology by the quantitative approach was used. A total of 12 houses across Abu Dhabi Emirate were chosen. The houses were located in different parts of Abu Dhabi, some in the heart of the city and some on the outskirts. This was done to assess IAQ and to extract correlation between the geographical location of selected houses and their IAQ through the regular measure of TSPs, CO, CO_2, formaldehyde, and VOC concentrations and some meteorological parameters such as humidity and temperature.

The target population was specifically Abu Dhabi residents, in apartments as well as villas. Indoor air quality measuring devices were used. Three specific locations were monitored in each home: the side door, kitchen, and bathroom. Measures were recorded every hour during 8 hours continuously.

The above-mentioned pollutants were measured using the following:

- Sensidyne Nephelometer: a real-time dust monitor, measuring the concentration of TSPs in the indoor air (expressed in $\mu g/m^3$);
- Q-Trak (TSI) IAQ Meter: a monitor with 3 sensors: oxygen, carbon monoxide, and carbon dioxide;
- Extech VFM200 (VOC/Formaldehyde Meter): measures VOC and formaldehyde concentrations in real-time found in the air. According to the user manual for the Extech VFM200 (VOC/Formaldehyde Meter), the international standard for formaldehyde (CH_2O or HCHO) is 0.00 to 9.99 ppm (mg/m^3) and VOC is 0.00 to 5.00 ppm (mg/m^3). TVOC, which stands for total VOCs, is defined as a grouping of a wide range of organic chemical compounds. Many substances, such as natural gas, could be classified as VOCs[34];
- Lutron CO Meter: it indicates the presence of CO in parts per million;
- Lutron CO_2/Humidity/Temp. Monitor: it measures the amount of CO_2 (expressed in ppm), relative humidity (expressed in %), and the temperature (expressed in °C).

Using the ASHRAE Standard 55-2010 ISO 7730[25] as a reference, the international standard found for the temperature parameter differs between summer and winter. For summer, the range of 23°C to 28°C was classified as the standard, whereas winter standard was the range of 20°C to 25.5°C. Also referring to the ASHRAE Standard 55-2010 ISO 7730, the standard for the relative humidity is between 30% and 65%.

Results and Discussion

Meteorological parameters (temperature and relative humidity) as well as TSPs, CO, CO_2, formaldehyde, and VOC concentrations were measured to better assess IAQ in different compartments (side door, kitchen, and bathroom) from selected 12 houses from different areas of Abu Dhabi Emirate, UAE.

Meteorological parameters' variability

Measured temperatures and relative humidity in side door, kitchen, and bathroom for each selected house regarding standard values are summarized in Tables 2 and 3.

Compared with standard temperatures, measured ones have been rarely exceeding 25.5°C in different compartments of selected houses and have been comparable, showing a difference in temperature degree oscillated between 1°C and 2°C (Table 3). Except for house 5, where the temperature in kitchen was exceeding the standard and higher than those recorded in side door and in bathroom, and house 8 where the side door temperature was less than standard temperature and higher than those recorded in kitchen and bathroom. For the former, cooking activities could explain such recorded high temperature in the kitchen. For the latter, low temperature in bathroom was responsible for significant difference (equal to 5.40°C)

Table 2. Measured temperature (°C) in different compartments of selected houses.

SAMPLING SITE	TEMPERATURE (°C)			AVERAGE TEMPERATURE (°C)
	SIDE DOOR	KITCHEN	BATHROOM	
House 1	20.50	21.00	21.40	20.97
House 2	21.10	22.40	22.20	21.90
House 3	21.90	22.20	21.80	21.97
House 4	21.60	22.40	21.90	21.97
House 5	22.00	27.60	22.50	24.03
House 6	23.00	22.40	22.60	22.67
House 7	21.70	21.50	22.20	21.80
House 8	23.20	20.90	17.80	20.63
House 9	21.80	22.40	22.30	22.17
House 10	22.80	22.40	23.80	23.00
House 11	22.20	23.00	22.90	22.70
House 12	24.90	22.50	21.90	23.10
Standard	**25.50**	**25.50**	**25.50**	**25.50**

Table 3. Measured relative humidity (%) in different compartments of selected houses.

SAMPLING SITE	RELATIVE HUMIDITY, %			AVERAGE RELATIVE HUMIDITY, %
	SIDE DOOR	KITCHEN	BATHROOM	
House 1	64.30	88.15	58.70	70.38
House 2	59.50	59.90	60.90	60.10
House 3	67.30	66.20	70.40	67.97
House 4	63.60	63.60	63.70	63.63
House 5	60.80	61.00	61.40	61.07
House 6	61.60	62.40	61.20	61.73
House 7	69.80	57.50	67.20	64.83
House 8	73.30	68.20	79.90	73.80
House 9	71.40	73.20	72.70	72.43
House 10	61.70	60.90	62.60	61.73
House 11	60.90	60.50	61.10	60.83
House 12	58.50	58.70	52.30	56.50
Standard	**65.00**	**65.00**	**65.00**	**65.00**

between temperature recorded in side door and in bathroom. Such difference could result from excessive use of air conditioner, adjusted at cold mode, in closed bathroom for a long duration[37].

Measured relative humidity in different compartments of selected houses showed a significant difference. In fact, lowest humidity has been recorded in the bathroom of house 12 (52.30%) and the highest was recorded in the kitchen of house 1 (88.15%). Such difference reflects the impact of indoor activities on recorded humidity. Moreover, in different compartment of houses 3, 8, and 9, recorded values of humidity were higher than the standard value. In the case of house 7, recorded humidity in side door and bathroom was higher than the standard, and in the case of house 1, measured humidity in kitchen exceeds by far the standard. This variability could highlight the impact of geographical localization of houses (coastal, center urban, rural, etc) and the indoor activities, behavior of residents, and their lifestyle.

Variability of indoor pollutants concentrations

Concentrations of pollutants including TSP, CO, CO_2, and CH_2O regarding their standards in different compartments (side door, kitchen, and bathroom) from selected 12 houses are summarized in Table 3. Results have revealed a significant variation of recorded concentrations at the same house between its different compartments as well as from one house to another. Standards limits have not been regularly respected, highlighting a poor IAQ.

Total suspended particles. Concentrations of TSP (expressed in μg/m³) in side door, kitchen, and bathroom of 12 selected houses were measured using Sensidyne Nephelometer. Recorded concentrations, ranging between 14.50 and 627.63 μg/m³, have showed a significant variability reflecting the contribution of diverse sources. In fact, highest levels of TSP concentrations were in the kitchen (627.63 μg/m³) and in the bathroom (422.38 μg/m³) from house "3" and in the side door of house "5" (497.20 μg/m³). On the contrary, lowest levels of TSP concentrations were recorded in different compartments of house "11" (Figure 1A). Based on levels of calculated average concentrations of TSP, selected houses could be ranged as the following descending order: House 3 > House 5 > House 6 > House 10 > House 9 > House 4 > House 8 > House 7 > House 1 > House 2 > House 12 > House 11 (Figure 1B).

Such fluctuations could be explained by the impact of outdoor pollution (road traffic, dust events, etc) demonstrated main sources of TSP in indoor environments.[26] On the contrary, and by the impact of activities in indoor environments, the structural system of a building, material characteristics, the way of air exchange, the operating mode of indoor environment in the presence of inhabitants, and on the other one[26]. Compared with a study performed in Košice city from Slovakia, recorded TSP concentrations in side door, kitchen, and bathroom from most of the selected houses showed important concentrations.[35] This could be attributed to the impact of outdoor activities in UAE around these houses and to the non-negligible effect of dust event originating from Saharan advection.[4] Such recorded concentrations, especially in houses 3, 5, and 6, could reveal a seriously pollution of indoor environments, affecting respiratory health of inhabitants. Moreover, previous studies have revealed that in comparison with the settled particles, higher percentage of metals has been detected in suspended particulate matter. Hence, fractioning and study of chemical composition of TSP seem to be highly recommended regarding the lack of standard yielding comparison and/or limitation of TSP in indoor environments.

Carbon Monoxide "CO.". Concentrations of CO (expressed in ppm) in side door, kitchen, and bathroom of the 12 selected houses were measured using Lutron CO Meter. Recorded concentrations in different house compartments ranged between 0 and 5.61 ppm, indicating that standard value (9 ppm) has been respected in all selected houses (Figure 2A). Highest levels of CO concentrations have been recorded in side door (5.35 ppm) of house "3," in kitchen (5.57 ppm) of house "5," and in bathroom (5.61 ppm) of house "3." On the contrary, indoor air of houses "1" and "7" has showed low level of concentrations. Moreover, house "12" has revealed indoor air unpolluted by carbon monoxide (Figure 2A).

Based on levels of calculated average concentrations of CO, selected houses could be ranged as the following descending order of polluted indoor air by CO: House 3 > House 5 > House 2 > House 9 > House 11 > House 10 > House 4 > House 6 > House 8 > House 1 > House 7 > House 12 (Figure 2B). While all measured CO concentrations have never exceeded World Health Organization's (WHO) international standard value, houses "3" and "5" recorded the highest levels of average concentrations indicating that attention should be paid at the IAQ of these houses to avoid risk of health incident to residents.

It is noteworthy to cite that indoor CO has been demonstrated mainly originated from combustion sources (cooking, heating, smoking, etc) and/or introduced through the infiltration of carbon monoxide from outdoor air into the indoor environment.[27] Consequently, IAQ in houses "3" and "5" could be affected by cooking and/or heating activities as well as by smoking inside houses. For the remaining houses, no damaging of IAQ is to reveal, indicating a high awareness of inhabitants about their well-being.

Carbon Dioxide "CO_2.". Concentrations of CO_2 (expressed in ppm) in side door, kitchen, and bathroom of 12 selected houses have been measured using Lutron CO_2/Humidity/Temp. Monitor. Recorded concentrations in different house compartments ranged between 574.75 and 1829.80 ppm, indicating that standard value (1000 ppm) has not always been respected in all selected houses (Figure 3A). In fact, indoor air of side door, kitchen, and bathroom from houses "2" and "4" as well as indoor air of side door, kitchen, and bathroom from houses "10," "7," and "1," respectively, revealed that the CO_2 concentrations exceed the standard, indicating a health risk on residents of above-mentioned houses (Figure 3A).

Examination of average concentrations of CO for all selected houses has revealed that only indoor air of 3 houses (2, 4, and 10) exhibited concentrations higher than standard, signaling a potential serious effect on resident health (Figure 3B).

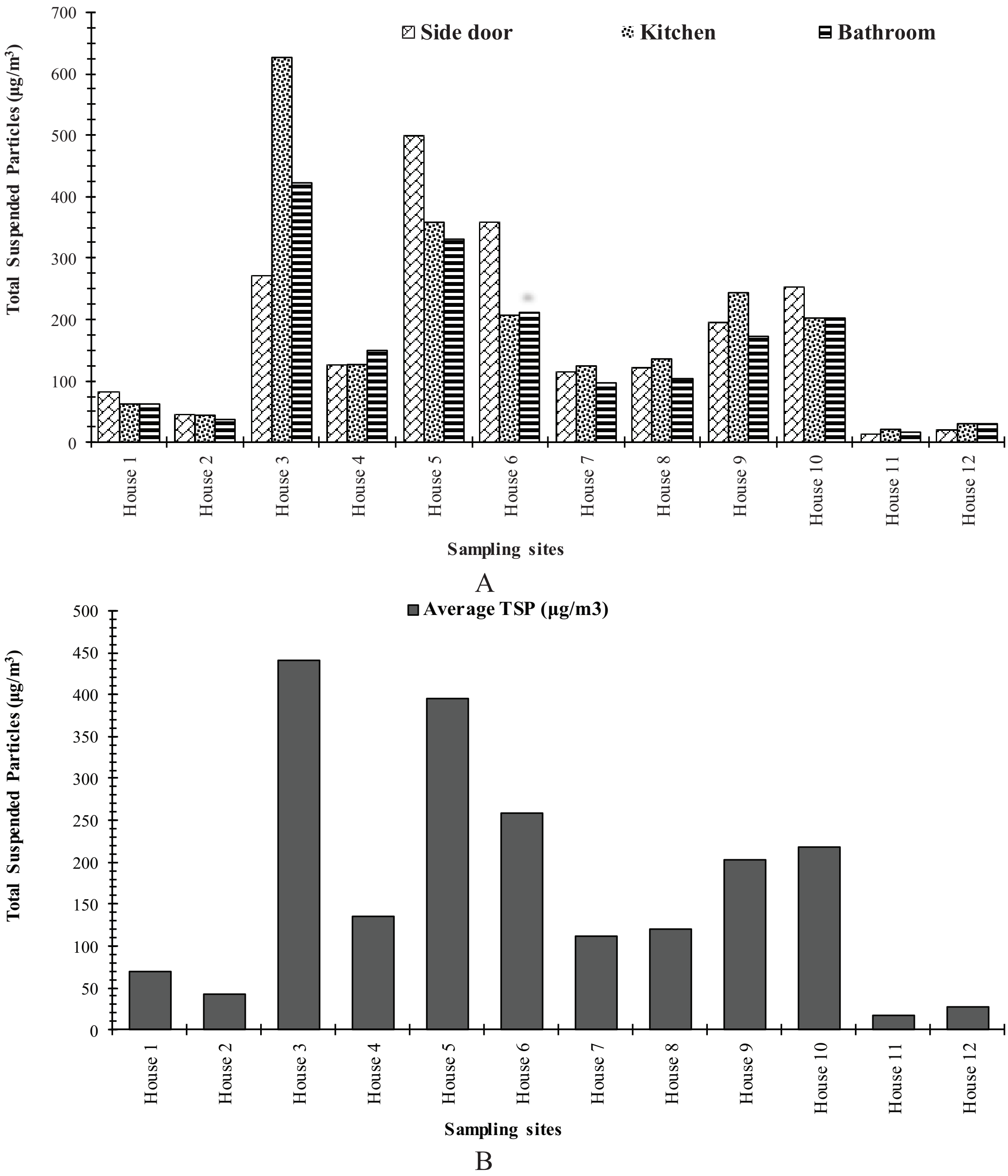

Figure 1. (A) Concentrations of TSP (expressed in μg/m³) in side door, kitchen, and bathroom of 12 selected houses and (B) average concentrations of TSP for all selected houses.

In these houses, air quality could be affected by overcrowded homes, air conditioning systems, fossil fuel combustion, dangerous types of gas such as the flammable ones used for cooking (eg, methane/natural gas, propane/liquefied petroleum gas), the operation of hot water boilers that use liquefied petroleum gas or natural gas and the gaseous products of combustion such as CO, CO_2, and hydrocarbons. To ameliorate air quality of such houses, it is highly recommended to guarantee a better ventilation and avoid using the carbon dioxide sources in enclosed environments.[38]

Referring to carbon dioxide concentrations in side door, kitchen, and bathroom from 12 houses in UAE, 42% of houses have exceeded standard limits and may develop health risk on residents. Especially, houses "4" and "2" have revealed the highest carbon dioxide concentrations in its all compartments, thus indicating the potential impact of cooking, fuel combustion, hot water boilers, air conditioning systems, smoking, and may be using electronic cigarettes (vaping) with closed windows and doors in the presence of high number of residents.

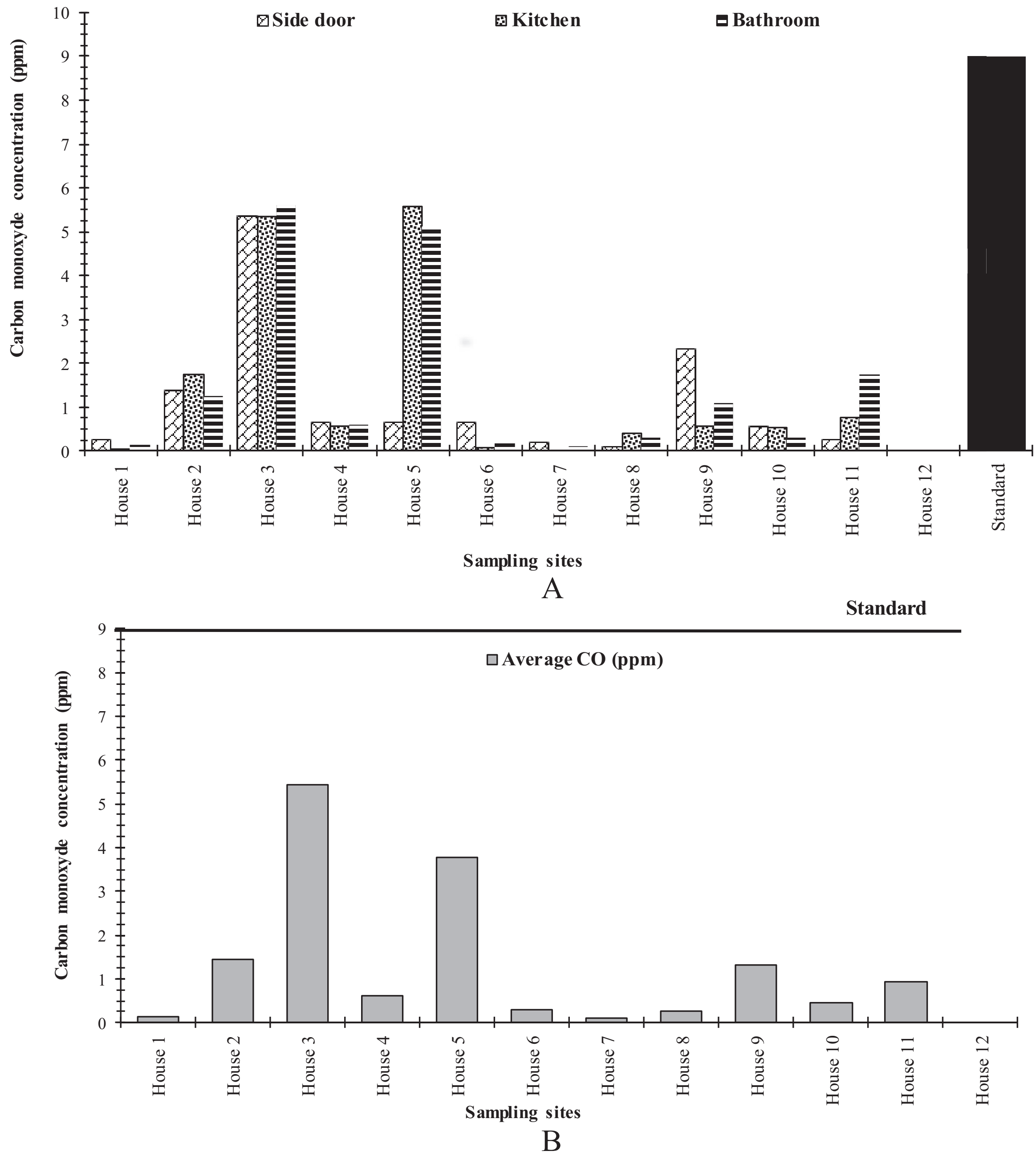

Figure 2. (A) Concentrations of carbon monoxide "CO" (expressed in ppm) in side door, kitchen, and bathroom of 12 selected houses and (B) average concentrations of CO for all selected houses.

Formaldehyde "CH_2O" and Volatile Organic Carbon "VOC.". Concentrations of CH_2O (expressed in ppm) in side door, kitchen, and bathroom of 12 selected houses have been measured using Extech VFM200 (VOC/Formaldehyde Meter). Registered formaldehyde concentrations in different house compartments (side door, kitchen, and bathroom) ranged between 1.19 and 1.70 ppm, largely exceeding the WHO guideline value of 0.08 ppm[16] (Figure 4A). In addition, the standard deviation between all measured concentrations from different compartments of selected houses has been equal to 0.1, revealing such houses probably showed the same main source of CH_2O. Moreover, formaldehyde average concentration levels in indoor air of the 12 selected houses, ranged from 1.40 to 1.65 ppm, have been 17 to 20 times higher than the guideline value, respectively (Figure 4B). Previous studies revealed that formaldehyde, considered as a reactive gas, could originate basically from furniture and wooden products containing formaldehyde-based resins such as particleboard, medium-density fiberboard, insulating materials, textiles, paints, wallpapers, glues, adhesives, varnishes, and lacquers. Also, the pollutant in focus may originate from household cleaning products such as detergents, disinfectants, softeners, and carpet cleaners; combustion sources such as wood-burning appliances; tobacco smoking; shoe products; cosmetics such as liquid soaps, shampoos, and

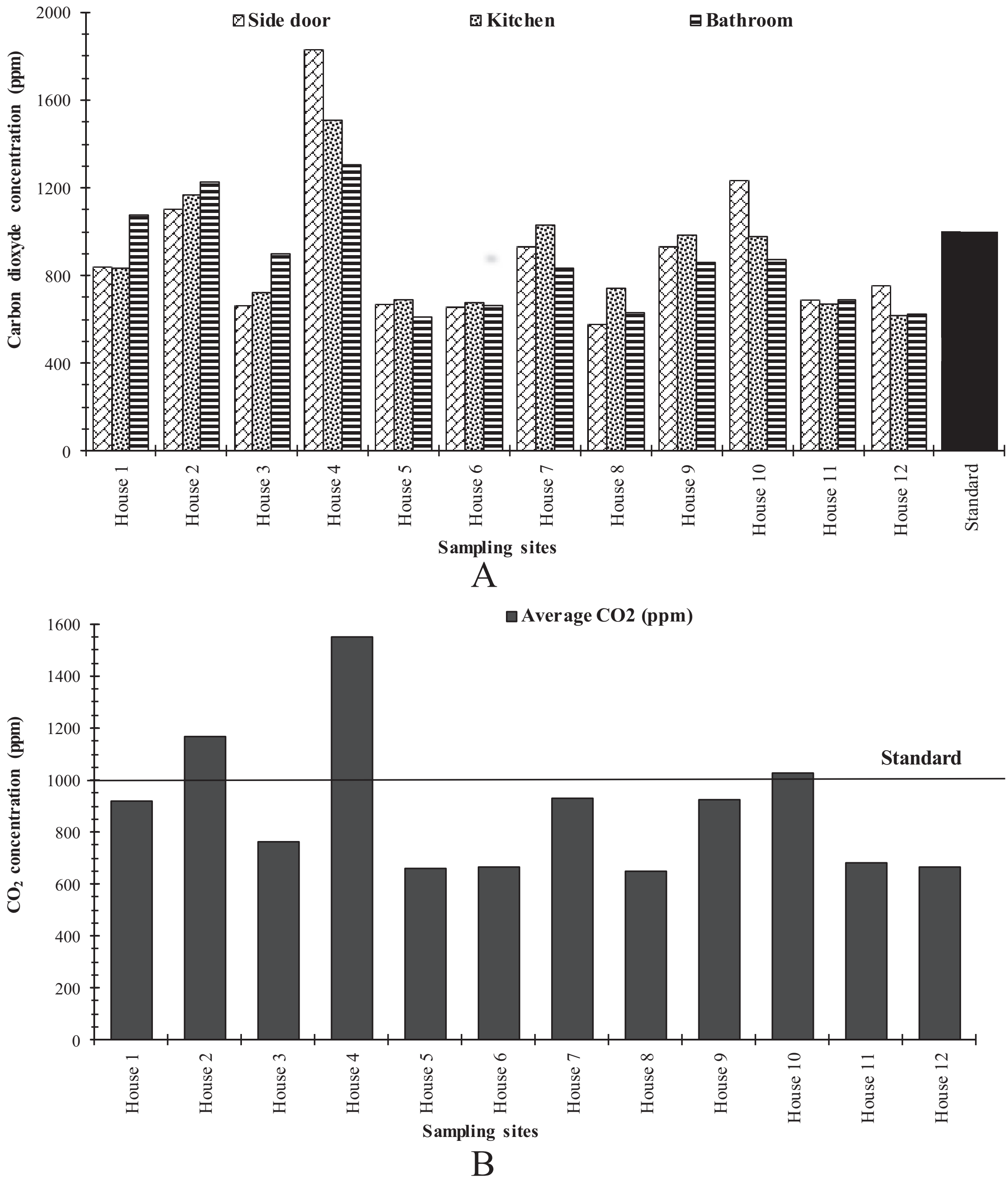

Figure 3. (A) Concentrations of carbon dioxide "CO_2" (expressed in ppm) in side door, kitchen, and bathroom of 12 selected houses and (B) average concentrations of CO_2 for all selected houses.

nail hardeners; electronic equipment, including computers and photocopiers; and other consumer items such as insecticides and paper products.[8,28-30] Hence, registered concentration levels of formaldehyde in indoor air of houses in focus confirmed that the above-mentioned sources have been frequently pronounced in UAE houses. Moreover, previous studies[31,32] have revealed a significant negative correlation between formaldehyde concentrations and air change per hour "ACH" of house. Consequently, highly recorded formaldehyde concentrations in UAE houses may result from a bad or infrequent aeration of such houses.

Referring to Nielsen and Wolkoff,[33] formaldehyde has been defined as a ubiquitous indoor air pollutant classified as "Carcinogenic to humans (Group 1)" (IARC, formaldehyde, 2-butoxyethanol, and 1-tert-butoxypropanol-2-ol) (IARC monographs on the evaluation of carcinogenic risks to humans, vol 88. World Health Organization, Lyon, pp. 39-325, 2006). Accordingly, urgent and efficient measures, to reduce formaldehyde concentration levels in different houses, should be implemented and executed to prevent resident health.

Investigation of VOC levels in indoor air from selected houses were below the detection limit, thus indicating no

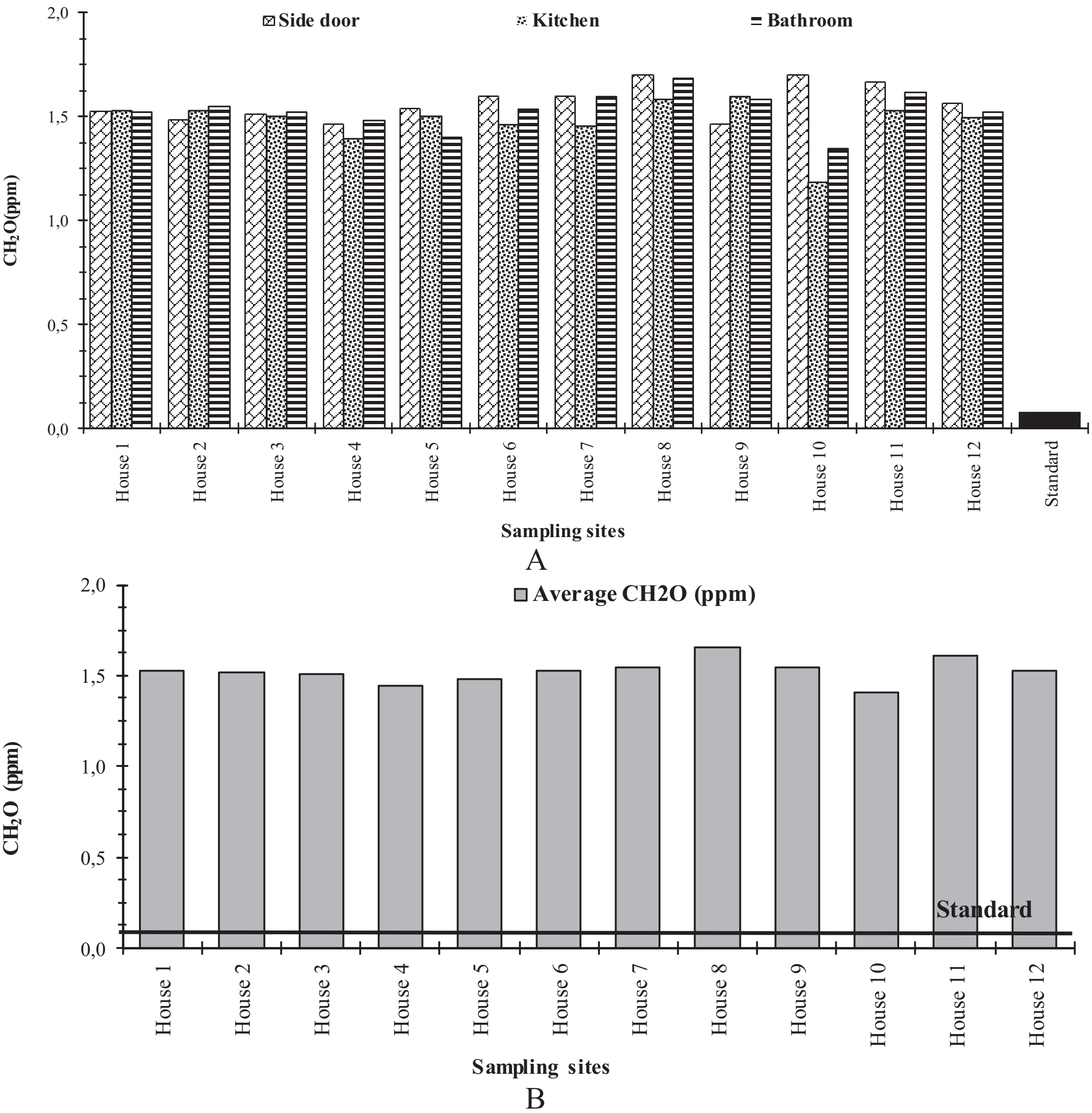

Figure 4. (A) Concentrations of carbon dioxide "CH_2O" (expressed in ppm) in side door, kitchen, and bathroom of 12 selected houses and (B) average concentrations of CH_2O for all selected houses.

pollution of indoor air is caused by VOCs in investigated houses from UAE (Extech, 2018).

Conclusions

Researches aimed to investigate IAQ in the UAE are limited. Hence, this study has been done to investigate the IAQ in 12 houses located in different parts from Abu Dhabi in UAE through a regular monitoring of TSPs, carbon monoxide (CO), carbon dioxide (CO_2), formaldehyde (CH_2O), and VOC concentrations and some meteorological parameters such as humidity and temperature in side door, kitchen, and bathroom of each selected house.

Compared with the standard values temperatures, measured ones have been rarely exceeding 25.5°C in different compartments of selected houses and have been comparable, showing a difference in temperature degree oscillated between 1°C and 2°C. The differences in recorded humidity results reflect the impact of indoor activities on recorded humidity.

Recorded TSP concentrations from most of the selected houses showed important concentrations and revealed a serious pollution of indoor environments, whereas recorded CO concentrations in different house compartments indicated that the standard value (9 ppm) have been respected in all selected houses.

Registered CH_2O and CO_2 concentrations in different house compartments (side door, kitchen, and bathroom) have largely exceeded the standard values equal to 0.08 and 1000 ppm, in the case of formaldehyde and carbon dioxide, respectively, thus indicating a grave pollution of indoor environments of houses in focus. Highest registered concentration levels may highlight that sources of such pollutants have been frequently pronounced in UAE houses which demonstrate badly and/or infrequently aerated.

The VOC concentration levels in indoor air from selected houses have been below the detection limit, thus indicating no pollution of indoor air caused by VOCs.

Author Contributions

MFBM substantial contribution to the article, worked on the research and experiments and approved the version to be published, takes primary responsibility for communication with the journal during the manuscript submission, peer review, and publication process, and typically ensures that all the journal's administrative requirements, such as providing details of authorship, ethics committee approval, clinical trial registration documentation, and gathering conflict of interest forms and statements.

NAQ working on the research and experiments, substantial contribution to the article and approved the version to be published.

MMB has made a substantial contribution to the article, revised the article critically, approved the version to be published and agreed to be accountable for all aspects of the work.

ORCID iDs

Manar Fawzi Bani Mfarrej https://orcid.org/0000-0003-1144-3125
Moez Mohamed Bahloul https://orcid.org/0000-0002-5059-413X

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