Assessment of the indoor air quality in some primary Schools Maisan

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Abstract

There is still a paucity of studies evaluating indoor air quality for classrooms nationwide. Poor indoor air quality in primary schools can increase the risk of health problems for children and affect their academic performance. The aim of the study was to assess the indoor air quality in some primary school buildings in one an Iraqi city, with the study of the internal characteristics and external factors affecting the levels of pollutants inside the classrooms, where 26 primary schools were selected in industrial and urban locations and near the countryside. They served as take-out sites sampling and monitoring the levels of parameters, particulate matter ($PM_{2.5}$, PM_{10}), carbon monoxide (CO), formaldehyde (CH2O), total volatile organic compounds (TVOC), ozone (O_3), and nitrogen dioxide (NO_2). By using specialized sensors. The results showed a strong impact of outdoor air quality on the indoor environment of the targeted school buildings, and $PM_{2.5}$ concentrations exceeded Environmental Protection Agency (EPA) standards in most classrooms. The indoor/outdoor (I/O) ratio of PM_{10} fine particles was greater than 1 in most of the classrooms as a result of the numerical density and high physical activity of the pupils, which causes the particles to be constantly re-suspended. While the rest of the targeted parameters of the study were within the approved standards in most classes and during the study period.

Keywords: Indoor air quality, Children, Schools, Classrooms, Iraq, Particulate matter.

Introduction

Schools are considered one of the most important types of places due to the impact of their internal conditions on the health and comfort of their residents, whose classrooms are usually one of the busiest indoor environments. (Haddad et al.,2021; Choe et al.,2022). Pollutants in school buildings can have different emission sources, from inside or outside the classrooms affecting indoor air quality (Marzocca et al.,2017). Potential indoor sources of release of chemical air pollutants can be categorized as construction materials (Tureková et al., 2022), wood furniture containing resin (Szabados et al., 2021), use of paints (IAQMG, 2019), cleaning products and air fresheners (Carslao and Shaw, 2022). As for indoor air pollutants of external origin, they are mainly represented in car exhausts in urban traffic (Sadrizadeh et al.,2022). Poor IAQ in schools can increase rates of asthma, allergies, headaches, fatigue, shortness of breath, coughing, sneezing, eye and nose irritation, dizziness, and affect pupils' performance on mental tasks such as concentration, arithmetic, and memory (Ukehaxhaj et al.,2023). In contrast, Healthy indoor air quality in classrooms can provide students with a productive, safe, and

comfortable environment, in which absenteeism rates decrease and test scores improve (Zhu et al.,2021). Due to the increase in complaints of illnesses in children, more attention has been given to research on indoor air quality in primary schools (Nissila et al.,2019). Children in primary school spend as much time as one-third of their usual day (Rawat & Kumar,2022). The age group of children is more sensitive and responds to the negative effects of air pollutants due to their physical, physiological and behavioral differences compared to adults (Gabriel et al., 2021), as their rate of inhalation of air is greater compared to their body sizes and their level of physical activity is higher, in addition to that their respiratory system is not fully developed Their lungs are in a developing stage and their body's defenses against infection are limited. In addition, many children breathe through their mouths,

Materials and Methods

2.1 Area of Study

The study area is located in Maysan Province, located in the southeastern part of Iraq, with an area of $16,072 \ km^2$, and is characterized by a hot and dry summer climate. The Province includes many oil fields and traditional brick factories, which are considered one of the main sources of emissions of gaseous air pollutants (NCCI, 2015). School sites were selected in crowded industrial and urban areas and near the

bypassing the natural defenses of the nasal passages, and they are relatively less able to distinguish or express their feelings about the presence of pollutants and make choices that would protect their health (Korsavi et al., 2020; Osborne et al., 2021, Rawat & Kumar 2022). Data on indoor air quality in primary school buildings is still not available at the national level; This leads to a gap in the literature review. And to our knowledge, this study is the first to assess indoor air quality in Iraqi schools. The primary objectives of our study were to describe indoor air quality levels in some primary schools by evaluating gaseous pollutants including concentrations of $PM_{2.5}$, PM_{10}, CH_2O, TVOC, CO, O_3 and NO_2. And compare them with global standards. These findings from multiple centers will provide factual information and may reveal the true level of exposure of children in classrooms in an Iraqi city.

countryside, with a total of 26 primary schools, It mainly depends on natural ventilation. And one classroom from each school was selected as a sample for the study and indoor air monitoring. The approval of the General Directorate of Education in Maysan Province was obtained to conduct the study. The coordinates of the schools' locations were determined using the Global Positioning System (GPS). Figure 1 shows the locations of the schools selected in the study.
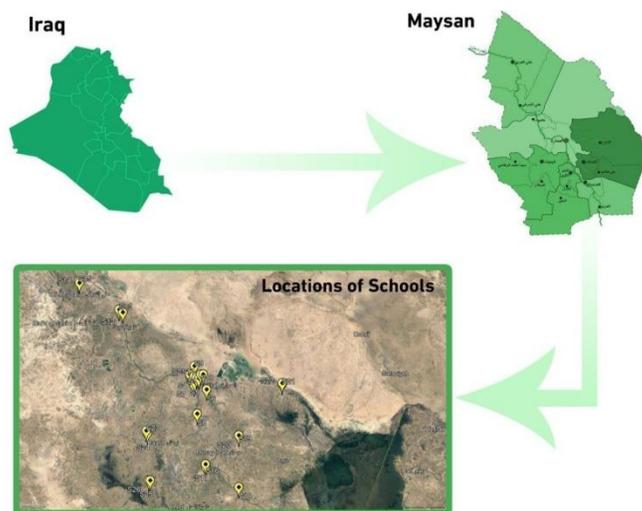
Figure 1. Locations of primary schools in the Maysan Province, Iraq

2.2. Sampling

The indoor air quality of the school buildings was monitored Once a month, due to the limited number of sensors and a large number of targeted schools, monitoring was carried out during the morning work periods throughout the study period and within the time limits 9:00 - 11:30 am. For this purpose, specialized and accurate sensors have been used that can detect some common air pollutants in parts per billion. The devices were placed inside the classrooms at a height of 1 meter, which is the ideal height for exposure of children while they are sitting on the benches, and for a period of not less than 45 minutes, which is the time allotted for one lesson, with 6 readings separated by a time period of 7 or 8 minutes between each reading and the next. The survey included taking outdoor air quality readings surrounding the school, and wind speed at a distance of no more than 40 meters. The study included monitoring and evaluating the indoor air of classrooms with a total of 182 samples throughout the study period that extended from October 2022 to the end of April 2023.

2.3. Sensors used for measurement:

All devices have been calibrated prior to use to obtain accurate data and some have been calibrated by the device manufacturer which is shown in Table 1.

Table1. The Sensors used in the study

Sensor	Model	Sensor origin	Used to measure the parameters.
Smart Air Monitor	uhoo	Taiwan	Dust ($PM_{2.5}$), Nitrogen Dioxide, Carbon Monoxide, Ozone.
Temtop	H2	USA	Formaldehyde, TVOC.
Air Quality Monitor	DM106	China	Particulate Matter (PM_{10})

2.4. Statistical analysis

For Particulate Matters, the ratios of indoor to outdoor (I/O) were computed in each classroom. Pearson correlations were used in order to investigate the impact of classroom features on indoor air quality and generalized linear models were fitted. Also, the lowest value, maximum value, average value, and standard deviation for the descriptive statistics were determined. The distribution's normality was evaluated using the histogram. The statistical analysis

3. Results and Discussion

3.1. PM concentration

Monthly $PM_{2.5}$ readings values ranged within classrooms between (6-131) µg/m^3. While the monthly values for PM_{10} ranged between (16 - 187) µg/m^3. Comparing the Environmental Protection Agency (EPA) standard of $PM_{2.5}$ (15 µg/m³) and PM_{10} (50 µg/m³), the results show that the mean concentrations of $PM_{2.5}$ shown in Table 1 exceeded the above standard in all schools, while the mean concentrations of PM_{10} exceeded the above standard in 24 of the targeted schools, and did not exceed it in only two schools, which can be attributed to the continuous cleaning activities that remove dust and particles accumulated on Floors and furniture inside the classrooms.

Indoor $PM_{2.5}$ concentrations show their severe effect on outdoor air quality, with $PM_{2.5}$ readings inside classrooms tending to increase significantly in locations with high emission sources of air pollutants such as oil fields and traditional brick factories such as the S8 school which recorded an average concentration of 113 µg/m3 during the study period. Also, in urban locations such as schools adjacent to traffic in crowded streets, or schools close to private electricity generators, it has been proven that the widespread use of gasoline and diesel

program was used to compare the concentrations of pollutants and to ensure the significance of the results, the probability values tests (P-values) were carried out by applying one-way ANOVA to examine whether there were statistically significant differences in the values of the quantitative variables at a significant level of 0.05, and the statistical package IBM SPSS Statistics 22 was used for correlation analysis, and using Microsoft Excel 2016 for data analysis. generators is one of the most important reasons for the high concentration of $PM_{2.5}$ in the air (Al-Sarji et al., 2022). On the other hand, $PM_{2.5}$ readings showed a decrease in schools located near the countryside, which are characterized by abundant vegetation and few sources of release of this pollutant, as the plant is one of the best methods of air purification based on its ability to absorb, degrade and analyze air pollutants (Mata et al., 2022).

In this study, the Indoor/Outdoor ratio of $PM_{2.5}$ particles was verified. The results of the ratios were less than 1 in most schools, which indicates that external sources in urban activities were the main contributors to the presence of these pollutants inside the classrooms, as shown in Figure 2. The above verification agreed with the study (Szabados et al. 2021) in that the origin of $PM_{2.5}$ was from external sources, represented by fuel-burning processes in the adjacent traffic. A study (Kalimeri et al., 2019) indicated that the I/O ratio is affected by several factors such as the type of ventilation, air exchange rates, the degree of tightness of the building, the behavior of its occupants such as opening windows, and the location of the building, including the distance from the source of external pollutants.
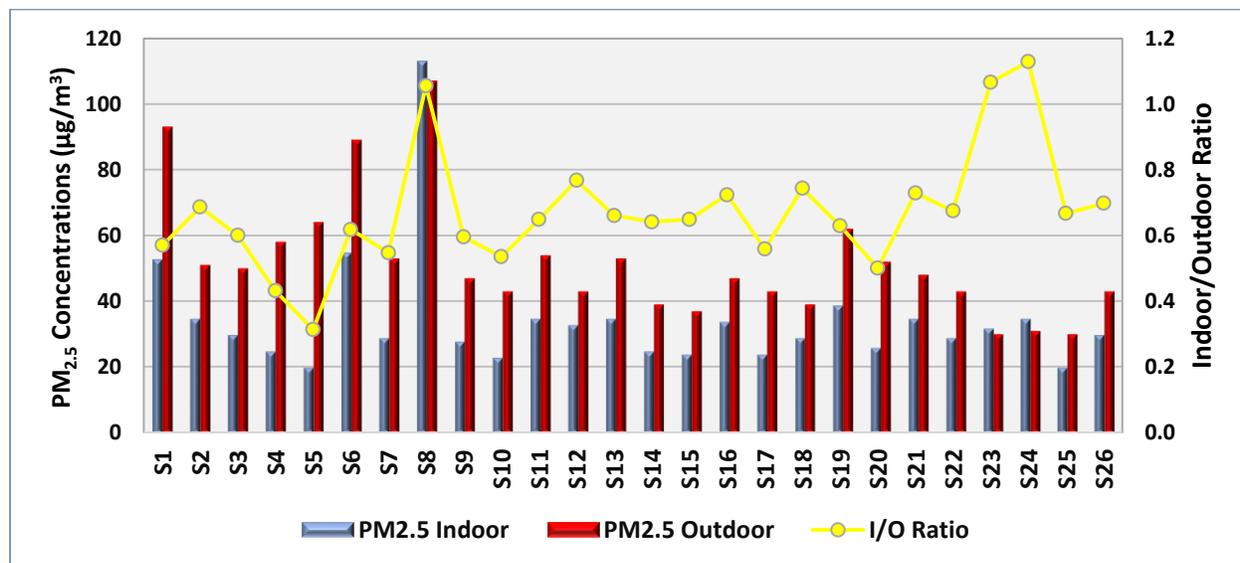
Figure 2. Indoor and outdoor concentration means PM$_{2.5}$ during the study period, with I/O ratio.

Different results were recorded when checking the levels of PM$_{10}$ particles, as the I/O ratio was greater than 1 in most schools, meaning that indoor PM$_{10}$ levels are higher than its levels in the external environment, and this can be attributed to the numerical density of students in classrooms and their high physical activity in particular At the beginning and end of the lesson, which causes the continuous suspension of particles from the floors and surfaces of the seating benches, and this explains what was recorded of the highest average concentrations of PM$_{10}$ during the study period in classrooms that contain numbers of students higher than 30, and Table 2 shows the categories of pupil occupancy in the target classrooms of this study. And Figure 3 shows the levels of PM$_{10}$ inside and outside the classroom with the I / O ratio.

Table 2. Categories of pupil occupancy within classrooms with mean and standard deviation.

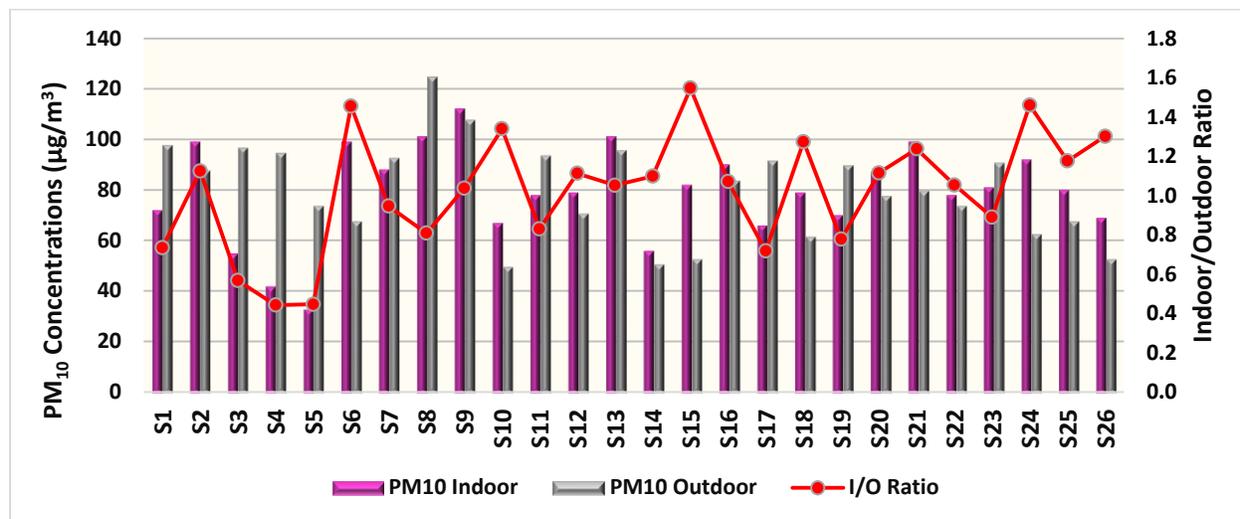| Categories of Pupil Numbers In Classrooms	classrooms	Number of classrooms	Mean of pupils	Standard Division	Percentage (%)
Under 20 pupils	S1, S4, S5, S17, S25	5	17	$\pm$ 2	19%
Between 20-30 pupils	S3, S6, S10, S11, S12, S15, S19, S23	8	24	$\pm$ 3	31%
Above 30 pupils	S2, S7, S8, S9, S13, S14, S16, S18, S20, S21, S22, S24, S26	13	41	$\pm$ 5	50%
Total		26	-	-	100%

Figure 3. Indoor and outdoor concentration means PM_{10} during the study period, with I/O ratio.

In addition, children contribute to bringing these particles into the classroom through their shoes and clothing, as the level of PM_{10} can be related to the degree of cleanliness of the classroom. Where a study (Lewis et al., 2018) indicated that the use of vacuum cleaners in classroom cleaning had a significant role in reducing the re-suspension of PM accumulated in floors, corners, and window sills. The results of this study coincided with my study (Babaoglu et al.,2022; Choe et al.,2022) in recording PM_{10} levels inside classrooms that are higher than the outside environment, and reported that the peak spread of these particles inside classrooms occurs during break times, in order to increase the movement of Pupils after a long period of stagnation in the lesson.

The results of this study concluded that the different meteorological conditions contributed to the variation in the concentrations of $PM_{2.5}$ and PM_{10} outdoors, which affects the rate of transmission of these particles from the outdoor air to the classrooms, where the hot and dry weather that characterizes the study area increases the chances of re-suspension Dust and dust in the air are accompanied by fine particles (Mainka et al., 2015), in contrast, the cold months are usually with high humidity with rainfall, which leads to the adsorption of water particles with fine particles and works to remove them from the air (Marcon et al., 2014). And the increase in wind speed leads to the spread of particles and their infiltration into the internal environments (Bai et al., 2020; Hussein et al., 2021).

3.2. CO concentration

The monthly variation results for classroom CO concentration readings ranged from (0 - 2.2) ppm, and compared to the EPA standard for CO that recommends concentration limits of 35 ppm at 1 hour exposure time. Monthly CO readings did not exceed the above permissible limit in all schools. Since there are no combustion sources inside the classrooms, the few concentrations detected inside the classrooms are from external sources and can be attributed mainly to the nearby traffic. A review of previous studies conducted by (Sadrizadeh et al., 2022) indicated that the main source of CO gas inside schools was car exhaust. In the current study, an increase in CO levels was noted in the classrooms of S1 school, which are located near a main street with a distance of 36 meters, as it recorded the highest reading during the study period. Our study coincided with the findings of (Lee, 2015)

on the effect of classroom air quality on CO gas in schools close to the main streets, and the study recommended that school buildings should be at least 250 meters away from these roads. As for the other main external source of CO gas release, it was the operation of private electricity generators near most of the targeted schools for long hours, in addition to that some schools have their own generators which could be the reason for the release of this gas and its infiltration into their classrooms.

3.3. CH$_2$O concentration

Formaldehyde is a common air pollutant that affects indoor air quality, and it requires great attention in assessing its levels in primary school environments because of its significant health impact on children. Used building materials, furniture, and chemical cleaners are the main sources of formaldehyde in classrooms. The problem of this gas is exacerbated by inefficient ventilation and increased temperatures and humidity (Hu et al., 2022). The results of the measurements conducted inside the classroom showed a significant variation in the values of formaldehyde gas concentration readings between the targeted schools, and the difference between the results was statistically significant (P<0.05), and ranged between (0.001 - 0.118) mg/m^3. The concentrations that were monitored for this gas in the current study can be attributed primarily to the presence of wooden furniture inside the classroom, which are seating made of compressed wood panels or plywood. And with a comparison of the monthly readings and average concentrations that appeared during the study period, with the World Health Organization standard for gas Formaldehyde (0.1 mg/m^3 with an exposure time of 30 minutes), where its levels did not exceed the above standard in most school buildings, as classroom furniture did not add a high contribution, and its concentrations did not pose a danger to students in the targeted

classrooms. And the temperature variation during the study period did not affect the gas readings significantly in each school, with the exception of the case that recorded the highest spread of gas in the S15 school, which is attributed to the recent establishment of the school in the year 2022, and it was equipped with new seating and large numbers inside the classrooms, which caused the accumulation of formaldehyde gas.

3.4. TVOC concentration

The proven sources of VOCs in classrooms are represented in the use of personal care products such as cosmetics, body fresheners, and nail polish, in addition to school supplies such as books, whiteboard pens, correction fluids, adhesives, and building materials such as secondary ceilings, furniture, and paint, as well as their infiltration from External environments when using fossil fuels, mainly represented in the movement of means of transportation, especially in urban locations (Dongiovanni, 2019). In addition, children engage in various types of art activities using crayons that may increase levels of VOCs within the classroom, and the use of cleaning products within the school environment is a potential source of VOC emission (Marzocca et al., 2017). In the current study, the results of the concentrations of total volatile organic compounds inside the classrooms showed a difference from one month to another and did not indicate a specific distribution pattern, and ranged between (0.006 - 0.311) mg/m^3. And compared to the guidelines of the Hong Kong Indoor Air Quality Management Group (HKIAQMG) which recommended that TVOC concentration should be maintained below 0.6 mg/m3 in indoor environments (Meyer, 2021). TVOC readings did not exceed the above criterion in all classrooms. The highest mean concentrations of TVOC were recorded in three schools: the first school (S1), was due to its location adjacent to the gas station and

adjacent to a main street with high traffic density, and the second school (S5), was attributed to the excessive use of cleaning products, with poor classrooms ventilation, as One of the hypotheses of this study is that the use of cleaning fluids and air fresheners affects indoor air quality. As a result of the chemicals that go into its production, such as volatile organic compounds (Casas et al., 2023). As for the third school (S9), it was due to the maintenance work of the school building, and it was represented by the use of paint in painting the external walls and facades of the classrooms and dyeing the iron quarries surrounding the schoolyard, which affected the air quality inside the classrooms. The successive readings of TVOC concentrations during the period of the monthly readings showed the relationship of the emission concentration with the coating time, as it showed a gradual decrease in the levels of these compounds with the passage of time. A study (McLeod et al., 2022) indicated that building materials used in building renovations can have a significant impact on IAQ, mainly due to the release of a wide range of volatile organic compounds for long periods, in some cases exceeding two years. Previous studies have highlighted contradictory associations between the concentration of VOCs and meteorological factors such as temperature, as the study (Huang et al., 2021) found that higher temperature is associated with increased evaporation and diffusion of VOCs in the indoor environment. On the other hand, a study (Portela et al., 2021) when evaluating the concentration of VOCs in kindergartens, concluded that high temperatures lead to an increase in the concentration of the hydroxyl ion, which interacts with volatile organic compounds and causes them to be removed. The study (Lima et al., 2020) to monitor VOCs in some schools, concluded that higher concentrations of this class of pollutants on cold days led to more stable atmospheres, which helped in the accumulation of volatile organic compounds in indoor environments. Table 2 presents the lower, upper, and average values with standard deviation for the parameters whose results showed statistically significant differences during the study period.

3.5. O_3 and NO_2 concentration

In general, the concentration of ozone gas in indoor environments is much lower than its levels in outdoor air, unless there is a dominant indoor emission source such as electrostatic air purifiers, photocopiers, and laser printers. And due to the absence of ozone generators inside classrooms, very low concentrations of it are usually recorded when evaluating indoor air quality in school buildings (Chithra, 2018), confirming the findings of the current study, as ozone levels within the targeted classrooms ranged between 6-8 in units ppb, and compared to the EPA standard for ozone that recommended a threshold of 0.12 in unit ppm, the recorded concentrations of O_3 were very low and did not pose a health risk to students. This applies to nitrogen dioxide, as very limited concentrations of this gas were recorded in classrooms ranging between 16 and 18 ppb units. The detected concentrations of O_3 and NO_2 can mainly be attributed to external combustion sources arising from traffic.

Table 2. The lower, upper, and mean values with standard deviation for the parameters whose results showed statistically significant differences during the study period 2022/2023.

schools	$PM_{2.5}$ (µg/m³)				PM_{10} (µg/m³)				Formaldehyde (mg/m³)				TVOC (mg/m³)			
	Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.
S1	36	79	53	14	54	98	72	14.5	0.005	0.019	0.01	0.005	0.098	0.151	0.12	0.02
S2	23	55	35	11	81	114	99	12.4	0.001	0.006	0.004	0.002	0.006	0.024	0.01	0.007
S3	14	49	30	14	37	99	55	20.6	0.003	0.023	0.012	0.007	0.021	0.095	0.05	0.027
S4	17	33	25	6	28	69	42	14.1	0.007	0.018	0.012	0.004	0.018	0.074	0.04	0.019
S5	12	41	20	10	16	57	33	12.9	0.006	0.024	0.014	0.007	0.046	0.194	0.09	0.056
S6	37	73	55	13	81	114	99	12.4	0.007	0.022	0.013	0.005	0.012	0.03	0.02	0.007
S7	9	58	29	16	57	127	88	25	0.001	0.009	0.004	0.003	0.008	0.021	0.01	0.005
S8	88	131	113	15	84	113	101	9.6	0.003	0.016	0.008	0.005	0.024	0.084	0.05	0.022
S9	11	46	28	13	84	156	112	24.8	0.004	0.02	0.011	0.006	0.018	0.311	0.08	0.106
S10	8	39	23	11	35	98	67	22	0.001	0.004	0.002	0.001	0.012	0.042	0.03	0.009
S11	21	53	35	12	57	96	78	13.9	0.003	0.008	0.006	0.002	0.024	0.065	0.04	0.013
S12	18	51	33	12	54	95	79	15.4	0.001	0.012	0.004	0.004	0.014	0.02	0.02	0.002
S13	25	49	35	9	81	125	101	16	0.009	0.028	0.015	0.006	0.019	0.047	0.03	0.01
S14	10	42	25	11	35	74	56	14.4	0.014	0.046	0.025	0.011	0.023	0.051	0.04	0.01
S15	16	34	24	7	59	116	82	19.3	0.022	0.118	0.052	0.036	0.026	0.139	0.07	0.036
S16	20	47	34	10	67	112	90	16.1	0.002	0.014	0.007	0.004	0.018	0.041	0.03	0.009
S17	15	35	24	7	49	95	66	16.8	0.008	0.026	0.017	0.007	0.026	0.071	0.04	0.016
S18	17	36	29	6	52	110	79	19	0.002	0.014	0.008	0.004	0.015	0.047	0.032	0.011
S19	30	53	39	8	39	103	70	20	0.002	0.014	0.007	0.005	0.029	0.062	0.05	0.012
S20	15	41	26	9	64	115	87	17	0.008	0.022	0.015	0.005	0.038	0.094	0.06	0.023
S21	28	45	35	5	73	142	99	25	0.003	0.016	0.008	0.005	0.024	0.09	0.05	0.022
S22	17	49	29	11	52	108	76	21	0.006	0.018	0.012	0.004	0.027	0.1	0.06	0.027
S23	18	50	32	11	59	108	81	18	0.032	0.072	0.048	0.013	0.032	0.072	0.05	0.013
S24	16	53	35	14	64	180	92	40	0.022	0.047	0.032	0.009	0.022	0.047	0.03	0.009
S25	6	39	20	11	61	104	80	16	0.018	0.068	0.042	0.016	0.018	0.068	0.04	0.016
S26	15	42	30	9	46	102	69	19	0.018	0.047	0.032	0.012	0.018	0.047	0.03	0.012

4. Conclusions

The results showed that the majority of classroom indoor environments contain air pollutants, and some pollutant concentrations exceeded the approved standards. There is a significant impact of outdoor air quality on the classroom environment. Cleaning and maintenance activities of school buildings have contributed to the effect on indoor air quality, as well as classroom characteristics such as Intensity of student occupancy and insufficient ventilation. More actionable advice is needed, such as planting lots of plants in schools that absorb pollutants and purify the air, and using environmentally friendly cleaning products to reduce chemical emissions. and taking into account the importance of choosing sites far from air pollution activities when establishing new schools.

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