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Premeasurement and analysis of the IAQ parameters

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Abstract

Indoor Air Quality is one of the most essential factors for ensuring a healthy and comfortable environment inside the buildings. In order to obtain precise and reliable measurements for IAQ, it is necessary to implement a pretesting phase and to perform an analyze of the the data resulted before using the measurement device Testo, according to standards: ISO 7730 and ASHRAE 55. Pretesting is important to identify and eliminated possible errors or external factors which can influence in the end the measurement data all of this so the quality of the data can be improved. This paper aims to analyze a data series of IAQ measurements by using a measurement device, special dedicated for monitoring and evaluation of different ventilation systems. Data taken out of the monitoring phase is processed and the results show the issues with the existing air ventilation systems as well as the potential improvement solutions for the identified nonconformities. The usage of the standards ISO 7730, ASHRAE 55 and Testo measuring device has a big potential in assuring good and reliable measurements of the IAQ. It is important to highlight the importance of pretesting phase and the analyze of the measurement data in order to ensure a good evaluation and finally a sum of solutions focused on providing healthy and comfortable environments.

Key words: indoor air quality, testing, measurement device, pmv, ppd, environment

1. Introduction

In modern industry, the analysis of indoor air quality (IAQ) parameters is particularly important to ensure a safe and healthy working environment for employees. In doing so, we will examine the importance of analyzing IAQ parameters in the manufacturing environment and consider various bibliographic sources that support this perspective.

A study [4] published in the Journal of Occupational and Environmental Hygiene focused on indoor air quality in a manufacturing environment using a ventilation system. Results identified there provided a positive correlation between the amount of carbon monoxide and carbon dioxide in indoor air and employee productivity. This emphasizes the importance of a complete analysis of IAQ parameters in production environments and their effects on employees.

Also, a study published in the journal Indoor and Built Environment [1] examined indoor air quality in a manufacturing environment in a garment factory. The results showed that the indoor air pollution had a

significant impact on employee performance and health. Authors recommended a detailed analysis of IAQ parameters to prevent these problems and ensure a safe and healthy work environment.

Additionally, another study [2],[3] examined the economic implications of ensuring indoor air quality in a manufacturing environment. This study found that although the initial costs may be high to implement an indoor air quality system, the long-term economic benefits may outweigh the initial costs.

In conclusion, the analysis of IAQ parameters in production environments is essential to ensure a safe and healthy work environment for employees. The previously mentioned studies emphasize the importance of this analysis and its implication in the performance of employees and the economy of the enterprise. It is essential that businesses take steps to achieve indoor air quality and protect the health and well-being of employees. According to a study by Anh Tuan Hoang and colleagues published in the journal Indoor and Built Environment, pre-testing IAQ measurements is important to identify possible errors and eliminate external influences on measurement data. They found that pretesting resulted in a significant reduction in measurement errors and improved data quality. Also, according to a paper published in the journal Building and Environment by Yi Jiang and collaborators, analysis of IAQ measurement data is important to evaluate and compare the performance of different ventilation and air conditioning systems. They found that analyzing measurement data can help identify problems with existing systems and improve their performance. As remarks, pre-testing and analysis of IAQ measurement data is essential to ensure the accuracy and reliability of measurements and to evaluate the performance of ventilation and air conditioning systems. This can be achieved by using ISO 7730 and ASHRAE 55 standards and by using a meter such as Testo. Literature sources consulted include the journals Indoor and Built Environment and Building and Environment.

2. Introduction of SR EN ISO 7730 : 2005 standard

This international standard was developed for measuring and analyze the moderate and extreme conditions to which people are exposed.

Thermal equilibrium of the human body is achieved when the internal heat production in the body is equal to the heat loss to the environment. The main factors influencing this balance are: physical activity, clothing and the parameters: air temperature, mean radiant temperature, air speed and air humidity.

When these parameters have been assessed and measured, body heat sensation can be predicted by calculating the PMV (mean estimated vote).

The PMV is intended for a large group of people exposed to the same environment.

This standard has been developed especially for working environments but it can also be applied to other environments, of course people with special needs or mental problems must be taken into account.

The PPD index (estimated percentage dissatisfied) establishes a quantitative prediction (the number of thermally dissatisfied people in a given group of people). The rest of the group will feel thermally neutral, slightly hot or slightly cold. It can be calculated after the PMV has been determined:

$$PPD = 100 - 95 * \exp(-0{,}03353 * PMV4 - 0{,}2179 * PMV2)$$

Fact: PMV and PPD express hot and cold discomfort for the body as a whole.

The most common local discomfort factors are radiant temperature asymmetry (cold or hot surfaces), draught (defined as local cooling of the body caused by air movement), vertical air temperature difference and cold or hot floors.

Thermal comfort is that condition of mind which expresses satisfaction with the thermal environment. Due to local or national priorities, technical developments and climatic regions, these PMV, PPD, current model, relationships between them can be used to determine different ranges of environmental parameters for thermal environment assessment and design.

PMV	PPD	Persoane prevăzute să voteze [a] %		
		0	-1, 0, +1	-2, -1, 0, +1, +2
+2	75	5	25	70
+1	25	30	75	95
+0,5	10	55	90	98
0	5	60	95	100
-0,5	10	55	90	98
-1	25	30	75	95
-2	75	5	25	70

[a] Bazat pe experimente care au implicat 1300 de subiecți.

Figure 1. PMV and PPD values

3. Scope of workpaper and the equipment used for measurement

From previous articles, we have reached a level of understanding of the need to monitor IAQ indicators, as well as the procedures for measuring PMV and PPD indicators in accordance with EN ISO 7726. Thus, the present work aims at using the measuring device and pre-testing it before performing actual measurements in a production space over a much longer period of time.

In this paper we present two different situations in which we performed the pre-testing, so that we can understand how to use the device according to the standard and how to evaluate the reports provided by it.

The measuring equipment used was the Testo 400 model for measuring IAQ and comfort level, equipped with a tripod. This equipment is the most efficient method for all IAQ users measuring ambient air quality and comfort level. This device gave us state-of-the-art support through measurement menus and an evaluation of measured values according to the traffic light principle for error-free measurements.

The probe heads can be changed very quickly and easily without restarting the instrument. Both the probe calibration, which is independent of the measuring instrument, and the adjustment function with up to six measuring points for displaying zero errors ensure less downtime and highly accurate measurements.

Advantages of the equipment:

- PMV / PPD parameters and comfort level can be determined and with the measuring tripod compliance with the standard is ensured using up to 3 probes at the same time.

- Using the IAQ recorder, measurements can be recorded over a longer period of time of up to two weeks.

- Carbon dioxide concentration, humidity value, air temperature and turbulence can be determined (including long-term).

- Turbulence and draft can be determined in accordance with ES ISO 7730 and ASHRAE 55.

- New probes can be added at any time.

For PMV/PPD measurement according to ISO 7730 and ASHRAE 55 it is necessary that the instrument is specifically configured. We initially set the clothing index and activity type, then at the time of measurement we recorded in parallel the values of ambient and radiation temperature, air velocity and relative humidity.

As a result the device provided for both pretests two reports in the form of a PMV/PPD curve, as can be seen in the following article, plus the measured values and the evaluation of the parameters.

4. Recording and sharing of the data

The device is used after it has been properly set. In the case of the present work the settings were similar. In the following the measurement mode is presented for the two environments analyzed.

As far as data collection is gathered, TESTO device generates a protocol after the end of the measurements: Measurement protocol.

In this protocol five chapters are identified:

- General information: this chapter identifies the measurement program and the date of the report completion.

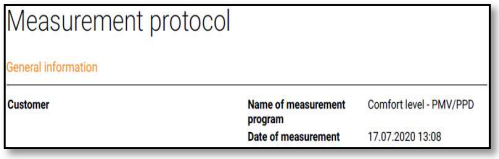

Figure 2. Measurement protocol

- Information about the device and probes used in the measurement: the name/series of the device, the parameters measured by each device, the calibration certificate, the date of calibration of the device and the necessary adjustments are highlighted.

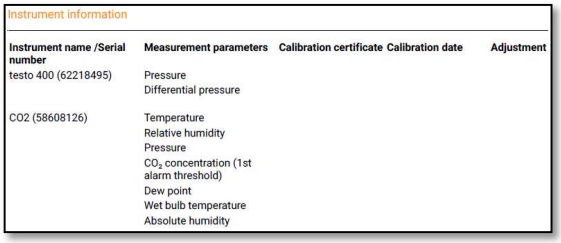

Figure 3. Instrument information

- The chapter which identifies the data of the measurement place.

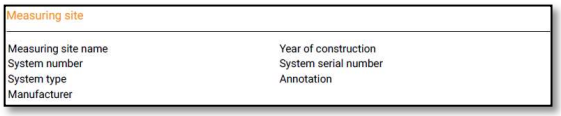

Figure 4. Measuring area information

- Measured parameters : measuring module, measuring cycle time, etc.

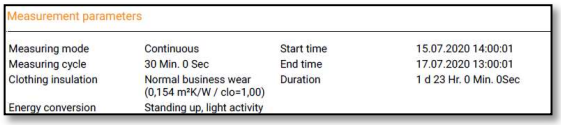

Figure 5. Measuring type

- Measured data section: in the form of tables the parameters and time of recording are identified.

Measurement

PMV
PPD

Date/Time	126 [°C]	126 [°C]	126 [%RH]	126 [hPa]
15.07.2020 14:00:01	27,3	17,5	37,8	973,6
15.07.2020 14:30:01	27,4	17,5	37,7	973,4
15.07.2020 15:00:01	27,4	17,5	37,7	973,2

Figure 6. Measured data overview

The device used for measurement is shown in Figure 7, except the main device it contains also additional probes which can be added according to the need or desire of monitoring. Each probe has different specification and purpose. The device was calibrated by an authorized company from Romania and has a calibration certificate. The calibration must be done once per year by a certificated company.

Figure 7. TESTO device

5.Pretesting of the device in environment number 1

Prior to commissioning, the appliance was subjected to measurements of two different environments in terms of thermal comfort values.

Ambient 1 for which measurements were taken was considered an optimal environment where, for the activity and clothing selected from the appliance settings, the comfort point is in the permissible green zone (between -0.5 and +0.5 PMV), as shown in Figure 1.

According to the standard, the PPD values must not deviate, so that they do not exceed the value of 15, which in this case is not the case, the value being ten.

In the table below we have highlighted the first 20 values recorded by the meter. As far as the values are concerned there is a clear correlation between most of the parameters. With red we have highlighted the highest values in the column and with green the lowest.

As a result of this visualization it is worth mentioning that the highest values of parameters such as carbon dioxide concentration, pressure, temperature define the highest values for the comfort parameters, namely: PMV and PPD.

One explanation for the decrease in values, taken from top to bottom, may be human intervention at the beginning of the programming/setting of the measuring devices. Thus the last measured values in the table define the stability of the measurement process.

Table 1. Measured values in environment 1

PMV	PPD	Temp. [°C]	Humid. Rel. [%RH]	Pressure [hPa]	$C0_2$ [ppm]	Density [g/m³]	Pressure dif. [hPa]	Air speed [m/s]
0.5	**10.2**	20.5	73.9	981.8	2,147	13.17	0.017	0.02
0.5	**10.2**	20.6	71.5	982	1,983	12.82	0.016	0.02
0.4	**8.3**	20.4	62.2	982.1	1,322	11.02	0.016	0.03
0.4	**8.3**	20.1	61	982	1,088	10.62	0.016	0.03
0.3	**6.9**	20	60.8	982	986	10.52	0.015	0.02
0.3	**6.9**	19.9	60.3	982	919	10.38	0.015	0.03
0.3	**6.9**	19.8	59.8	982.3	889	10.23	0.015	0.02
0.3	**6.9**	19.7	59.4	982	865	10.1	0.015	0.03
0.3	**6.9**	19.7	59.8	982.1	860	10.17	0.014	0.02
0.3	**6.9**	19.6	59.5	982.1	848	10.06	0.015	0.03
0.3	**6.9**	19.6	59.6	982.1	863	10.08	0.014	0.03
0.3	**6.9**	19.6	59.8	982.1	863	10.11	0.013	0.03
0.3	**6.9**	19.5	59.3	982.1	851	10.03	0.014	0.03
0.2	**6.8**	19.6	58.8	982.1	867	9.94	0.013	0.03
0.3	**6.9**	19.5	58.6	982.1	854	9.85	0.014	0.03

0.3	**6.9**	19.5	58.9	982.1	849	9.9	0.013	0.02
0.2	**5.8**	19.3	58.7	982.1	848	9.75	0.014	0.04

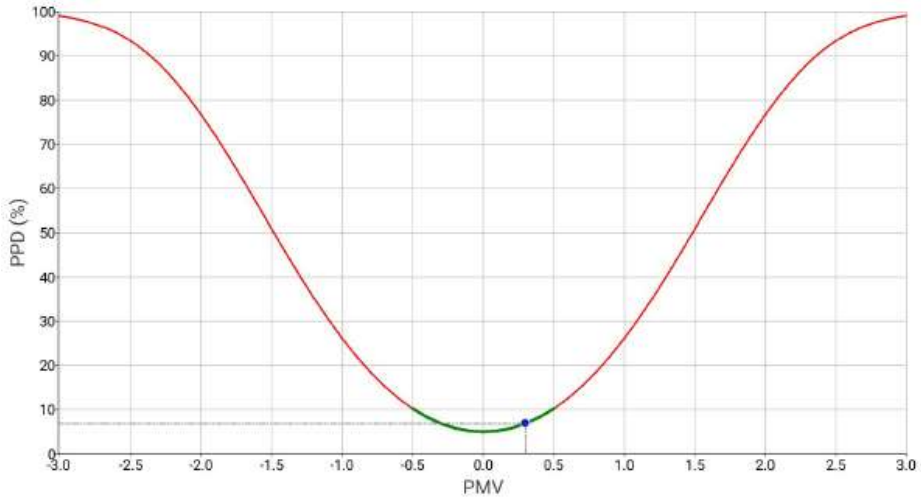

Figure 8. PMV/PPD graph -measuring in environment 1

Measurements were made over 24 hours with a 5-minute recording cycle, the season in which the measurements were made was cold.

According to SR EN ISO 7730 the PMV and PPD values are simultaneously respected in terms of their classification in category B, which gives an allowed tolerance for the measured parameter values so that both temperature and air speed have optimal values.

Table 2. Pretesting values in environment 1

PMV	PPD	Temp. [°C]	Humid. Rel. [%RH]	Pressure [hPa]	$C0_2$ [ppm]	Density [g/m³]	Pressure dif. [hPa]	Air speed [m/s]
0.3	6.9	19.8	67.5	982.6	1,616	11.34	0.011	0.03

The measurement parameters selected from the device were:

- Measurement mode: continuous
- Measuring cycle: 5 min. 0 sec
- Clothing: normal business wear (0.154 m²K/W / clo=1.00)
- Energy conversion: standing up, light activity.

6.Pretesting of the device in environment number 2

In case 2, the appliance was tested in an ambient environment 2, which does not meet the conditions for carrying out an activity in terms of thermal comfort. The measurement parameters were selected indistinctly as for the measurement in ambient 1 in particular in order to achieve a clear and objective comparison of the two environments under measurement.

In this case the comfort point obtained by the intersection of the PMV and PPD values is outside the green zone, far away from the green zone, which results in extreme negative comfort values.

In the case of the second mean, the same correlation can be observed between the measured parameters. However, as mentioned above, the thermal comfort values are more pronounced.

The measured values are much higher than the limits allowed by the standard, which defines the measured area as being in thermal discomfort and brings into question the first measures to be taken to restore comfort.

The explanation given in the chapter in which I mention the values measured in environment 1 may also be valid for environment 2.

Human intervention, the use of hands or touching clothes can have an impact on the measurements even

after a few minutes.

Moreover, any movement in the room generates a deviation on the environment, which is identified/measured by devices with high sensitivity.

Table 3. Measured values in environment 1

PMV	PPD	Temp. [°C]	Humid. Rel. [%RH]	Pressure [hPa]	$C0_2$ [ppm]	Density [g/m³]	Pressure dif. [hPa]	Air speed [m/s]
2.4	**91.1**	31.1	37.3	986.5	589	7.9	0.006	0.04
2.6	**95.3**	31.3	34.6	986.6	569	7.71	0.005	0.19
2.6	**95.3**	31.5	34.8	986.5	604	8.11	0.005	0.13
2.6	**95.3**	31.4	33.2	986.4	598	7.87	0.005	0.23
2.3	**88.3**	29.7	35.7	986.4	611	7.91	0.005	0.03
2.5	**93.4**	30.1	34.3	986.4	588	8.04	0.004	0.12
2.5	**93.4**	30	35.1	986.4	627	8.14	0.004	0.2
2.4	**91.1**	29.4	35.6	986.4	641	8.21	0.004	0.31
2.3	**88.3**	29.1	34.6	986.4	590	8.02	0.003	0.02
2.3	**88.3**	28.8	36	986.3	589	7.98	0.004	0.27
2.3	**88.3**	29.1	35.6	986.4	577	7.98	0.003	0.2
2.4	**91.1**	29.1	36.6	986.5	594	8.2	0.004	0.07
2.3	**88.3**	28.7	36.4	986.3	568	8.02	0.003	0.06
2.2	**84.9**	28	38.3	986.2	591	8.02	0.004	0.04
2.2	**84.9**	27.7	38.9	986	577	8.1	0.003	0.13
2.1	**81.1**	27.3	40.8	986.1	580	8.21	0.003	0.03
2	**76.8**	27	42.4	986	560	8.15	0.003	0.02

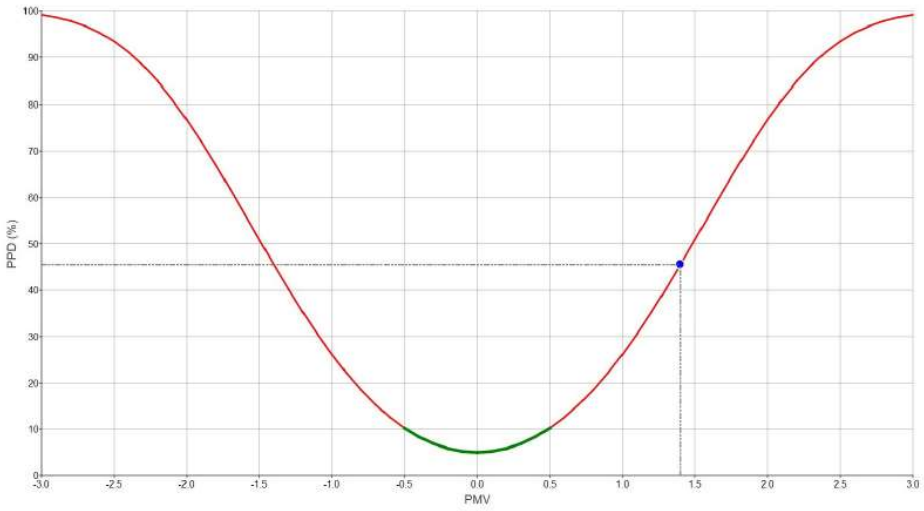

Figure 9. PMV/PPD graph -Measurement in environment 2

At the same time, the carbon dioxide value is close to the maximum permitted value of 4000 ppm, much higher than in ambient 1.

The temperature is 0.4 degrees higher than the tolerance field highlighted in the standard for the selected measurement parameters.

Another important factor to mention is the lower air velocity, which in this case together with the high temperature induces thermal discomfort in the human body.

Table 4. Pretesting values in environment 2

PMV	PPD	Temp. [°C]	Humid. Rel. [%RH]	Pressure [hPa]	$C0_2$ [ppm]	Density [g/m³]	Pressure dif. [hPa]	Air speed [m/s]
1.4	45.5	22.4	57	979	2,671	11.34	0.011	0.03

7. Results and comments

Following the two measurements and analyses, differences in values for the parameters measured in this way can be shown in Table 5(data comparison).

Table 5. Data comparison

	PMV	**PPD**	**Temp. [°C]**	**Humid. Rel. [%RH]**	**Pressure [hPa]**	**$C0_2$ [ppm]**	**Density [g/m³]**	**Pressure dif. [hPa]**	**Air speed [m/s]**
Optimum	Min: -0,5 Max: +0,5	Max:15	Min: 12 Max: 26	*	*	Max: 3000	*	*	*
Environment 1	0.3	6.9	19.8	67.5	982.6	1,616	11.34	0.011	0.03
Environment 2	1.4	45.5	22.4	57	979	2,671	11.34	0.011	0.03

According to SR EN ISO 7730 the values marked with "*" do not represent a major influence factor considering the options set at the beginning, for the comfort of people.

The attached table shows the deviations from the standard for the main values measured and interpreted by the devices. Thus it can be seen how environment 1 is represented by values tolerated by the standard while in the case of environment 2 major deviations from the allowed values are observed. The verification carried out helps us to identify whether the given thermal environment meets the comfort criteria and moreover to establish requirements for different levels of acceptability. A very important aspect to which the standard refers is related to the thermal discomfort that can be caused by local cooling/heating of the body. So depending on the people in a given room the discomfort is felt differently. For example, a person with sedentary activity is more sensitive than a person with a high level of activity.

The presented monitoring and evaluation of the indoor air quality parameters in a premeasured phase, conducted to an application on an industrial model, in a factory. This application provided results for a future work paper.

8. Conclusion

The pre-testing process of the device finally helped me to easily identify the differences between a thermally comfortable environment and an uncomfortable environment, which is evidenced by the values of all measured parameters.

Also an important aspect when testing the appliances is the stability phase that the environment should reach after installation. Any movement or even the presence of humans in the vicinity of the devices can give values outside the stability range.

Moreover, the pre-test is an opportunity to understand the functionality of the devices, the data and the connection between them. The measuring devices should be positioned as close as possible to the workstation so that the resulting data can lead to measures being taken if necessary to improve thermal comfort.

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