Indoor Environment Quality Indicators in Co-Op Supermarkets in Kuwait

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***Abstract*—In this paper, the indoor quality indicators were investigated in a Co-Operative (Co-Op) supermarket in Kuwait by both subjective and objective evaluations. A questionnaire with Likert scale basis was conducted to reflect the customers and workers health environment satisfaction. Measurements were carried out to examine the parameters that determine the air and acoustic pollution inside the Co-Op supermarket. The perceived air quality (PAQ) was calculated, and indoor air quality index (IAQ) was investigated. Three pollutants, carbon dioxide (CO2), carbon monoxide (CO), and formaldehyde (HCHO) were studied. The CO2 concentration was notably high.**

***Index Terms*—indoor quality management, air pollution, acoustics pollution, subjective evaluation, objective evaluation**

I. Introduction

Co-Operative (Co-Op) supermarkets in Kuwait, 73 supermarkets, are attractive supermarkets scattered within the State of Kuwait. Each Co-Op supermarket is managed by a yearly elected group, from the designated residential area, with governmental oversight. Due to its comparative prices and governmental support, Co-Op's are popular supermarkets.

Studying how healthy the supermarkets' buildings are, and how safe the customers (and the workers) from the exposure to modern-day air pollutants (such as CO2, CO, HCHO) and the noise turbulence is crucial.

To the best of the author's knowledge, unfortunately; no study was performed to examine the indoor environment quality, and especially the status of the air and acoustics pollution within these supermarkets. However, there are some studies examined these type of pollution on other part of the world [1]–[5]. This study aims to examine the air and acoustics pollution in Co-Op supermarkets in Kuwait. To do so, two types of indoor quality evaluation were adopted, the subjective evaluation and the objective evaluation [6]–[8]. In the subjective evaluation, the perceived air quality (PAQ) which is considered as an important factor of air quality will be determined along with the impact of the acoustics on customers and workers will be investigated. On the objective evaluation approach, measurements will be taken to test the status of air and acoustics pollutions in Co-Op supermarkets.

Among the 73 Co-Op supermarkets in Kuwait, one Co-Op supermarket will be chosen to perform the study on.

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II. Research Methedology

A. Subjective Evaluation

The subjective evaluation of the indoor environment is obtained from two parts; firstly the perceived air quality which expressed by air acceptability, and secondly the questionnaire investigation of acoustics.

1) Perceived Air Quality (PAQ)

PAQ is an important factor in assessing the indoor environment[5] which can be determined by equation (1):

$$PAQ = 112(\ln[PD] - 5.98)^{-4} \quad (1)$$

where PD is percentage dissatisfied with air quality, %, which can be determined by equation (2).

$$PD = \frac{\exp(-0.18 - 5.28ACC)}{1 + \exp(-0.18 - 5.28ACC)} \times 100 \quad (2)$$

where ACC is the acceptability rating of the indoor air condition, which is obtained from the questionnaire. The respondents vote for the acceptance condition using the acceptability scale coded as follows: 1 = Clearly acceptable, 0 = just acceptable and/or just not acceptable, -1 = Clearly not acceptable.

2) Questionnaire investigation of acoustics

The questionnaire was carried out to determine the source of the acoustic pollution, and it was designed on Likert scale.

B. Objective Evaluation

1) Indoor Air Quality Index (IAQ)

The indoor air quality index can be determined by equation (3).

$$IAQ = \sqrt{\left(max\left|\frac{C_1}{S_1}, \frac{C_2}{S_2}, \frac{C_3}{S_3}\right|\right) \times \left(\frac{C_i}{S_i} \cdot \frac{1}{n}\right)} \quad (3)$$

where, Ci is the concentration of pollutants; Si is the upper limit of standard; n is the quantity of pollutants [9].

Three pollutants were selected; namely, CO2, CO, and HCHO. The concentrations of these three pollutants were measured with portable air quality monitors (Aeroqual Series 500). The monitors were distributed on five measurement spots, as labeled with letters IA in Fig. 1.

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The IAQ monitors (and the sound meters) were placed in the allocated position to function 8-hours a day. For the sake of comparison, only three data points were selected, namely; the ones at 9 am (morning), at 1 pm (noon), and 7 pm (night). The threshold limit values are 700 ppm for CO_2, 10 ppm for CO, and 10 ppm for HCHO [10].

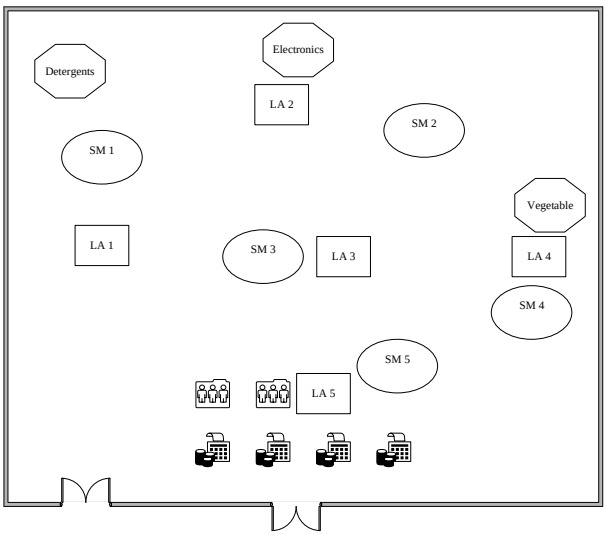

Figure 1. General layout of the spots in the Co-Op supermarket.

2) Acoustics measurements

Acoustics measurement was made according to the 8-hour continuous equivalent sound level, and it was measured with sound meters (Fluke 945). The meters were distributed on five measurement spots, as labeled with letters SM in Fig. 1.

The Time Weighted Average Noise Levels (TWA) is a measure of a person's daily exposure to noise, usually normalized to an 8 hour a day for a worker, and the occupational safety and Health Administration (OSHA) has defined the Time Weighted Average Noise Levels (TWA) as:

$$TWA = 16.61 \log_{10} \frac{D}{100} + 90 \quad (4)$$

where D is the Dose %, which defined as:

$$D = 100 * \sum_{i=1}^{n} \frac{t_i}{Tn_i} \quad (5)$$

where, ti is the time spent at each noise level; and Tni is a function in the measured sound level Li and has the following formula;

$$Tn_i = \frac{8}{2^{(L_i - 90)/5}} \quad (6)$$

In this context, the TWA is widely known as the 8-hour Time Weighted Average Sound Level.

3) Questionnaire investigation

The questionnaire was designed on Likert scale basis to examine the source of noise which can be categorized in five sources of actions: talks (1), TV broadcasts (2), footsteps (3), cooling chillers (4), and carts movement (5). Also, it was meant to test the noise in the following six sections: wholesale (1), stationary (2), Cashiers area (3), silverware (4), vegetable (5), and electronics (6). A hundred and eight questionnaires were sent out and 168 were received with a complete response. The complete answered questionnaires were considered only.

The answers, to the questionnaire's questions, were: strongly agree (1), agree (2), neutral (3), disagree (4), and strongly disagree (5).

III. RESULT AND ANALYSIS

A. Subjective Evaluation

1) PAQ

Table I shows the perceived air quality results.

TABLE 1. PAQ RESULTS AT NIGHT.

No.	Recorded Scores	Frequency	Percentage %	ACC
1	0.9	6	3.57	0.032
2	0.8	6	3.57	0.029
3	0.7	6	3.57	0.025
4	0.5	13	7.74	0.039
5	0.4	25	14.88	0.060
6	0.2	19	11.31	0.023
7	0.1	6	3.57	0.004
8	-0.1	25	11.90	-0.012
9	-0.2	20	11.31	-0.023
10	-0.3	19	8.93	-0.027
11	-0.4	15	4.76	-0.019
Total		168	100 %	***0.130***

Using equation (2), PD = 16 %, and using equation (1), PAQ = 1.05 decipol. According to the standard values provided by ASHARE [10], the calculated PAQ values is acceptable when compared to the standard values on Table II.

TABLE II. THE STANDARDS VALUE OF PAQ BY ASHARE.

Decipol	**Air Quality**
10	Sick Building
1	Healthy Building
0.1	Town Outdoor Air
0.01	Mountainous Area Outdoor Air

2) Questionnaire investigation of acoustics

Approximately 26 % of the respondents were unsatisfied with acoustics pollution in the Co-Op supermarket, while 27 % were satisfied, and the remaining voted for the noise level as acceptable. Fig. 2 shows the results.

The un-satisfaction percentage can be read as the percentage of people threaten by focusing loss and low shopping performance [7]. Even for the respondents voted for the acceptable option, they are on the critical line and their percentages may go for the un-satisfied option when customer's number notably increased.

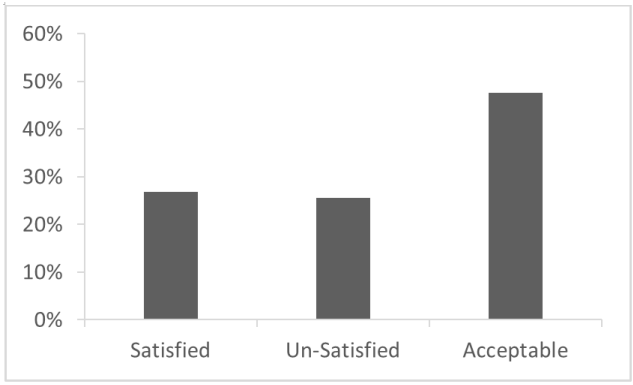

Figure 2. Acoustics satisfaction.

The other parts of the questionnaire will be discussed in the following section.

B. Objective Evaluation

1) IAQ

The measurements result of the three pollutants are documented in Table III.

TABLE III. AVERAGE MEASUREMENTS OF CO2, CO, AND HCHO AT NIGHT.

Pollutant	Values	
	Average C_i (ppm)	C_i/S_i
CO_2	1057	1.51
CO	0.05	0.005
HCHO	0.26	0.026

CO_2, notably, is the main harmful contaminant among the tested pollutants. CO_2 Concentrations vary with spot and time as indicated in Fig. 3.

The average concentrations of CO_2 in Co-Op supermarket at the morning, noon, and night was 914 ppm, 1006 ppm, and 1039 ppm respectively. For some measurement spots, CO_2 exceeded 1350 ppm. That is a serious sign for the discomfort of the occupants.

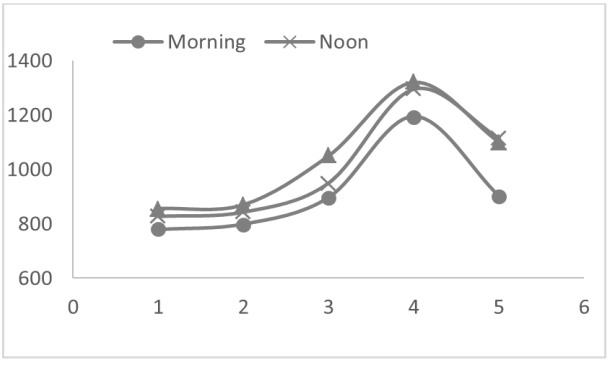

Figure 3. CO_2 Concentrations in different spots and time. On the x-axis 1 is spot LA1, 2 is spot LA2, and so on.

2) Acoustics measurements

The measurement results of the sound pressure level in the designated spots in the supermarket are documented in Table IV.

TABLE IV. SOUND MEASUREMENTS RESULTS OF THE CO-OP SUPERMARKET.

Spot	Measured Sound level (dBA)	
SM1	min	65
	max	85
	avg	70.5
SM2	min	64
	max	79
	avg	69.3
SM3	min	67
	max	82
	avg	73
SM4	min	54
	max	80
	avg	70
SM5	min	72
	max	88
	avg	77.2

A comparison between the highest average spot, SM5, and the lowest average spot, SM4, over 200 points of measurement (average of three data sets of four hours at night) is depicted in Fig. 4. If a worker located in SM5 spent 10 hours, which is the average working shift, in that location, then the calculated TWA would be:

$$Tn_i = \frac{8}{2^{(L_i-90)/5}} = \frac{8}{2^{(77.2-90)/5}} = 47.2$$

$$D = 100 * \frac{10}{47.2} = 21.2\ \%$$

$$TWA = 16.61 \log_{10} \frac{21.2}{100} + 90 = 79$$

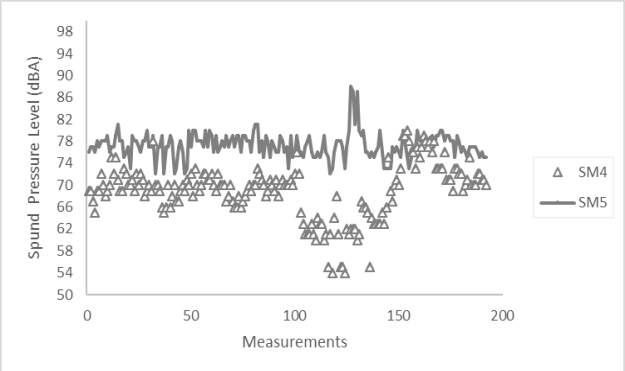

Figure 4. Comparison between the highest average spot, SM5, and the lowest average spot, SM4.

The 8-hour Time Weighted Average Sound Level analysis was carried out for the entire measurement for spot SM5, and the result is shown on Fig. 5.

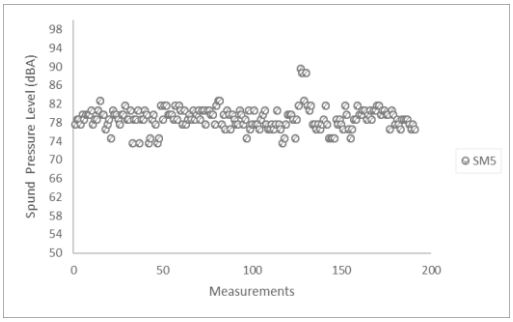

Figure 5. The 8-hour time weighted average sound level analysis for spot SM5.

3) Questionnaire investigation analysis

The questionnaire results on the source of noise are shown on Fig. 6 and Fig. 7.

It is clear that the cashier's area and the wholesale sections were the noisiest spot on the Co-Op supermarket for many people. This finding goes along the spot measurement that was taken on spot SM5. More than thirty-seven percent agreed that the silverware section was noisy. Unexpectedly, the electronics spot was recorded a low noise level on both measurements and people pint of view which his may refer to the management's instructions to control the noise in this section.

More than fifty-eight percent of the respondents agreed on the noise produced by the movement of the carts. TV broadcasts was indicated by forty-six percent respondents as a noise source.

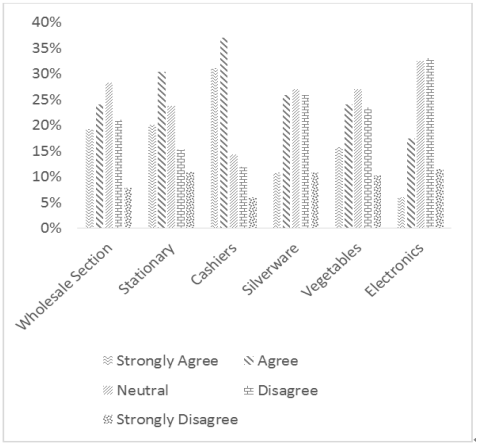

Figure 6. Responses on "How can you assess the noise in the following sections?".

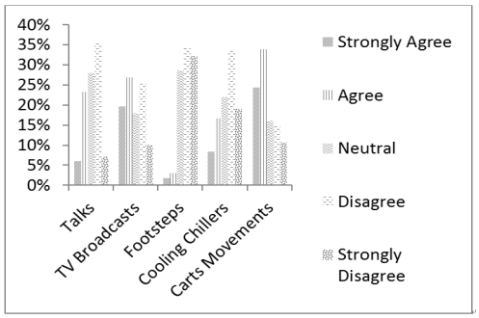

Figure 7. Responses on "how can you assess the noise of the following actions?".

IV. Conclusion

The subjective and objective evaluations are effective approaches in determining the indoor environment health and comfort. CO_2 was found an important air pollutant in the Co-Op supermarket, especially in the vegetable section. A reliable ventilation design is highly recommended in the vegetable section. Acoustics pollution is considerable in the studied Co-Op supermarket, especially the TV broadcast and the cashier's area.

Conflict of Interest

The authors declare no conflict of interest.

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