

Evaluating Indoor Air Quality (IAQ) as Modifying Factor in Designing Public School Buildings in Jordan

Hikmat H. Ali, Ph.D.

Hind Al-Momani

Department of Architecture
Jordan University of Science and Technology
Irbid-Jordan
Hikmat_ali@yahoo.com
Hikmat@just.edu.jo
 Phone (962) 2-7201000
 Fax (962)2- 7095018

ABSTRACT

The most fundamental goal in the design of educational facilities is to provide an environment that encourages learning achievement for students and teachers. Poor indoor air quality (IAQ) can negatively affect student health, comfort and performance that will eventually produce unacceptable learning environment. Poor IAQ can decrease a person's ability to perform specific mental tasks requiring concentration, calculation and memory. Therefore, schools should be designed, built and maintained in away to minimize and control the source of pollution.

Around 29% of Jordanians occupy school buildings each day. A specific prototype building design was applied in the different locations of the country. This prototype could be appropriate for one location but it is not for the entire country that has diversity in climatic and environmental conditions

The purpose of this research paper was to evaluate the indoor air quality in public school buildings in urban and rural area, through investigations of the causes and its effects on student health, comfort, and performance.

Achieving healthy indoor air quality is a multifaceted a problem which can be arrived at by a comprehensive and interdisciplinary approach to the design, construction and operation of the school building. Results indicate that the prototype system used was not appropriate as healthy school design, and it did not take into consideration the indoor environmental factors as crucial issue in designing school buildings.

INTRODUCTION

The architectural design process is more about creating beautiful and functional spaces. Architecture is a balancing act that involves many factors like functionality, practicality, occupant, safety, comfort

and health. These factors are important in order to achieve successful and beautiful buildings.

Achieving healthy indoor air quality, which involves these balancing factors, are related with the site, pathway systems, building design, construction and occupants. The importance of creating and maintaining a clean and healthy indoor environment should be a part of the architect's job, as a member of the design, construction, and operation team.

There is an increase in public awareness about the environment and its affect on our health. The quality of indoor air has received considerable attention in the recent years. The main reasons for this interest are that the indoor air can be two to five times more polluted than outdoor air¹. In addition, the public spends about 90% of the time indoors (Burton, 1993).

The World Health Organization (WHO) suggested that up to 30% of new and remodeled buildings may be the subjects of complaints that are related to indoor air quality (Arnold, 2001). General Mortgage and Housing Corporation (GMHC) estimated 6% of Canadian population had several problems that are related to air quality. This number has risen to 25%, which indicate how the number of indoor air quality problems has increased (Mathews, 1992).

It is apparent that there is a relation between illness complaints and building environments in a large number of problem building investigations. In the U.S a team of National Institute of Occupational Safety and Health (NIOSH) reported that the potential factors to complaints for 529 investigations (conducted between 1971 & 1988) are 53% because of inadequate ventilation and 15% because of contamination from indoors sources (Godish, 1997).

¹ "Indoor air quality "air conditioning, heating, and refrigeration news". vol.210,12/17/2001,Issue16,p18

Architect K.Cheong and H.Lan (2002) mentioned that good indoor air quality (IAQ) in schools provide a comfortable and healthy environment for students to learn in. They examined the IAQ status in the learning environment by using monitoring of thermal comfort parameters, dust particles and the concentration of carbon dioxide (CO₂), carbon monoxide (CO), HCHO, total volatile organic compound (TVOCs), air exchange, ventilation effectiveness. In addition, they distributed a questionnaire to the students and staff to make the study more reliable (Cheong, 2003).

Arnold, (2001) in his study emphasized on the building investigation to identify and solve IAQ problem. He mentioned that the investigation should review the history of building and complaints; complaint areas in order to expected and develop possible explanation for the complaints. Also air sampling (temperature, relative humidity, CO₂, air movement) provides information about possible cause. Sampling for specific pollutant concentration does not require that containment concentration level rarely exceed existing standards.

In order to characterize symptom prevalence rate, there was a study for 14 non-complaint Danish buildings and 11 Swedish sick buildings. This study showed that building-related health complaints occurred in all buildings, but its rate was generally higher in sick building compared to buildings in which problems have not been previously reported (Godish, 1996).

Wilson, (2001) stated that IAQ could negatively affect student health and results unacceptable learning environments. Different schools, elementary middle and high schools, require different approaches. Elementary schools, because of cost issues, heating, ventilation and air conditioning systems are the norm solution to IAQ-details approach-. Middle and high school benefit from larger design and construction budget so there is a need to more thinking about IAQ treatments, - design process-.

Kathleen in (2001) pointed out that school design influence the achievement of elementary school students. In the study, the population was 24 elementary schools that are located in the East Central Georgia Regional Education Service Area. She used site visit and Internet to collect data.

As a succes case study there was the Inter-district Downtown School in Minneapolis, Minnesota. In this project the architect "Cunningham Group" used

microclimate and environmentally responsive site design strategies, the study provide a sample for air pollutant control and thermal comfort. Sustainability was introduced in the school by defining it as a green building. IAQ was a main goal that design team established².

On a survey, held to look at what impact the design and condition of school facility have on teacher and learning, 1350 teacher and principles in nine cities in the United States, include sufficient heating and air conditioning were the two most issues that affected educations quality followed by technology. 91% said that these issues affect educations quality, 71% said that the design of classrooms and condition has a strong impact on test scores (Fuller, 2001).

The previous studies indicated that indoor air quality is a major factor in design process of school buildings. Taking this factor into consideration will lead to healthy indoor environment in schools that will affect student health and performance.

SCHOOL BUILDINGS IN JORDAN

Schools environment is a crucial part of the design process. Therefore, we need to change our thinking about the physical environments of schools, and increase our awareness and understanding of the health impact on students. In Jordan, as a developing country, there are no previous studies that investigate the school environment. As a mater of fact, there are about 1,463,484 children (93% from the total number of children in Jordan) entering about 5,137 schools (56.7% are public schools)³. The occupancy rate in school in Jordan is high compared with other developed and developing countries. This is because Jordan suffered from many wars on the region that increased number of student with limited resources for the schools. The standard density of students is 1.25m²/students, while in the U.S. it is 2.15m² /student and in Switzerland it is 2.25m² /student (Shbool, 1997).

The early beginning of school buildings in Jordan began with a small room attached to the mosque called Al-Kuttab. Number and design of school buildings increased rapidly after the independence of the state in 1946. The first building prototype used after Al-Kuttab was the municipality prototype, then

²

<http://www.sustainabledesignguide.umn.edu/MSDG/case/downtown/downtown.html>," WMEP Inter-district Downtown School",20/5/2003

³ Department of statistics, Ministry Of Education

they developed another system called Hi-Nazzal prototype. Another comprehensive design systems were provided, started in 1972 with the first educational project. In 1975 and 1981 they developed the second and third educational project. In 1996, around 200 schools were design based on a section education system. This system was funded by the World Bank, JICA, and the local government, (Shbool, 1997).

Hi-Nazzal prototype, which could be considered as the early systems of school building design in Jordan, was built to accommodate a large number of students. It consists of a rectangular shape with double loaded corridor. It was built using concrete bricks and steel windows. Usually this system was ignoring the environmental conditions and usually stamped in any location regardless of climatic and environmental situation. Number of students in each class room exceeded 45 students. The total area size of class room was not more than 35 m²

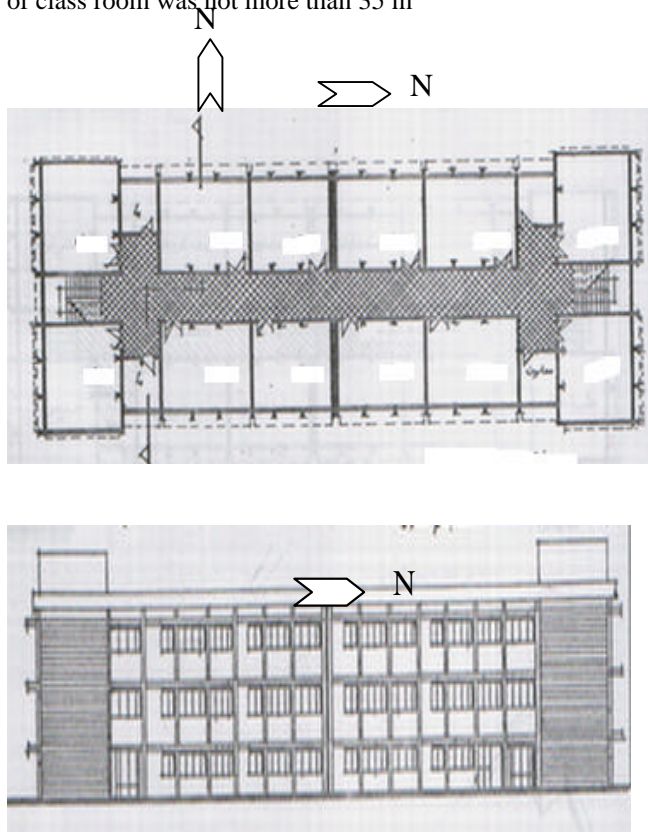


Figure 1. Plan and elevation of Hai –Nazzal prototype

The recent building design system called the sixth educational prototype system. They started using this system in 1987. It consists of finger plan with two wings of classes; each wing has three classes room with a dimension of (6*9 meter). The

design has single corridor that serve the classes. The main wing includes administration, multipurpose hall and laboratory (figure 3). This system was built using concrete bricks and stone. The windows were aluminum and glass. One major problem of this type is the size of the windows which are small compared to the number of students in each room.

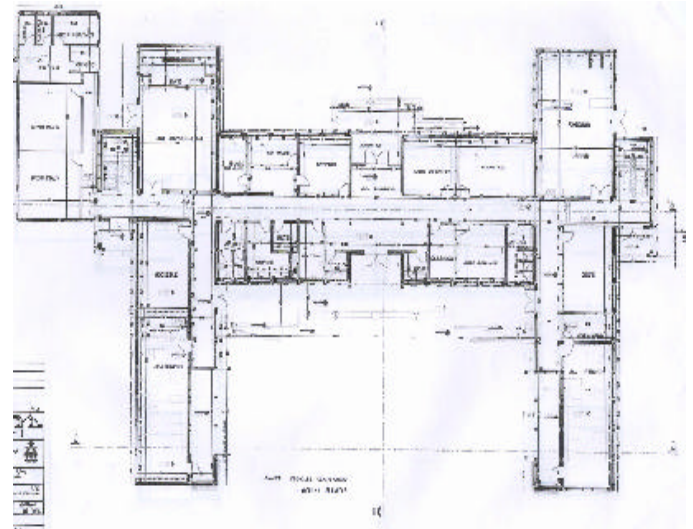


Figure 2. Sectional prototype plan

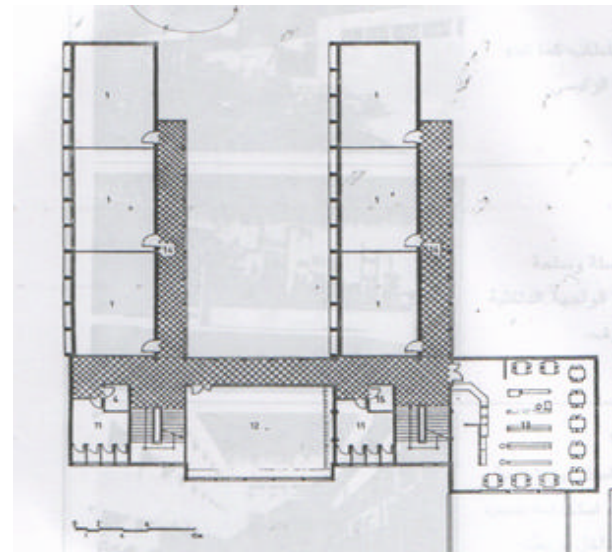


Figure 3. Plan of Sixth educational prototype

RESEARCH PROBLEM STATEMENT

For many years efforts to eliminate environmental pollution focused on outdoor air quality. This was precipitated by public complaints about industrial smog, automobile pollution exhausts, toxic waste sites, etc. Most countries were spending large amount of money addressing outdoor air pollution problems, the air quality of indoor environments was going virtually unchecked, particularly when most people today spend 80 to 90% of their time indoors.

Children may be especially susceptible to the effects of indoor air pollution for a number of reasons related to their physiology. This is because the same concentration of pollutant results in higher body burdens in children than in adults because children breathe a greater volume of air relative to their body weight. Also, children are less resistant to infections as their immune systems are still under development.

IAQ problems in schools arising from poorly designed and maintained ventilation systems, and from poorly handled indoor sources such as art, science and janitorial materials.

Previous studies that are related to public school design in Jordan showed a gradual dissatisfaction from class environment, such as lightening, humidity, temperature, noise, comfort and other factors. These environments affected the achievement of the main educational objectives. (Shbool, 1997).

The premise of this research builds on the assumption that poor architectural design such as lay out, site planning, materials, construction method and openings affect the indoor air quality, which have a negative affect on the human health, comfort and performance. Therefore this research proposed to investigate, analyze and evaluate the affect of indoor air quality in school building design in Jordan

RESEARCH QUESTIONS

1. What is the existing situation of the environmental conditions in governmental schools in Jordan?
2. Are these conditions in agreement with or meet the international quality standards?
3. How indoor air quality affects schools design?

OBJECTIVES

This research evaluated the prototype building schools that are used in Jordan, according to environmental factors, by achieving these objectives:

1. Define the types of IAQ problems, sources, indicators and effects
2. Evaluate the existing environmental situation in the governmental schools in Jordan, as a case in Irbid and compare it with standards, cods. (Related to IAQ)
3. Develop better understanding of the effect of the air quality on school design as
A: inside environment; class rooms laboratories, libraries,
B: outsides environment like layout, location
4. Provide a baseline data for future use that could help decision makers, architects, and engineers in their efforts to improve schools environment.

METHODOLOGY

Research design

According to the research questions and specific research context, across multiple design was adopted, in it we used multi methods of data collection. These methods are: monitoring technique, questionnaire, archival data, physical measurements and calculation within a case study

1. Monitoring techniques (data loggings):
Monitoring was used by semi-conductor data loggers, which continuously monitor the relative humidity, air movement, and temperature.

The data logger s which used in the study use the outdoor as a reference point (standardization). The data, which obtained was compared with a control or standard numbers.
2. Questionnaire : a structured questionnaire was used to determine the causes of complaints that are expressed by students, it included the students age, sex, location, which healthy symptoms did the students have; headache, Fatigue, erythematic, throat irritation, cough, nausea...etc to expect the causes.
Some variables are scored by giving weight for each one ranged from 0 (min) to 5 (max), others are scored just by yes or no.
3. Observation
An initial walk- through, on site investigation to gather information to identify or confirm potential causes and sources, it includes gather information about level of school, address of school, maintenance techniques, during the

investigation we made a meeting with some ones who are knowledgeable about the problem and with those who are complaining.

4. Physical measurements and calculations
Measure ratios of opening to spaces, areas; dimensions, orientations, masses to spaces ...etc, used building sketches to determine buildings orientation, fungal areas, air zones.

Archival data

Students' health records were used to investigate student health to report any health problems related to indoor air quality.

Standard determine the acceptable indoor air quality either "the air in which there are no known complaint at harmful levels as determined by appropriate authorities and air with which 80% or more of the people don't express dissatisfaction (Burton, 1993).

THE SETTING OF THE STUDY

The study examined and evaluated the school building prototype in the governmental schools in Irbid city. The sample size and location was depended on the followings:

1. Schools are built based on a prototype that is used in most urban areas in Jordan; therefore, these prototypes are representative to the large number of school buildings.
2. The sample was chosen in Irbid city because it has a large number of populations with high percentage of schools.

In Irbid, as a case study, there are 6 prototypes: al- Hussein collage, second educational, Hai-Nazzal, sixth educational, seventh educational, and sector educational project, four of them used in both elementary and secondary level.

RESULT AND CONCLUSIONS

The study was conducted in November, 2003 in Irbid city. At that time, the weather was cloudy, the temperatures were between (12- 20) c, and the wind direction was west- north. This study used three schools as pilot for the main study that will include 30 schools.

Numbers of students in each school were 1115, 936 and 912 students respectively, and the working hours for these schools are from 8am to 2pm.,

In each school, a questionnaire was distributed to both students and teachers. Students in the 6th, 7th, 8th grades answered the questionnaire.

Data logger and gas analyzers were used to measure the percentage of gases in each room. Health records were studied to know if there are any respiratory health problems between students,

The Major Conditions:

- 1- Building characteristics.

The sample included three schools in Irbid city.

These schools are:

-Al-Andalus Primary School for Girls (Hai-Nazzal prototype): this school has about 912 students, and school area is 6861 m². The building is three storeys. The school consists of 23 classrooms which are oriented to east and west, each class room has an area of 48 m², the average number of student per class room is 40 students.

- Sukaina Bnt Al- Hussein Primary School For Girls (6th educational prototype): the area of the school is 4390 m². The building is 3 levels with 18 classes oriented to north and south directions, each class room is 54m², and the average number of student per class room about 34 students.

- Abu- Baker Primary School for Boys (sectional prototype): its 3 stories building with 1115 students divided in to 26 classes, each class has about 42 students, and it has three wings: east , west and north.

All schools built from brick, with same painting color which is white, and they used fans in summer for cooling, and portable kerosene heater in each room in winter.

The personal space in the three schools is as follows: In Abu-Baker school (sectional prototype) equal 0.95, in Al-Andalus school (Hai-Nazzal prototype) equal to 1.2, and in Sukaina school (6th educational prototype) equal to 1.52. Comparing with the Jordanian standards (1.25 m²/student), and the USA standards that state the personal space should exceed 2.15 m² /student, and in Switzerland standards the percentage is 2.25m² /student.

A compact design was used in the sectional prototype, with a ratio of window size in each class

equal to 0.2 of the class area. In Hai-Nazzal prototype, double load corridors were used, and the window size ratio to the area of the class equal to 0.143. While on the 6th educational prototype, a single load corridors were used, and the window size ratio to the area of the class room equal to 0.3. The standards indicate that the ratio size of window to the area size should not exceed 0.2.

ASHRAE in proposed standard 62-1989 recommended 3ppm above out door level as an alert level Small increase in Co of 2-4 ppm are the first indication of possible sources contamination of Co, 9ppm indicate a health problem.

From the data loggers and gas analyzer, it appeared that *Al-Andalus* (Hai-Nazzal) has the highest concentration of CO, that it reached 5 ppm, comparing with *Abu -Baker* (sectional prototype) which has 3ppm, and *Sukaina* (6th educational Prototype) which has just 1ppm of CO concentration.

Table 1. General output of the survey conducted in three school buildings in Irbid.

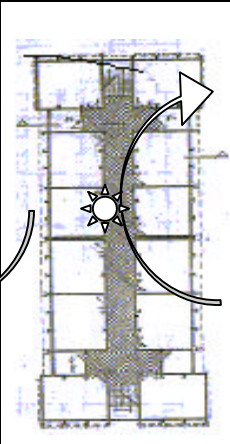
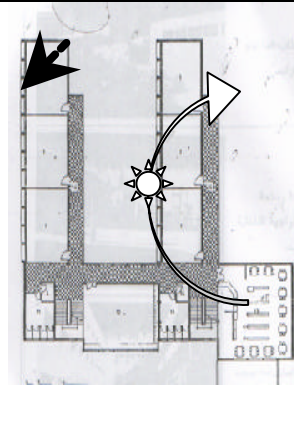

Variable	<i>Al-Andalus School</i>	<i>Sukaina Bnt Al- Hussein School</i>	<i>Abu- Baker School</i>
Check list			
Prototype	Hai-nazzal	6 th educational prototype	Sectional prototype
Students no.	912	1600	1115
Whole area	6861m2	4390 m2	7912 m2
Storey area	1035 m2	1700 m2	950 m2
Classes no.	23	18	26
Class area	48 m2	54 m2	40 m2
Personal space	1.2st/m2	1.52 st/m2	0.95 st/m2
Windows ratio to area of class	0.143	0.3	0.2
Corridors	Double loaded	Single loaded	Compact design
Location	Main,Minor street	Minor street	Main ,minor street
Data logger (gas analyzer)			
Indoor temperature	12.53	15.41	18.81
Outdoor temperature(C)	15.5	10.5	17.2
CO(ppm)	5	3	1
NO(ratio /appearance)	0.43	0.4	0.0
NOX(ppm)	0.22	0.6	0.0
SO2(ppm)	0.0	0.2	0.64
Plans And wind directions and sun movement			

Table 1 shows the percentage of gas in the three schools, temperature, area size and occupancy rate for each school. It shows that NO, NOX levels are not exceed 1ppm.

Indoor temperature was 15.4 C in *Sukaina school* comparing with 15.5C at outdoor, indoor temperature was 12.35C in *Al-Andalus school*, and the indoor temperature was 18.8C in *Abu-Baker* and the outdoor is 17.2 C. According to ASHRAE standards 55-1992 that recommends temperature level between 20 and 23.5C for winter, so it's clear that all schools are below standards.

Al-Andalus school has the highest temperature difference between indoor and outdoor, and the cause of that is that it has the lowest personal space with highly compact design, and double loaded corridors. *Abu-Baker school* has smallest storey area, with high class numbers, which produce a high concentration of polluted air with less natural air flow. Also the orientation of building did not take into consideration the normal wind direction i.e. the class's wings sit in the low pressure zones.

Table 2. Students and their responses to questionnaire

	<i>Total %</i>
Is there a symptom	
Have a respiratory problem	89.66
Didn't know the reason	77.0
When	
The suffer begins in the morning	57.7
There is a relation with weather changes	65.4
Uncomfortable in summer	62.0
Uncomfortable in winter	58.0
Where	
Suffering from noise	72.4
Suffer from high traffic	45.0
Physical measurement	
Need to open windows in the summer	90.0
Think the place is polluted	76.0
The ceiling is high enough	83.0

2- Students and their responses to questionnaire.

The symptoms of SBS tend to appear at the beginning of the day, increase until leaving the school. Most students suffer from uncomfortable situation in their schools, about 62.1% of students responded that the general situation is uncomfortable in summer, and about 58.6% of the students suffered in winter. The percentage of answers on the questionnaire can be summarizing in table 2.

The questionnaire results indicated that there are about 89.7% of students who have SBS symptoms like headache, eye irritation, and dry throat. About 57.7% of the symptom appears with them in the morning without knowing the reason. 65.4% of them think that the environmental change affects their symptoms.

The questionnaire showed that the highest ratio of symptoms syndromes appear in the morning in all schools, but in *Al-Andalus school* the situation appear clearly that there were about 0.67 of students said that the suffering from their symptoms begin in the morning. On other hand, the percentage is about 0.4 in *Abu-Baker* school, and 0.5 in *Sukaina school*.

The critical time of discomfort in summer was in the *Al-Andalus school*. While, the critical time in winter was in *Sukaina School*. The situation in *Abu-Baker school* could be (bad) all the year. This conclusion could be a result of the layout of *Sukainah school*, that faces the winter wind with high ratio of opening and this make the school very cold in winter, on the other hand *Al-Andalus School* is very compact and this make the temperatures height in summer.

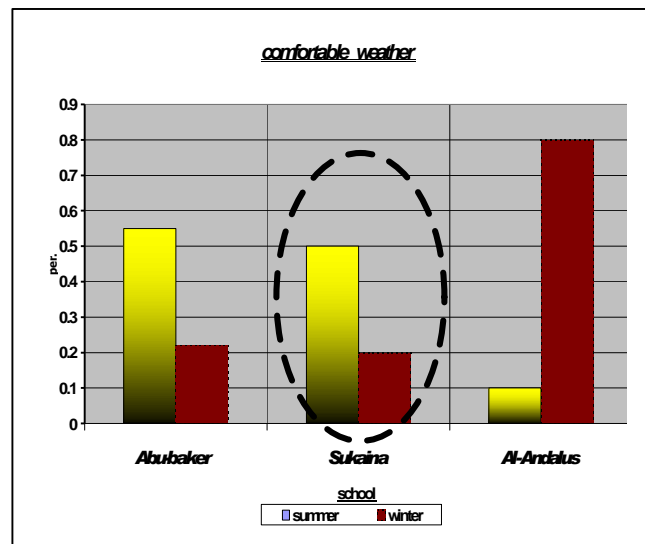


Figure 4. Comparison among three schools in summer and winter

EXPECTATIONS

Building shape and size, orientation, layout, location of pollutant generating activities, building materials, types of windows and doors, and general ventilation system are affecting indoor air quality. It is important to consider these items the early phase of

design any school building. Moreover, to include provisions in the contract documents, that address indoor air quality issues. This will help to reduce any health problem associated with building design and construction.

No standards for indoor air contaminant levels have been established specifically for Jordanian school building. However, various governmental agencies and professional organizations have recommended concentration limits for various contaminants for affected populations. This study assumes that the prototype that used in the governmental schools in Jordan does not take environmental factors in to consideration, therefore it is very important to evaluate this prototype to give indications how this prototype appropriate for our local environment conditions, taking in consideration the variety of climate and the increase number of students .

Good indoor climate can be achieved not just by expensive concepts, but by developing a rationale approaches deal with fundamental needs like using natural ventilation flow within the building specially if we know that HVAC systems not used in the governmental schools in Jordan ,define a criteria to the school locations that take in consideration nearby pollution sources ,traffic flow movements

This research may give a base line to decision makers, architects, engineers and also educators that could be used later to create an efficient 'environmental responsive buildings '.

REFERENCES

Amold Kim L.,” Sick Building Syndrome Solution “, Professional Safety, Jun2000, vol.46.

Bas, Ad, ”School to get Abcs of Cleaner Air ” Conditioning, Heating And Refrigeration News, Vol. 195.

Cheong K., Lau H., ”Development and Application of An Indoor Air Quality Audit to an Air-Conditioned Tertiary Institutional Building in The Tropics”, Building And Environment Journal, April 2003,vol.38.

Fuller, ”Breathing, Riting and Rithemic: Fixing Iaq Problem in School”, Engineered System, March2001, vol.18.

James A. Black, dean J Champion, ”Methods and Issues in Social Research,” 1976

Jeff Burton, PE, CPS, CIH, ” Iaq and HVAC work book”, IUE inc., 1993.

Leedy, Paul D., ”Practical Research Planning And Design “, 5th edition ,1998

”Sick Building Syndrome”, World Health Organization, Local Authorities, Heath and Environmental Briefing Pamphlet Series; 2, 1995.

Scheel, Christian ,”Rosing, Archieves Of Environmental Health, Possible Sources Of Sick Buildings Syndrome In Tennessee Middle School,” Sep./ Oct.2001, Vol.56

Thad Godish, ” Air Quality,” Lewis Publishers, Third Edition, 1997.

Tang g. lee, ” Vital Signs, Health and the Built Environment, “1996.

Utzinger,m. Wasley H. ,”Environmental Quality in Architecture,” *School of Architecture and Urban Planning* ,Uni. Of Wisconsin-Milwaukee Johnson Controls Institute.

Wilson, Scott, ”Graduating to Better Iaq “, Consulting Specifying Engineer, jun2001, vol.29

<http://www.consumer voice usa.com>, sick building and toxic mold.27/3/2003

<http://www.consumer voice usa.com>, do you have a “sick building “? 27/3/2003

<http://www.epa.gov/iaq/schools/tfs/guide5.html>. Iaq tools for schools kit –Iaq coordinator’s guide.4/6/2002

Norland, Jim, ”Sick Schools May Hold Iaq Remediation Opportunity” conditioning, heating and refrigeration news, vol. 212

<http://www.epa.gov/iaq/schools/performance.html>, ”i ndoor air quality and students performance.24/4/2002

<http://www.sustainabledesignguide.umn.edu/MSDG/case/downtown/downtown.html>, ” WMEP Inter district Downtown School”,20/5/2003