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# AN INDOOR AIR QUALITY SURVEY OF TWENTY-SIX SWISS OFFICE BUILDINGS

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In an effort to characterize the major factors influencing air quality in buildings in Switzerland, 26 representative buildings were selected for this study. Each building was subjected to the same indoor air quality survey methodology. The most significant cause of air quality problems was found to be poor ventilation, followed by inadequate filtration and poor hygiene. Control of Legionella bacteria and asbestos-containing materials may also require high priority in order to prevent immediate and long term hazards to building occupants.

## INTRODUCTION

There is a continuing requirement for air quality data on buildings not classified as "sick" which are representative of buildings as a whole within a specific region or country. Currently, data on levels of many common indoor pollutants in Switzerland are sparse. In addition, it has been shown in the U.S. (1,2,3) that maintenance activities and the condition of air handling equipment can have a profound affect on indoor air quality. Information on these factors in Switzerland is equally hard to find.

This survey selected and evaluated a representative group of 26 commercial office buildings comprising a total of approximately 102,300 square meters of office space in 20 cities in Switzerland. The objective of this survey was to provide contributory data for future mitigation policies, as well as to help set guidelines for suitable ventilation rates and filtration standards in particular. These studies were carried out from the 7th of February to the 15th of March 1989. The buildings selected for this survey were of a wide variety in terms of their size, construction and use. However, a standard methodology to investigate each building was applied.

## METHODOLOGY

Although a standard approach was used to survey each building, it required flexibility to cope with different types of buildings examined.

### Initial Walk Through

Since one of the objectives of this survey was to assess maintenance standards, each study commenced with an interview with the personnel responsible for maintenance of the building. Questions were designed to elicit operative details such as system on/off times; fresh air, return air and exhaust settings; scheduled maintenance routines; and complaint areas, if any, but did not include questioning of the occupants. There was a walk through of each building to identify obvious building configurations or design features which could influence air quality in the occupied areas. This was followed by a complete visual inspection of the internals of the building's ventilation system, if any. A visual inspection was also made of the internals of the main air supply ductwork leaving each air handling unit. Where necessary, access was gained to this ductwork by the installation of a small access port and the insertion of a fiber optic borescope.

## Qualitative Sampling

In each air handling unit and main air supply duct, a series of samples were also collected on cellulose ester filters for light microscopy analysis. Surface microbe samples were collected on Random Organism Detection and Counting (RODAC) agar plates, to be subsequently incubated, counted, and identified.

A laser particle counter with a size-selective inlet for sampling particles with an aerodynamic diameter of 0.5 microns and above, was used to count particles inside the ductwork. At least two points were sampled inside each major run of ductwork. This qualitative information on the building, along with the location of the samples and the building engineer questionnaire, was prepared on a set of standard field notes to ensure consistency. In the case of buildings not equipped with forced air ventilation systems, this walk through and sampling phase was obviously more limited in scope.

## Quantitative Air Sampling

A set of locations were identified in each building to be used for quantitative airborne sampling. These locations were spread evenly throughout the study area of each building with a minimum of two locations per floor, as well as an outdoor control sample point. The following parameters were measured at each location where relevant and appropriate:

- Respirable airborne particle counts, using a piezoelectric microbalance;
- Carbon dioxide levels, using a non-dispersive infrared absorption portable gas analyzer;
- Carbon monoxide concentrations, using a controlled potential electrolysis detector;
- Airborne nicotine (after Ogden et al (4)), with a personal universal flow sampling pump;
- Temperature, using a miniature platinum Pt 100 resistance sensor; and
- Relative humidity, using a chromed layered capacitative electrode.

The following parameters were measured in at least two selected locations in each building:

- Miscellaneous gases, using Gastec calibrated detector tubes
- Airborne microbial counts, using a centrifugal air sampler employing impaction onto an agar lined drum;
- Formaldehyde, using midget impingers containing sodium bisulphite, followed by spectrophotometric analysis;
- Radon gas in basement areas, using Track-Etch radon detectors;
- A range of volatile organic compounds, using a GC/MS in one or two locations per building, plus an outside control for each city;
- Bulk asbestos analysis of any materials in the air stream of the ventilation system, or exposed to the building occupants, which were suspected of containing asbestos fibers;
- Sampling and counting of airborne asbestos fibers;
- Sampling of selected water sources, and analysis for the presence of *Legionella pneumophila*, along with a hazard assessment of the water source for possible future contamination and dissemination of this organism.

## RESULTS AND DISCUSSION

This survey yielded a large amount of data which can be broadly classified as either quantitative analytical data or more empirical assessments of the condition of the air handling systems. The quantitative data is shown in Tables I, II and III, with the qualitative data assessed and ranked on Figure 1.

Nitrogen dioxide, lower and higher range hydrocarbons, ozone, ammonia, and sulphur dioxide were not found above the detection limit of the method used and are, therefore, not included in these tables.

### TABLE I. MECHANICALLY VENTILATED AREAS

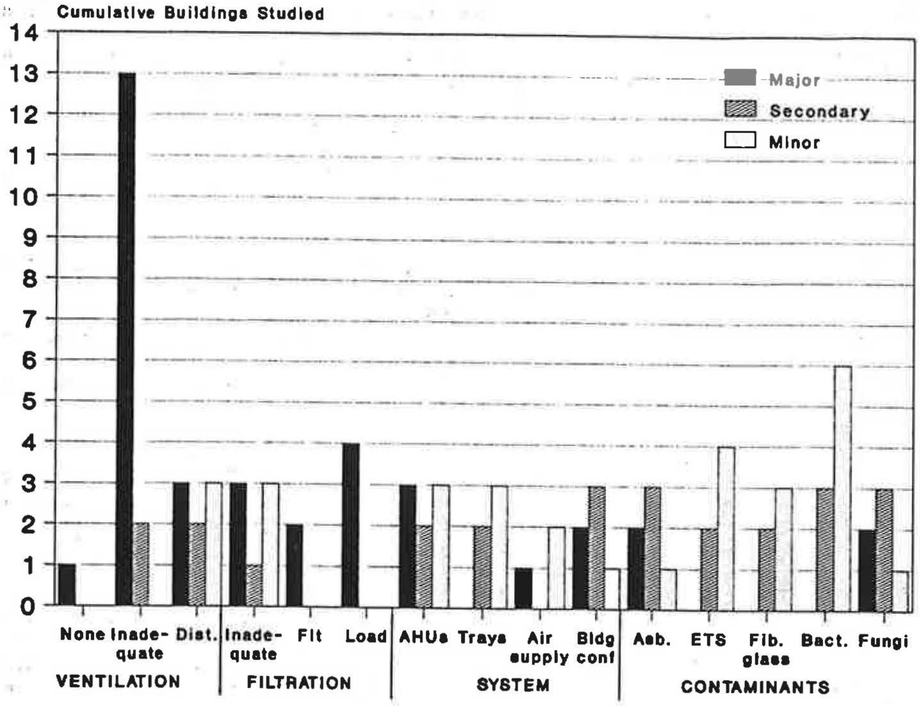
| Building Area | $CO_2$ (ppm) am | $CO_2$ (ppm) pm | CO (ppm) am | CO (ppm) pm | RSP ($\mu gm^{-3}$) am | RSP ($\mu gm^{-3}$) pm | Total HCHO (ppm) | VOCs ($\mu gm^{-3}$) | Nicotine ($\mu gm^{-3}$) | Radon ($Bqm^{-3}$) | Airborne microbes ($cfum^{-3}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A (all) | 628 | 545 | 4.3 | 4.1 | 41 | 35 | 0.03 | 1161 | 6.6 | -- | 238 |
| C (all) | 408 | 408 | 2.5 | 2.7 | 53 | 53 | 0.01 | 64 | <DL | 40 | 340 |
| F (all) | 454 | 587 | 3.6 | 3.7 | 13 | 19 | 0.01 | 2030 | 4.0 | 18 | 111 |
| I (all) | 496 | 442 | 4.3 | 4.4 | 29 | 35 | 0.04 | 515 | 2.9 | 29 | 170 |
| R (all) | 528 | 492 | 2.5 | 0.8 | 20 | 28 | <DL | -- | -- | 33 | 374 |
| Y (all) | 473 | 491 | 3.5 | 3.3 | 14 | 12 | 0.02 | 276 | 3.5 | 81 | 600 |
| Z (basement) | 500 | 600 | 3.0 | 2.5 | 15 | 10 | 0.03 | 772 | -- | 66 | 1000 |
| **MEAN** | **498** | **509** | **3.4** | **3.1** | **26** | **27** | **0.02** | **900** | **3.4** | **44** | **405** |

### TABLE II. NATURALLY VENTILATED AREAS

| Building Area | $CO_2$ (ppm) am | $CO_2$ (ppm) pm | CO (ppm) am | CO (ppm) pm | RSP ($\mu gm^{-3}$) am | RSP ($\mu gm^{-3}$) pm | HCHO (ppm) | Total VOCs ($\mu gm^{-3}$) | Nicotine ($\mu gm^{-3}$) | Radon ($Bqm^{-3}$) | Airborne microbes ($cfum^{-3}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| D (B-2F and 5F-8F | 523 | 564 | 2.4 | 3.4 | 21 | 36 | 0.06 | -- | -- | 77 | 334 |
| E (all but lab | 600 | 622 | 2.7 | 6.7 | 92 | 56 | 0.06 | 824 | <DL | 62 | 768 |
| G (all but reception | 858 | 642 | 6.2 | 4.2 | 118 | 357 | 0.06 | 991 | 23.4 | 37 | 775 |
| H (all but computer/conference rooms) | 669 | 572 | 2.1 | 3.5 | 14 | 16 | 0.12 | 2693 | 3.9 | 44 | 116 |
| J (all) | 679 | 871 | 3.4 | 3.6 | 29 | 34 | 0.20 | 1206 | 41.9 | 29 | 533 |
| K (all) | 817 | 817 | 1.5 | 1.8 | 98 | 87 | 0.04 | 2859 | 18.3 | 48 | 268 |
| L (all) | 938 | 588 | 2.5 | 2.0 | 31 | 14 | 0.07 | 2033 | 2.8 | 59 | 157 |
| M (total study area) | 733 | 544 | 2.0 | 2.0 | 49 | 30 | 0.01 | 562 | 17.8 | 23 | 366 |
| N (all) | 746 | 750 | 2.0 | 2.0 | 16 | 16 | 0.02 | 414 | 15.1 | 275 | 254 |
| O (complete study area except 3F conf, lounge, and 2F lounge) | 692 | 713 | 3.3 | 2.4 | 33 | -- | 0.02 | 935 | -- | 29 | 273 |
| P (all) | 670 | 895 | 2.4 | 2.0 | 25 | 33 | 0.02 | 702 | <DL | 37 | 171 |
| T (all) | 731 | 613 | 2.5 | 2.0 | 32 | 24 | 0.03 | 146 | 9.0 | 209 | 156 |
| U (Ground floor offices, basement) | 600 | 475 | 3.0 | 2.5 | 100 | 85 | 0.04 | -- | -- | 37 | 500 |
| V (all) | 683 | 692 | 3.5 | 2.5 | 33 | 15 | 0.04 | 84 | 5.3 | 92 | 325 |
| W (all) | 556 | 600 | 2.7 | 2.6 | 46 | 52 | 0.02 | 910 | <DL | 532 | 372 |
| X (all) | 900 | 720 | 2.4 | 2.4 | 144 | 78 | 0.03 | 138 | <DL | 14,641 | 38 |
| Z (all but basement) | 575 | 658 | 2.3 | 2.3 | 45 | 78 | 0.02 | -- | 3.0 | -- | 454 |
| **MEAN** | **704** | **667** | **2.8** | **2.8** | **55** | **63** | **0.05** | **1036** | **10.0** | **106*** | **345** |

*This mean figure does not include the result from Building X.

**Figure 1. Indoor Air Quality Problems from 26 Swiss Buildings**




None - no fresh air
Inadequate - limited fresh air
Dist. - poor fresh air distribution
AHUs - dirty air handling units
Trays - blocked or dirty condensate trays
Air supply - dirty air supply ducts
Bldg Conf - building design or configuration problems

Inadequate - low efficiency filters
Fit - poor fitting filter
Load - excessively dirty filters
Asb. - presence of asbestos
ETS - environmental tobacco smoke
Fib. glass - loose in air supply system
Bacteria - presence of infectious or allergenic bacteria
Fungi - presence of infectious or allergeni fungi

Overall, dust levels were higher in the naturally ventilated buildings not equipped with a filtration system. This is not surprising since dusts generated by occupant activities are more likely to be suspended in the room air for long periods instead of being drawn into a return system. In the more sophisticated buildings, a number of filter systems were found to be subjected to poor maintenance -- most commonly the selection of filters which are likely to rate less than 10% efficient in the respirable size range. Most commercial systems should be fitted with filters at least 20% efficient in this size range. A minority of these filters were poorly fitted, allowing air bypass, and four buildings were found to have filters which were excessively loaded. We still require a standard test which evaluates the ability of the filter to remove sub-micron size particles since these are the ones that penetrate deep into the respiratory system. We currently do not have such a test which is applied routinely to commercially available filters.

Due to poor maintenance, heavy dirt created problems in most of the air handling units inspected. Condensate trays and air supply ducts were also found to be loaded with various levels of dirt, slime or scale. Sampling for *Legionella pneumophila* in building water using the Legionella Rapid Assay method, revealed trace levels of the organism in five buildings, and strongly positive results in three buildings. These made up the majority of the bacterial problems found in this survey and demonstrate that this organism may be quite widespread in cooling and humidifying systems in Swiss buildings. In all twenty-six buildings, airborne microbial samples yielded wide ranges of fungal species. These were generally similar to outdoor air sample results. Better attention to hygiene of air handling systems may be one of the more effective ways of reducing occupant exposure to irritants in many Swiss buildings.

A minority of buildings exhibited poor use of fibrous glass, creating the potential for release of fibers either into the air stream of the ventilation systems, or directly into the room air. This is a maintenance item which is relatively simple to correct. More complex problems are raised by asbestos containing materials which were found to be a significant problem in two of the buildings examined, and secondary or minor problems in a further four. The control of fiber release from asbestos containing products in Swiss buildings may be a topic which requires significant educational effort in the future.

Environmental tobacco smoke was found to be a secondary or a minor irritant in a total of six of these buildings, usually associated with pockets of poor ventilation. Ventilation rates which maintained carbon dioxide levels consistently below 800 ppm, resulted in low levels of ETS, both as measured by nicotine and RSP levels.

The most room for improvement in these buildings was found with ventilation rates, which were inconsistent, and, in mechanically ventilated buildings, with overall levels of maintenance, especially with regard to filters and cleaning schedules. In particular, there is a need for a standard filter testing method for respirable dust removal. Furthermore, if these buildings are representative of many Swiss buildings, control of *Legionella* bacterium in cooling systems, improvement of hygiene of air handling units to maintain low levels of bacteria and fungi, and abatement of asbestos containing materials in exposed areas may need to be given high priorities in order to prevent immediate and long term hazards to building occupants.

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