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TEMPORAL AND SPATIAL ASSESSMENT OF INDOOR AIR QUALITY (IAQ) ON PHYSICAL AND CHEMICAL PARAMETERS IN PRIMARY SCHOOLS

MUHAMAD HILMAN BAZLI YAHAYA[1], AMALINA ABU MANSOR[2], AIMI NURSYAHIRAH AHMAD[1], SAMSURI ABDULLAH[1]*, ZAMZAM TUAH AHMAD RAMLY[3], MOHD RADHIE MOHD SALLEH[4], MOHAMMAD FAKHRATUL RIDWAN ZULKIFLI[1], SURIANI MAT JUSOH[1], WAN NURDIYANA WAN MANSOR[1] AND MARZUKI ISMAIL[2]

[1]Faculty of Ocean Engineering Technology and Informatics, 21030 Kuala Nerus, Terengganu, Malaysia. [2]Faculty of Science and Marine Environment, 21030 Kuala Nerus, Terengganu, Malaysia. [3]EnviroExcel Tech Sdn. Bhd, 43300 Seri Kembangan, Selangor, Malaysia. [4]INet Spatial Sdn. Bhd, 81300 Skudai, Johor, Malaysia.

Corresponding author: samsuri@umt.edu.my
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Abstract: Indoor Air Quality (IAQ) is very important for children's health and well-being since children are particularly vulnerable and sensitive to the presence of air pollutants. Poor Indoor Air Quality brings negative health effects to young children, especially primary school students. The objective of this research was to analyze the chemical and physical parameters inside the classroom at two sites representing institutional and residential area. Spatial mapping was conducted by using Surfer® and Sketchup®. Data were measured using Dust Trax^{DRX} Aerosol 8454, Kanomax IAQ, and TSI IAQ 9545 for three days from 0700 hours to 1400 hours. This research analyzed the chemical and physical parameters inside the classroom, such as particulate matter less than 10 microns (PM_{10}), carbon dioxide (CO_2), air temperature, air movement and relative humidity. Results show that the concentration of carbon dioxide (635.5 ppm – 756 ppm) and (723 ppm - 806.5 ppm) for institutional and residential areas are within the limits. The concentration of PM_{10} was (0.039 mg/m^3 – 0.129 mg/m^3) and (0.061 mg/m^3 – 0.109 mg/m^3), relative humidity (76.15% - 88.6%) and (60.9% - 86.75%), air movement (0.08 m/s – 0.82 m/s) and (0.08 m/s – 0.88 m/s) and temperature (27.25˚C – 30.8˚C) and (26.75˚C – 31.0˚C) for institutional and residential area respectively, did not comply with the (ICOP-IAQ 2010) standard. Spatial analysis shows the critical points were at the teacher's desk, the middle section of the classroom and at the back of the classroom. The critical point was observed in the middle section of the class, as most of the students resided at the back of the classroom where there was furniture that contained particulates.

Keywords: Air quality, primary school, chemical parameter, physical parameter, spatial mapping.

Introduction

Air pollution occurs as the result of solid and gaseous material emitted into the atmosphere in elevated concentrations. Outdoor or ambient air pollution is the primary concern, but indoor air pollution has a greater impact, as the sources might come from sweeping the floor, cleaning activities, ventilation issues and cooking activities (Swamy, 2021; Mannan & Al-Ghamdi, 2021; Mata *et al.,* 2022). Indoor Air Quality (IAQ) is defined as the air surrounding or within the building or structures the most related to the health and comfort of the occupants (Mansor *et al.,* 2020). IAQ is of interest as 91% of people perform their daily activities indoors (Śmiełowska *et al.,* 2017). It has been shown that air pollutants are commonly two to five times higher indoors compared to outdoors and sometimes 100 times greater than outdoor levels (Idris *et al.,* 2020; Wu *et al.,* 2020). Primary school students are particularly vulnerable to IAQ as they spend their time mostly in the classroom and their breathing rate is higher, allowing more pollutants to be lodged in their system (Korsavi *et al.,* 2020). The students' low height also makes it easier to inhale the pollutants as they are more susceptible to the particulates on the floor (Jiang *et al.,* 2020).

Children spend 30% of their time in school and 70% of children stay inside the classroom during the school day (Lazovic *et al.,* 2016). Every day, children are exposed to various kinds of pollutants, especially those sourced from indoor areas. More studies should be conducted to obtain information regarding the IAQ in the school building. The presence of indoor air pollutants can be detrimental to the student's health as they breathe in more rapidly, their lungs are not yet fully developed and their immune system is still developing, putting them at risk of getting acute or chronic health effects resulting from poor IAQ (Yu *et al.,* 2020). Inadequate IAQ may lead to student illness, absenteeism, loss of concentration, drowsiness and tiredness, adverse health symptoms such as respiratory problems or headaches and decreased academic performance (Tuck *et al.,* 2019; Mansor *et al.,* 2020). This study is significant in providing practical information regarding indoor air pollutants detrimental to human health, especially young children.

Materials and Methods

Study Areas

The study areas were in the District of Kuala Nerus, Terengganu. Site selection with different surrounding activities was determined based on I-plan Terengganu from the Urban and Regional Planning Department of Kuala Terengganu website. The study area chosen had different surrounding institutional and residential area activities. Sekolah Kebangsaan Mengabang Telipot (5.423436, 103.066875) (Site 1, S1) represents the institutional area, while Sekolah Kebangsaan Tok Jembal (5.709444, 103.119167) (Site 2, S2) represents the residential area as shown in Figure 1.

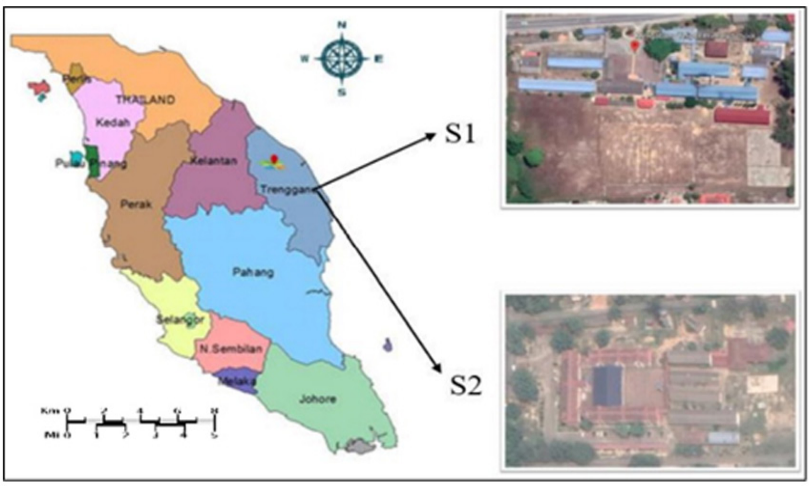


Figure 1: Study areas

Sampling Campaign

The data were collected for three days during school days for both schools. The sampling duration for each school was six hours from 0700 hours to 1400 hours. The reading was taken every 5 minutes. The Industrial Code of Practice 2010 (ICOP-IAQ) was used as a guideline to place the instrument and number of sampling points per area of the classroom (Abdullah *et al*., 2019). Coarse particulate matter (PM_{10}) and Carbon Dioxide (CO_2) were the chemical parameters sampled. Physical parameters measured are temperature, relative humidity and air movement. The device was placed at a height of 1.2 meters from the floor (DOSH, 2010).

Data Analysis

Measured data were described in terms of temporal and spatial distribution. The temporal analysis was conducted by evaluating the statistical indices and displayed in a boxplot. Spatial analysis via Sketchup® was used to construct the engineering drawing of the classroom. To ensure the sampling point is accurate when sampling, the diameter of the classroom was measured (meter). By obtaining the real-life diameter of the classroom, we can plot the sampling point inside the engineering drawing and the data can be digitalized. Surfer® was used to digitize the data to show the critical points of the study areas. The data obtained at the twelve points during sampling were plotted into digitized data and overlaid together to form spatial mapping. The colour grade chosen to portray the data is 'rainbow'. The red colour of the mapping represents the most critical point of each parameter and the blue colour shows the lowest value of the parameter. To ensure that the spatial mapping is more accurate, readings at the twelve measurement points were taken at 5 minute intervals in each of the classrooms.

Results and Discussion

Based on the ICOP-IAQ (2010), the concentration of CO_2 can be a benchmark for ventilation effectiveness. In the morning (7:00 am – 7:30 am), students' parents are often in the classroom taking care of the children and waiting for the bell to ring, alerting students to go to assembly. This affects the reading of the CO_2 during that time. High concentrations of CO_2 at S2 were detected as all the windows and doors were closed for security. However, students are not allowed to occupy the classroom and have to wait at the assembly area [Figure 2(a) and Figure 2(b)]. The reading of particulate matter varies for both study areas [Figure 2(c) and Figure 2(d)]. S1 shows a significant PM_{10} increment when students enter the classroom after assembly and these levels are maintained until school is over. At S2, the reading of PM_{10} shows a surge after assembly as students enter the classroom but the reading gradually decreases over time. This might be due to the number of students which affects the reading of the particulate matter level. A study by Madureira *et al.* (2015) found that the occupancy level of certain rooms can affect the pollutants reading inside a room. Zubir *et al.* (2022) found that building age can also influence the reading of pollutants inside a room, particularly in older buildings that have more blemishes, holes and mold that can reside in the building over a period of time.

Figures 2(e) and Figures 2(f) show the level of air movement at each school. Air movement can influence the dispersion rate of chemical and physical pollutants. At S2, the ventilation is aided by three ceiling fans and one pedestal fan. At S1, the ventilation is aided by only three ceiling fans. Figures 2(g) and Figures 2(h) displays the reading of relative humidity at S1 and S2, respectively. The relative humidity reading is often highest during the morning (7:00 am) and gradually decreases throughout the day. It is found that the relative humidity and the temperature [Figures 2(e) and 2(f)] are inversely proportional to each other. When the temperature increases, the relative humidity decreases. This is because the saturation point of the air is enhanced in the morning (low temperature). Overall, the temporal patterns fluctuate over time and the boxplot analysis shows that the reading is within the safe limit set by ICOP-IAQ (2010) for CO_2 and PM_{10}.

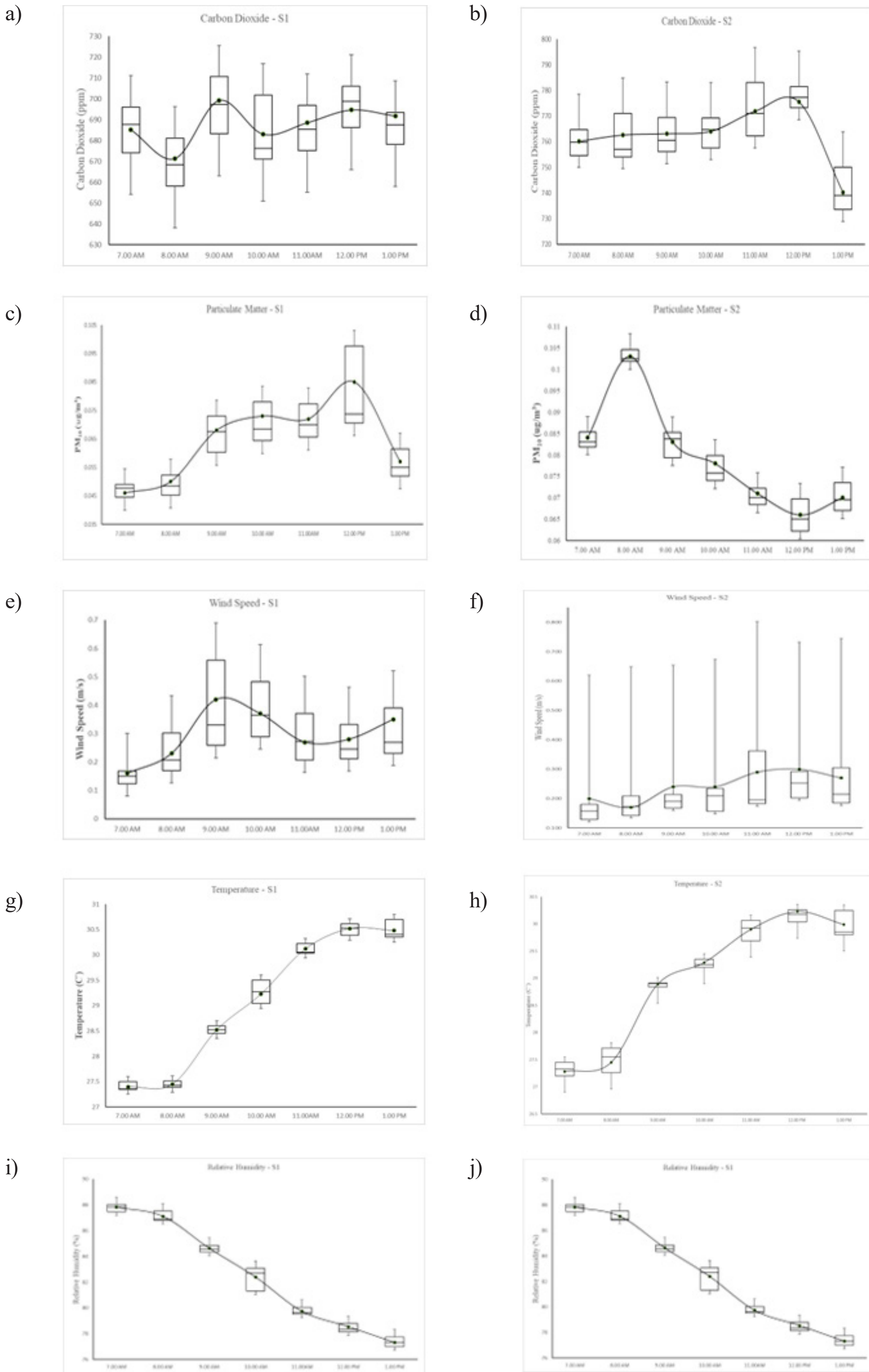
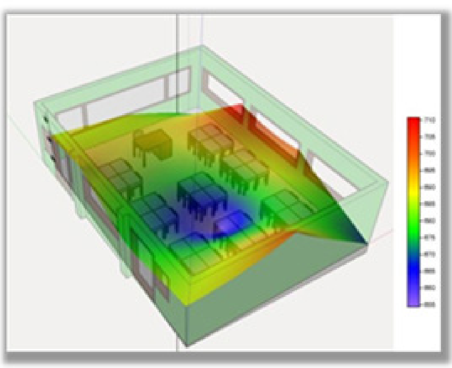


Figure 2: Boxplot of chemical and physical parameters

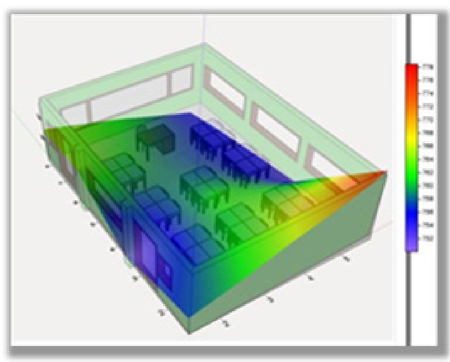
All the physical and chemical parameters of classrooms at S1 and S2 were drawn using Sketchup® and the data were digitized using the Surfer® software. The colour grade chosen to portray the data is ‘rainbow’. For this colour grade, red c represents the most critical point of each of the parameters and blue shows the lowest value of the parameter. To ensure that the spatial mapping is more accurate, readings at the 12 measurement points were taken at 5 minutes intervals. Figure 3(a) shows the CO_2 concentration of S1. The red zone indicates the area where the concentration of the pollutants is the highest. This red zone is typically between students’ desks, where the density of students is the highest. The CO_2 can represent the ventilation rate inside a room (Fu *et al.,* 2021). S2 is equipped with an additional pedestal fan at the front of the classroom which helps to disperse the pollutants. The students at S2 are also very active when the teacher is not inside the classroom. Young students breathe in more rapidly (Lazovic *et al.,* 2016) and when they are actively moving in the classroom, the concentration of CO_2 increases and can cause discomfort for the students.

Figures 3(c) and Figures 3(d) show the mapping of the PM_{10} concentration. The number of students inside the S1 classroom is 26, while in S2, there are 40 students. Students' movement inside the classroom can cause the particulate matter that settles on the floor to be resuspended. The ease of movement inside the S1 classroom is more accessible as it has fewer desks and chairs compared to S2, with 40 desks and chairs. This affects the student movement and students at S1 move a lot compared to S2 due to restricted movement. Figures 3(e) and Figures 3(f) shows the mapping of the relative humidity (RH) inside the classroom. The analysis shows that the RH is inversely proportional to the temperature. Both parameters affect the children’s well-being as they affect learning (Madureira *et al.,* 2015). They are important in maintaining good IAQ (Vornanen-Winqvist *et al.,* 2020). The red zone in both maps shows that the parameters exceed the ICOP-IAQ (2010) guidelines, where the temperature should be between 23-26˚C and RH should be 40-70%. The maximum temperature for S1 and S2 is 30.8˚C and 31˚C, respectively. The maximum RH for S1 and S2 is 88.6% and 86.75%. The high RH can affect perceived IAQ comfort, causing irritation to the eyes and airways, changes in work performance and voice disruption. Synergistic effects may occur with air pollutants as well (Khalid *et al.,* 2018).

a)



b)



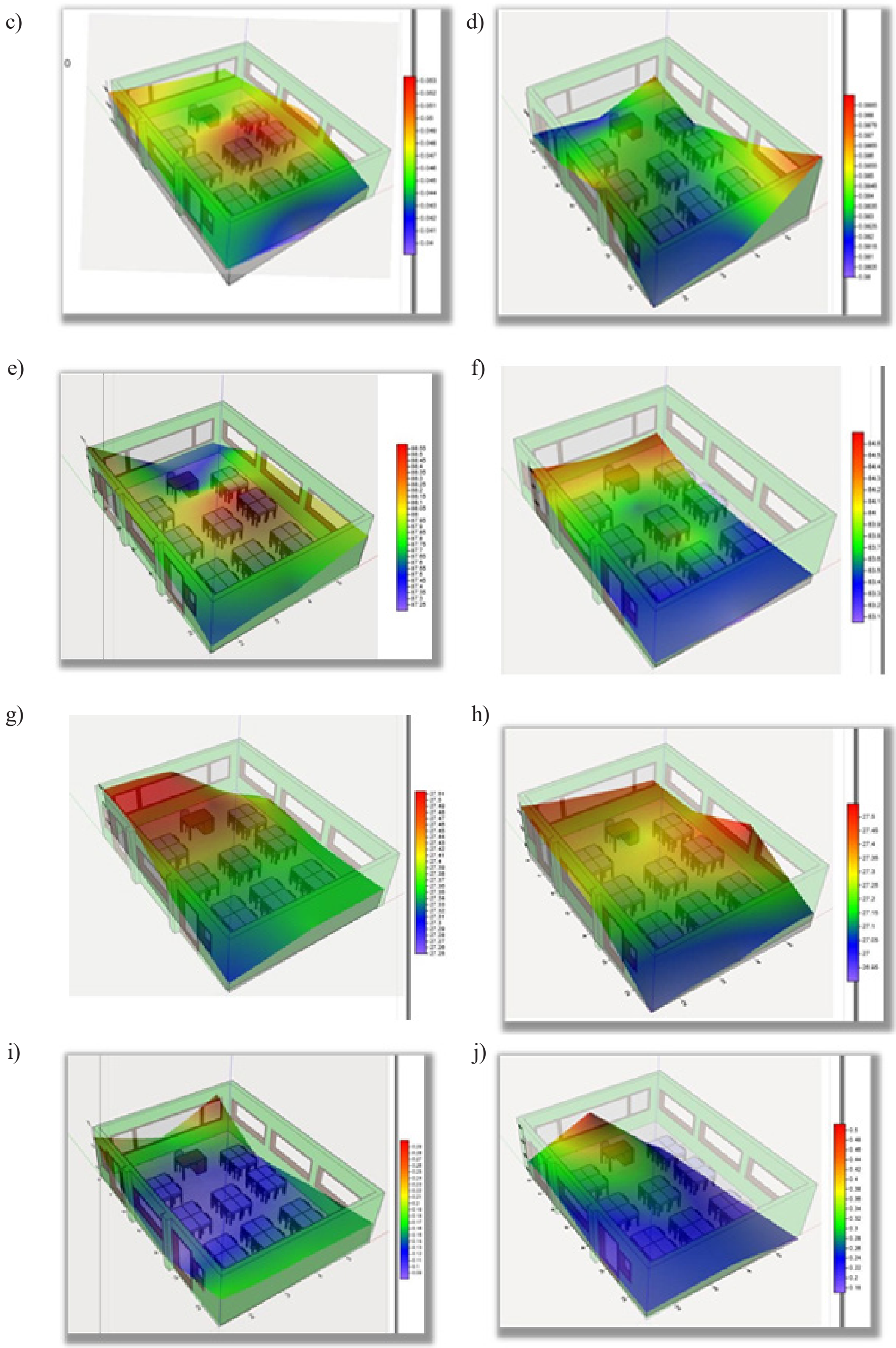


Figure 3: Spatial maps of (a) CO_2 at S1, (b) CO2 at S2, (c) PM10 at S1, (d) PM10 at S2, (e) RH at S1, (f) RH at S2, (g) Temperature at S1, (h) Temperature at S2, (i) Air movement at S1 and (j) Air movement at S2

Conclusion

Physical parameters of air movement, relative humidity and temperature did not comply with the ICOP-IAQ standard. Among the reasons for this are the types and number of fans used. The mapping shows the critical area in red and the less critical area in blue. The pollutants are well distributed with a high concentration near the desk and back section of the classroom. In maintaining the comfort of pupils and teachers in the learning process, the physical parameters must be within standards.

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