Journal of Environmental Science, Computer Science and Engineering & Technology

An International Peer Review E-3 Journal of Sciences and Technology

*Available online at*www.jecet.org

Section A: Environmental Science

Review Article

A Study on Assessment of Indoor Air Quality in Secondary Schools of Hyderabad City, India

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Received: 28 January 2015; **Revised:** 14 February 2015; **Accepted:** 20 February 2015

Abstract: Poor indoor air quality in schools is associated with diminished learning, health risks to students and staff, and economic costs. The objective of this investigation is to establish a relation between spatial qualities of built environments with regard to school buildings and indoor air pollutants. The investigation selected 30 secondary schools that fall under from GHMC area of Hyderabad City for this study. Phase I of the study was a questionnaire completed by 150 students. Phase II of the study was to collect data on spatial factors from each school selected for study using walk through forms. The walk through survey form used in phase II is used to document each school's site plan, classroom orientation, setbacks of school, open spaces, classroom dimensions, number of students in the class, class room flooring, ceiling of the class, walls, doors, window material and school location. Phase III of the study was to collect data of indoor air quality parameters from one classroom in each school selected for study including comfort parameters (respirable and non-respirable air particles, VOC emissions, carbon monoxide, carbon dioxide, temperature, and relative humidity).The major findings of this study concern school management, school characteristics, building materials and finishes used in construction of schools, indoor air concentrations indoors and outdoors, schools

located in different zones, miscellaneous factors like cleaning procedures , teaching medium and indoor air quality parameters. This paper even reports on a comprehensive review of the worldwide literature which relates health of building occupants with the different aspects of the indoor environment which are believed to impact these issues, with a particular focus on studies in this field. Ultimately, the findings of this study enable the development of best practices for school design for improved indoor air quality.

Key words: Indoor air Quality, Indoor air pollutants, School design, Classroom, Ventilation,

INTRODUCTION

The present study was designed to examine the air quality and how it impacts learning in learning institutions. Quality of air both in the indoor and outdoor environment impacts the physical wellbeing of students, which in turn influence their learning in the classroom[1]. Clean air both indoor and outdoor implies that the students have access of clean air for their respiration, hence they can stay healthy as they study while contaminated air in the classroom environment and outdoor is likely to make students suffer from chronic diseases that affect respiratory system, which in turn can impact negatively on their learning and performance.

Indoor air quality has been ascertained to be a product of outdoor air quality, the plan of surrounded spaces, and the plan of the ventilation system[2].This implies that determination of indoor air quality in classrooms start at the very planning stage. It is argued that people spend most of their time indoors hence air quality actually determine the general wellbeing of people with respect to health. It has been established that majority of people spend about 90% of their time indoors. Therefore, indoor air quality is a crucial consideration, since if the hours spent sleeping, working in offices or at school is summed; individuals on an average spend most of the times inside different buildings where they are regularly subjected to indoor air contaminants[3].

The importance of school buildings has been recognized as a fundamental element of modern society. Today, roughly a quarter of India's population, including our youngest citizens, spends the majority of their days in school buildings. As a result, schools have become a contentious and heavily scrutinized part of civil society[4].While designing for children one must realize that children understand their environment indifferent ways from adults. Also, children have different architectural needs and wants, and for the design to be successful it must evolve, be flexible and be able to adapting the book Design for Kids, Sharon and Peter Exley convey the essence of what Architecture for Children should be. As they state: Designed to foster an ethic of social and environmental responsibility in each student, the building design demonstrates a responsible relationship between the natural and the built environment. As stated in Design for children By Sharon Exley& Peter Exley, 2007,

Architecture for children should be as follows:

- Sensitive to place and experience.
- Use relevant iconography in elegant, evocative, and intelligent fashion.
- Bring education and play together –as play is a child's vocation and preoccupation.
- Encourage design as expectation, rather than exception, and beginning in childhood setting the tone for a lifetime of awareness.
- Educate, referencing developmental, architectural, educational and inclusive pedagogical theories be fulfilled.

Environmental quality support and hinder peoples comfort, performance, and satisfaction thereby impacting directly the outcome of students' performance. Appropriate indoor environmental qualities of air, temperature, sound, light, visible and physical space, and occupants ability to personally control are the building's contributions to the biological bases of occupant comfort, health, and well-being (Buildings, Benchmarks, and Beyond- Minnesota Sustainable Building Guidelines6. In schools, this would be an evaluation of students' opinions and perceptions of the influence that environment has on their learning. Poor environment may be hazardous to students' health leading to poor attendance, and low performance in the learning institutions, the better the learning environment, the better the students' outcome. Strange and Banning[7] cited research that links improved classroom attractiveness and lighting to students' improved motivation and task performance. Graetz and Goliber[8] observed that lighting arouse psychology, overheated spaces to hostility, all these gives evidence of direct impact of environment to the students' outcome. The sitting arrangements, school furniture, technology such as computers and modernized library, spacing, human resource like the kind and qualification of teachers, are some of the external environmental factors that impact directly on the outcome of a student performance either positively or negatively. Therefore, positive performance of a student requires a conducive and well-furnished and established institution which hosts all the necessities required for a student to perform better.

Literature Review: Indoor air quality is affected by many reasons such as maintenance activities, the presence of contaminant sources (e.g. building materials, furnishings and equipment), the levels of contamination outdoors, the season, indoor humidity and temperature, and ventilation rates[9]. The levels of concentrations of specific contaminants in indoor air can often be considerably elevated than concentration levels outdoors[10]. Indoor pollutants include formaldehyde, volatile organic compounds (VOCs), particles, pesticides, radon, fungi, bacteria, and nitrogen oxides. In addition to indoor air

contaminants, occupants can experience similar discomfort and health symptoms similar to those attributed to indoor contaminants due to indoor environmental factors such as lighting levels, day lighting, and noise. Often, the presence of both indoor contaminants and other indoor environmental factors makes it difficult to identify direct causes of occupant discomfort and health symptoms.

The Washington State Department of Health recently conducted a survey that revealed that 33 of 132 (25%) schools constructed or remodeled within the last five years had experienced indoor air quality (IAQ) problems. The survey found that the average cost to address these IAQ problems was $134,750. Because buildings and building systems are interconnected, it can be very difficult to identify specific causes of IAQ problems. Generally, HVAC systems and water damage to the building envelope are the most common sources of building-related IAQ problems[11]. Other causes of IAQ problems can be attributed to various phases of the building process including poor site selection, design approach, roof design, and inappropriate choice of materials, poor construction quality, improper installation or any number or combination of other factors. It is also important to make the distinction between items that are the cause and those that merely aid in distribution of contaminants because IAQ problems must be addressed at the source to eliminate the unwanted result. Cleaning the pathway between the source of a particular contaminant and an occupant does not adequately address the problem. In most cases, a remedy is required for both the source of the problem as well as the pathway to the occupant[9] **.Table 1** gives the list of prominent research works done on Indoor air quality so far and their outcomes as results and findings along with the study area.

Table 1: Indoor Air Quality Literature Reviews

Research work	Subjects	Study area	Results and findings
Berry 2004	Not Applicable	Carpets in schools	Smooth flooring has lower concentrations of bio contaminants than carpet flooring, Tiled flooring had high air borne bio-contaminants
Daisy et.al. 2003a	Scientific data published in conference proceedings of 1999	School building-related Health problems	Inadequate ventilation in classrooms, relationship between CO_2 concentrations and health symptoms exposure to molds and VOCs resulting in asthma, respiratory problems and sick building syndrome symptoms.
Mendell and health 2005	Scientific data -2003	Relation between academic performance and school environments.	Dampness and molds link to respiratory infections and reduction in attendance and performance. Low ventilation is associated to reduce performance.
Seppanen et al 1999	30000 subjects and 21 studies reviewed	CO_2, ventilation, health problems	Low levels of ventilation, high levels of CO_2 resulting in health related outcomes.
Wangocki et al 2002	EUROVEN scientific committee Review of 105 peers	Ventilation, CO_2 health problems	Ventilation, improper maintenance associated with health, comfort and productivity. Artificially ventilated buildings increase risk of health problems than natural ventilated schools.

In Canadian schools studied by Bartlett, Kennedy, and Brauer, 71% of the classrooms failed to meet the ASHRAE ventilation standard, and 45% of the classrooms had average CO2 concentrations above the ASHRAE maximum limit of 1000 ppm. Inadequate and inefficient ventilation of occupied zones has been associated with higher CO2 levels and increased frequency of IAQ complaints by many researchers. Respiratory diseases like asthma and allergies, especially in children, rose over the past decade[12]. After the home, school is the most important indoor environment for children[13]. This is especially noteworthy because individuals with asthma or allergies are potentially more susceptible to indoor air contaminants[10].Children may be more susceptible to indoor air pollution than adults. The U.S. Environmental Protection Agency attributes this to the greater volume of air inhaled by children relative to their body weight, and thus a greater mass of pollutant uptake per body weight[14].Building Related Illness (BRI),attributes illness to environmental agents in the indoor air. These specific environmental agents produce symptoms that allow for illness diagnosis. An example of a BRI with life-threatening consequences is Legionnaire's disease, which is a severe pneumonia associated with the Legionella species of bacteria. Such illnesses result from uncontrolled sources of contaminants and poor building maintenance[15].**Table 2** presents findings from literature reviews relative to associations between health and the environment of classrooms. Specifically, the table outlines findings on the health symptoms and environmental factors that affect health. In most cases, the literature indicates that such correlations do exist. The literature found a connection between health and the environment in all studies.

Table 2: Summary of associations between Health Symptoms and the Environment

Research work	Subjects	Links and findings
Dautel et al.1999	10 classrooms and 2 districts	Significant relation between HVAC systems and irritant score
Karlsson 2002	35 classrooms	Dissatisfaction of children with indoor air quality associated with allergen levels.
Meklin et al 2002a	32 schools	Moisture damaged buildings had more cases of common cold than non-damaged buildings
Norback et al.2000	12 schools,234 personnel	High concentrations of molds associated with low degree of nasal patency.
Norback et al.2002	10 schools, 30 classrooms	Higher concentrations of bacteria and molds associated with respiratory related problems
Sahlberg et al,2002	38 schools,101 classrooms,1410 employees	Inadequate ventilation associated with respiratory problems
Smedge et al 2002	1 school,184 students, 2 Air handling units	New filter associated with increased nasal patency and decreased concentration of lysozyme.

In 2002, the U.S. Environmental Protection Agency (EPA) conducted a survey to determine the prevalence and implementation of Indoor Air Quality (IAQ) programs in U.S. schools.

Key findings include:

- 42% of U.S. schools have an IAQ Management Program, although with a wide range of success in implementation
- Benefits of these programs include:
    - Improved workplace satisfaction
    - Fewer asthma attacks
    - Fewer visits to the school nurse
    - Lower absenteeism
    - Improved learning environment

Inadequate ventilation is a common issue that affects school occupants. Negative perceptions of ventilation correlated with negative health effects. Low ventilation rates generally increase the risk for health symptoms. There is also a consistent relationship between health symptoms and ventilation rates or CO2 concentrations. Seppanen[16] found that some increases in ventilation rates up to 20LS-1 per person decreased prevalence of SBS symptoms or improved perception of IAQ. Wargocki[17] also found that air-conditioned buildings may increase risk of SBS systems compared to those that are naturally ventilated. High levels of CO_2 can result from inadequate ventilation systems, inadequate air exchanges from the opening and closing of windows and doors, and overcrowded classrooms. Occupied and air conditioned rooms measured higher levels of CO2 than rooms cooled with ceiling fans. Rooms with desiccant active control systems met standards for ventilation, while rooms with conventional HVAC systems did not[18].Other study findings indicate that low ventilation rates were associated with worsening health or perceived air quality outcomes. Also, the literature associates increases in CO2 with decreased attendance[19].

The most common building factors associated with indoor environmental complaints are related to the Ventilation systems. The recommended ventilation rate for a classroom is 15 cfm/person with a specified maximum occupancy of 50 persons per 1000 ft^2 for schools[20]. The ASHRAE 62.1-2007 ventilation standard provides outdoor air requirements for classrooms of 15 cubic feet per minute (CFM) per person. ASHRAE Standard 55-2004 provides the thermal comfort guideline for temperature and relative humidity. The literature referenced standards for acceptable comfort measurements of temperatures below 23 °C and 30% - 60% relative humidity. Recorded temperatures generally met this comfort range, although temperature was difficult to control in naturally ventilated buildings. Sacrificing ventilation achieved acceptable relative humidity levels in some cases [20]. Several investigators found correlations between measured conditions, bacteria or contaminants and humidity, occupied rooms and ventilation[21].

Air quality, levels of cleaning, dust, varying room temperatures, smoke, noise, bad odor and lighting affect allergic student's more than non-allergic students[20]. Lower ventilation rates correspond with the worsening of one or more health or comfort outcomes[22]. The literature associates increased ventilation rates with decreased levels of SBS, and reported SBS symptoms decreased[23] with decreasing CO_2. Also, prevalence of negative health symptoms was greater with old filters[24].**Table 3** presents findings from literature reviews related to the prevalence of health symptoms to the perception of indoor

quality. The findings indicate that that allergy, asthma, hay fever and eczema were the most common health complaints associated with perceived poor indoor quality.

Table 3: Associations of Health Symptoms to Comfort

Research work	Subjects	Health Problems and symptoms	Quality of Indoor air
Lundin, 1999	1715 students	Min one allergy-57%, Eczema, High Fever, asthma and – 33%	>75% reported acceptable indoor air quality,
Seppanen et al.1999	21 studies , 30,000 subjects	Not applicable	Low ventilation rate associated with decrease in air quality outcomes
Siskos et al 2001	10 schools, 20 classrooms	Not applicable	Noise being main problem reported by teachers and pupils.
Smedje et al, 2002	2 air handling units, 1 school	Students exposed to new filters reported less eye, throat and general problems	Good Indoor air quality response associated with students exposed to a new filter.
Dautel et al. 1999	10 schools 2 -districts	High CO_2 concentrations increased health problems	SBS symptoms decreased with decreasing CO2

Research Methodology: This primary research study is based on data collected from a sample of 30 schools located in different municipal regions of Hyderabad, a city in the state of Telangana, in southern part of India. The study aims to compare the indoor air quality parameters (temperature, humidity, CO level, etc.) across schools, based on school's characteristics (management type, municipal zone, nearby land usage, etc.). In addition, the study aims to explore various design aspects and spatial factors of school buildings (building material used, type of furniture, type of ventilation etc.) and their relationship with indoor air parameters.

This research uses qualitative and quantitative data analysis techniques. In general, qualitative data analysis techniques are used to classify features and count what is observed, whereas, quantitative data analysis techniques are used to analyze data in a highly objective manner. For this study, initially descriptive statistics are used to describe and summarize the collected information, and provide simple summaries about the sample and about the observations that have been made. In particular, this research study used frequency tables and graphical visuals to summarize school characteristics and design aspects of school buildings. A frequency table shows us a summarized grouping of data divided into mutually exclusive classes and the number/percentage of occurrences in a class.

Next, inferential statistics are used to compare the indoor air quality parameters across schools with different characteristics. In particular, this research uses t-test and ANOVA to draw inferences about whether the samples have been drawn from populations having the same mean. The ANOVA

technique is important in the context of all those situations where one wants to compare more than two populations, and t-test is considered an appropriate test for judging the significance of a sample mean or for judging the significance of difference between the means of two independent or paired samples in case of small sample with unknown population variance. It can also be used for judging the significance of the coefficients of simple and partial correlations. The analysis was performed using SPSS v16.0 and MS Excel 2010.

The study was designed to answer eight main questions, which include whether

1. Does Indoor air quality level change with respect to the school characteristics?
2. Do IAQ parameters differ with respect to type of school (government or private)?
3. Does indoor air quality vary between indoors and outdoors of the classrooms?
4. Do building materials and interior finishes used for the indoors of the schools effect indoor air quality?
5. Do various environments affect the indoor air quality of the occupants?
6. Do various design aspects of the school building design affect the indoor air quality?
7. Does indoor air quality differ between schools located in different zones?
8. Do miscellaneous factors like usage of fresheners and cleaners along with medium of teaching effect IAQ (indoor air quality) levels in classroom?

Data Collection: Case study was used in this study [25]. A case study is a qualitative research method or particular field of investigation of phenomenon as they exist without any important investigators intervention. The case study research is the research in which core data are collected similar to one individual event or program for the need of studying more about poorly or unknown understood condition. The present research study is said to have adapted case study approach to study the affect of spatial qualities of school buildings on Indoor air quality with specific reference to Hyderabad city. Sample population identified in the study was students from different schools. Students from 30 different schools were identified allowed to participate in the research. Both primary and secondary data is collected in this study. The researcher used students questionnaires, walk through survey and IAQ instruments in order to gather both qualitative and quantitative primary data from students of a population sample size of 30 schools.

The data collected in this study is done in three phases. Phase one being collection of data using questionnaires. Questionnaires were used to gather the opinions and views of 150 students studying at 30 schools in Hyderabad that come under the governance of Greater Hyderabad Municipal Corporation. The information collected from the students was biased with reference to managements, hence it was not used in analysis. Phase 2, data collection is in the form of walk through survey which helped in collecting detailed information about each school selected for research using case study method. Lastly, phase 3 data collection was done by measuring Indoor air quality parameters in one classroom per each school selected for study using designated instruments. In this research primary quantitative and qualitative data is collected with the help of questionnaires, walk through survey and using IAQ instruments. The questionnaires were intended to collect data from students, like time they spend in the class room, satisfaction of lighting and ventilation levels in the classrooms, do they observe any odors in the classrooms, and are they suffering with any symptoms of illness, their rating on maintenance of their classrooms and surroundings of the school premises. The walk through survey of building morphology is useful in collecting data like school site plan, classroom orientation,

setbacks of school, open spaces, classroom dimensions, number of students in the class, class room flooring, ceiling of the class, walls, doors, window material and school location etc. The quantitative data is collected with instruments which were designed with 7 practical recording measurements. They are relative humidity, temperature, carbon dioxide, VOC, particulate matter as -2.5, 4,10(respirable and non-respirable) and carbon monoxide.

Analysis: Since data gathered in the study were both qualitative and quantitative data, it therefore follows that quantitative statistical analysis methods and qualitative tools were used in the data analysis. Statistical tools used in the research to analyze the data collected include Graphical method, Simple percentage method, ANOVA and T-test. Simple percentage analysis was used in the analysis process to make comparison between two or more series of data. Percentages are used to describe relationship and percentages can also be used to compare the relative terms in simple percentage analysis.Analysis of variance, also known as ANOVA was used for quantitative data analysis in the study. ANOVA is enormously a process for measuring the dissimilarity among various groups of information for homogeneity.

The real meaning of ANOVA is that it is the total quantity of difference in a position of information is segmented behind into two kinds. T-test was also used in the analysis of the quantitative data gathered in the study. According to Atkinson and Hamersley[26] .T-test is the method of comparing the sample mean with the accepted value or to compare the two sample means and to test Zero. T-test helps in establishing whether the regression slope curve differs statistically and significantly from zero. Two software tools used in the study to analyzed quantitative data gathered include Microsoft Excel which used to create graphs for the percentages calculated from the collected primary data and SPSS (Statistical Package and Service Solutions) was used to conduct statistical analysis of quantitative data in the study. SPSS is one of the vast used programs for making statistical analysis in research and social science practices. The most similar area of SPSS uses are product research, marketing research, government research, marketing organizations, medical and health research, companies survey, educational research and so on. SPSS make statistical analysis more accessible for beginner and easier for the experienced user. It provides an efficient and easy spreadsheet like facility for entering data and searching the working data file. For windows SPSS is a package that will operate a vast number of statistical procedures. The data analysis and management can be handled well with SPSS. Using SPSS the user can make graphs, manipulate data and perform statistical techniques varying from means to regression.

Qualitative data collected in the research was analyzed using a single method known as case study. Case study analysis is basically a detailed or in depth study or analysis of a certain situation. Case study does not rely upon statistical survey. Case study analysis is used in narrowing down a research field that is very broad into an easily understandable topic. A case study research does not answer a research question completely. Rather, a case study research provides some indication and paves way for hypothesis creation and further elaboration on a particular subject[27]. In this research case study approach was adapted in analyzing qualitative data, since this study considers the ventilation mechanisms of schools in Hyderabad and explores their impact on the Indoor air quality of the premise.

Findings of The Study: Ventilation, thermal comfort and indoor air quality are a crucial consideration for any building, but even more so for schools. Children and teachers spend over six hours a day in

close quarters within their small teaching spaces. The design needs to consider the health and comfort of the buildings occupants for long periods of time.

The following are the major findings of the study obtained from the analyses of spatial factors of schools and evaluating the corresponding indoor air quality parameters.

- No differences found in the indoor air quality across schools with different school characteristics like the age of the buildings, approach to the site via main road or sub road, density of population in neighborhood and lastly the public transportation system near the school statistically. But it has an impact on its indoor air quality with reference to VOC levels in urban and sub-urban located schools statistically.
- No differences in the indoor air quality across the schools run by private as well as those run by the government except for Carbon monoxide which is different statistically. Hence, the type or the management of school does have impacts on the indoor air quality of the schools to certain extent.
- The air quality standards such as air temperature, relative humidity, CO, CO_2 and VOC levels differ at both indoors and outdoors while the reparable and non- reparable particles remain the same at both the indoors and outdoors of the schools.
- The impact of indoor air quality on various building materials and finishes is observed. We can see that schools were chemically treated walls and metal furniture existed had high concentrations of air contaminants.
- The difference in the indoor air quality is encountered across the schools located in different types of environments. The schools located in residential environment are more preferable over industrial environments to provide a healthy environment for students who are vulnerable to poor indoor air problems.
- The design aspects of the school buildings such as the school design, orientation; type of ventilation; opening area; type of lighting; provision of play ground or open space; landscape and setbacks in school impact on its indoor air quality. Therefore schools have to be designed as per standards and bylaws to provide an acceptable level of thermal comfort and indoor air quality.
- No changes in reparable and non-reparable particles other than the significant differences noticed in indoor air quality parameters of the schools located in different zones.
- There were differences found in the indoor air quality across schools which use floor cleaners, room fresheners, and varied medium of instructions. For example schools which used white boards with ohp markers recorded higher levels of indoor air pollutants over blackboards.

CONCLUSIONS

Indoor air quality is a function of large parameters that includes the design of enclosed spaces inside the building, outdoor air quality, the ventilation system design, the way the HVAC system is properly maintained and operated. Rates of outdoor air ventilation recommended by ASHRAE, is laid down as one trail to comply with that of the standard[28]. Even though, the technique does not engage a definite fortitude of indoor air quality, it is foreseen by the standard that if the HVAC system of a building distributes the design intensity of the outside air to internal space, the construction is in fulfillment and the quality of indoor air will not be besmirched[29].It is understood from the observations that these stipulations pointed out by ASHRAE have to be obtained not only in the plan of construction but also in its process.There are number of factors that affect the indoor air quality, which include inadequately maintained or poorly designed temperature control and ventilation systems, fungal and microbial

matter such as moulds and bacteria, carbon monoxide from tobacco smoke, automobile exhaust such as loading ducts, air intakes, pollutants that enters from vehicle parked and more[30] . Besides, a poorly maintained system or a poorly designed system, poor designed and maintained built spaces can also cause problem in indoor air quality.

Source:http://eatmydustjanitorial.com/

Outdoor climate may also affect the indoor air quality.[31] There are indoor sources that affect the indoor air quality which include housekeeping activities such as cleaning materials, building materials and furnishings, deodorizers or dust, personal activities such as personal hygiene or smoking, maintenance activities such as new carpet or furniture, pest control and remodeling. Others include miscellaneous activities such as emissions from equipment such as VDTs, photocopier machines, room occupant load, liquid leaks or spills, humidity and/or thermal comfort. Indoor air quality meaning is of paramount significance to people's health[32]. Therefore, significance of maintaining a clear indoor environment must be understood, recognized and widely appreciated to the wellbeing of the population health wise[33]

Recommendations: The guidance instructs that the design of all newly built academic institutions must adhere to the recommendations to ensure they meet the standards for ventilation, thermal comfort and indoor air quality. Recommendations for practice are as follows:

- To have national standards, guidelines or regulations on indoor air quality for all regions of our country is urgently needed.
- Professional training and certification programs are needed for architects, designers and builders on ventilation systems.
- Cleanliness and hygiene of existing ventilation systems should be improved including the potential problems related to moisture in the systems.
- Actions with respect to maintenance and use of ventilation system should be encouraged.
- Decision makers should pay attention to life cycle cost of ventilation including health of wellbeing of occupants and environmental impacts.
- Indian health Associations should come forward to participate in the educational and information work on ventilation practice for good IAQ.
- Ventilation in Indian schools should be improved essentially to protect pupils and from pollutants which may have life time effects.

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