The Mechanisms Used to Measure the Indoor Air Quality in Classrooms

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Abstract:

Recently, concerns about the effect of air pollution on school kids have increased. There is a growing body of evidence about asthma's development, as well as the worsening of symptoms of people with asthma, and exposure to air pollutants associated with traffic. For this reason, air quality control in the internal environment is considered one of the important things to monitor pollution levels, assess the appropriateness of the child's environment in the classroom, ensure a safe environment, activate the activities of air filtration, stimulate environmental awareness among the decision makers, and develop technologies according to data. Due to the absence of a standard tool for the data of indoor air quality of classrooms in The Hashemite Kingdom of Jordan schools, this research provides: a proposed system to measure air quality. It consists of: distributed sensors connected to a developed system and constitutes a **wireless sensor network** (WSN).

Sensor nods are based on low energy ZigBee movements, and transmit field measurement data to the cloud through a portal. An improved cloud computing system has been applied, monitored, processed and visualized to store the data received from the sensor network.Data-processing shall be implemented and analyzed in the cloud through the application of artificial intelligence techniques, to improve pollutants and compounds technology. The proposed system is: low cost, small-scale, and low energy consumption which can enhance the effectiveness of air quality measurements, therefore a large number of nodes can be published, as well as the provision of the relevant information in order to distribute the air quality in different areas.

Keywords:

Monitoring the quality of the surrounding air, wireless sensor network, air pollution, indoor pollutants,

The Importance of the Research:

The importance of the research lies in the fact that it is discussing the control of the indoor air quality, to improve the internal environment of classrooms in school buildings; the place in which students spend the major part of their time; which necessarily requires classrooms

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preparation in terms of the technological development, and the involvement of the modern technological means to overcome the problem affecting comfort and environmental compatibility between indoor space and the surrounding environment.

Introduction:

Carbon dioxide is often considered as reference laboratories for measuring indoor air quality, because its high concentrations indicate that: Conditions of poor ventilation, probable accumulation of pollutants in indoor air. This is mainly related to technical difficulties in monitoring the quality of indoor air in classrooms, in contrast staff members and students inside the classroom relate ventilation to thermal comfort instead of the quality of indoor air (2: page 556), through the control of the mechanisms of direct exchange with the external air, regardless of the conditions of external air quality, and the exposure to pollutants, which arising from the surrounding environment in general, especially schools neighboring public roads.

Research Problem:

The problem of the research is summarized in the following question: in the light of the endeavor to present the best internal environment to our children inside classrooms, how can modern technological means contribute in measuring and controlling air in the internal environment, to reflect on the enhancement of the internal environment quality of classrooms?

Research Objective:

The aim of the research is to propose the use of modern technological means which coming within the reach at the Hashemite Kingdom of Jordan schools, through the design of effective WSN system in applications in real time; by the wireless sensor networks that is based on ZigBee Protocol (which will be illustrated later). This enables schools to assess the air health and quality for school children, and the extent to which children expose imperceptible gases in the internal environment of classrooms, which in turn affect the indoor air quality associated with the student's and user's comfort.

Research Hypothesis:

The impact of physical environment elements as an active factor of ecosystem, which includes the thermal comfort (ventilation, heating and air conditioning), and **the indoor air quality (IAQ**) that is related to the concentrations of pollutants, bacteria and viruses, is associated directly with the improvement of student's behavior, increasing its capacities to acquire knowledge and skills and resilience and the sustainability of the educational process.

Research Delimitation:

This research is based on illustrating the importance of employing the modern technological means related to the interior design, and its role in the achievement of indoor air quality in classrooms.

Research Methodology:

This research relied on the descriptive analytical method: through the study, we found that the elements of the comfort discipline for the elements of indoor environment quality which is related to the indoor air quality. We also analyzed the wireless control system of the indoor air

quality (IAQ), based on the solar powered and low-cost Zigbee WSN protocol, which can be easily deployed in environments to monitor the indoor air quality of classrooms.

The internal environment of the classroom:

The occupancy rates of classrooms are considered high in general, during teaching hours at school. Considering that students spent about 8 hours daily (at the rate of 20% of their times annually) inside classrooms, for this reason, the comfortable thermal environment in buildings with natural and mechanical ventilation is clearly required for their educational performance.

Discipline of comfort:

The published researches indicate that: there is a relation between the poor indoor air quality (IAQ), and the thermal comfort with a number of factors which include:

1. Low human productivity and dissatisfaction of adults (7: page 92).
2. Negative impacts that affect school children's education (8: page 588).
3. The growth of bacterial and fungal spots (blackening) of walls and the internal ceilings of the building (9: page 7592).

Sources of pollutants in classrooms:

The indoor air pollution is determined through: a set of sources of pollution associated with place, climate, and culture (surrounding air- physical characteristics of the building- internal activities). These classrooms consist of special furniture (chairs, tables, shelves, books and projectors …), paints, adhesive materials, and soundproofing materials. Owing to the diversity of the existing materials and the implemented activities, the existing of a huge number of different volatile organic compounds can be expected in the air of the class, as well as, imperceptible gases.

The internal and external exchange of pollutants:

There are three ways of exposure to pollutants: (inhalation, ingestion and dermal absorption). Inhalation is considered as: the main way of volatile organic compounds, and gases in the internal environment. Gaseous and volatile organic compounds, formaldehyde, Nitrogen dioxide, carbon dioxide and particulate matters resulting from the biological factors such as, fungus and the airborne bacteria are considered as the most common pollutants in primary schools (13: page 80).

Carbon Dioxide in classrooms:

It is important to reach to low concentration of Carbon Dioxide in classrooms in order to provide a stimulating environment for the enhancement of learning processes. For this reason, the development and implementation of ventilation strategy is considered as an important tool. It is also recommended to supply classrooms with surveillance equipment of carbon dioxide levels, temperature and relative humidity, in order to ensure that the target values of carbon dioxide concentrations remain less than 1000 parts per million, and temperature between 20 to 22 degree Celsius during the winter, and between 22 to 24 degree Celsius during the summer, and the relative humidity in the range of 40% to 60% (17: page 222).

Sensing Technology of Indoor Air Quality (IAQ):

The Need for use:

The traditional ways used to measure and monitor the sources of pollutants are considered as expensive tools, not capable to provide highly accurate, big, and noisy spatial and temporal data and need someone with experience. But with the technological development, a portable, low-cost, and easily used air pollution control devices has appeared using the sensor technology, which provide highly accurate data in the real-time to improve the air quality control. New potentials and applications working to change the ways of managing the indoor air quality has also appeared.

Sensors:

The main component in these devices is the elements that respond to changes in the chemical and physical characteristics, and they are converted to electrical signals by the energy transformers. The chemical gas sensors are used to measure the concentration of gases by analyzing the interactions between the sensor material and the target gases such as, O_3, CO, SO_2, CO_2 (carbon dioxide), NO_2 (nitrogen Dioxide), and volatile organic compounds (VOCs).

The probable benefits of the indoor air quality (IAQ) sensor proposed in schools:

Sensors with direct readings are considered as a beginning of a new era in the high resolution of the spatial temporal sensors used to measure the indoor air quality (IAQ). At the same time, they enable individuals to control their specific environments. The proposed benefits of this new approach cover some aspects:

- Real-time characterization of the concentrations in closed areas.
- Identification of emission sources resulting from internal activities.
- Provision of the air data.
- Improving the indoor air quality (IAQ) management.
- Health benefits: through reducing the cost of air pollution control.

Employment strategies of modern technological means in schools:

Wireless sensor network (WSN) showed great potentials for the wide application in the areas of control, and supervision within the framework of new scientific fields such as, identifying, integrating and publishing the information of the physical environment as an information readable (28: page 2- 020063). This research provides a solar powered and low-cost wireless IAQ control system based on Zigbee WSN protocol, due to the availability of modern and smart sensors smaller and cheaper, in recent years. This system can be deployed easily in environments to control the indoor air quality of classrooms.

The wireless sensor network based on ZigBee:

ZigBee: is a standard open wireless network protocol, accredited to standard (IEEE 802.15.4). This protocol works to determine the media layer and the target layer. This system works effectively and with low cost and low energy on a small scale, on the other hand, the wiring system might be expensive and ineffective (30: page 2264). These networks consist of a large number of distributed sensor nodes, which can be easily deployed and organized in a wireless

network with multiple focal points. The standard range is 50 linear meters and it can reach to 500 meters with routers (32: page 321), thus, which is extremely expanding network.

The system design:

This system consists of Zigbee terminal nodes, routers, data portal/ and a wireless coordinator attached to a laptop/ computer for direct use with an integrated management system established by (LabVIEW[1]) platform to show data on the computer. The terminal nodes (sensors) found in the internal environment can be used to measure the elements of air quality in the environment at the same time, and these data will be sent back inside by a router.

Details of the system components (35: page 4):

a. Sensor Nodes: consist of an improved electronic panel, a set of sensors, and a power saver unit. They are supported by a power supply unit (rechargeable batteries), and combined with a solar panel (10 Watt) as well.

b. Router: due to the limited transmission range of radio sets, and the absence of the radio communication over long distances, routers are relied upon to expand the environment scale to be covered.

c. Data receiver/ coordinator: it is a portal that is responsible for establishing, reprogramming and managing the network.

d. Desktop Computer: monitoring station that connected to a router with an integrated management system designed using the platform of (LabVIEW).

The proposed network of the researcher:

Through this study, an applicable proposal based on the use of wireless sensor network and Zigbee protocol is provided, and specialized in the field of supervision and monitoring of pollutants in the physical environment of classrooms. The proposal will be provided for the study sample: Some High School in Irbid- Hashemite Kingdom of Jordan, in order to analyze and publish the data that were monitored by the proposed system in the form of information readable, through the following:

1. Monitoring station: a new room shall be developed in the first floor of the school in the center of the building (a central connection point of the system), by reducing the whole space of the science lab from (78) m^2 to (63) m^2, so that the total space of the developed monitoring station shall be (15) m^2. This space shall be enough and consist of an office for a computer disk and a server for data archiving, data receiver/ the central coordinator, and a chair for the responsible for monitoring the system.
2. Router: in the research sample, it is noted that the furthest distant between the sensor and the data receiver is almost 40 linear meters. For this reason, the existing of the router is not necessary for the direct correlation between the sensor unit and the data receiver.
3. Sensor Node: is a terminal node of the system, consists of a main box containing an improved electronic panel with a set of the required sensors (temperature- humidity- carbon dioxide and particles), a power saver unit, and a battery supported by a specific solar panel that connected by the windows of the classroom (an external unit is installed above the window from outside). The sensor nodes shall be distributed in classrooms according to the following:

- One sensor node shall be used to cover the whole space of the classroom 46 m^2, it is expected that it will serve a number of students between (20- 34) students.
- This sensor node shall be affixed on the ceiling, provided that it has to be over the space occupied by students and in the last third facing the architectural openings (as classrooms have only one direction to the architectural openings that are looking out). It shall not face the airstream coming to the classroom by windows directly.

Findings:

The high resolution of the spatial temporal sensors used to measure the indoor air quality (IAQ) enables the competent authorities in schools to control the environment of classrooms, in order to be a new approach in the internal environment management, by which the following will be achieved:

– The ability to conform the data of indoor air quality to the international or applicable standards in Jordan.

– Determination of the emission sources in the classrooms space during the times (before work, during work and after work).

– Provision of a large database about the repeatedly monitored pollutants, and times in which the concentration of pollutants has been increased. Therefore, they can deal with pollutants with flexibility, especially in seasonal fluctuations of the climate throughout the four seasons.

– The ability to achieve the comfort discipline in classrooms, through health benefits provided by the low cost to the indoor air quality sensors and the reaction of officials to the immediate processing of the internal environment if pollution levels rise.

Conclusion:

Through the findings of the research and what is discussed in the research, we can know the importance of keeping up with the technological development, to achieve the proper and targeted employment of this technology in the interior design. Therefore, this is reflected in the indoor air quality in the classrooms of the school buildings.

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١ LabVIEW: Laboratory Virtual Instrumentation Engineering Workbench, it is considered as one of the most common software engineering, produced by the American Electronic Company of (National Instruments). It works on all computers' operating systems, and used in the fields of data acquisition, arbitration tool, automation system tests, signal processing and the industrial control.