The Link between the User´s Health and Deficiencies in the Physical Indoor Environment

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Abstract— *In this project we study a school building where users for many years have complained about health problems. The symptoms reported are often nonspecific and are also common among the population in general, such as headache, fatigue, mucosal and skin problems. The purpose of this project is to investigate whether physical deficiencies in the indoor environment can be identified by measurements that can be linked to the health problems that users complain about. The starting point is to use a working model that not only seek damages in the building itself as the cause of the problems, but considering all polluting factors affecting the air environment. The measurement results, both the survey and the study of the physical measurements, show that there are problems with the air environment in the school building. The study shows that a link has been identified, that is the physical measurements show deficiencies in the air environment that is directly linked to the health problems that users complain about. Through a program of action a significant improvement of the indoor environment has been achieved, since the unhealthy emissions have been eliminated. Dry air prevails most of the year in the school building, below 40% and periodically below 20%. The cause of the dry air, are the air flows that the ventilation system creates. In Sweden the authorities pose far-reaching demands on the ventilation flow, causing technological systems installed to create these air flows. This would however go beyond the framework of this project.*

Keywords— Hygiene and Health, Indoor Air quality, Indoor Humidity, Indoor Temperature.

I. INTRODUCTION

Complaints on the indoor environment of the residents have in recent decades become a common problem in the Swedish property portfolio. The buildings themselves are considered to be the cause of problems and a diffuse image is created by both the exposure and the effect of the problems. The symptoms that residents and users report are often unspecific and moreover common in the population in general, such as headache, fatigue, mucosal and skin problems. In a study of public health authorities reported that the equivalent of 18% of the adult population in Sweden has these symptoms, and the explanation is considered to be deficiencies in the building itself [1, 2]. There are parties, both in the public sector and in the private ranks, carrying out various measurements and refers to the deficiencies found in the building's design that causes that the occupants of these buildings become ill. The methods used are not validated and no comparisons can be made between the different parties since there is no calibration between different measurement procedures. It should be emphasized that the measured levels are extremely low in relation to exposure limits of The Swedish Work Environment Authority [3]. It is also said by many researchers that there are no established dose-response relationship in the matter and this is supported by intensive research that has taken place in recent decades [4-11]. However, the action continues by the authorities and private parties, as if the dose-response relationships are confirmed. This situation has created the conditions to allow the use of a working model that lacks a scientific working hypothesis [12]. The Swedish authorities have embraced this and an inadequate working model is now allowed to control the actions of the authorities [13, 14, 15].

Already in the early 1990s, the incidence of problems increased in Sweden. In a survey of this period, involving more than 200 people on municipal technical offices, the results showed that the problem was widespread. In addition, they demonstrated great difficulty in dealing with the situation when the problem occurred. It is noteworthy that the authorities' actions already perceived as unclear and they were out of touch with everyday situation in the Swedish property portfolio [16]. Working models must not be too tight so that the critical parameters affecting indoor environment and human health are omitted [17]. Instead, all the factors that affect the environment in a particular building must be included. Different environments may not be interchanged, i.e., so that the external environments that users are exposed to not unduly are transferred to and condemn a certain designated building. The model used must be clear.

1. Dose-response relationships; the level of a particular substance is established that provides health problems, alternatively, combinations of several substances.

2. The analysis must take into account both the total human environment they are exposed to and the activities in the current building, which today does not occur [13, 14, 15].

Is not a viable working model in use it is very likely that there are shortcomings in the indoor environment that is not taken into account and therefore cannot be rectified. The result is that problems with the indoor environment persists despite extensive measures are implemented [18]. This project is based on the study of a school building, which for many years has been exposed to problems and despite extensive efforts, the problems have not been solved and the activities suffer major disruptions. The purpose of this project is to investigate whether it is possible to identify the link between the health problems that users complain of and deficiencies in the building's air environment. This means that the potential to eliminate the source of the problems that cause the users of the building increases, than the use of incomplete work models. A parameter that must be considered in terms of the air environment in buildings is the relative humidity. Studies show that dry air, with respect to human health, often prevails in buildings and that the situation becomes even more pronounced during the winter months. It is well documented that the incidence of respiratory infections increases in winter when people during long periods are exposed to low relative humidity levels indoors [19 – 28]. Regarding the relative humidity there is an optimum zone between 40-60%, and this level should be sought, see ”Fig. 1”.

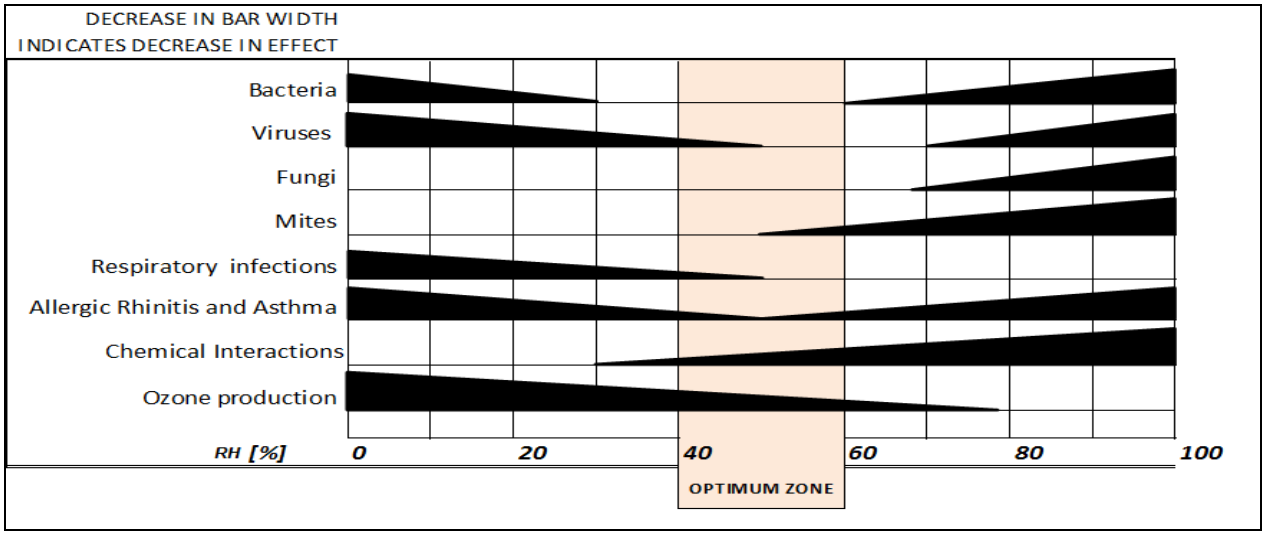

FIGURE 1: The effect of relative humidity, on biological and chemical factors, is graphically summarized above. The optimum zone is in the range between 40% - 60% relative humidity to minimize the negative health effects of common air pollutants [19].

II. MATERIAL AND METHOD

This project includes the study of a school building where the users for many years have complained that they suffer from health problems. Health complaints are substantiated by a medical report and the evidence supporting the statement are investigations with a one-sided focus on the health symptoms to be linked to deficiencies in building structure [12, 29]. Despite comprehensive measures by rebuilding the problems have not been resolved, but the health symptoms recur. The purpose of this project is to investigate whether physical hygiene deficiencies in the indoor environment can be identified through measurements in the school building related to the health problems that users complain about. The starting point is to use a working model that not only focuses on the building, but also takes into account that for the physical indoor environment all influencing factors. The project begins with a questionnaire to the school staff to document how the school environment is perceived. The questionnaire is divided into three sections; 1. Concern- Health, 2. Air Quality and 3. Comfort parameters (including the measurement parameters relative humidity and air temperature). The survey is designed so that if the result shows that there are deficiencies in the indoor environment, the source of these could be derived using physical measurements in air. The physical measurements of the air environment include emissions, the relative humidity and air temperature. The air people normally breathe contains regularly pollution of various kinds and the composition is important for human health. Its ingredients are both gaseous pollutants and particulate pollutants where the gaseous pollutants have undergone extensive research studies in recent decades. It should be emphasized that the gaseous pollutants are commonly found in outdoor air and thereby also in indoor air. The concentrations are low, 100 or 1000 times lower than the current

limits in the work environment and research studies have indicated that no dose-response relationship has been demonstrated [3-11]. The indoor particulate emissions have not received the same attention as the gaseous, but studies indicate that high levels prevailing in Swedish schools [16, 17, 18]. In this project particulate emission measurements are implemented with validated instruments that are taken from cleanroom industry. The emission measurements are carried out as a point effort in a day and a measurement series consists of five individual measurements, which means that the total treated air is about fifteen liters. The meter calculates and presents results in cubic meters of air. All the results from the measurements in the school environment are based on an activity that is comparable to the activity normally pursued, but with one important difference which is the number of persons present. When the time of measurement is conducted only a few people are involved compared, to normal operation when far more people are staying on the premises. This ratio is important because each person affects the environment and provides a direct issuance addition to the air but will not be included in the results of this study. All cells of a human being, except for neurons, are continually renewed. Old skin is continuously replaced by newly formed skin and man usually changes its entire outer layer of skin after four days [30]. Examples of various activities emission contributions are reported in Table 1.

TABLE 1

The number of particles larger than 0.5 microns as a human gives off at different body movements [30].

	THE NUMBER OF PARTICLES AS A HUMAN EMITTING
Sedentary:	100 000 particles per minute
Sitting, rotating arm movements:	500 000 particles per minute
Standing up, sitting down:	2 500 000 particles per minute
Climbing stairs, running:	10 000 000 particles per minute

Regarding the measurement of relative humidity and temperature indoors the measurement ran from December 4, 2014 and ended April 19, 2016, which means that the results include the seasonal variations that the Swedish climate exposes buildings to. The instrument used is equipped with a data logger with the logging interval set to every two hours. The results presented from the physical measurements are taken from a classroom that is representative of the building. The basis for the environment in the building is the conditions found outdoors around the building and therefore implemented the same physical measurements outdoors and indoors. The project includes a visual inspection of the building to assess the building's standard, both from a technical point of view and how the building is used. The project is complemented by studying how the concerned authority relates to the problem at the school. The goal is to obtain an insight into the intentions of the Swedish Parliament and Government through the legal system, reaches out to the Swedish property portfolio.

III. RESULT

The measurement results, both the survey and the study of the physical measurements, show that there are problems with the air environment in the school building. This project presents measurable hygiene deficiencies in the indoor environment that causes the health problems that users complain about.

3.1 **The questionnaire study** covering 53 of the 56 total respondents, i.e. a response rate of 96%, shows the following results:

1. Concerns - Health: 23% said they suffer from health problems when they are staying in the school building and it is noteworthy that the entire 53% complain of anxiety just by staying in the building.
2. Air quality: The air is generally perceived as bad by 62%, unpleasant odors experienced by 53% and 32% that the air environment is dusty.
3. Comfort: Within this area the major problems are pointed out and this during the winter months when 66% experiences the dry air and 74% have a complaint about the temperature.

3.2 **Emission measurements**, report that the amount of pollutants in indoor air is affected by indoor air around the building. From “Fig. 2”, it appears that there are significant variations in the outdoor environment of the minimum interval between measurements, to the greater advantage of coherent modest levels.

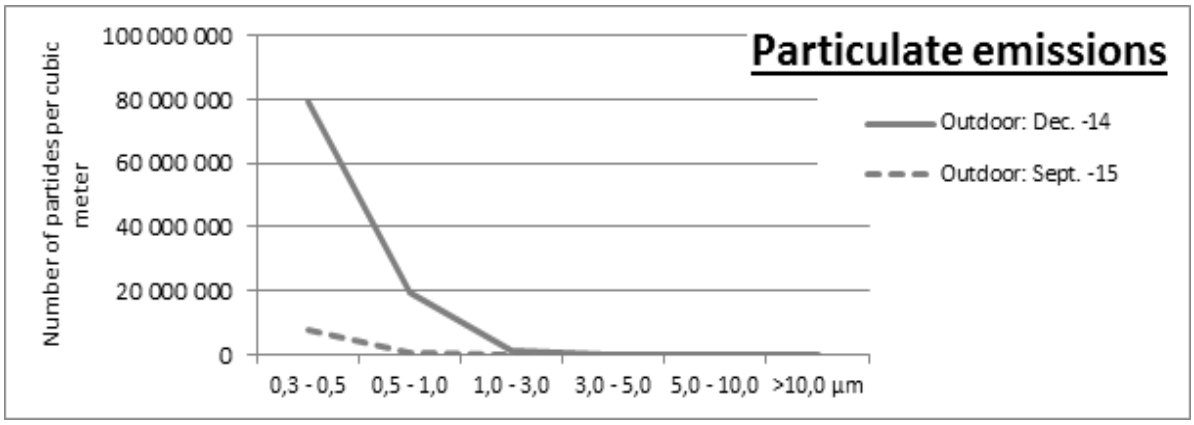

FIGURE 2: Emissions outdoors, particles in the range of 0.3 - 10.0 microns. As can be seen, there is substantial variation in the outdoor environment of the minimum intervals for the larger, at both measurement occasions, be consistent and at very modest levels.

One reason for the sharp fluctuations in the smallest interval is that these pollutants mainly occur from emissions in other countries. These particles can remain in the atmosphere for several days and the number from which the inward transport to Sweden takes place is controlled by the winds [5]. To read the issue results in the larger particle ranges and where to make comparisons between the different measurement occasions are used in the diagrams in "Fig. 3-5", the same scale and the maximum limit, the maximum value set at 9,000,000 particles per cubic meter of air.

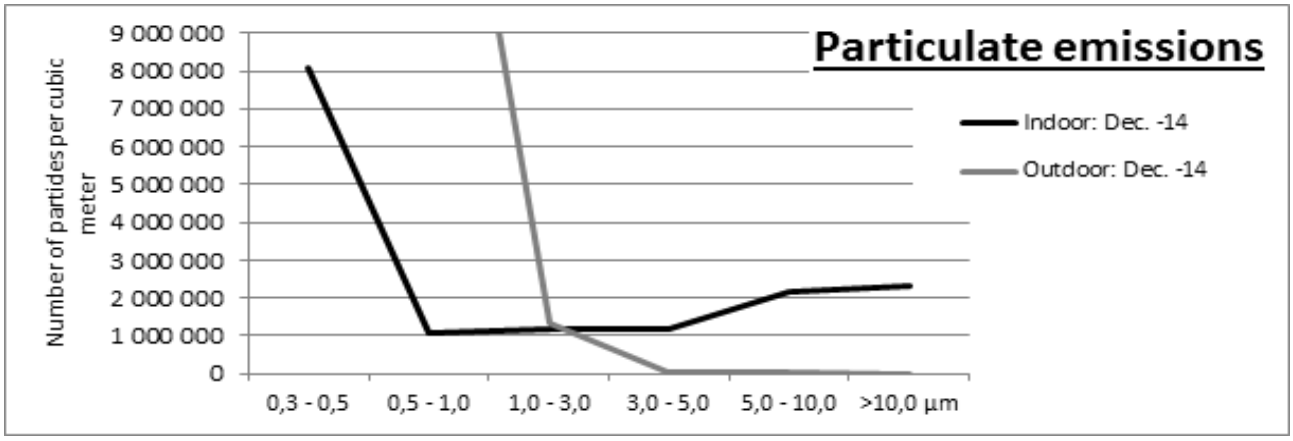

FIGURE 3: Emissions indoors and outdoors for the particles in the range of 0.3 - 10.0 microns. As shown, there are important differences between outdoor and indoor environments. In the smaller ranges there is substantially larger numbers of particles outside to the larger intervals to be much more modest, unlike the indoor environment where the particle numbers turns and increases in larger intervals.

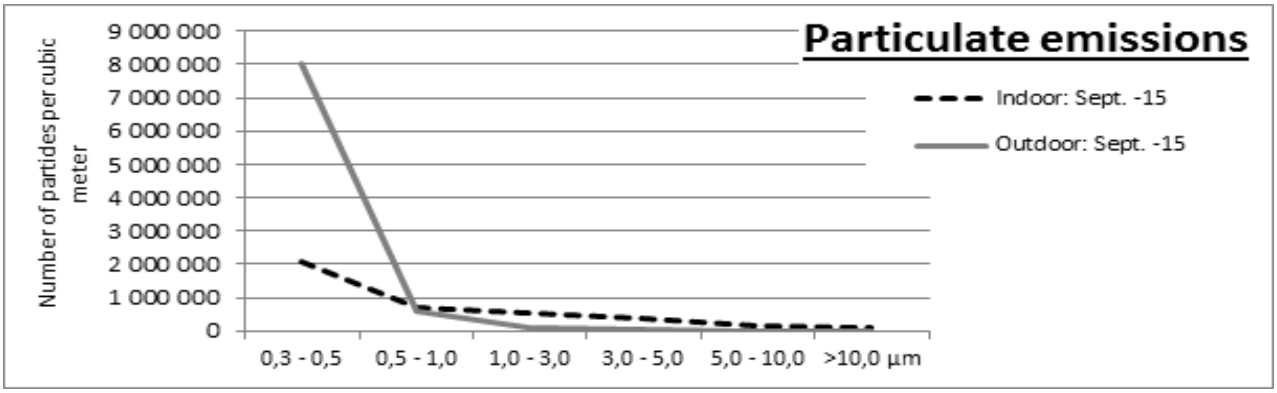

FIGURE 4: Emissions indoors and outdoors for particles in the range of 0.3 - 10.0 microns. As shown, there are important differences between the outdoor and indoor environment in the smaller ranges, with many more particles outdoors than indoors. In the larger interval the graphs are more attuned.

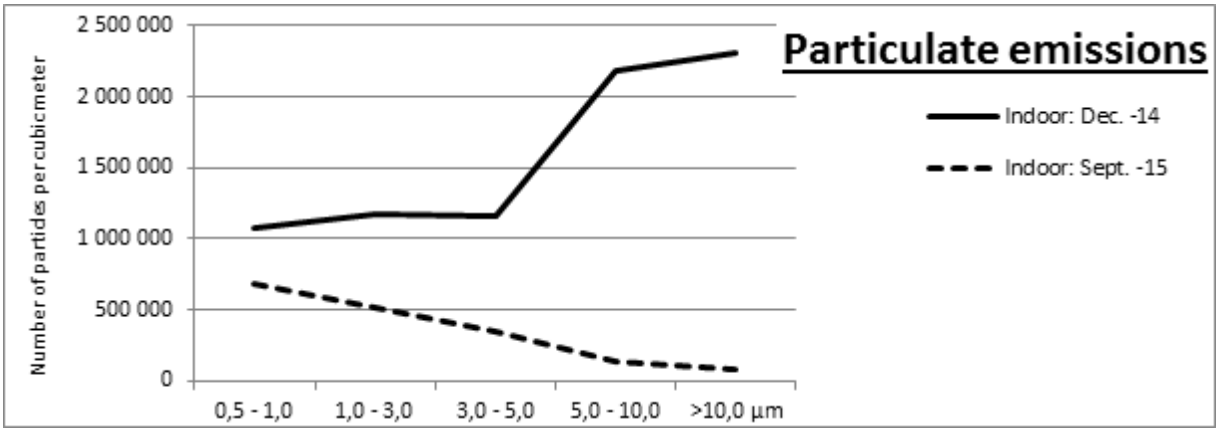

FIGURE 5: Emissions of particles in the range of 0.5 - 10.0 microns on two occasions. As shown, there are important differences between the different measurement times and it is considerably better air quality during September 2015. The reason for this improvement is the cleaning up of the school premises between the two measurement occasions.

This means that the smallest particle range during the measurement in December 2014, will not be visible in its entirety, but it is of less importance in this context. Preferably emissions greater than 5.0 microns are interesting from a health perspective since they are carriers of negative health agents such as allergens and microorganisms [6, 30, 31]. The visual inspection showed that the schools are overloaded, which means that the emission sources are created [32], and this relationship is evidenced by the physical measurements that show that the air environment is loaded. The graphs in "Fig. 3" is clear, divergence is greater in the emission intervals to the detriment of the environment. Regarding the minimum interval, less than 0.5 microns, the emission levels higher outdoors and contaminate the indoor environment in the particle range. However, this spread is relatively modest and cannot technically be addressed when the spread from the outdoor environment is transmitted through the communication that regularly is going on through doors and windows. Considering the amount of emission in indoor air regarding particles larger than 3.0 microns, it can be concluded that the source is not from the outdoor environment, because the level outside is significantly lower. These emissions are formed indoors and "Fig. 4" shows the graphs in the chart a better coherence between the outdoor and indoor environment, that is, after the measures have been implemented. "Fig. 5" shows a direct comparison of the two measurement occasions from the opening intervals greater than 0.5 microns and the graphs in the chart shows that the measures taken have achieved major improvements in hygienic indoor environment. To clarify the situation for the larger particles 5.0 microns is reported in "Fig 6", a direct comparison between the two measurement occasions for this fraction.

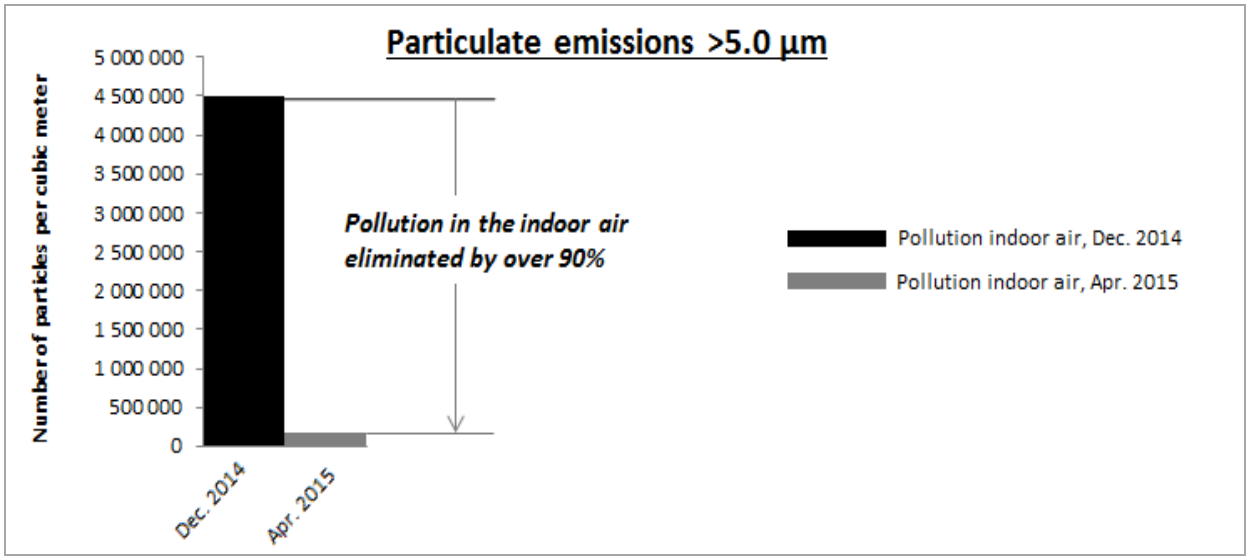

FIGURE 6: Emissions of particles larger than 5.0 microns. As shown, there are important differences between the different measurement times and it is considerably better air quality during September 2015. The reason for this improvement is the cleaning up school passed between the two measurement occasions.

The hygienic improvement of the indoor environment is palpable, the emission amount of the unhealthy size ranges have been greatly reduced, from over four million particles per cubic meter to a level below 200 000 particles per cubic meter. After the measures being implemented by remediating the material that was not needed and to adapt the interior to be more appropriate for the business, the emission sources had been eliminated and the exposure load in the air environment was reduced by over 90%. It should be emphasized that the maintenance work in the building has not changed, but the results have been achieved due to the maintenance of all the surfaces become possible, which was not feasible before the clean-up. The problems and the health problems that users complain of

- Health Problems (area 1 of the questionnaire)
- Air quality (part 2 of the survey)

are correlated with measurements of the indoor environment.

The emission level indoors in ”Fig 3” is high, and this provides a significant higher contamination of allergens and bacteria unlike the emission level indoors in ”Fig 4”. The source of the problem is identified by the emission measurements and thus the emission sources may be eliminated.

3.3 **The temperature** shows that a fairly steady level prevailing with a mean of 20.5 °C and the lowest measured 18.6°C and a maximum value of 24.6 °C. The results are shown in full in ”Fig 7”**.**

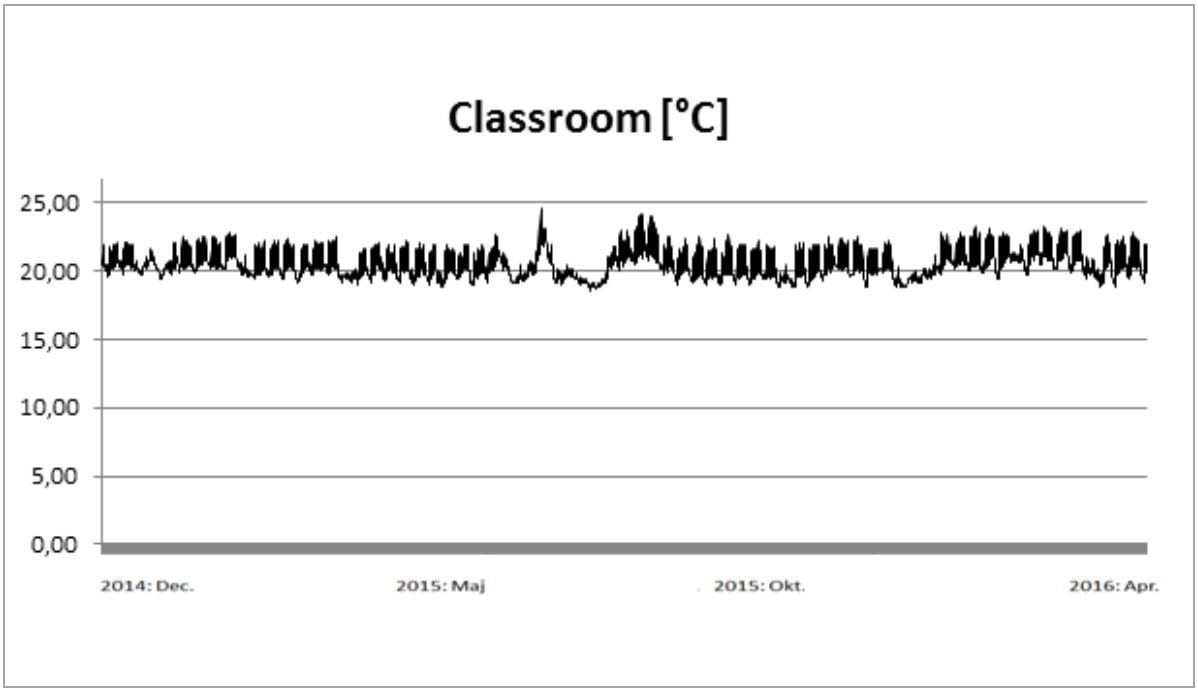

FIGURE 7: The air temperature in the school building from December 4, 2014- April 19, 2016.

According to the Swedish authorities, the temperature should be a minimum of 18 ° C and below 26 °C with operational measurement for not being considered a nuisance to human health [33]**.** The problems and health problems that users complain of in the questionnaire survey concerning area 3, Comfort - temperature, is a subjective experience where both the experience and the different perceptions of great scattering frequency between different people. What a person experiences as cold can of another person perceived as too hot. Temperature is a difficult issue to handle and arbitrary as it is important for the authorities to provide clear information on the issue at hand.

3.4 **The relative humidity,** this measurement shows an unhealthy level that is below 40% most of the measurement period. ”Fig. 8” and Table 2 reveals that the rate is even below 20% for long periods and the lowest recorded levels are below 10%.

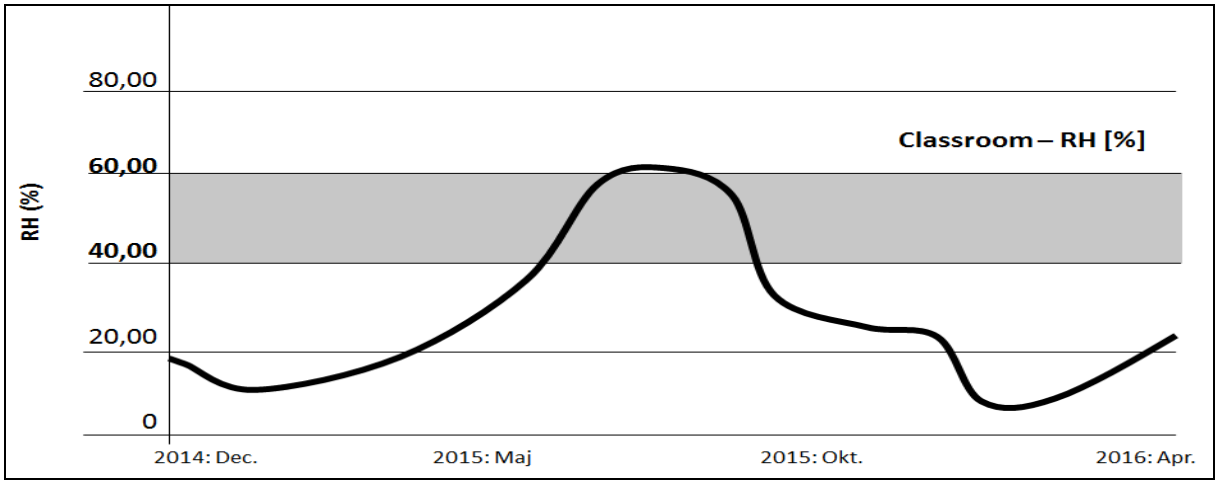

FIGURE 8: The relative humidity in a school building from December 4, 2014 –April 19, 2016.

TABLE 2
The relative humidity and the air temperature in a school building.

Period: December 4, 2014 – April 19, 2016.		
	RH (%)	**°C**
Average	32,6	20,5
Highest	64,9	24,6
Lowest	8,3	18,6

The average for the entire performance period is 32.6%. The problems and health problems that users complain of in the questionnaire study regarding,

- Health problems (part 1 of the questionnaire) and
- Comfort (area 3 of the questionnaire)

the source of the problem has been identified by measurement of the relative humidity [19-28]. The problem of the dry air environment is more difficult to deal with in the framework of this project, as this is preferably controlled by the air flows prevailing in the building. The reason for these air flows is the mechanical ventilation system installed. The installation is based on the requirements authorities make regarding air flows and it is these air flows that are the cause of the dry air prevailing in school [28].

Regarding the guidelines that the Swedish authorities have to abide by, there is preferably two laws in question:

1) *Miljöbalken* (The Environmental Code) and with reference to Chapter 9, § 9, prompting the following: Residential and commercial buildings for public purposes shall be operated in such a way that risks to human health arises and kept free of vermin and other pests. The owner or utilization holders of the affected property shall, with regard to human health, take the steps reasonably required to prevent the creation or elimination of the inconvenience that exist [34].
2) Arbetsmiljölagen (The Work Act) announces that the Act's purpose is to prevent illness and accidents at work and generally to achieve a good work [35].

These laws are fairly clear and the conditions prevailing at the relevant school and presented in ”Fig. 3 and 8”, and before the action in ”Fig. 5 and 6”, should not be the subject of school because the above laws should be followed. How do the responsible regulatory authorities act in this matter? Checks are carried out regularly in schools and the local authority is involved and follows the instructions of the central authority. The central authorities decide on national enforcement projects, programs aimed at developing indoor environment in schools and local regulators to check that operations in the geographical area they are assigned follow these directives [36]. The background to the central government projects are the health problems that exist and which they believe are linked to children's working environment in the school. The overall objective of the central authority is that the indoor environment for children and young people in Sweden's schools will be

improved and that the Environmental and safety legislation requirements on the indoor environment can be met. With these achievements, the central authority to get an overall picture of the situation of the relationship in the Swedish school environment and provide a picture of how the local supervisory units require schools with deficiencies [37, 38]. The local regulators announced property owner after the inspection of the schools involved in this project that "they believe that the school worked well and it has generally a well-functioning self-control" [39]**.** Supervisory inspection was carried out 2 months prior to the measurements reported in ”Fig .3”, that is, when the high emission levels and dry air prevailing in school. It can be concluded that the supervisory authority of the inspection and its management could not detect the serious deficiencies in the school regarding air environment. This indicates that there are deficiencies in the Swedish official system and chances are that the image the central government holds does not match the reality of the Swedish school population. Is the relationship in this way the central authority receives a distorted picture of the situation in the Swedish school population, meaning limited opportunities to, considering the problem area, give any directives needed. This study clearly shows that the current law system does not reach out to the school that this project studied, and an unhealthy environment exists without the regulator intervenes.

IV. CONCLUSION

As seen from the results in ”Fig 3 and 8”**,** the air environment of the school is not good. The situation with regard to the high emission quantities and the low relative humidity must be highlighted and addressed in an entirely different way than is the case today. Repeated complaints about health problems, due to staying in a particular indoor environment is an issue that is constantly discussed and the problem situation only increases. What is lacking in a society that is generally considered to be both high-tech and with well-educated people? As shown the supervisory authority in the school takes no account to the deficiencies identified in this project;

- the high particulate emissions quantities and
- low relative humidity.

Instead the central authority focus on other parameters they consider to be the cause of problems and that is the actual building construction [13, 14, 15]. The following can be stated:

A. Problems with the air environment prevailing in the school, but the supervisory authority doesn´t intervene despite inspections [39].

B. The legal system does not reach out to the school that this project concerns and the local supervisory authority cannot handle the problem [39, 40].

C. This project has identified deficiencies in the environment, but despite this information the local supervisory authority refuses to acknowledge this information. Instead, the local authorities refer to the central authorities´ directives [40] and it can be stated that something in the Swedish authority's system fails.

It is important for those who are staying in school buildings that the authorities' actions are not deficient. If so, it is necessary to identify and also correct these deficiencies. Regarding emission load in the air this project shows that it is possible to correct, see ”Fig. 6”.

However, it is more difficult to rectify the dry air indoors, which studies show is caused by the mechanical systems installed in buildings [28, 41]. One problem is that the authorities require high air flows, but there are questions regarding these flow requirements and it is also necessary to evaluate this [13, 14, 15]. In the future, we need a careful analysis of what it is lacking in the Swedish system. A functional working model must be developed and the measuring methods used must be based on scientific working hypotheses, and clarity of dose-response relationships is required for factual development. Otherwise, the risk is great for emission loaded indoor environments with poor hygiene that spread illness, diseases and epidemics continue to develop. The problem is further enhanced by the dry air environment that the Swedish regulations are creating, i.e. dry air combined with high amounts of emissions is a very unfortunate combination.

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