Journal of Environmental Protection, 2016, 7, 1730-1744
http://www.scirp.org/journal/jep
ISSN Online: 2152-2219
ISSN Print: 2152-2197

# Indoor Air Environment—Hygienic Factors and Limits

**Thomas Alsmo**

Library Research, Olten, Switzerland
Email: administrator@libraryresearch.eu

**How to cite this paper:** Alsmo, T. (2016) Indoor Air Environment—Hygienic Factors and Limits. *Journal of Environmental Protection*, **7**, 1730-1744.
http://dx.doi.org/10.4236/jep.2016.712140

**Received:** September 16, 2016
**Accepted:** November 11, 2016
**Published:** November 14, 2016



## Abstract

Complaints on the indoor environment of the residents in recent decades have become a common problem in the Swedish housing. The buildings themselves are said to be the cause of problems, and it is given a vague picture of both the exposure and the effect of the problems. The symptoms that residents and users state are often common in the population such as headache, fatigue, mucosal disorders and skin problems. It must be considered that the air that people routinely inhale contains impurities of various kinds, both in- and outdoors. An important source of contamination indoors is the microorganisms that are pathogenic, so called agents. Examples of infectious agents are viruses, fungi, bacteria and protozoa. The purpose of this project is to examine whether a physical measurement is possible to obtain for identifying a possible threshold level of air pollution in the indoor environment. In this study, carried out through physical measurements, the results show major deficiencies in the Swedish school environment. If we study the emissions in the important health-related size range of particles larger than 5.0 microns, before and after measures, the environmental benefits are clarified since over 90% of contaminants larger than 5.0 microns have been eliminated.

## Keywords

Hygiene and Health, Indoor Air Quality, Indoor Humidity, Indoor Temperature

## 1. Introduction

Complaints on the indoor environment of the residents in recent decades have become a common problem in the Swedish housing. The buildings themselves are said to be the cause of problems, and it is given a vague picture of both the exposure and the effect of the problems. The symptoms that residents and users state are often common in the population such as headache, fatigue, mucosal disorders and skin problems. A fifth of the adult population in Sweden say they have one or more of these symptoms which they relate to the indoor environment in the home, school or work. There is a national authority on matters relating to safety, health and object-borne infection. These authorities

- are bringing forth directives and the requirements to be imposed on the indoor environment.
- compile the local supervisory work undertaken to create a comprehensive national picture of the problem area [1] [2] [3].

The Swedish authorities' annual monitoring of the area announced that complaints about the indoor environment are essentially about moisture and mold, ventilation and emissions and odor. The problems are so extensive that national enforcement projects are to come to terms with them. In the years 2014-2015, a project was focused on schools that are considered to be a sensitive environment, given the situation for children. The results show that many schools do not meet the law requirements to prevent problems with the indoor environment [4]. The basic legislation is the Environmental Code [5] and the Work Environment Act [6] which are the starting points for any oversight that occurs in health. They aim to promote sustainable development so that present and future generations can live in a healthy environment. Local supervisors should check that the laws are followed, provide information and advice and check that the activities are not involving a nuisance to human health [5] [6]. A basic problem is that it is not possible to determine what is causing health problems, that is, what kind of hygienic deficiency that may exist in the environment that cause people harm. Hygiene is a wide term which basically means cleaning the body or the human environment. What level of cleanliness that can be considered hygienic depends on what is the context. In a broader sense, the concept of activities aimed at removing any unwanted that is harmful or offensive, whether it physically exists in reality or whether it is more mentally linked. Hygiene can in this respect be a sensitive concept because it is not only about what is actually harmful, but also has to do with deeper psychological factors. However, the concern of this project is not the psychological factors, but only the physically real emissions that spread illness in buildings. The air that people normally breathe regularly contains of pollution of various kinds, both indoors and outdoors. Air pollution is present in two forms, gases and particles. Content and distribution are factors that affect air quality. An important source of contamination indoors is the microorganisms that are pathogenic and examples are viruses, fungi, bacteria and protozoa. These are often spread through airborne particles, preferably those larger than 5.0 microns. That means these particles are an important factor in the air since they are carriers of these microorganisms. Moreover, considered the situation for those suffering from allergy and asthma, these particles are also spreaders of allergens [7]. Particles in the air also affect the well-being of people through the respiratory system, cardiovascular system and studies show the link with lung cancer. It should be stressed that the impact on health is proportional to the concentration of particles. Even brief exposure to high concentrations of PM10 (PM10 = particles less than 10 microns) can lead to serious effects [8]. Overall, it is important that the amount of particles can be kept as low as possible. The base of the indoor air is the air surrounding a building. Regarding particles they are a normally occurring air pollution and outdoors are several different particle sources, including the burning of fossil fuels and biofuels, road and vehicle wear and tear, road sand, forest fires, sea, desert sand and other soil materials. Emission sources vary between countries and especially the size determines how far a particle can be transported. Particles less than 10 micrometers (PM10.0) can be divided into three different size ranges, *coarse*, *fine* and *ultrafine*.

1) Coarse particles consist of sizes between about PM10 (less than 10.0 microns) and PM1 (less than 1.0 microns) and consist mainly of particles formed by including wear and tear of the roadway, brakes, tires, and sand on roads and streets.
2) Fine particulate matter consists of sizes between about PM1 and PM0.1 (less than 0.1 microns) and in Sweden these particles originate mainly from emissions in other countries. Whence arrival is determined by the wind because the fine particles can stay in the atmosphere a number of days.
3) Ultra-fine particles are particles smaller than about PM0.1. These come from local vehicles, wood burning and energy facilities. The ultra-fine particles are numerically the majority of the total PM10 level [8].

As for the gaseous pollutants, it has not demonstrated any dose-response relationship, despite intensive research in recent decades in the environments that this project concerns [9]-[26]. With a dose-response relationship is meant the concentration of a substance *i.e.* pollution required to inconvenience or disease to occur. A fundamental problem for the indoor environment research is the lack of validated methods and that there are no validated limits for the air environment indoors for residential. There is a great need to be able to physically measure the indoor air environment with a view to putting a limit on the emission level indoors in homes, schools and offices.

## 2. Measurements

The purpose of this project is to investigate whether through physical measurements we can identify a possible threshold level of air pollution in the indoor environment. The project includes physical measurements in 45 schools, school areas where students normally stay. The school buildings constitute a representative sample of the Swedish conditions, both in number and in geographic distribution across the country, to obtain an idea about the hygienic status of the indoor environment in Swedish schools. It is necessary to create a suitable level sensor or appraiser for indoor air that clarifies whether deficiencies exist or not. For this purpose, it is examined whether the outdoor air can be used as a parameter to be able to make comparisons between different indoor environments. Within the framework of this project, measurements are performed in outdoor air at the 45 sites where school buildings are located. The average of these measurements are used and then evaluated if this might be the appropriate method to use as a parameter in the evaluation of indoor air. Emission measurements are performed using the TSI instrument laser sampler model 8220. The instrument measures six compartment sizes particles, 0.3, 0.5, 1.0, 3.0, 5.0 and 10.0 microns. At each test site an instrument is programmed for a measurement time of one minute per measurement. A series of measurements comprises five individual measurements, which means that approximately 15 liters of air is treated. For the five individual values are calculated an average for all test sites for each school and used as a comparison value in the assessment of the various school environments. The results of the measurements in this project are reported in the number of particles per cubic meter of air. The measurement is complemented by visual inspection of the school premises and the objective is to visually identify sources of hygiene deficiencies. If it appears from the measurements and the visual inspection that there is need for improvements to reduce the amount of pollutants in the air, a few representative buildings are selected from the 45 units that are fixed with the aim of reducing the amount of pollutants in the air. All the results from the measurement in the school environment is based on an activity that is comparable to the activity normally pursued in the school environment, but with an important difference and that is the number of people present. When measurements are conducted only a few people are involved, unlike during normal activities when far more people are staying at the premises. It is important to know that each person affects the environment. All cells of a human being, except for neurons, are continually renewed. Old skin is continuously replaced by newly formed skin.

As a rule a normal person exchanges an entire outer layer of skin after four days. The following number of particles larger than 0.5 microns, the body gets rid of during different movements [20].

- Sedentary: 100 000 particles per minute.
- Seated, rotating arm movements: 500,000 particles per minute.
- Stand up, sit down: 2.5 million particles per minute.
- Climbing stairs, running: 10,000,000 particles per minute.

This means that the emission supplement that normally occurs when the activity is in progress will not be included in the measurements in this study.

## 3. Results

The base of the air environment indoors is the air surrounding the building and as shown in Table 1 and in the graph in Figure 1 the emission level in the outdoor environment is high in the smallest size range. As shown in Table 1 the levels vary widely, preferably in the smaller ranges to subside in the larger ones. To eliminate the various instantaneous changes in the outside air from one point to another, the average value of all the 45 locations is used. The reason for this is that it evens out the level and variety of extreme values can be excluded that would otherwise pose a risk in a direct comparison with the outdoor environment of the respective test site. The compilation of the average value of the buildings studied in this project is presented in Table 2 and with the graphs in Figure 2 where the emission amount indoors and outdoors is compared. The graphs in Figure 2 show higher emission level outdoors in the smallest size range, to the greater ranges diverge to the detriment of the indoor environment. The reason

**Table 1.** Particulate emissions from outdoor air, each fraction larger than 0.3 - 10.0 microns (number of particles per cubic meter), the average value of a series of measurements at 45 locations in Sweden.

| Unit | >0.3 | >0.5 | >1.0 | >3.0 | >5.0 | >10.0 |
|---|---|---|---|---|---|---|
| 1 | 27,725,000 | 1,749,000 | 718,000 | 15,000 | 5000 | 1000 |
| 2 | 50,277,000 | 4,020,000 | 174,000 | 29,000 | 12,000 | 4000 |
| 3 | 20,998,000 | 2,079,000 | 256,000 | 84,000 | 27,000 | 3000 |
| 4 | 53,491,000 | 3,882,000 | 151,000 | 27,000 | 10,000 | 2000 |
| 5 | 22,644,000 | 2,015,000 | 229,000 | 72,000 | 25,000 | 4000 |
| 6 | 23,572,000 | 1,703,000 | 191,000 | 62,000 | 27,000 | 4000 |
| 7 | 34,004,000 | 3,912,000 | 818,000 | 384,000 | 174,000 | 29,000 |
| 8 | 17,828,000 | 4,502,000 | 1,520,000 | 669,000 | 56,000 | 9000 |
| 9 | 21,097,000 | 3,809,000 | 485,000 | 112,000 | 42,000 | 9000 |
| 10 | 28,424,000 | 2,216,000 | 172,000 | 53,000 | 16,000 | 3000 |
| 11 | 4,104,000 | 461,000 | 83,000 | 30,000 | 10,000 | 2000 |
| 12 | 6,800,000 | 1,703,000 | 314,000 | 17,000 | 3000 | 1000 |
| 13 | 12,111,000 | 4,995,000 | 1,489,000 | 165,000 | 30,000 | 1000 |
| 14 | 38,473,000 | 3,523,000 | 287,000 | 61,000 | 21,000 | 5000 |
| 15 | 6,194,000 | 708,000 | 78,000 | 22,000 | 8000 | 0 |
| 16 | 101,243,000 | 17,675,000 | 900,000 | 88,000 | 40,000 | 20,000 |
| 17 | 8,037,000 | 663,000 | 145,000 | 52,000 | 20,000 | 4000 |
| 18 | 19,694,000 | 12,980,000 | 3,010,000 | 658,000 | 73,000 | 1000 |
| 19 | 4,845,000 | 1,775,000 | 748,000 | 98,000 | 16,000 | 2000 |
| 20 | 2,905,000 | 739,000 | 380,000 | 188,000 | 95,000 | 25,000 |
| 21 | 6,139,000 | 520,000 | 104,000 | 4000 | 1000 | 0 |
| 22 | 24,007,000 | 1,236,000 | 152,000 | 40,000 | 14,000 | 4000 |
| 23 | 6,783,000 | 1,665,000 | 801,000 | 204,000 | 71,000 | 13,000 |
| 24 | 12,283,585 | 1,418,047 | 479,385 | 59,951 | 19,362 | 5580 |
| 25 | 1,600,300 | 511,057 | 209,921 | 53,823 | 22,131 | 4895 |
| 26 | 2,867,000 | 138,806 | 69,046 | 23,627 | 9293 | 1844 |
| 27 | 2,371,000 | 1,380,000 | 256,609 | 84,874 | 38,410 | 8364 |
| 28 | 6,992,000 | 1,902,000 | 609,000 | 78,000 | 23,000 | 4000 |
| 29 | 7,835,000 | 3,377,000 | 1,213,000 | 193,000 | 52,000 | 14,000 |
| 30 | 198,900,000 | 17,796,000 | 2,115,000 | 188,000 | 31,000 | 2000 |
| 31 | 5,646,000 | 1,814,000 | 641,000 | 78,000 | 21,000 | 2000 |

**Continued**

| | | | | | | |
|---|---|---|---|---|---|---|
| 32 | 2,882,000 | 982,000 | 651,000 | 82,000 | 15,000 | 1000 |
| 33 | 1,631,000 | 224,000 | 138,000 | 64,000 | 12,000 | 0 |
| 34 | 6,254,000 | 999,000 | 226,000 | 37,000 | 12,000 | 2000 |
| 35 | 54,620,000 | 6,429,000 | 654,000 | 136,000 | 65,000 | 11,000 |
| 36 | 18,402,000 | 2,285,000 | 341,000 | 48,000 | 15,000 | 3000 |
| 37 | 17,432,000 | 2,001,000 | 719,000 | 150,000 | 6000 | 2000 |
| 38 | 39,711,000 | 3,030,000 | 185,000 | 29,000 | 15,000 | 4000 |
| 39 | 29,982,000 | 2,790,000 | 437,000 | 98,000 | 32,000 | 3000 |
| 40 | 54,912,000 | 3,288,000 | 261,000 | 17,000 | 9000 | 2000 |
| 41 | 22,614,000 | 3,901,000 | 249,000 | 172,000 | 24,000 | 4000 |
| 42 | 25,712,000 | 1,356,000 | 201,000 | 159,000 | 29,000 | 4000 |
| 43 | 34,431,000 | 4,023,000 | 799,000 | 285,000 | 89,000 | 29,000 |
| 44 | 7,801,000 | 2,073,000 | 401,000 | 16,000 | 3000 | 1000 |
| 45 | 26,430,000 | 4,011,000 | 419,000 | 128,000 | 34,000 | 3000 |
| Average outdoors | 24,949,000 | 3,206,000 | 544,000 | 118,000 | 30,000 | 6000 |

**Table 2.** Particulate emissions in 45 schools, each fraction larger than 0.3 - 10.0 microns (number of particles per cubic meter), the average value of a measurement series.

| Unit | >0.3 µm | >0.5 µm | >1.0 µm | >3.0 µm | >5.0 µm | >10.0 µm |
|---|---|---|---|---|---|---|
| 1 | 8,138,000 | 5,014,000 | 4,374,000 | 3,856,000 | 3,286,000 | 2,297,000 |
| 2 | 36,798,000 | 30,056,000 | 28,375,000 | 25,383,000 | 20,752,000 | 12,480,000 |
| 3 | 13,808,000 | 8,792,000 | 7,629,000 | 6,604,000 | 5,346,000 | 3,145,000 |
| 4 | 67,085,000 | 57,661,000 | 52,531,000 | 44,348,000 | 33,189,000 | 15,219,000 |
| 5 | 21,104,000 | 11,210,000 | 9,491,000 | 8,084,000 | 6 300 000 | 3,386,000 |
| 6 | 9,979,000 | 1,942,000 | 1,026,000 | 711,000 | 515,000 | 315,000 |
| 7 | 21,366,000 | 16,607,000 | 15,140,000 | 13,252,000 | 10,723,000 | 6,436,000 |
| 8 | 23,509,000 | 17,340,000 | 16,303,000 | 15,132,000 | 12,930,000 | 7,681,000 |
| 9 | 13,259,000 | 4,301,000 | 2,429,000 | 1,644,000 | 1,195,000 | 653,000 |
| 10 | 15,909,000 | 11,935,000 | 8,580,000 | 7,435,000 | 6,283,000 | 3,520,000 |
| 11 | 9,774,000 | 6,820,000 | 5,655,000 | 4,805,000 | 4,043,000 | 2,512,000 |
| 12 | 18,834,000 | 14,396,000 | 11,961,000 | 10,211,000 | 7,792,000 | 4,508,000 |
| 13 | 10,996,000 | 6,252,000 | 3,599,000 | 3,000,000 | 2,703,000 | 1,898,000 |
| 14 | 4,360,000 | 3,065,000 | 2,619,000 | 2,356,000 | 1,983,000 | 1,194,000 |
| 15 | 16,015,000 | 10,613,000 | 7,335,000 | 5,974,000 | 4,691,000 | 2,550,000 |
| 16 | 16,489,000 | 6,770,000 | 5,168,000 | 3,751,000 | 2,707,000 | 1,513,000 |

**Continued**

| | | | | | | |
|---|---|---|---|---|---|---|
| 17 | 3,959,000 | 2,001,000 | 1,919,000 | 1,815,000 | 1,674,000 | 1,208,000 |
| 18 | 3,922,000 | 1,221,000 | 935,000 | 805,000 | 698,000 | 523,000 |
| 19 | 5,268,000 | 4,899,000 | 4,564,000 | 3,469,000 | 2,388,000 | 1,014,000 |
| 20 | 5,811,000 | 2,859,000 | 2,246,000 | 1,695,000 | 1,216,000 | 676,000 |
| 21 | 4,755,000 | 2,791,000 | 1,945,000 | 1,333,000 | 898,000 | 444,000 |
| 22 | 12,282,000 | 8,158, 00 | 6,599,000 | 5,661,000 | 4,803,000 | 3,037,000 |
| 23 | 51,320,000 | 16 484 000 | 11 664,000 | 9,884,000 | 8,111,000 | 4,948,000 |
| 24 | 52,420,000 | 11 166 000 | 5,787,000 | 4,749,000 | 3,730,000 | 2,085,000 |
| 25 | 51,017,000 | 12,511,000 | 7,355,000 | 5,689,000 | 4,108,000 | 1,987,000 |
| 26 | 34,325,000 | 22,520,000 | 20,997,000 | 19,170,000 | 16,338,000 | 10,566,000 |
| 27 | 9,328,000 | 4,418,000 | 3,864,000 | 3,466,000 | 2,957,000 | 2,026,000 |
| 28 | 9,500,000 | 7,315,000 | 5,849,000 | 4,182,000 | 3,074,000 | 2,007,000 |
| 29 | 25,652,000 | 22,650,000 | 20,095,000 | 16,494,000 | 12,671,000 | 6,817,000 |
| 30 | 5,450,000 | 4,077,000 | 3,678,000 | 3,211,000 | 2,532,000 | 1,498,000 |
| 31 | 14,511,000 | 3,399,000 | 2 147 000 | 1 449 000 | 1,016,000 | 556,000 |
| 32 | 9,710,000 | 7,308,000 | 5,980,000 | 3,988,000 | 2,587,000 | 1,329,000 |
| 33 | 10,927,000 | 8,564,000 | 7,575,000 | 6,738,000 | 5,763,000 | 4,315,000 |
| 34 | 45,557,000 | 42,070,000 | 37,797,000 | 32,378,000 | 23,330,000 | 11,659,000 |
| 35 | 7,116,000 | 5,699,000 | 4,727,000 | 3,582,000 | 2,527,000 | 1,421,000 |
| 36 | 2,838,000 | 2,642,000 | 2,410,000 | 1,895,000 | 1,373,000 | 767,000 |
| 37 | 14,002,000 | 11,062,000 | 9,020,000 | 7,637,000 | 6,216,000 | 3,617,000 |
| 38 | 16,423,000 | 11,438,000 | 10,308,000 | 4,126,000 | 2,247,000 | 1,065,000 |
| 39 | 17,604,000 | 14,334,000 | 12,278,000 | 10,282,000 | 6,127,000 | 2,886,000 |
| 40 | 19,896,000 | 16,650,000 | 14,912,000 | 12,726,000 | 9,731,000 | 6,166,000 |
| 41 | 18,551,000 | 12,509,000 | 10,985,000 | 9,253,000 | 6,978,000 | 4,070,000 |
| 42 | 27,714,000 | 18,386,000 | 10,751,000 | 6,200,000 | 3,254,000 | 1,089,000 |
| 43 | 3,719,000 | 3,337,000 | 3,013,000 | 2,262,000 | 1,568,000 | 730,000 |
| 44 | 53,360,000 | 49,053,000 | 46,568,000 | 40,470,000 | 30,792,000 | 15,727,000 |
| 45 | 30,022,000 | 11,247,000 | 8,414,000 | 6,797,000 | 5,249,000 | 2,700,000 |
| Average indoors | 19,431,000 | 12,301,000 | 10,369,000 | 8,623,000 | 6,631,000 | 3,694,000 |

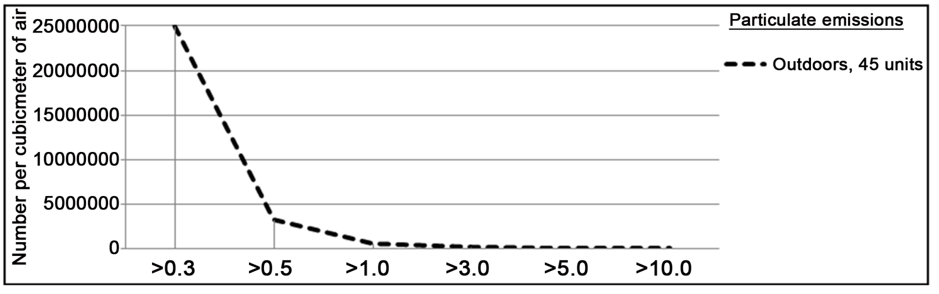


Figure 1. Emission level of outdoors, open interval larger than 0.3 - 10 microns, number of particles per cubic meter, average value from 45 geographically distributed sites in Sweden.

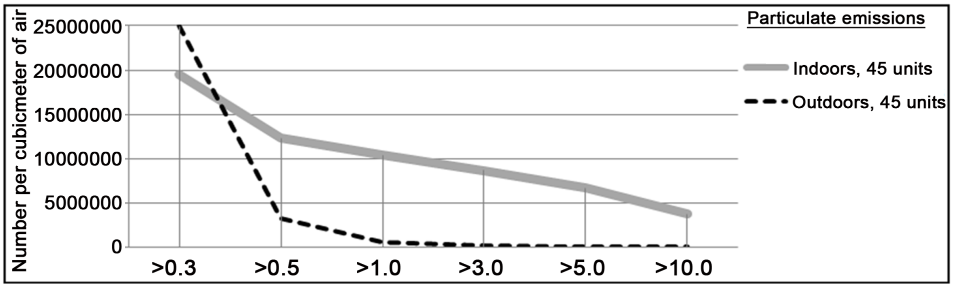


Figure 2. Emission level, open interval larger than 0.3 - 10 microns, number of particles per cubic meter, average value of outdoor air around the building and indoor air in 45 schools.

for these high emission levels indoors in the larger interval is not due to outside air, but depends on the emission sources available in the environment. An important source of contamination indoors is the microorganisms that are pathogenic, called agents, and examples of infectious agents, viruses, fungi, bacteria and protozoa. These are often spread through airborne particles, those larger than 5.0 microns. That means these particles are an important factor in the air as they are carriers of these microorganisms. Moreover, considered the situation for people suffering from allergy and asthma these particles are also spreaders of allergens [7] [20] [27]-[47]. The National Public Health Institute in Sweden showed already in 1995 that the number of particles smaller than 1.0 microns will constitute the entire 99.9% of all particles in the air [28].

In conjunction with the visual inspections of the buildings it revealed that there are a variety of materials in schools that are not used, but that it is both generates emissions and causes the environment, from a hygienic point of view, becoming overloaded and cannot be maintained to the extent required. Four of the above school environments were selected as representative units regarding emission load and where measures were taken to correct the identified deficiencies. The graphs in **Figure 3** show the emission levels of outdoor air for all 45 units and for the four selected units separately, indicating that a similar load level prevails in the air environment as the average for all 45 units. The measures taken in the 4 units consisted of cleaning up and remove the material that was not needed. Then, there are better opportunities for appropriate handling and storage of the material remained. Through these measures, opportunities are created from a hygiene perspective maintains the premises to the extent necessary, and then new measurements can be performed. Significant improvements have been achieved, results can be seen in **Table 3** and graphs in **Figure 4**, which show that the emission level indoors after measures follows the outdoor level in a satisfactory manner. The study has been conducted with physical measurements have reported significant deficiencies in the Swedish school environment. If we study the important size range larger than 5.0 microns, before and after measures, the environmental benefits is made clear since over 90% of contaminants larger than 5.0 microns have been eliminated. **Figure 5** shows all particles larger than 5.0 microns, before and after measures, of the four selected units. The result is striking, emission load of negative health topics have been reduced by over 90%. **Figure 6** reports using a logarithmic scale that allows direct comparison of each

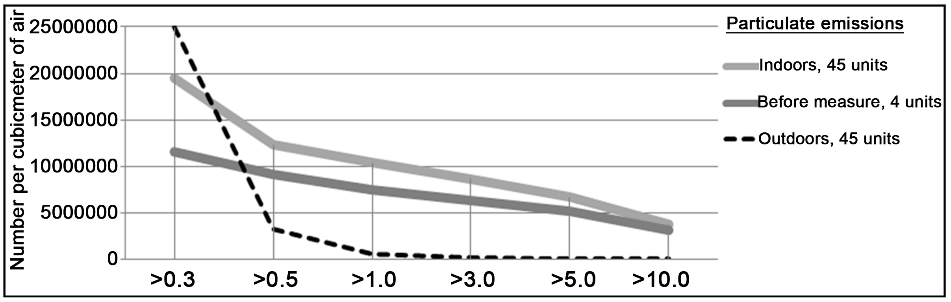


**Figure 3.** Emission level, open interval larger than 0.3 - 10 microns, number of particles per cubic meter, average value of outdoor air around the building and indoors in 45 schools, and from these four selected schools that are recognized separately.

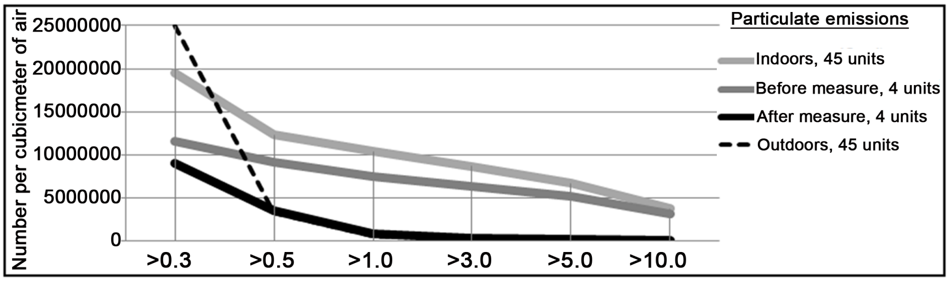


**Figure 4.** Emission level, open interval larger than 0.3 - 10 microns, number of particles per cubic meter, average value of outdoor air around the building and indoors in 45 schools. From these 45 buildings 4 selected schools that are recognized separately in the diagram before and after measure.

**Table 3.** Particulate emissions, each fraction larger than 0.3 - 10.0 microns (number of particles per cubic meter), the average value for four schools, before and after measure.

| | >0.3 | >0.5 | >1.0 | >3.0 | >5.0 | >10.0 |
|---|---|---|---|---|---|---|
| ***Before*** | | | | | | |
| Unit 10 | 15,909,000 | 11,935,000 | 8,580,000 | 7,435,000 | 6,283,000 | 3,520,000 |
| Unit 19 | 5,268,000 | 4,899,000 | 4,564,000 | 3,469,000 | 2,388,000 | 1,014,000 |
| Unit 33 | 10,927,000 | 8,564,000 | 7,575,000 | 6,738,000 | 5,763,000 | 4,315,000 |
| Unit 37 | 14,002,000 | 11,062,000 | 9,020,000 | 7,637,000 | 6,216,000 | 3,617,000 |
| Average | 11,526,500 | 9,115,000 | 7,434,750 | 6,319,750 | 5,162,500 | 3,116,500 |
| ***After*** | | | | | | |
| Unit 10 | 18,271,000 | 10,211,000 | 2,587,000 | 517,000 | 197,000 | 48,000 |
| Unit 19 | 4,473,000 | 1,434,000 | 109,000 | 64,000 | 34,000 | 16,000 |
| Unit 33 | 5,998,000 | 843,000 | 202,000 | 101,000 | 68,000 | 41,000 |
| Unit 37 | 7,141,000 | 1,686,000 | 396,000 | 612,000 | 459,000 | 272,000 |
| Average | 8,970,750 | 3,543,500 | 823,500 | 227,333 | 189,500 | 94,250 |

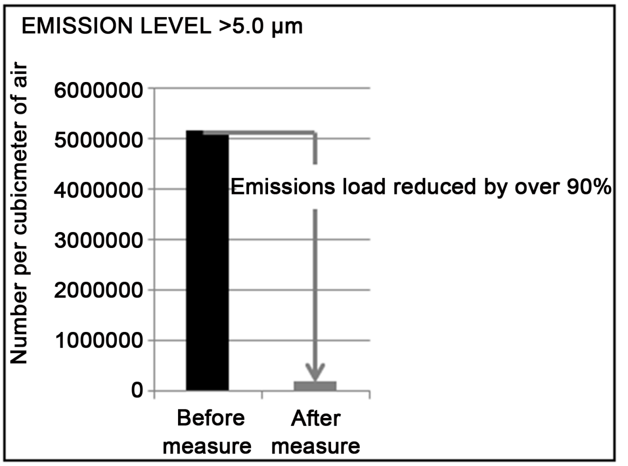


Figure 5. Particulate emissions in the open interval larger than 5.0 microns, before and after measure.

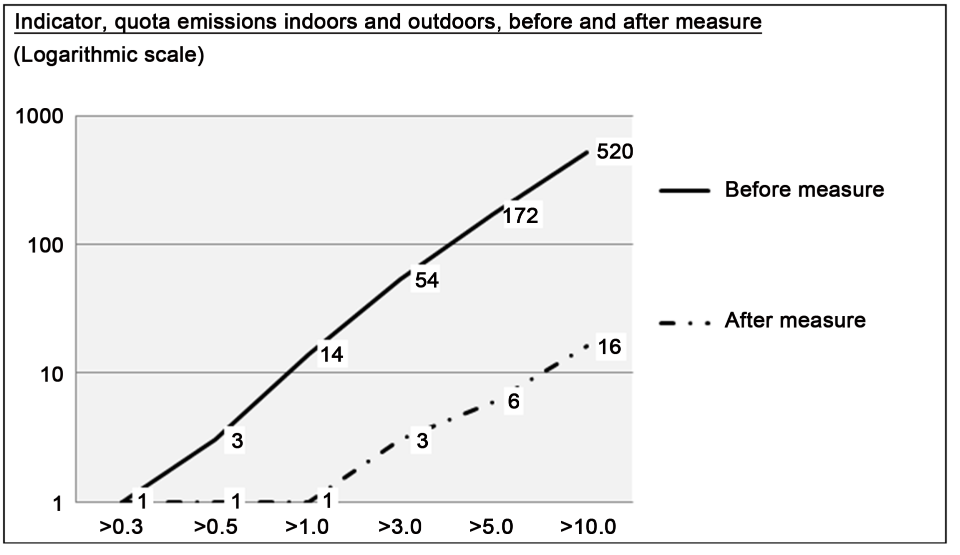


Figure 6. Quota, particulate air pollution, possible level for each fraction larger than 0.3 - 10.0 microns. Results for indoor- and outdoor air from four schools, before and after measure.

fraction and clarifies the big health gain achieved. The results of this study show that the curve for action in Figure 6 is a perfectly level sensor for how many emissions should be tolerated in the Swedish residential and school environment. These results are also shown in Table 4.

## 4. Conclusions

The results presented in this project show that outdoor air can be advantageously helpful in the evaluation of the indoor environment. By using a plurality of values from the outdoor environment, a neutral value is created, a constant, which eliminates the instantaneous fluctuations that occur in the outdoor air from time to another. We use the average of all 45 sites outliers removed and instead use this constant to the respective

**Table 4.** Quota, particulate air pollution, possible level for each fraction larger than 0.3 - 10.0 microns. Results for indoor- and outdoor air from four schools, before and after measure.

| | >0.3 | >0.5 | >1.0 | >3.0 | >5.0 | >10.0 μm |
|---|---|---|---|---|---|---|
| ***Before*** | | | | | | |
| Unit 10 | 0 | 4 | 16 | 63 | 209 | 587 |
| Unit 19 | 0 | 1 | 8 | 29 | 80 | 169 |
| Unit 33 | 0 | 3 | 14 | 57 | 192 | 719 |
| Unit 37 | 0 | 3 | 17 | 65 | 207 | 603 |
| ***After*** | | | | | | |
| Unit 10 | 0 | 3 | 5 | 4 | 7 | 8 |
| Unit 19 | 0 | 0 | 0 | 0 | 1 | 3 |
| Unit 33 | 0 | 0 | 0 | 1 | 2 | 7 |
| Unit 37 | 0 | 0 | 0 | 5 | 15 | 45 |

measured level of a building, the calculation done by the simple formula, "amount of emission indoors divided by constant". The four selected units that are used to evaluate this process recognize that the results are clarified by the difference between the two graphs in **Figure 6** drastically increasing in the larger particle size fractions. The level values for emissions larger than 5.0 microns are 172 before measures and 6 after measures and emission levels for larger than 10.0 microns are 520 before measures and 16 after measures. As the results of this study show the air environment in the Swedish school buildings is congested and unhealthy particulate emissions are very high compared to what is possible to achieve. It indicates that there are some deficiencies in the Swedish system. **Figure 5** shows that the emission amount can be significantly improved in terms of health in the sensitive range larger than 5.0 microns. The emission load has been reduced by over 90% and this with cost-effective measures. An important question is how the current situation of high emission levels can proceed. Results show that this relationship was identified already in the 1990s, with no reaction from the Swedish authorities, who maintained the building focused direction, without further examination [48]. In direct inquiries to the relevant authorities on two occasions, in 2007 and 2014, what they do to remedy the grievance that this problem was neglected. Instead, they refer to others, in this context, non-validated parameters and measurement methods, with their view that measures must be made in the building construction [49] [50] [51]. A basic question is who owns the problem, the business or the property owner. According to the authorities, property owners in Sweden has a so-called reverse burden of proof, *i.e.* when the diffuse health problems related to indoor environment occurs, the property owner shall report to the Authority that they, as the authorities put it, "have a functioning self-control" [52]. The situation is often difficult to interpret when problems occur. What does the authority require from the property owner? This is by no means clear. However property owners are, for unclear reasons, forced to extensive technical measures by rebuilding and strengthening ventilation with mechanical systems. These are measures that often require large financial resources. The results achieved are difficult to identify and problems usually reappear after some time with new requirements on the property owner [53] [54] [55] [56]. It is very important for the development of the indoor environment in Swedish buildings, to critically examine the methods used today. Can there be deficiencies in the working models and analysis procedures used? Are important parameters overlooked that affect the indoor environment and human health, but not related to deficiencies in building design? The working model must not be too tight, which means that critical parameters are not included, which misleads development. There are fundamental deficiencies in the working methods that the authorities now require. In this context, not performing necessary technical measures will ultimately affect those staying in the building [51] [57] [58] [59] [60].

- It is important to state what affects the environment in buildings, *i.e.* which is the emission sources.
- The hypothesis should not only focus on people, with an emphasis on the health problems found in an inadequate building construction.
- What are the conditions that the working model to work as crucial parameters omitted?

The model must of course be complete and correctly account for all the sources of the problems. In this context, it means to take into account the total human environment, the activities in the building and the building itself. Apart from the large waste of resources that occurs in connection with meaningless technical measures, it becomes ultimately the occupants of the premises that suffer when the real weaknesses are not taken into account since the actual emission sources are not taken into account.

## References


[1] Merritt, A.S. and Emenius, G. (2013) Environmental Health Report (Miljöhälsorapport). Institute of Environmental Medicine, Karolinska Institutet, Stockholm, Sweden. (In Swedish)

[2] The Public Health Agency of Sweden. (In Swedish)
https://www.folkhalsomyndigheten.se/livsvillkor-levnadsvanor/miljohalsa-och-halsoskydd/inomhusmiljo-allmanna-lokaler-och-platser/
https://www.folkhalsomyndigheten.se/livsvillkor-levnadsvanor/miljohalsa-och-halsoskydd/inomhusmiljo-allmanna-lokaler-och-platser/tillsynsvagledning-miljobalken/

[3] Swedish Work Environment Authority. Sick-Buildings.
https://www.av.se/inomhusmiljo/inomhusmiljo-och-halsobesvar/

[4] The Environmental Goals. Annual Follow-Up of Sweden's Environmental Quality Objectives and Milestones 2016, Report 6707 Sides 267 - 268, Mars 2016, The Swedish Environmental Protection Agency.

[5] Environmental Code (Miljöbalken), Swedish Code of Statutes 1998:808 (Svensk författningssamling 1998:808), Ministry of the Environment and Energy (Miljö-och energidepartementet), Government Offices (Regeringskansliet/Lagrummet.se). (In Swedish)
http://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/miljobalk-1998808_sfs-1998-808

[6] The Work Environment Act (Arbetsmiljölagen), Swedish Code of Statutes 1977:1160 (Svensk

författningssamling 1977:1160), Ministry of Labour (Arbetsmarknadsdeartimentet), (Regeringskansliet/Lagrummet.se). (In Swedish)
https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/arbetsmiljolag-19771160_sfs-1977-1160

[7] Ljungqvist, B., Nydahl, R. and Reinmüller, R. (1989) Measurement in Rooms with Increased Purity Requirements (Mätteknik i rum med förhöjda renhetskrav). Royal Institute of Technology in Stockholm och Kabi Stockholm. (In Swedish)

[8] Lundberg, I. and Johansson, J. (2002) The Amount of Harmful Particles in the Air Must Be Reduced (Mängden skadliga partiklar i luften måste minska). County Board in Stockholm (Länsstyrelsen), Sweden.

[9] Wålinder, R. and Friis, L. (1999) Medical Investigation of Indoor Related Disorders 5/99 (Medicinsk utredning av inomhusrelaterade besvär). Occupational and Environmental Medicine, Uppsala, Sweden. (In Swedish)

[10] Brauer, C. (2005) The Sick Building Syndrome Revisited. Department of Occupational Medicine, Copenhagen University, Denmark, 2005

[11] Thörn, Å. (1999) The Emergence and Preservation of Sick Building Syndrome. Department of Public Health Sciences, Division of Social Medicine, Karolinska Institute.

[12] Stridh, G. (2003) Are We Measuring the Chemistry for Floor Coverings and How We Interpret in This Case, Measurement Results (Skall vi mäta kemin under golvbeläggningar och hur tolkar vi I så fall mätresultat)? Inomhusklimat 203, sidor 102 - 108, A Wellness and Healthcare Center, Örebro University Hospital, Sweden. (In Swedish)

[13] Eriksson, B., Snaar, J. and Wärn, B. (1994) Environmental and Quality of Building Repairs (Miljö-och kvalitetsmärkning av byggreparationer). Sides 22 - 23, Folksams Research Foundation, Stockholm, Sweden. (In Swedish)

[14] Alsmo, T. (1994) A Study with Questionnaires and Particle Measurements (En studie med enkäter och partikelmätningar). Division of Construction Management, Royal Institute of Technology, Stockholm, Sweden. (In Swedish)

[15] Alsmo, T. and Holmberg, S. (2007) Sick Buildings or Not: Indoor Air Quality and Health Problems in Schools. *Indoor and Built Environment*, **16**, 548-555.

[16] Alsmo, T. and Holmberg, S. (2010) A Study of Sources of Airborne Pollutants and Poor Hygiene in Schools. *Indoor and Built Environment*, **19**, 298-304.

[17] Alsmo, T. and Alsmo, C. (2013) A Study of Hygiene in Swedish Schools and Pre-Schools-Sources of Air Pollution. *Journal of Environmental Protection*, **4**, 1349-1359.

[18] Alsmo, T. and Alsmo, C. (2014) Ventilation and Relative Humidity in Swedish Buildings. *Journal of Environmental Protection*, **5**, 1022-1036.

[19] Alsmo, T. and Alsmo, C. (2016) A Comparison of Relative Humidity between Two Swedish Buildings with Different Ventilation Solutions. *Journal of Environmental Protection*, **7**, 855-873.

[20] Ramstorp, M. (1999) Purity Technique and Clean Rooms—An Introduction (Renhetsteknik och rena rum—En introduction). Sides 17 - 18, Bioteknisk Processdesign AB, Malmö, Sweden. (In Swedish)

[21] Ekstand-Tobin, A. (1993) Correlation between Asthma and Indoor Environments (Samband mellan astma och inomhusmiljö). Borås, Building Research and SP Technical Research Institute of Sweden. (In Swedish)

[22] OSHA (1989) Carbon Dioxide, Comments from the January 19, 1989, Final Rule on Air Contaminants Project Extracted from 54FR2332 et. seq. This Rule Was Remanded by the U.S. Circuit Court of Appeals and the Limits Are Not Currently in Force.

[23] Berglund, B. and Johansson, B. (1996) Health Effects of Volatile Organic Compounds in Indoor Air. Stockholm's Universities and Karolinska Institute, Stockholm.

[24] Bornehag, C.G. and Stridh, G. (1995) Volatile Organic Compounds (VOC) in Indoor Air in the Swedish Housing (Flyktiga organiska ämnen (VOC) i inomhusluften i det svenska bostadsbeståndet). Karlstad University, Örebro University Hospital, Sweden. (In Swedish)

[25] Bornehag, C.G. (2000) Damp Buildings and Health (Fukt i byggnader och hälsa). Building Research, Stockholm, Sweden. (In Swedish)

[26] Bornehag, C.G., Sundell, J., Bonini, S., Custovic, A., Malmberg, P., Skerfing, S., Sigsgaard, T. and Verhoeff, A. (2004) Dampness in Buildings as a Risk Factor for Health Effects, EUROEXPO: A Multidisciplinary Review of the Literature (1998-2000) on Dampness and Mite Exposure in Buildings and Health Effects. *Indoor Air*, **14**, 243-257. http://dx.doi.org/10.1111/j.1600-0668.2004.00240.x

[27] Månsson, L. (1991) High-Tech Invisible Enemy (Högteknologins osynliga fiende). Corona AB, Malmö, Sweden. (In Swedish)

[28] Sundell, J. and Kjellman, M. (1995) The Air We Breathe Indoors (Luften vi andas inomhus). Public Health Institute (Folkhälsoinstitutet), Sweden. (In Swedish)

[29] Couch, R.B. (1981) Viruses and Indoor Air Pollution. *Bulletin of the New York Academy of Medicine*, **57**, 907-921.

[30] Smith, E.B. (1983) Atmospheric Factors Affecting Transmission of Infections. *The Practitioner*, **227**, 1667-1677.

[31] Hatch, M.T. and Wolochow, H. (1969) Bacterial Survival: Consequences of the Airborne State. In: Dimmick, R.L. and Akers, A.B., Eds., *An Introduction to Experimental Aero Biology*, John Wiley and Sons, New York.

[32] Anderson, J.D., Dark, E.A. and Pbto, S. (1968) The Effect of Aerosolization upon Survival and Potassium Retention by Various Bacteria. *Microbiology*, **52**, 99-105. http://dx.doi.org/10.1099/00221287-52-1-99

[33] Rosebury, T. (1947) Experimental Airborne Infection. Williams and Wilkins, Baltimore.

[34] Langmuir, A.D. (1980) Changing Concepts of Airborne Infection of Acute Contagious Diseases: A Reconsideration of Classic Epidemiologic Theories. *Annals of the New York Academy of Sciences*, **353**, 35-44. http://dx.doi.org/10.1111/j.1749-6632.1980.tb18903.x

[35] Moffet, H.L. (1980) Clinical Microbiology. J. B. Lippincott, Philadelphia.

[36] Gwaltney, J.M. (1980) Epidemiology of the Common Cold. *Annals of the New York Academy of Sciences*, **353**, 54-60. http://dx.doi.org/10.1111/j.1749-6632.1980.tb18905.x

[37] Harper, G.J. (1961) Airborne Micro-Organisms: Survival Tests with Four Viruses. *Epidemiology and Infection*, **59**, 479-486. http://dx.doi.org/10.1017/S0022172400039176

[38] Schulman, J.L. and Kilbourne, E.D. (1962) Airborne Transmission of Influenza Virus Infection in Mice. *Nature*, **182**, 1129-1130. http://dx.doi.org/10.1038/1951129a0

[39] Korsgaard, J. (1982) Preventive Measures in House-Dust Allergy. *American Review of Respiratory Disease*, **125**, 80-84.

[40] Arlian, L.G., Bernstein, I.L. and Gallagher, J.S. (1982) The Prevalence of House Dust Mites, *Dermatophagoides* spp, and Associated Environmental Conditions in Homes in Ohio. *Journal of Allergy and Clinical Immunology*, **69**, 527-532. http://dx.doi.org/10.1016/0091-6749(82)90178-6

[41] Murray, A.B. and Zuk, P. (1979) The Seasonal Variation in a Population of House Dust Mites in a North American City. *Journal of Allergy and Clinical Immunology*, **64**, 266-269. http://dx.doi.org/10.1016/0091-6749(79)90142-8

[42] Arlan, L.G., Brandt, R.L. and Bernstein, R. (1978) Occurrence of House Dust Mites, *Der-*

*matophagoides* spp. during the Heating Season. *Journal of Medical Entomology*, **15**, 35-42. http://dx.doi.org/10.1093/jmedent/15.1.35

[43] English, P.T. (1980) Medical Mycology. Edward Arnold, London.

[44] NAS (National Academy of Sciences) (1981) Indoor Pollutants. National Academy Press, Washington DC.

[45] IEC Beak Consultants Ltd. (1983) Indoor Air Quality, Cambridge Sealed Homes: A Report for Ontario Ministry of Municipal Affairs and Housing. IEC Beak, Mississauga, Ontario, October.

[46] Sheppard, D., Wong, W.S. and Uehora, C.F. (1981) Lower Threshold and Greater Bronchomotor Responsiveness of Asthmatic Subjects to Sulfur Dioxide. *American Review of Respiratory Disease*, **122**, 873-878.

[47] Zeterberg, J.M. (1973) A Review of Respiratory Virology and the Spread of Virulent and Possibly Antigenic Viruses via Air Conditioning Systems. *Annals of Allergy*, **31**, 228-234.

[48] Becker, M. (1996) The National Board of Health and Welfare (Socialstyrelsen). Indoor Environmental Studies at a nursery in Vårgårda Municipality (Inomhusmiljöundersökningar vid ett daghem I Vårgårda kommun).

[49] Lundh, A.L. (2007) Swedish Work Environment Authority. Solna, Sweden, Diarienummer: CTB 2007/35764.

[50] Haux, F. (2014) The Public Health Agency of Sweden (Folkhälsomyndigheten). Correspondence 2014-02-11.

[51] SWESIAQ, Swedish Chapter of International Society of Indoor Air Quality and Climate. http://www.swesiaq.se/ http://www.swesiaq.se/swesiaq-modellen.aspx

[52] The Public Health Agency of Sweden. https://www.folkhalsomyndigheten.se/publicerat-material/publikationer/Fastighetsagarnas-egenkontroll/

[53] Henåns School, Orust Municipality, Sweden (2012). www.orust.se

[54] Ljungbyholms Preschool, Kalmar Municipality (2011). www.kalmar.se

[55] Tallparksgårdens Retirement Home, Östhammars Municipality (2012). www.osthammar.se

[56] City Hall, Falu Municipality (2015). www.falun.se

[57] Blom, N. (2014) General Advice on Ventilation. The Public Health Agency's, FoHMFS 2014:18. The Public Health Agency of Statutes, Solna, Sweden. https://www.folkhalsomyndigheten.se/publicerat-material/foreskrifter-och-allmanna-rad/fohmfs-201418/

[58] Blom, N. (2014) The Public Health Agency of Public Moisture and Microorganisms, FoHMFS 2014:14. The Public Health Agency of Statutes, Solna, Sweden. https://www.folkhalsomyndigheten.se/publicerat-material/foreskrifter-och-allmanna-rad/fohmfs-201414

[59] Swedish Work Environment Authority, Workplace design, Provisions AFS 2009:2. https://www.av.se/globalassets/filer/publikationer/foreskrifter/arbetsplatsens-utformning-foreskrifter-afs2009-2.pdf

[60] Boverket, National Board of Housing, Building and Planning (2016). http://www.boverket.se/sv/boende/halsa--inomhusmiljo-i-ditt-boende/luft-och-ventilation-i-bostader/