ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

EUROPEAN AUDIT PROJECT TO OPTIMISE INDOOR AIR QUALITY AND ENERGY CONSUMPTION IN OFFICE BUILDINGS

NATIONAL REPORT OF SWITZERLAND

Research funded in part by
THE COMMISSION OF THE EUROPEAN COMMUNITIES
in the framework of the JOULE II - Programme
Sub-programme
Energy Conservation and Utilisation
Funded in Switzerland by the OFEN/BEW, Swiss Federal Office of Energy

LABORATOIRE D'ÉNERGIE SOLAIRE ET DE PHYSIQUE DU BÂTIMENT - ITB-DA

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Contract JOU2-CT92-0022

NATIONAL REPORT OF SWITZERLAND

by

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TITLE: EUROPEAN AUDIT PROJECT TO OPTIMISE INDOOR AIR QUALITY AND ENERGY CONSUMPTION IN OFFICE BUILDINGS

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Contractors:

C1. TNO-Building and Construction Research, Department of Indoor Environment, Building physics and Systems, The Netherlands

C2. Technical University of Denmark, Laboratory of Heating and Air Conditioning, Denmark

C3. Danish Building Research Institute (SBI), Denmark

C4. Building Research Establishment (BRE), United Kingdom

C5. EA Technology, United Kingdom

C6. University of Athens, Department of Applied Physics, Greece

C7. CSTB, France

C8. Belgium Building Research Institute (CSTC-WCTB), Belgium

C9. Swiss Federal Institute of Technology Lausanne (EPFL), Solar energy and building physics laboratory

C10. Technical Research Centre of Finland, Finland

C11. Norwegian Building Research Institute (Byggforsk), Norway

Sub-contractors:

S1. University of Lausanne, Institute of Occupational Health Science

S2. Sulzer-Infra company in Whinterthur

S3. Swiss Federal Institute of Technology - Zürich, Institute of Occupational Health and Hygiene

S4. OFIAMT, Service de Médecine et d'Hygiène du Travail; Swiss Federal Office of Industry, Craft, Trade and Work, Service of Occupational Health and Hygiene.

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Key words: Indoor Air Quality, ventilation, guidelines, sensory evaluations

ABSTRACT

This report summarises the work performed in Switzerland within the frame of the Joule II project "Indoor Air Quality Audit".

Eight office buildings located in three important areas were audited. Minimum commitment is 6 buildings. The two supplementary buildings are the pilot study, and an additional audit supported by the owner of the building. The main results obtained in Switzerland are as follows.

Assessment procedure

The questionnaire is without doubt an important part of the audit. It could however be shortened and its interpretation simplified. In questionnaires responses on building related symptoms (BSI), there is not much difference between occupation type. Therefore it is proposed to make corrections only for sexual effects. Since there is a strong correlation between BSI's based on short and full symptom lists and on past month and today periods, it is also proposed to limit the questionnaire to one period (e.g. past month) and a short list of symptoms. Questions on interest in job and on social environment should be added, as well as a better description of the location of the respondent.

Measurements of air flow rates in air handling units (AHU) were not planned in the procedure, but performed in most AHU of the audited buildings. These measurements often showed large discrepancies between measured and planned air flow rates. Is some cases, unexpected shortcuts between exhaust and pulsed air were detected. Moreover, they provide a possibility to assess the ventilation performance for the whole building. It is therefore proposed to implement these measurements into the audit procedure.

Fresh air flow rates in each room can be estimated by counting the persons in room and measuring the CO_2 concentration in room and in air supply. On the other hand, measurements with tracer gas seldom proved to be accurate enough to assess the contaminant source strength with good confidence. It is hence proposed to delete tracer gas measurements from the procedure and to use instead more CO_2 concentration measurements and more attention on occupancy.

If CO is to be analysed, analysers with a sensitivity of 10 ppb should be used and outdoor concentration shall also be measured. In any case, CO is not a good indicator for the calculation of tobacco smoke pollution load.

Some results from building audits

Ventilation rates in all buildings are high enough to eliminate occupants generated contamination, but large differences were found in indoor air quality as judged by occupants or by chemical analysis. The average number of building related symptoms per occupant (BSI) vary strongly among buildings. AHU were all clean and well maintained.

No clear relation was found between BSI and sensory or chemical indoor air quality, ventilation rate or energy consumption. BSI's are however significantly lower when it is allowed to open the windows.

The best building (according to occupant's health) is also the one with the lowest energy index and the lowest air flow rate, hence a high (1000 ppm) CO_2 concentration. It is partly naturally ventilated. All the buildings with high BSI's are sealed and air conditioned.

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AIMS OF RESEARCH

The main scopes of the European project are:

- Contribution to the European Indoor Air Quality (IAQ) database of existing European office buildings with respect to symptoms/complaints of occupants, perceived indoor air quality evaluations with a trained panel, pollution sources, ventilation and energy consumption.
- Development of assessment procedures and guidance on ventilation and source control to optimise indoor air quality and energy use in office buildings.
- Development of a common agreed Europe-wide method to investigate indoor air quality in office buildings.
- Comparison of IAQ-related parameters across several European countries.

In addition, the following scopes were followed in Switzerland:

- Assessment of effective ventilation performance in mechanical ventilation systems
- Information of the building owners on the results concerning their buildings
- Proposals to building owners to improve the performance of their buildings.

DATA BASE REPORT

Contract number: JOU2-CT92-0022

Title: European Audit Project to optimise Indoor Air Quality and Energy consumption in office buildings

Co-ordinator: TNO-Building and Construction Research, Department of Indoor Environment, Building physics and Systems, The Netherlands

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Main objectives:

. Development of assessment procedures and guidance on ventilation and source control to optimise indoor air quality and energy use in office buildings.

. Development of a common agreed Europe-wide method to investigate indoor air quality in office buildings.

Description

The European IAQ audit project consists of five phases.

Phase 1: Planning seminar

A seminar is held for the participants to develop an European IAQ Audit procedure for office buildings in the form of a manual to execute phase 2, 3 and 4. The seminar is held in Morges (Switzerland). The seminar is concluded with a manual some months after.

Phase 2: Pilot Study

The participating organisers and/or assistants are invited to the selected country (Denmark) and learn how to execute the manual, produced in phase 1, in a pilot-study of one selected office building. The manual is revised.

Phase 3: Preparation IAQ Audit project

Each participating country (except Belgium) selects 6 buildings according to the selection criteria presented in the revised manual of phase 2. In each country the team which will perform the auditing is taught with the use of the manual how this should be done.

Phase 4: IAQ Audit Project

The 6 selected buildings are investigated as described in the determined manual.

Detailed studies, for example on source identification, ventilation and energy consumption, are specifically done by WCTB (Belgium) and SBI (Denmark).

Phase 5: Final Reporting

In this last phase of the project, all results and findings are summarised, and correlations, comparisons, recommendations and conclusions are given.

Key words: Indoor Air Quality, ventilation, guidelines, sensory evaluations

1. INTRODUCTION

1.1 Objectives

This report presents the national contribution of Switzerland to the EC-Audit project, that was initiated by the Commission of European Communities DG XII in the Joule II programme.

The main objective of the national contribution is to contribute to the European IAQ database with respect to:

- assessment of symptoms/complaints in existing European office buildings, according to a standard questionnaire survey, in relation to perceived indoor air quality evaluations from a trained panel of assessors who visit each building;
- identification and quantification (chemical and sensory) of pollution sources in existing European office buildings;
- assessment of pollution load caused by the building itself in different parts of Europe;
- assessment of ventilation rates and evaluation of ventilation performance in existing European office buildings;
- assessment of energy consumption in existing European office buildings.

Further objectives on national, but specifically on international level are:

- Development of assessment procedures and guidance on ventilation and source control to optimise indoor air quality and energy use in office buildings. The challenge of the near future is simultaneously to aim at a low energy consumption and a comfortable and healthy environment. The guidance will be available to committees responsible for CEN-standards and other European guidelines.
- Development of a common agreed Europe-wide method to investigate indoor air quality in office buildings.
- Comparison of IAQ-related parameters across several European countries.

In addition, the following scopes were followed in Switzerland:

- Assessment of effective ventilation performance in mechanical ventilation systems
- Information of the building owners on the results concerning their buildings
- Proposals to building owners to improve the performance of their buildings.

This report represents the national contribution of Switzerland to the EC-Audit project.

1.2 Method

The European IAQ audit project consists of five phases. In a first step, the Audit methods and planning, to be followed by each participating institution, was established. A pilot study, which was performed in Denmark, allowed the participants to test and improve the audit methods. Then, a multi disciplinary audit team, comprising specialists of measurement techniques and a panel evaluating the perceived air quality was prepared and trained. The audits were performed in at least six buildings of each of 9 participating countries. Finally the results were interpreted and reported.

The audit concerns the building itself and its technical equipment, in particular its ventilation system, the opinion of the occupants on the comfort and health condition, the thermal comfort, the lighting and noise level in some office rooms. The indoor air quality was examined as well for its olfactive or sensory aspect as for its chemical composition. All this audit was performed in less than a day, in order to obtain synchronous information all

concerning the same working conditions, without perturbing too much the work in the visited firm. In particular the following observations were performed:

- **General overview of the building and its equipment.** Important characteristics of each building were assessed during a technical survey using a check list. A part of these data are obtained during a preliminary visit. Important data are, for example, the yearly energy consumption (oil, electricity, gas, district heat, etc.) or the date of the last maintenance of the ventilation system.
- **Questionnaire to officers.** A questionnaire was distributed to about 150 officers, at a given time, and collected back some time later. This anonymous questionnaire contains questions on the well-being of the employees, on possible physiological symptoms they experience now and during the last month, and on some characteristics of theirworking places. This questionnaire should be filled up in less than 15 minutes. Filled questionnnaires were interpreted in a confidential way and only statistical results are issued.
- **Working conditions in some office rooms.** Some office rooms, or only one large open office, are selected during the preliminary visit for more measurements, which are described below. These office rooms should be representative of the rooms occupied by the employees answering the questionnaire, and should not present major measurement difficulties.
  - **Thermal comfort**: Air and radiant temperatures are measured, as well as air moisture and air speed at some working places. These data will be compared to the opinion on comfort conditions the employees may have.
  - **Illuminance and noise level** : simple measurements at working places will be performed. Illuminance will be measured at table level from the window to the opposite wall.
  - **Sensory assessment of air quality**: A trained panel of 10 to 12 "noses" judge the concentration of bad odours in the air and express it directly in Pol. This unit corresponds to the odour load of one average person diluted in an air flow of one litre per second. During this measurement, the panel should be allowed to refresh by inhaling outdoor air either by going out, or in a neighbouring room with open windows.
  - **Chemical analysis:** Concentrations in carbon dioxide (normally generated by occupants), in carbon monoxide (coming from tobacco smoke, incomplete combustion in appliances or traffic) and volatile organic compounds (paint or glue solvents) are measured at some points. Dust concentration will be also assessed. The scope of these measurements is to check a possible relation between the well being of the occupants and the absence of such chemicals.
  - **Ventilation measurements**: In order to obtain the contaminant source strength form the contaminant concentration, it is necessary to determine the rate at which fresh air is introduced in each room. These air flow rates are measured either with air flow meters or with harmless and odourless tracer gases at very low concentrations.

Data harvested during these survey were recorded in standard files, and interpreted according to commonly agreed procedures, described in the manual.

The measuring team included the persons listed in Table 1. The responsibilities of these institutions are listed in Table 2.

Table 1: Swiss measuring team. The sensory panel is not listed.

Name	Institution	Location
Cretton Pascal Foradini Flavio Loesch Pierre Rodriguez José Antonio Roulet Claude-Alain	LESO-PB: Laboratoire d'Energie Solaire et de Physique du Bâtiment EPFL: Ecole Polytechnique Fédérale, Lausanne	Lausanne
Bernhard Claude-A. Charrière Nicole	IURST, Institut Universitaire Romand de Santé au Travail	Lausanne
Carlucci Lucio Eser Prisca Meier Sybille Samimi Nanda Scholz Elisabeth	IHAP, Institut für Hygiene und Arbeitsphysiologie, ETH-Zentrum	Zürich
Böck Oskar	Sulzer Infra	Winterthur
Rüedi Arno E.	Periso SA	Isone
Meier S.	Stäfa Control AG	Stäfa
Knutti Rudolf	Arbeitsärtzlicher Dienst der BIGA	Zurich
Piller Georges	Office Fédéral de la Santé Publique	Fribourg

Table 2: Responsibilities of the various Swiss institutions

Institution	**Responsibility**
LESO	Contractor, coordination, official contacts Collection of data, development of database Questionnaire interpretation and French translation Panel training and performing in buildings A, F, G, and H Ventilation measurements in rooms and air handling units Check list, noise and light measurements Measurements related to thermal comfort Radon samplers installation and collection.
IURST	Questionnaire distribution and collection Dust and VOC sampling and interpretation
IHAP	Continuous measurements of temperature, air moisture, air velocity, dust, CO and CO_2 Questionnaire distribution and collection, and German translation Panel training and performing in buildings A, B, C, D, and E
BIGA	VOC analysis for all buildings in Europe within this project
OFSP	Radon samples analysis
PERISO	Ion concentration measurements
STÄFA CONTROL	IAQ multigas sensor, temperature and air moisture monitoring

2. SELECTED BUILDINGS

In February 1993, 9 letters were sent to selected institutions owning office buildings either in the Zurich area (the most populated one) or in the south-west part of Switzerland, which has another climate and another way of life. The audited buildings should represent, as well as possible, the office building stock in each country. They are in any case not selected because they have problems. The selection criteria for this operation were the following:

The Swiss government itself owns about 10'000 buildings (1% of the Swiss building stock). Since this survey is paid by the government, it could be interested to participate. The building A was proposed by the Swiss Building Management Office, since an important retrofit was planed in a near future. This building, located in Bern, was chosen for the pilot study.

A few insurance companies were also asked to provide a building. One replied quickly and was already known for being investigated by IHAP-ETHZ and its main building was found interesting for this study. This is building B.

The survey was also offered to a few banking companies. Only one replied and proposed its new central office building, building C.

A new building with an interesting ventilation system was proposed by its ventilation engineer. The direction was asked for permission and proposed its two buildings: the new one (D) and an older one (E). These buildings are located in the country.

A large food industry was asked to accept a survey in one of its main buildings. It was found that this building should be soon refurbished. The building manager was so interested by this survey, that he asked if it were possible to make a survey, at own expenses, in the second, more recent building. These are buildings F and G.

Finally, the town authority of Lausanne accepted a survey in its main office building, i.e. building H.

There were enough buildings, hence it was good luck that other insurance and banking companies did not reply to our letters. All these buildings were visited for a first time in autumn 1993, to fill in the building check lists and to verify if these buildings satisfy the survey criteria. The criterion found most difficult to satisfy was a convenient refreshing room for the trained panel. Buildings A, D, F and G provided such a room with open window. Buildings B, C and E are huge buildings, without openable windows. We have however found, in these cases, an emergency exit or a staircase window and used it to refresh the panel. Building H was the only building where the distance between the refreshing place (in front of the main entrance) and the measured locations was too large. The building seeming nevertheless very interesting from many points of view, it was decided to audit it anyway.

None of these buildings was known as sick. Damp spots, mould growth and mould odour were detected nowhere. Non smokers have a strong influence in Switzerland. Even where there are no general smoking ban in buildings, the opinion of one person is enough to ban smoking in a room. For this reason, we have noted that it is allowed to smoke in separate rooms for all the buildings.

Description of the buildings follows, and a summary will be found in 2.3. More information can be found in appendices.

2.1 Building A

2.1.1 Description

Building

This building, investigated first as our pilot study on December 9, 1994, is an office tower located downtown Bern. It has 11 office levels above ground level and a large ground level and underground area mainly occupied by shops, parking and storage lots.

Building year: 1972

Size: 14 floors (2 below ground), total floor area: 7'400 m²

Orientation: square plan N-S and E-W (see Figure 1)

Situation: Downtown

HVAC Systems

Water radiator heating

One air handling unit for ventilation only, (heating, humidification and cooling installed but disconnected) with recirculation.

Design fresh air supply: 47 l/s person or 34'800 m³/h

Air supplied and extracted in the ceiling: supply near the facades, extract by the centre of building.

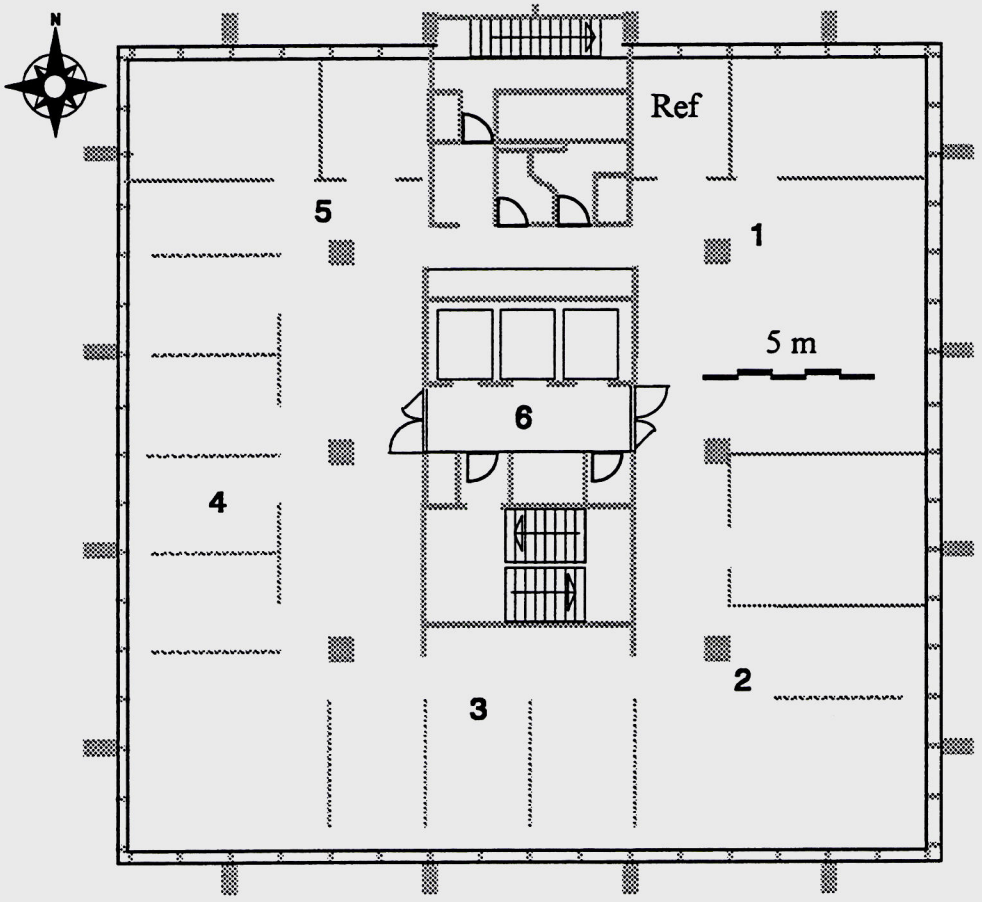

Figure 1: Building A: plan of measured floor. Numbers are measurement locations. Special measurements were performed at location 4.

2.1.2 Population

The office part of the building is completely occupied by the same government agency. The 240 employees are mainly professionals involved in planning, building, and maintenance of buildings (architects, engineers). They are very often out of office. Out of these, 78 filled up the questionnaire.

2.1.3 Offices

The investigated office is located at the 10th floor. Its plan, shows a large open office located all around the building with service rooms, elevators and staircase in the centre of the North facade (Figure 1). This office contains 18 employees. The other floors, where other questioned persons are working, are identical to this floor.

Wall material inside insulation	metal
Wall covering	dispersion paint
Floor covering	felt carpet
Ceiling material	acoustic tiles
Lighting	ceiling fluorescent tubes and daylighting
VDU/work place	23/18
Laser printers in room	6
Floor area/workplace	22 m^2
Volume/workplace	55 m^3
Fleece factor	0,44 m^2/m^3
Shelf factor	0,025 m/m^3

2.1.4 Peculiarities

The building is in poor condition and consumes much heating energy. The owner intends to refurbish it completely in a near future. Smoking is allowed in separate rooms. Windows can be open but are generally not.

2.2 Building B

2.2.1 Description

Building

This building is the main office of an insurance company. Is located downtown in a quiet area of Zurich. The office area are very large, open, and structured with fleecy mobile walls.

Building year: 1980

Size: 6 floors, total floor area: 21'300 m^2

Orientation: Not very important, since most occupants are far from windows (see Figure 2)

Situation: Downtown, quiet area.

HVAC Systems

Full air conditioning by 5 dual duct air handling units, with recirculation and glycol heat exchangers.

Spray humidification sterilised with ultraviolet radiation

Filters Eu3 and Eu8, clean installation

Design fresh air supply: 22 l/s person or 60'000 m^3/h.

Measured fresh air flow rate 20±2 l/s person or 54'000 m^3/h.

Air is supplied and extracted in the ceiling, grids are evenly distributed. There is an obvious shortcut between supply and extract in the rooms, mainly in winter because the supply air supplied is heated.

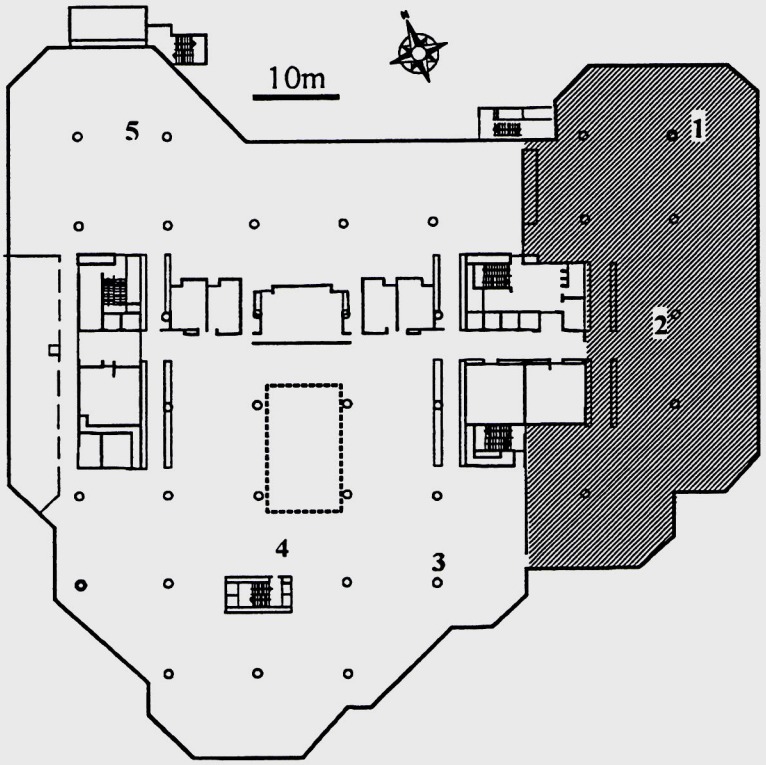

Figure 2: Building B: plan of measured floor. Numbers are measurement locations. The hatched zone is the S-E office, equipped with ionizers in the ventilation system. Special measurements were performed at locations 2 and 4.

2.2.2 Population

The 750 employees are mainly clerical.

2.2.3 Offices

The investigated office is located at the third floor. Its plan shows two very large open offices, one at the S-E side, and the other having facades to all other orientations. Service rooms, elevators and staircases are in a in a centre row oriented SE to NW (Figure 2). These offices contains 71 and 207 working places respectively. The other floors, where other questioned persons are working, are similar to this floor.

Wall material inside insulation	polymer
Wall covering	Textile
Floor covering	felt carpet
Ceiling material	acoustic tiles
Lighting	ceiling fluorescent tubes
VDU/work place	308/278
Laser printers in room	67
Floor area/workplace	16,0 m^2
Volume/workplace	48 m^3
Fleece factor	0,41 m^2/m^3
Shelf factor	0,18 m/m^3

2.2.4 Peculiarities

Smoking is allowed but not recommended in office space. Windows are closed, but could be opened for cleaning. They are not opened by occupants, since the buildings is completely closed. Special to this building is the large average distance from occupants to the windows, and the large fleece and shelf factors. There are also many large green plants, and occupants like them.

A large amount of relatively high separations combined with suspended supply air elements forming a 40 cm high frame under the ceiling hinder air movement and light propagation.

2.3 Building C

2.3.1 Description

Building

This building is the main office of a bank. Is located in the suburbs of Zurich, in a relatively flat land topography, between a railway station and a highway. It is recent and has an atrium in its centre.

Building year: 1990

Size: 5 floors, total floor area: 38'000 m²

Orientation: North and South-oriented offices with a central atrium (see Figure 3)

Situation: Downtown

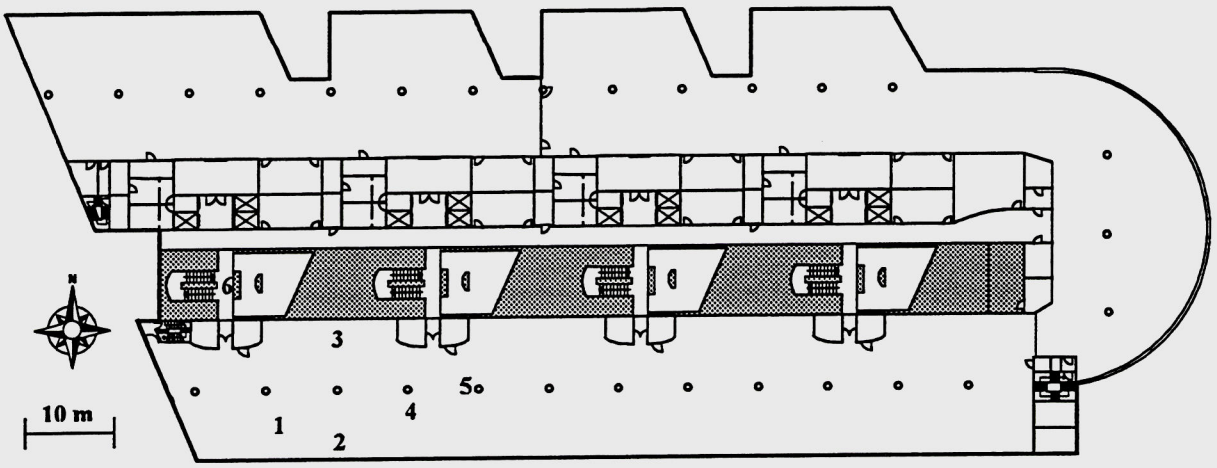

Figure 3: Building C: plan of measured floor. Numbers are measurement locations. Special measurements were perfomed at location 5 . Dotted zones are full height volumes in the atrium.

HVAC Systems

Full air conditioning by 4 air handling units, without planned recirculation, but rotating wheel heat exchanger seem to introduce some recirculation..

Spray humidification purified with biocides

Filters Eu6, clean installation

Design fresh air supply: 31 l/s person or 135'000 m³/h.

Measured fresh air flow rate 12±2 l/s person or 52'000 m³/h.

Air is supplied and extracted in the ceiling: supply distributed evenly in the ceiling extract close to the centre of building.

2.3.2 Population

The 1200 employees are mainly banking clerical.

2.3.3 Offices

The plan shows two large open offices, one North oriented and the other looking towards South. The investigated office is located at the 4th floor, South. The centre of the building is occupied by a 5-level high atrium, containing staircases and cafeterias. North of this atrium are service rooms, elevators and toilets. The other floors, where other questioned persons are working, are identical to this floor.

Wall material inside insulation	concrete
Wall covering	dispersion paint
Floor covering	felt carpet
Ceiling material	acoustic tiles
Lighting	ceiling fluorescent tubes and daylighting
VDU/work place	112/99
Laser printers in room	3
Floor area/workplace	16,8 m^2
Volume/workplace	47 m^3
Fleece factor	0,36 m^2/m^3
Shelf factor	0,018 m/m^3

2.3.4 Peculiarities

Smoking is allowed in office space only after 16:00. It is allowed to smoke in the atrium, which is connected to office space through untight closed doors. Windows are closed, but could be open for cleaning. They are not opened by occupants, since the buildings is completely closed, with high safety control at entrance.

2.4 Building D

2.4.1 Description

Building

Buildings D and E contain the European main office of a chemical company. They are located in the country, in a hilly area, not far from a lake. Building D is recent and has an open court with a garden in its centre.

Building year: 1991

Size: 5 floors, total floor area: 12'000 m^2

Orientation: Offices are oriented East or West. (see Figure 4)

Situation: In the country, not far from a small town, in the vicinity of a lake.

HVAC Systems

Rooms are heated by radiators and cooled by cold water circulation in ceiling structure.

Outer offices are naturally ventilated by window openings, while conference rooms and inner offices are mechanically ventilated by 2 air handling units, without recirculation, bt equipped with a rotating wheel heat recovery.

Mechanical ventilation with ultrasonic humidification purified with osmotic system

Filters Eu3 and Eu7, clean installation. One system equipped with active charcoal filters.

Design fresh air supply: 11 l/s person or 8800 m^3/h.

Measured fresh air flow rate 11±2 l/s person or 8500 m³/h.

Air supplied in each mechanically ventilated office under the ceiling and extracted on top of walls close to corridor. Temperature of pulsed air is adjusted in such a way that a pretty good ventilation efficiency is obtained.

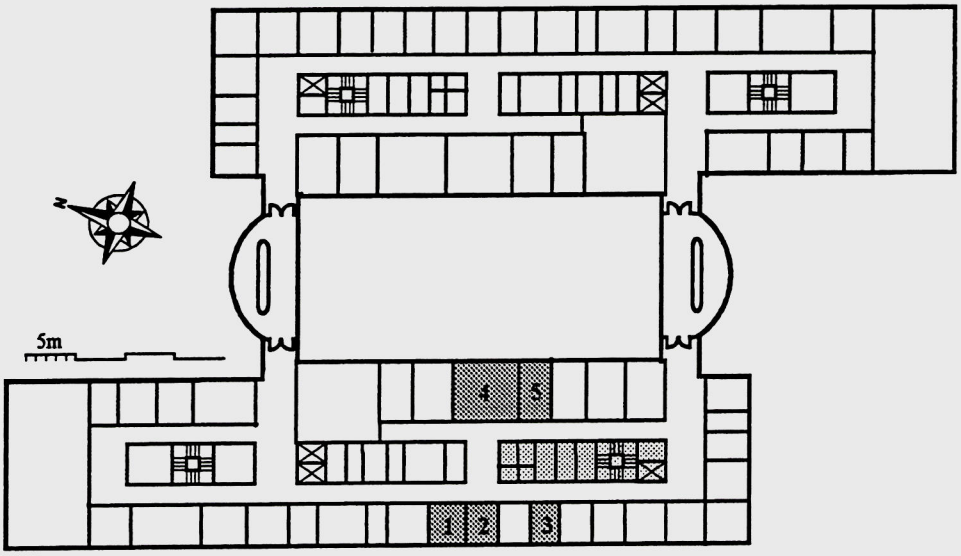

Figure 4: Building D: plan of building. The 5 floors are very similar. Measured zones are in grey. Special measurements were performed at locations 2 and 4.

2.4.2 Population

40% of the 223 employees do managerial work, while 26% are specialists and 23% clerical.

2.4.3 Offices

The investigated office rooms are located at the second floor. The building plan shows the East and West wings connected by two corridors closing the central open court (Figure 4). A total of 7 employees are working in these 5 rooms. The first three rooms are naturally ventilated, while the two other, looking to the central court, are connected to the mechanical ventilation system. Windows in these rooms can nevertheless be open, and were so. The other floors, where other questioned persons are working, are identical to this floor.

Wall material inside insulation	plaster board
Wall covering	dispersion paint
Floor covering	nap carpet
Ceiling material	concrete
Lighting	ceiling fluorescent tubes and daylight
VDU/work place	9/7
Laser printers in room	none
Floor area/workplace	12,7 m²
Volume/workplace	36,9 m³
Fleece factor	0,39 m²/m³
Shelf factor	0,15 m/m³

2.4.4 Peculiarities

Smoking is allowed in office space. Windows can be open. This building is characterised by a very careful planning, aiming at a good comfort. In particular, the ventilation engineer really intended to ventilate efficiently with a minimum energy consumption.

2.5 Building E

2.5.1 Description

Building

Buildings D and E contain the European main office of a chemical company. They are located in the country, in a hilly area, not far from a lake. Building E is relatively old.

Building year: 1974

Size: 7 floors, total floor area: 9070 m²

Orientation: square plan (see Figure 5)

Situation: West of building D, in the country, not far from a small town, in the vicinity of a lake.

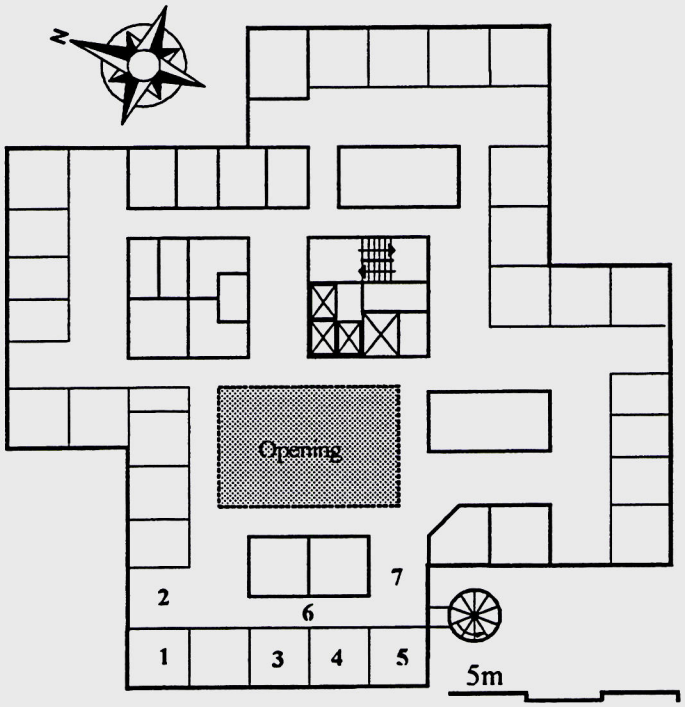

Figure 5: Building E: plan of measured floor. Numbers are measurement locationsSpecial measurements were performed at location 4. Dotted zone is double height volume over the entrance hall.

HVAC Systems

Full air conditioning by 3 air handling units, with recirculation (22% measured).

Steam humidification.

Filters Eu3 and Eu7, clean installation

Design fresh air supply: unknown.

Measured fresh air flow rate 50±5 l/s person or 36'000 m³/h.

Air supplied at windowsill through induction units. Air is extracted in the ceiling.

2.5.2 Population

The 200 employees do mainly managerial (33%) and clerical (44%) work. The remaining are specialists.

2.5.3 Offices

The investigated office rooms are located at first floor, on the West facade (Figure 5). 8 employees were occupying these rooms. Office rooms are located all around the floor, while service and conference rooms are in the centre.

Wall material inside insulation	none (extruded polystyrene insulation visible through the induction units grids)
Wall covering	dispersion paint
Floor covering	nap carpet
Ceiling material	acoustic tiles
Lighting	ceiling fluorescent tubes and daylighting
VDU/work place	8/8
Laser printers in room	1, in hall (location 7) where two women were working
Floor area/workplace	9,1 m^2
Volume/workplace	23,7 m^3
Fleece factor	0,45 m^2/m^3
Shelf factor	0,095 m/m^3

2.5.4 Peculiarities

Smoking is allowed in office space, but there are few smokers (less than 20%). Windows cannot be open. The ventilation system has a complex recirculation network, allowing a recirculation rate smaller in office rooms than in centre part.

2.6 Building F

2.6.1 Description

Building

Buildings F and G host the world centre of a food company. F was built first and is the oldest investigated building in Switzerland.

Building year: 1958

Size: 6 floors, total floor area: 35'000 m^2

Orientation: three wings direction North, south-east and south-west (see Fig)

Situation: At the limit of a town, but directly facing a lake located south-west of the building.

HVAC Systems

Conditioned air is pulsed by 3 units into the office rooms, through inlet gridslocated in windowsills. Exhaust air leaves the room to the corridor (through open door or ad-hoc grid when door is closed) and is finally extracted out of the building by a fan located at top of the central helical staircase. A part (75% planned, 50% measured) of this air is recirculated.

Spray humidification without purification.

Filters Eu1 and Eu4, clean installation

Design fresh air supply: 26 l/s person or 75'000 m^3/h.

Measured fresh air flow rate 30±3 l/s person or 85'000 m^3/h.

2.6.2 Population

The 800 employees are mostly specialist (45%) and clerical (30%).

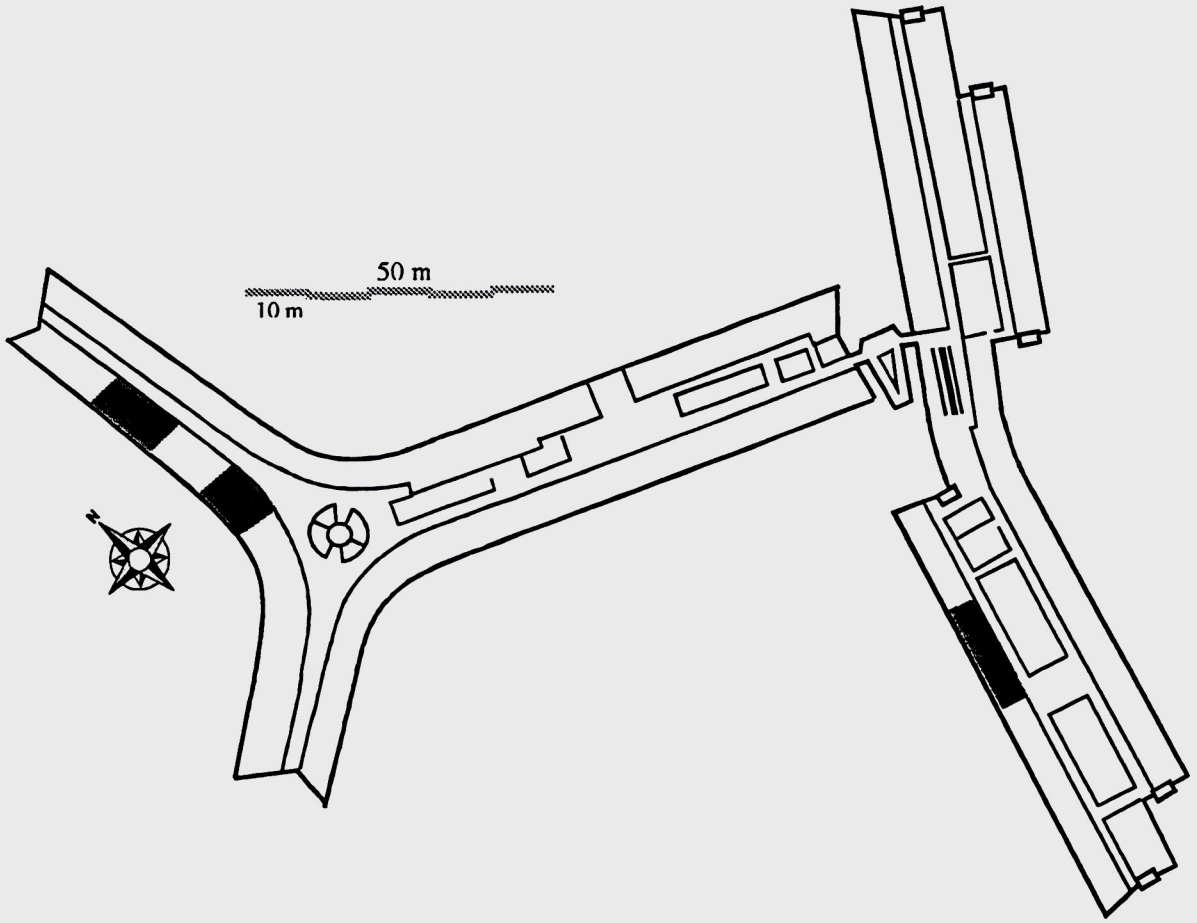

Figure 6: Buildings F (left) and G (at right). Grey zones are measurement locations.

2.6.3 Offices

The investigated office rooms are located at the third floor (Figure 7). These office rooms host 14 employees, and all are oriented to West. The other floors, where other questioned persons are working, are identical to this floor.

Wall material inside insulation	glass (no insulation, triple pane)
Wall covering	enamel paint
Floor covering	felt carpet
Ceiling material	acoustic tiles
Lighting	ceiling fluorescent tubes, daylighting, and individual incandescent lamps
VDU/work place	12/14
Laser printers in room	1 or 2 in each room + 1 photocopier in two rooms
Floor area/workplace	12,5 m^2
Volume/workplace	36,4 m^3
Fleece factor	0,34 m^2/m^3
Shelf factor	0,07 m/m^3

2.6.4 Peculiarities

Smoking is allowed, but only 20% of questioned person are smokers. Windows can be opened, but this is not recommended, and only 10% of questioned person open the windows. The building is now being refurbished. Air cooling is provided by lake water.

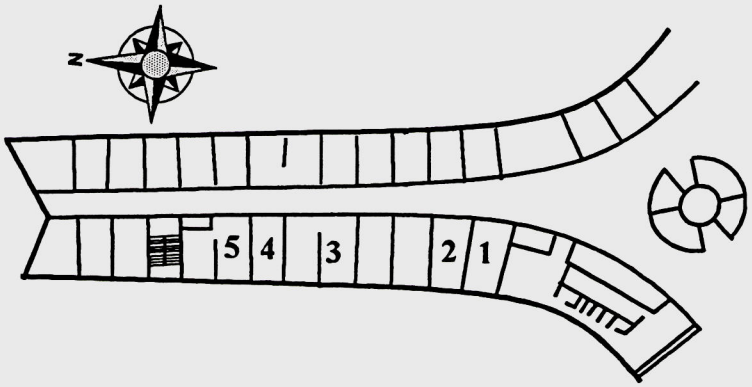

Figure 7: Plans of third floor of North wing, with measured office rooms (1 to 5). Special measurements were performed at location 3.

2.7 Building G

2.7.1 Description

Building

Buildings F and G host the world centre of a food company. G is a more recent extension.

Building year: 1976

Size: 9 floors, total floor area: 42'000m²

Orientation: North-South (see Fig)

Situation: Downtown, but directly facing a lake located South-west of the building.

HVAC Systems

Air conditioned by 4 air handling units, without recirculation, with glycol heat exchanger. Air supplied at windowsill through induction coil units, and extracted at the ceiling, close to the corridor.

Spray humidification sterilised with ultra-violet lamps

Filters Eu3 and Eu7, clean installation

Design fresh air supply: 35 l/s person or 100'000 m³/h.

Measured fresh air flow rate 23±2 l/s person or 66'000 m³/h.

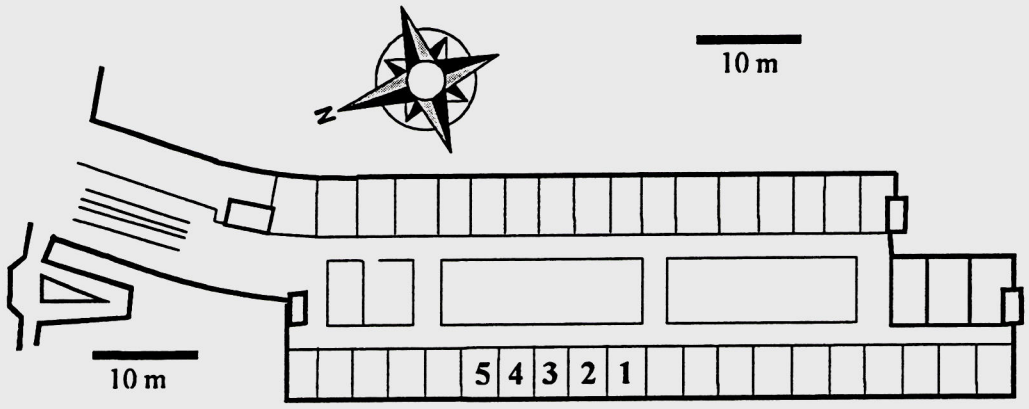

Figure 8: Building G: plan of south wing of measured floor. Numbers are measurement locations.. Special measurements were performed at location 2.

2.7.2 Population

The 800 employees are mostly clerks (49%) and specialists (31%).

2.7.3 Offices

The investigated office rooms are located at the fifth floor, on West side of the south wing (Figure 8). 12 employees were working in these rooms. The other floors, where other questioned persons are working, are identical to this floor.

Wall material inside insulation	metal
Wall covering	enamel paint
Floor covering	felt carpet
Ceiling material	acoustic tiles
Lighting	daylighting, ceiling fluorescent tubes and individual incandescent lamps.
VDU/work place	10/12
Laser printers in room	one laser printer in each but one room
Floor area/workplace	10,3
Volume/workplace	28 m^3
Fleece factor	0,42 m^2/m^3
Shelf factor	0, 18 m/m^3

2.7.4 Peculiarities

Smoking is allowed, but only 20% of questioned person are smokers. Windows can be opened, and 62% of questioned person do it. Cooling is provided by lake water.

2.8 Building H

2.8.1 Description

Building

This building hosts a town administration and services. Is located downtown, in a busy and hilly area. It is sealed and fully air-conditioned.

Building year: 1973

Size: 8 floors, total floor area: 11'300 m^2

Orientation: E-W building (see Figure 9)

Situation: Downtown, with busy roads along N, W and S facades.

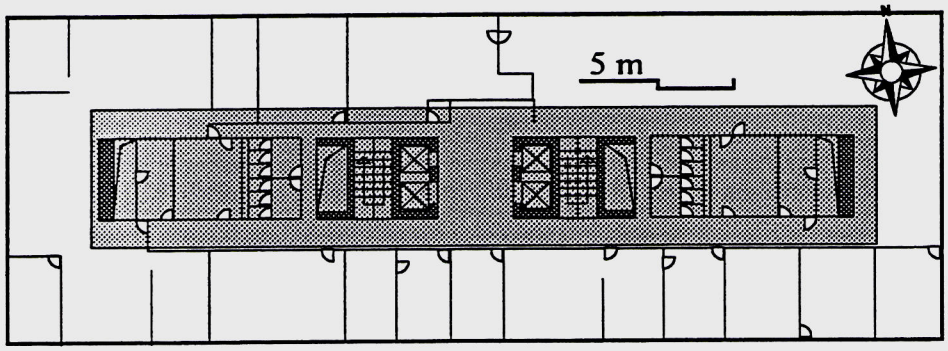

Figure 9: Building H: plan of measured floor. Grey zone is the central zone, ventilated with partly recirculated air.

HVAC Systems

Full air conditioning by 2 air handling units, with recirculation in the central zone.

In offices, air is supplied by induction coil units at windowsills, and extracted at the ceiling. In central zone, air is supplied and extracted at the ceiling.

Spray humidification without purification.

Filters Eu1 and Eu7, clean installation

Design fresh air supply: 67 l/s person or 58'000 m³/h.

Measured fresh air flow rate 44 l/s person or 38'000 m³/h.

Air supplied and extracted in the ceiling: supply distributed, extract by the centre of building.

2.8.2 Population

The building is occupied mostly by clerical personal (72%).

2.8.3 Offices

The investigated office is located at the west part of the first floor (Figure 10). This half open office contains 13 employees. Doors between office rooms are all open, but the measured zone was closed.

The other floors, where other questioned persons are working, are similar to this floor.

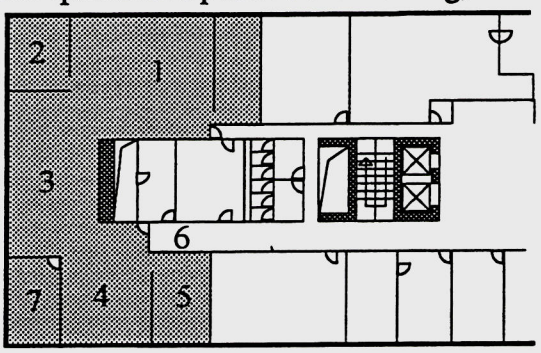

Figure 10: Building H: plan of measured zone (grey). Numbers are measurement locations. Special measurements were performed at location 3.

Wall material inside insulation	metal
Wall covering	enamel paint
Floor covering	felt carpet
Ceiling material	acoustic tiles
Lighting	ceiling fluorescent tubes and daylighting
VDU/work place	13/13
Laser printers in room	2 in measured zone
Floor area/workplace	27 m²
Volume/workplace	73 m³
Fleece factor	0,37 m²/m³
Shelf factor	0,05 m/m³

2.8.4 Peculiarities

Smoking is allowed in office space. Gold-mirror windows are sealed, and there is no solar protection. This office building was planned as open office, but later mobile walls (from floor to ceiling) were installed to arrange closed office rooms.

2.9 Summary of building characteristics

Table 3: Building characteristics

Building	A	B	C	D	E	F	G	H
Date of investigation	9.déc	25.jan	26.jan	1.fev	2.fev	26.jan	26.jan	1.mar
Construction year	1972	1980	1990	1991	1974	1958	1976	1973
Number of floors	14	6	5	5	7	6	9	8
Total floor area [m²]	7'406	21'275	38'440	12'000	9'067	34'980	42'000	11'309
Number of office rooms	60	19	10	320	205	1'500	680	
Number of occupants	240	750	1'200	223	200	800	800	240
Located downtown	✔	✔	✔			✔	✔	✔
Countryside				✔	✔			
Open office	✔	✔	✔					
Office rooms				✔	✔	✔	✔	4

Table 4: Characteristics of the ventilation systems in the investigated buildings.

Building:	A	B	C	D	E	F	G	H
Mixing ventilation	✔	✔	✔		✔	✔		✔
Piston "				✔			✔	
Ceiling inlet grids	✔	✔	✔	✔	✔			
Inlets in induction coil						✔	✔	✔
Number of ventil. units	1	5	4	2	2	3	3	2
Air heating			✔			✔	✔	✔
Radiator heating	✔	✔		✔	✔			
Air conditionning		✔	✔	½*	✔	✔	✔	✔
Planned recirculation	✔	✔			✔	✔		✔
Heat recovery		Plates	Rotat.	Rotat.			Glycol	

* A large part of building D is naturally ventilated by opening the windows.

Common to all buildings are:

- Smoking allowed in some locations in the buildings, everywhere with some restrictions.
- Road traffic and parking lots in the vicinity
- Heavy construction (concrete decks) with curtain facades.
- False ceilings everywhere except building D
- Nap or felt carpet everywhere.

3. PROCEDURE AND METHODS

Only techniques or methods not described in the Audit Manual are described below.

3.1 Sensory evaluation

Two panels were selected and trained in Switzerland. Since the buildings are located as well in the North as in the South West of the country, it appeared cheaper to train two panels than one. The training cost is largely compensated by the cost of travel and travelling time. On the other hand, both LESO and IHAP were interested in gaining experience for training and using such a panel.

3.1.1 Lausanne panel

3.1.1.1 Selection

The candidates for the olfactive panel were recruited by an advertisement in the internal journal of the EPFL, published twice. In this advertisement, calling for "noses", it was asked to be interested to the research program which was very shortly described.

It is often not allowed to smoke in office buildings, and smoke could perturbate non smoking members of the panel. Therefore, smokers should refrain from smoking most of the time and may therefore be themselves perturbed, hence only non smokers were allowed to apply.

Sixty persons registered after publication of the advertisements. They were all invited to come for selection in November 93 by groups of 6 each. 46 attended the selection. These were all students, aged from 19 to 30, 16 female and 30 male.

The training was performed at different times with different methods and cones on the olf bar. We began with Teflon cones manufactured at our laboratory (we had 10 cones), for 5 days training before the pilot audit (building A). In this building, we tested both panels, and it appeared that the Lausanne panel had a bigger standard deviation than the Zurich one.

By the end of January, ('mieux vaut tard que jamais') we received the glass cones from the Netherlands. We did a test and two more training days before auditing two more buildings (F and G), and finally two more training days before the last building (H).

The training was first performed with 2-propanone ("pro analysi" grade) and then with different materials. The training with 2-propanone was straightforward and the panel had good results. With different materials they began to smell and give their opinions. At this moment, big standard deviation was observed. Then we discussed and came to a similar opinion for the whole panel (± 1 decipol). After this, we used these different materials as calibration, since the people began to like 2-propanone.

We have experienced strong variations of the sensibility of the panel members from one day to another. All panel member selected were aged between 20 and 27 years.

Table 5: Characteristics of the Lausanne panel after selection with five 2-propanone bottles

Person	Sex [M/F]	Smoker [Y/N]	Total difference [decipol]	Rank. Bottle1	Rank. Bottle 2	Rank. Bottle 3	Rank. Bottle 4	Rank. Bottle 5	Tot. rank	Final ranking
Schaller	M	N	4.5	1	1	9	23	6	40	1
Spiridon	F	N	5	1	16	1	13	11	42	2
Gerber	M	N	5.5	1	2	4	9	26	42	2
Melchior	M	N	5	1	16	9	6	11	43	4
De Luca	M	N	6	1	2	9	13	21	46	5
Leuppi	F	N	11	1	2	43	1	1	48	6
Marti	M	N	6	1	16	1	13	21	52	7
Schwartz	F	N	7	1	2	9	30	11	53	8
Eschmann	M	N	7	1	2	9	13	32	57	9
Berney	M	N	6.5	1	16	32	4	6	59	10
Henderson	F	N	5	25	16	1	1	21	64	11
Saint-Ghislain	M	N	9	1	2	9	13	39	64	11
Dewarrat	M	N	6	25	2	9	13	21	70	13
Lechene	M	N	7.5	1	16	20	9	26	72	14

Table 6: Exam results with 8 bottles. First on 19.1.94, then on 15.2.94, after two more training days (the difference between decipol and ranking is because we use the ranking from every bottle and we did the sum of all the ranking).

Nr	Correct vote		Maximum 2 bad votes		Unacceptable votes		Passed	
	19.1.94	15.2.94	19.1.94	15.2.94	19.1.94	15.2.94	19.1.94	15.2.94
Schaller	5	6	2	2	1	0		X
Spiridon	6	6	1	1	1	1		
Gerber	6	6	2	2	0	0	X	X
Melchior	5	5	2	2	1	1		
De Luca	7	7	1	1	0	0	X	X
Leuppi	5	7	1	1	2	0		X
Marti	6	6	1	2	1	0		X
Schwartz	7	7	1	1	0	0	X	X
Eschmann	4	7	3	1	1	0		X
Berney	0	7	0	1	0	0		X
Henderson	0	7	0	1	0	0		X
Saint-Ghislain	7	7	0	0	1	1		
Dewarrat	7	8	0	0	1	0		X
Lechene	4	6	3	2	1	0		X

Table 7: Samples used, other than 2-propanone.

1: newspaper 2: fresh cigarettes	3: old cigarettes (3 hours)	4: plastic sheets 5: after shave	6: carpet 1 7: carpet 2

Table 8: Results on sources other than 2-propanone, before discussion.

Sample	1	2	3	4	5	6	7
Mean vote [decipol]	4	12	22	5	25	1	7
Standad deviation	3	4	7	2	6	1	2

Table 9: Training, test and measurement schedule

NAME	MONDAY 29.11.93 training	TUESDAY 30.11.93 training	WEDNES. 1.12.93 training	THURSD. 2.12.93 training	FRIDAY 3.12.93 training	WEDNES. 8.12.93 training	THURSD. 9.12.93 Building A	WEDNES. 19.1.94 test	WEDNES. 9.2.94 when test -	MONDAY 14.2.94 training	TUESDAY 15.2.94 Building F	WEDNES. 16.2.94 Building G	WEDNES. 23.2.94 test	MONDAY 28.2.94 training	TUESDAY 1.3.94 Building H
Gerber F.	17:00-18:00	13:00-14:00	13:00-14:00	13:00-14:00	13:00-14:00	13:00-14:00	11:00-12:00 13:30-16:30	13:00-14:00	13:00-14:00	17:00-18:00	11:00-12:00 13:30-16:30		13:00-14:00	17:00-18:00	11:00-12:00 13:30-16:00
Eschmann	17:00-18:00	13:00-14:00	13:00-14:00	13:00-14:00	13:00-14:00	13:00-14:00	11:00-12:00 13:30-16:30	13:00-14:00	13:00-14:00	17:00-18:00	11:00-12:00 13:30-16:30	11:00-12:00 13:30-16:30	13:00-14:00	17:00-18:00	
De Luca A.	17:00-18:00	13:00-14:00	13:00-14:00	13:00-14:00	13:00-14:00	13:00-14:00	11:00-12:00 13:30-16:30	13:00-14:00	13:00-14:00	17:00-18:00		11:00-12:00 13:30-16:30	13:00-14:00	17:00-18:00	11:00-12:00 13:30-16:00
O.Lechène	18:00-19:00	13:00-14:00	13:00-14:00	13:00-14:00	13:00-14:00	13:00-14:00		13:00-14:00	13:00-14:00	18:00-19:00	11:00-12:00 13:30-16:30	11:00-12:00 13:30-16:30	13:00-14:00	18:00-19:00	11:00-12:00 13:30-16:00
Henderson	18:00-19:00	18:00-19:00	18:00-19:00	18:00-19:00	18:00-19:00	18:00-19:00	11:00-12:00 13:30-16:30	18:00-19:00	18:00-19:00	18:00-19:00			18:00-19:00	18:00-19:00	11:00-12:00 13:30-16:00
J. Leuppi	18:00-19:00	18:00-19:00	18:00-19:00	18:00-19:00	18:00-19:00	18:00-19:00	11:00-12:00 13:30-16:30	18:00-19:00	18:00-19:00	18:00-19:00	11:00-12:00 13:30-16:30		18:00-19:00	18:00-19:00	11:00-12:00 13:30-16:00
St Ghislain	16:00-17:00	13:00-14:00	13:00-14:00	13:00-14:00	13:00-14:00	13:00-14:00	11:00-12:00 13:30-16:30	13:00-14:00	13:00-14:00	16:00-17:00		11:00-12:00 13:30-16:30	13:00-14:00	16:00-17:00	11:00-12:00 13:30-16:00
Marti G.	18:00-19:00	18:00-19:00	18:00-19:00	18:00-19:00	18:00-19:00	18:00-19:00		18:00-19:00	18:00-19:00	18:00-19:00	11:00-12:00 13:30-16:30		18:00-19:00	18:00-19:00	
Melchior A.	17:00-18:00	17:00-18:00	17:00-18:00	17:00-18:00	17:00-18:00	17:00-18:00		17:00-18:00	17:00-18:00	17:00-18:00	11:00-12:00 13:30-16:30	11:00-12:00 13:30-16:30	17:00-18:00	17:00-18:00	11:00-12:00 13:30-16:00
Schaller V.	16:00-17:00	18:00-19:00	18:00-19:00	18:00-19:00	18:00-19:00	18:00-19:00	11:00-12:00 13:30-16:30	18:00-19:00	18:00-19:00	16:00-17:00	11:00-12:00 13:30-16:30	11:00-12:00 13:30-16:30	18:00-19:00	16:00-17:00	11:00-12:00 13:30-16:00
Berney M.	17:00-18:00	18:00-19:00	18:00-19:00	18:00-19:00	18:00-19:00	18:00-19:00	11:00-12:00 13:30-16:30	18:00-19:00	18:00-19:00	17:00-18:00	11:00-12:00 13:30-16:30		18:00-19:00	17:00-18:00	11:00-12:00 13:30-16:00
S. Dewarrat	16:00-17:00	17:00-18:00	17:00-18:00	17:00-18:00	17:00-18:00	17:00-18:00		17:00-18:00	17:00-18:00	16:00-17:00	11:00-12:00 13:30-16:30	11:00-12:00 13:30-16:30	17:00-18:00	16:00-17:00	11:00-12:00 13:30-16:00
M. Schwartz	17:00-18:00	18:00-19:00	18:00-19:00	18:00-19:00	18:00-19:00	18:00-19:00	11:00-12:00 13:30-16:30	18:00-19:00	18:00-19:00	17:00-18:00	11:00-12:00 13:30-16:30		18:00-19:00	17:00-18:00	
M. Spiridon	16:00-17:00	17:00-18:00	17:00-18:00	17:00-18:00	17:00-18:00	17:00-18:00	11:00-12:00 13:30-16:30	17:00-18:00	17:00-18:00	16:00-17:00	11:00-12:00 13:30-16:30	11:00-12:00 13:30-16:30	17:00-18:00	16:00-17:00	

3.1.1.2 Training room:

The training room is a cabin prepared in an experimental hall for ventilation testing purposes, and primarily not planned for olfactive tests. Its building materials are:

- chipboard for floor and ceiling
- plastic (PVC) bricks covered with polyethylene foils for walls.

Floor and ceiling are made of two chipboard layers, with a 6 cm air gap in-between. The inner surfaces have many 6 mm diameter holes through which the ventilation air is blown or taken away. The air is blown trough the floor and taken away from the ceiling, at a rate of 430 m^3/h. Thus, the room gets a piston ventilation with a vertical average speed of 11 cm/s.

During training, the acetone concentration was always measured below 5 ppm in room. Moreover, the result for the room, tested by the 46 untrained candidates, was 11% dissatisfied, corresponding to 1 decipol. Despite the fact that parts of the room were made of chipboard, the room complies with the conditions given in the Audit Manual. The probable reasons are that the construction is at least 4 years old, that it was overheated and ventilated during a month before use, and that the chipboard plates smell mainly a pine odour, which is accepted by most Swiss people.

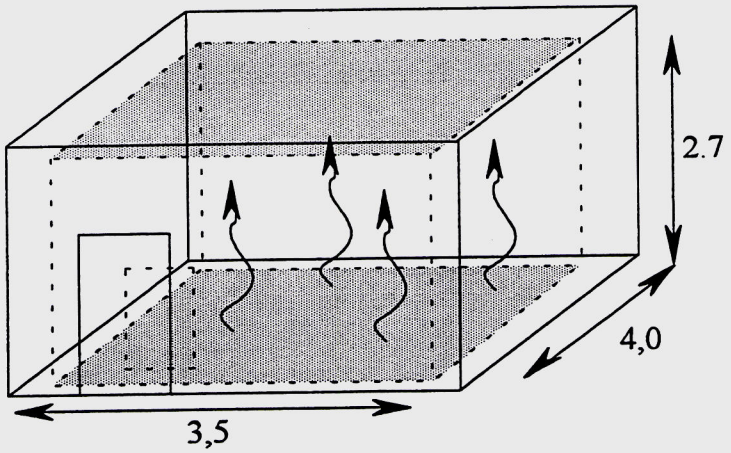

Figure 11: Sketch of the test room used for training the panel.

3.1.2 Zürich panel

3.1.2.1 Selection:

15 people have been selected out of a total of 35. The panel has been selected with only 6 bottles (the material from the Netherlands arrived late). All the members are non-smokers and between 22 and 30 years old.

3.1.2.2 Training and Test:

The training was performed as indicated in the manual. After the first test (individual test) some more training followed. A second test has not been made, however, at this point we could not afford to substitute the panel. We put the time and money in training it.

Only 12 out of the 15 people where used for one field assessment.

3.1.2.3 Calibration:

The calibration in the morning of the auditing day was done on 2-propanone concentrations prepared the night before. We tried to keep everything constant, but the data from this calibration is not necessarily exact and useful. The panel was indeed alone in the calibration room, and the concentration in the bottleswere not calibrated in the morning.

Table 10: Selection test and error scoring: 22. Nov. 93

	Votes						Deviation							
Bottle	A	B	C	D	E	F	A	B	C	D	E	F	Err.	Rank
Correct:	6.5	8	2.5	4.5	20	11							Sum	
Bachmann	5	10	2	5	20	10	1.5	2	0.5	0.5	0	1	5.5	2
Bösch.S.	4	7	3	5	18	12	2.5	1	0.5	0.5	2	1	7.5	5
Bosshard G.	3	8	2	5	20	15	3.5	0	0.5	0.5	0	4	8.5	8
Brauss S.	4	10	2	5	20	17	2.5	2	0.5	0.5	0	6	11.5	11
Doulakas L.	8	6	3	5	17	11	1.5	2	0.5	0.5	3	0	7.5	6
Faist.M.	8	12	2	5	16	10	1.5	4	0.5	0.5	4	1	11.5	12
Mathys P.	8	6	3	5	18	15	1.5	2	0.5	0.5	2	4	10.5	10
Mecklenburg	10	6	4	7	19	15	3.5	2	1.5	2.5	1	4	14.5	15
Münch J.	5	7	2	4	18	12	1.5	1	0.5	0.5	2	1	6.5	3
Samimi N.	5	9	2	3.5	18	14.5	1.5	1	0.5	1	2	3.5	9.5	9
Studer A.	8	10	2	5	20	14	1.5	2	0.5	0.5	0	3	7.5	7
Rädler U.	6	9	4	5	18	18	0.5	1	1.5	0.5	2	7	12.5	13
Udatney D.	8	6	3	5	25	15	1.5	2	0.5	0.5	5	4	13.5	14
Udatney R.	7	8	2	4	22	11	0.5	0	0.5	0.5	2	0	3.5	1
Venzin R.	4	8	1	5	20	13	2.5	0	1.5	0.5	0	2	6.5	4

Table 11: Exam results on 19.1.94. Individual Test with 7 concentrations

	Correct	2	3	5	6	8	10	12	passed
1	Udatney R.	2	3	4.5	6	7	10	11.5	X
2	Bachmann D.	2	2.5	3.5	5	9	8	12	X
3	Münch J.	3	3	4	6	7	10	11	X
4	Venzin R.	2	3	4	7	7	11	10	X
5	Doulakas L.	2	2.5	3	6	9	10	12.5	X
6	Bösch.S.	3	3	4	7	8	8	13	X
7	Studer A.	2	3	4	6.5	8	10	12	X
8	Bosshard G.	3	3	4	6	6	11	10	X
9	Samimi N.	2.5	3.5	4.5	6	9.5	11	11	X
10	Mathys P.	2.5	3	4	8	8	9	13	X
11	Brauss S.	3	3	4	7	9	10	10	X
12	Faist.M.	2	3	4	8	6	10	13	X
13	Rädler U.	2	2.5	4	5	8	13	9.5	X
14	Udatney D.	2.5	3.5	4	8	9	10.5	11.5	X
15	Mecklenburg	3	4	6	5	10	12	13.5	X

3.1.3 Field measurements

After morning retraining, the appropriate panel was transported in the building. The locations to be measured were shown to the whole panel. Then the panel was driven to the refresment place, and each member tested each location one after the other, only once.

3.2 Questionnaire

The questionnaire described in the Audit Manual was translated into French by the LESO and into German by IHAP. The French version was checked by IUMHT and CSTB (France), while the German version was also sent to University of Berlin. These questionnaires are provided in Appendix.

German questionnaires were mainly used in buildings A to E, while French versions were mostly used in buildings F to H. However, French versions were also offered to French speaking employees in buildings C to E, English versions were also distributed in buildings D and E.

The distribution and collection procedure described in Audit Manual was not followed in every building. In building A, the number of employees was not too large, and these are very often out of office. Therefore, the questionnaire was sent to the building management a week before the audit, with the recommendation, if possible, to fill it during the audit day. Most questionnaires were collected in the afternoon of the audit day. However, several occupants, absent on the audit day, filled the questionnaire before, or even after the audit day.

In buildings F and G, the building management did not want to let our personal go everywhere and disturb the managers and employees. Therefore, the building management distributed the questionnaire by internal mail, the day before the audit, to a representative sample of the occupants (they are used to do so). The questionnaires were also collected by internal mail. The response rate was nevertheles surprisingly high (78%).

In other buildings, the questionnaires were distributed and collected by our personal.

3.3 General IAQ measurements

Instruments used for chemical and physical analysis of the air are listed in Table 12. Procedure was as described in Audit Manual.

Table 12: Instruments used in Switzerland for the chemical and physical analysis of the air

Physical quantity	Instrument	Locations	Schedule
TVOC	Adsorption tube (Tenax) TD/GC/MS/FID	5 + A	P
CO	DRÄGER PAC 2 CO	5 + A	P
CO_2	AROX 425A photo-acoustic gas detection	5 + A	P & C
CO_2	BINOS 100 - 2 channels non-dispersive IR	5 + A	P & C
Dust	Pump and TEFLON filter (gravimetric)	5 + A	P
Dust	Grimm Dust Monitor 1.102 (continuous)	1	C
Multiple gas	STÄFA-CONTROL Air quality sensor	3	W
Ions	PERISO Ion analyser	5 +	P

Locations: 5+: at five locations in open offices or in 5 rooms, and in adjacent zone
A: in ventilation air inlets
1 (or 3): At one (or three) location(s) in offices

Schedules: :P: point measurements, between 13 and 15 h (pumps on from 9 to 17 h for dust, ≈ 1 m^3 sampled volume)
C: continuous from 9:00 to 17:00.
W: continuous for a week around the audit day.

In addition to standard quantities mentioned in Audit Manual, we have measured the ion concentration and the "air quality" as given by a multigas semiconductor sensor connected to a portable data logger. Instruments were lent by the corresponding factories, which also took

care of the measurements and first data interpretation. From the methodological point of view, it seems very interesting to have "long term" (at least a week) monitoring of a few quantities ("air quality" signal , air temperature and humidity in the present case). The recorded data allows us to check that the audit day is not a special one, to control the ventilation schedule, if any, and to observe possible unexpected phenomena in absence of the audit team.

In the first building, much more instruments were brought in, in order to compare their results. In particular, continuous measurement of dust were performed. However, concentrations of dust are so low that the obtained data do not have much sense. In particular, it was seen that dust concentration was strongly related to the presence and movement of the measurement team.

3.4 Comfort parameters

Instruments, location and schedules for measurement of comfort related parameters are listed in Table 13.

Table 13: Instruments used for measurement of comfort parameters

Physical quantity	Instrument	Locations	Schedule
Air temperature	Pt-100-Air probe CONDUSTRIE-MET AG	5 1 (3 heights)	P C
Operative temperature	B&K 1212	5 1	P C
Mean radiant temperature	Calculated from above temperatures also measured with DELTA RADIOMETER UDRM-HUND	5	P
Air velocity	DANTEC 54 N50 FLOWMASTER	5 (3 heights)	P
Relative humidity	ROTRONIC HYGROSKOP DV-2 with YA-100, Air Probe	5 + 1	P C
Light	BBC luxmeter	5 or more	P
Noise	SEL Sonometer, A weighing	5 +	P

Location and schedule coded as in Table 12. Noise measurements were taken at 8:30, before starting sampling pumps and other noisy instruments.

3.5 Measurement of air flow rates to the rooms

3.5.1 Methods used

For the ventilation measurements in monitored rooms, we have used the CESAR (Compact Equipment for Survey of Air Renewal), which was developed at the LESO and is described below. It measures the air flow rates using three tracer gases, using any injection strategy, in particular constant injection, decay or constant concentration; the latter being particularly developed and the most used. Up to 10 locations can be measured simultaneously The analysers are non dispersive IR spectrometers, the tracers being N_2O, SF_6 and Halon R1301. The complete equipment can be transported.

In most cases, SF_6 was used in office rooms, and N_2O in adjacent spaces. Since Halon R1301 is harmful to the ozone layer, we have used it sparsely, only in cases where a third zone had to be measured. Before elaborating the injection strategy, pressure differential measurements and smoke tests were performed in openings between zones. Since the scope of the measurements was to assess only the air flow rates coming into the monitored offices, tracer was not injected in zones not giving any air to the office rooms. With this injection strategy,

and assuming steady state, dilution of SF6 in the room is a measure of fresh air flow rate and increase of other tracers is an indication of air flow rates coming from other zones.

It would be the simplest way to inject the tracer gas into the inlet ventilation duct in order to measure the air flow rates from ventilation to measured offices only. This was however nowhere possible. In some cases, these ducts where not accessible, and in other cases there were several ducts to one room, or several rooms on one duct.

Constant concentration technique was used everywhere it was possible. In large open offices (>2000 m^2) however, the maximum injection rate allowed by the instrument was too small to obtain a high enough tracer concentration. In these offices (buildings B and C), we have used manual constant rate injection, followed by a decay. An improvement of the instrument is under study now, allowing its use in large enclosures.

Multizone, dynamic and bayesian interpretation technique (see AIVC TN 34) was used to interpret the measurement of tracer gas concentrations and injection rates in order to obtain the air flow rates. This sophisticated method was in some cases the only one able to provide reliable results.

In some special cases, where air inlets were well localised and of convenient size, a FLOWFINDER was also used. This was possible only in buildings D and H, for a few grids.

3.5.2 CESAR: principle of operation

The hart of this instrument is the controller, which monitors the programmable sampler, collects concentration data from the 10 analysed locations, computes the amount of tracer to be injected and pilots the injection valves. It is based on a MS-DOS compatible personal computer.

The control method used in the program for constant concentration measurements is a digitised and modified PI (proportional-integral) which can achieve a very stable concentration, even when the air flow rate changes strongly. The control parameter are chosen in an optimal way and do not depend much on the air flow rates. Overshoots are avoided by non linear modification of the control algorithm.

The air flows are computed off line and are displayed by the controller, taking into account the residual small variations of the concentration of the tracer, the cross sensitivity of the analysers and the variations of the density of air.

This equipment has the following parts:

1- Four non dispersive infrared spectrometers (BINOS of Leybold Heraeus company), one tuned for water vapour and the others for the three tracers used: nitrous oxide (N_2O, 200 ppm fsd†), sulphur hexafluoride (SF_6, 20 ppm fsd) and Halon 1301 (R13B1, 20 ppm fsd). The necessary correction on the tracer concentration due to the presence of water vapour is automatically performed. Other analysers may be installed with minor modifications. Once analysed, the sample is flushed outdoors.

2- An 11 channel programmable sampling unit (developed at the LESO), the eleventh channel being the outdoor air. This sampler contains the sampling pumps and sets of electrovalves enabling the sampling of the rooms in an arbitrary sequence. While the air of a given room is sampled and injected into the analyser, the sampler pre-pumps the sampling duct of the next channel. The analysing time is short enough to scan 11 channels (e.g. 10 rooms and the outdoor air) in less than 10 minutes.

3- A 10 channel programmable tracer injection unit (also developed at the LESO), which can inject, in any sequence, one of the three tracers in a duct leading to a room. Each channel has two supersonic nozzles, adjusted for two different flow rates. The control of the injected quantity is achieved by electrovalves controlling the injection time through the

chosen nozzle. The tracer injected in the duct is then flushed with outdoor air, while the unit injects another tracer in the duct connected to the next room.

4- A process controller (an MS-DOS operated PC) and a data processing unit (Hewlett Packard 3852A). These control, by means of the CESAR software, the time-shared injection and sampling sequences and the data logging.

5- An anemometer to record on site the simultaneous values of wind direction and speed.

6- Temperature sensors (Pt 100 Ohm) to measure the indoor and outdoor temperatures.

3.5.3 Procedure

3.5.3.1 Mixing the tracer gas

The main problem in tracer gas measurement techniques is to obtain a good mixing of the tracer in the air to be measured. The best solution depends on the ventilation system, especially on its inlet and exhaust grids. In principle, the tracer injection should be located in a turbulent area, upstream of the analyser. The best solution we have found by experience in the investigated buildings are presented below.

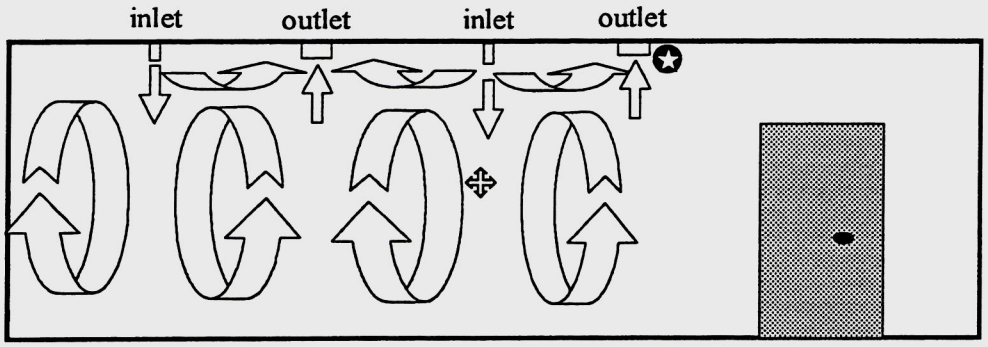

Figure 12: Position of injection and analysis when air inlet and outlet are at the ceiling.
✪ *analyser*
✣ *injector (preferably with multiple head, so tracer can be injected in many different inlets,)*

The best position for the injection is just in the inlet, but when there is a short circuit between the inlet and the outlet, it is better to inject in the middle of the room (otherwise, a large amount of tracer gas is directly lost in the outlet, before mixing). For the analysis the best position is in one outlet.

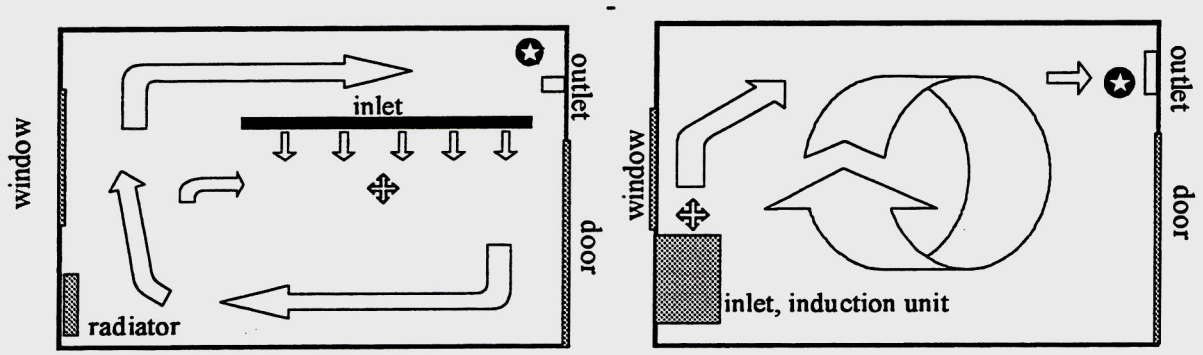

Figure 13: Position of injection and analysis when inlet and outlet are in different locations of the room.

Figure 13 shows two different situation where the mixing is easy to obtain when inlet and outlet are in different locations and air movements are known from smoke test. Engineers

project often also show arrow representing the planned air movement, but unfortunately, the air does not always follows the arrows.

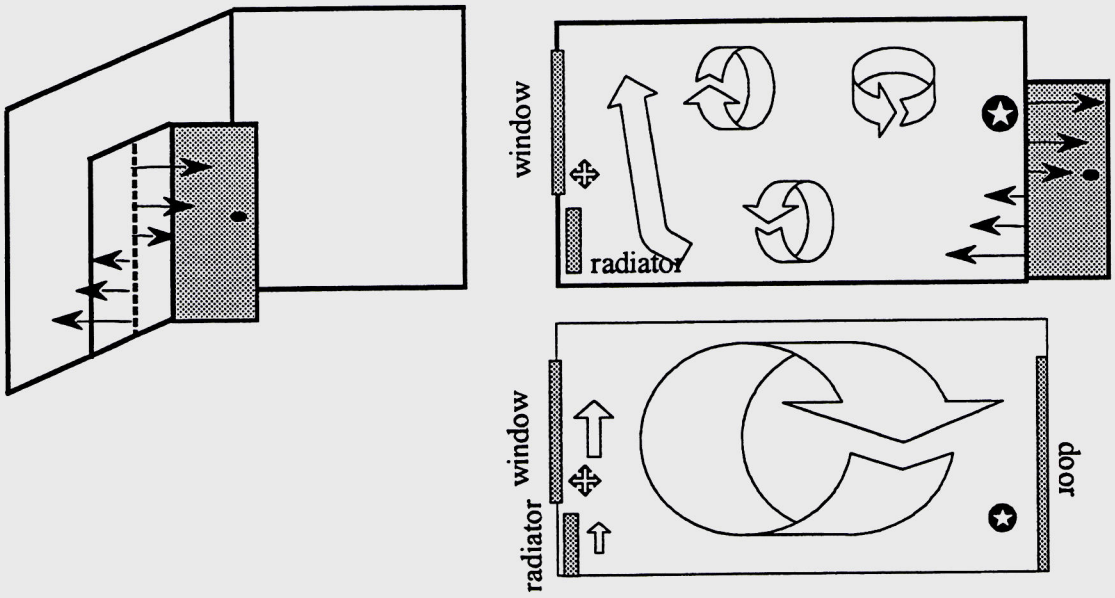

Figure 14: Position of injection and analysis with -natural ventilation

In case of natural ventilation the air movements caused by the radiator or stack effect should be used. In open doors the air come into the room through one half of the door (the upper or lower, depending on temperature differences) and goes out through the other half. This situation can be used by placing the analyser close to the exhaust. In any case, the injection should not be placed where the air goes out and the analyser shall not be located in the fresh air.

As a general test, the measured concentrations should be followed during the first hour of measurement. If they are relatively continuous and slowly changing, the mixing could be good. At the contrary, if there are large and quick variations of a concentrations, it is certain that the mixing is not achieved, and one should change the injection and analysis locations to obtain a better evolution.

3.5.3.2 Use of the tracer gases

Basically, in order to get all air flow rates, one tracer gas is required for each zone, including the ventilation system considered as a zone. However, only air flow rates coming into the monitored rooms are required, and this reduces drastically the number of required tracers. A supplementary reduction is obtained by testing the direction of inter-zonal air flows with smoke: injection of a tracer is not required in adjacent zones not giving air to the audited rooms. From our experience, it is not sufficient to measure the pressure differential, especially if it is small or when there are open doors.

Figure 15 shows three examples of tracer gas injection strategies used in different situations.

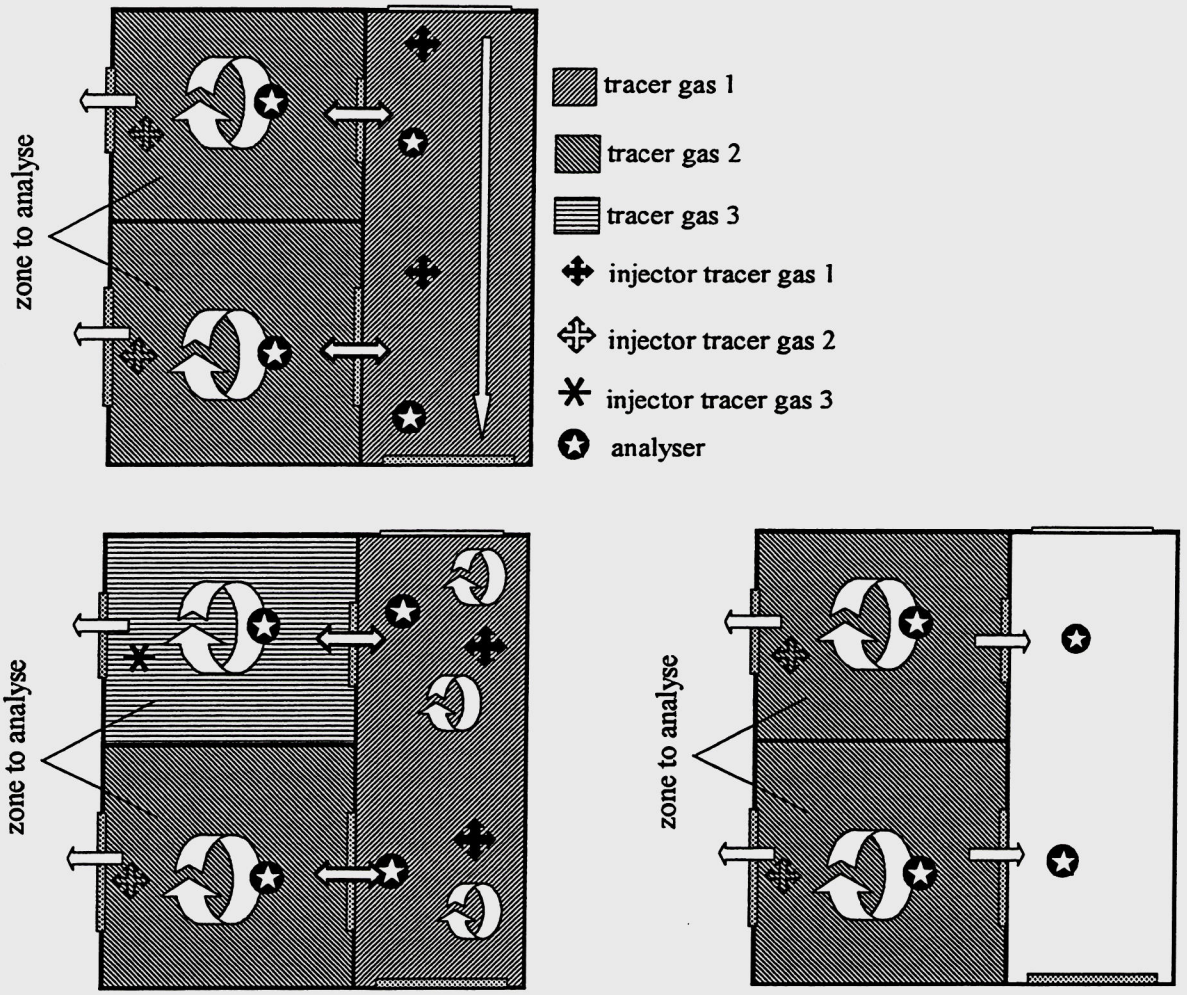

Figure 15: Three examples of tracer injection in order to measure air flow rates incoming in the two zones at the left.

3.6 Measurements of air flow rates in ventilation systems

In addition to standard measurement, the air flow rates in the ventilation systems were measured in order to check if these were functioning as planned.

The measurement procedure is based on tracer gas dilution at constant injection rate. Tracer gas is injected at known, constant rate in a duct, upstream enough from a location where the air in the duct is analysed. The measured concentration, C, is linked to the tracer source rate, S, and to the air flow rate in the duct, Q, by:

$$C - C_o = \frac{S}{Q} \quad \textit{hence} \quad Q = \frac{S}{C - C_o} \tag{1}$$

where C_o is the tracer concentration upstream the injection port. Noting ϵ_Q and ϵ_C for measurement errors of tracer flow rate and concentrations, the error for air flow rate is:

$$\epsilon_Q^2 = \frac{1}{(C - C_0)^2}\left[\epsilon_S^2 + \frac{2S^2}{(C - C_0)^2}\epsilon_C^2\right] \quad \text{assuming } \epsilon_C^2 = \epsilon_{C_0}^2 \tag{2}$$

In a usual ventilation system, as illustrated on Figure 16, there could be recirculation, short-circuits, mixing tees, etc. In order to obtain all the air flow rates, either several tracers should be injected at the same time, or the experiment should be repeated several times, injecting the tracer at various locations. These procedure are planned in order to get at least as much flow equations as air flow rates to be measured.

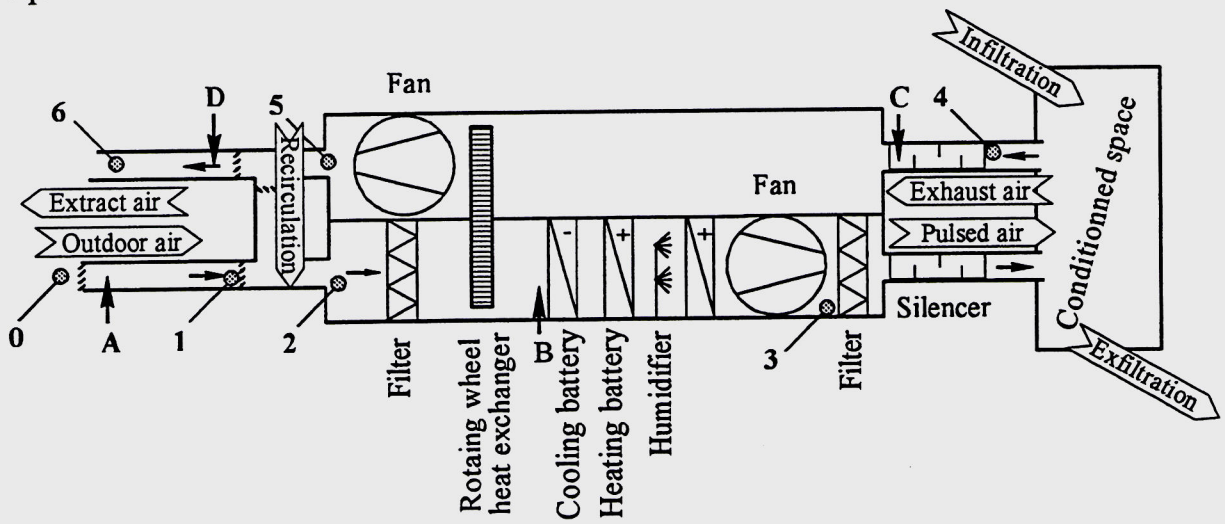

Figure 16: Schematics of a ventilation system. A, B, C, D: tracer gas injection points; 0, 1, 2, 3, 4, 5, 6: concentration analysis locations.

Proper tracer gas injection and analysis locations for the system are shown on Figure 16 and in Table 14 . These measurements allow one to assess all air flows in the installation. In many cases, it can be safely assumed that some air flow rates are negligible or non existent, and the planning of the experiment can be greatly simplified.

Table 14: Examples of injection and analysis locations for measurement of air flow rates in ventilation system.

Injection location	Analysis port	To measure		Equation used
A	0 and 1	Q_o	outdoor air flow rate	$Q_o(C_1-C_o) = S_A$
B	2 and 3	Q_p	pulsed air flow rate	$Q_p(C_3-C_2) = S_B$
C	4 and 5	Q_{ex}	exhaust flow rate	$Q_{ex}(C_5-C_4) = S_C$
	0, 3 and 5	Q_r	recirculation flow rate	$Q_r=(Q_pC_3-Q_oC_0)/C_5$
D	5 and 6	Q_e	extract air flow rate	$Q_e(C_6-C_5) = S_D$
B	0, 3 and 4	Q_i	infiltration flow rate.	$Q_i = Q_e+Q_{ex}-Q_o$
		Q_x	exfiltration flow rate.	$(C_0-C_3)Q_x=(C_0-C_3)Q_p + (C_4-C_0)Q_{ex}$

Other experimental designs are possible, allowing measurement of many air flows with fewer experiments. They lead however to more complex equations (AIVC TN 34). The most important condition is that the tracer is perfectly mixed to the air at the concentration measurement location. This requires either a very long straight duct, or some flow perturbing elements such as bends or fans between the injection and the analysis locations. The most convenient experimental plan should be chosen after taking account of the practical possibilities for injection and analysis, and of the tracer mixing elements.

The tracer gas mixing should be verified by checking the concentration variation along a traverse in the duct or upon time. If the concentration remains steady, the mixing is likely to be good. If not, mixing can be improved by multiplying the injection ports in the section of the duct, or by mixing air samples taken at several locations in a traverse.

3.7 Weather conditions

Weather conditions were obtained mostly from ISM, the Swiss Meteorological Institute, and were provided to LESO by the EMPA, Swiss Federal Institute for Testing Materials. Such data can easily be obtained, but with a delay of 2 months. For this reason, the climatic data recorded at the LESO building were taken for building H, which was the last tested.

Table 15: sources of weather data.

Building	Meteorological station
A	Bern
B and C	Zurich
D and E	Wädenswil
F and G	Pully (near Lausanne)
H	LESO-EPFL

3.8 Energy consumption

Annual energy use for heating, cooling and other appliances was provided by the building management, generally without much difficulty. For some cases (buildings D and E, and F and G) where two different buildings were owned and managed by the same organisation, the consumption's were not known separately for each building. In this case, an estimate of the heating requirement of each building was calculated with a simplified model (LESOSAI, similar to prEN 832). The hypothesis (e.g. air change rate, furnace efficiency) on which these estimates are based were adjusted in such a way that the sum of the estimates equal the known total consumption. Electricity for office appliances was shared proportionally to floor area.

3.9 Time schedule

Buildings were audited as shown in the Table 16. The first visit (half a day), was used to choose the monitored rooms, to asses information for measurement planning, and to fill-in the building check list.

Table 16: Visit schedule

Building	First visit	Audit day
A	18.05.93	9.12.93
B	13.05.93	25.01.94
C	13.05.93	26.01.94
D	12.05.93	1.02.94
E	12.05.93	2.02.94
F	02.06.93	15.02.94
G	02.06.93	16.02.94
H	25.05.93	1.03.94

Figure 17 shows the hourly schedule for a typical audit day. In most cases, the audit team arrived late in afternoon the day before the audit, in order to install the instruments. Buildings C, E and G, were audited the day after buildings B, D and F respectively. Each pair of buildings was close each other, so the beginning of installation could immediately follow the dismantling in the preceding building.

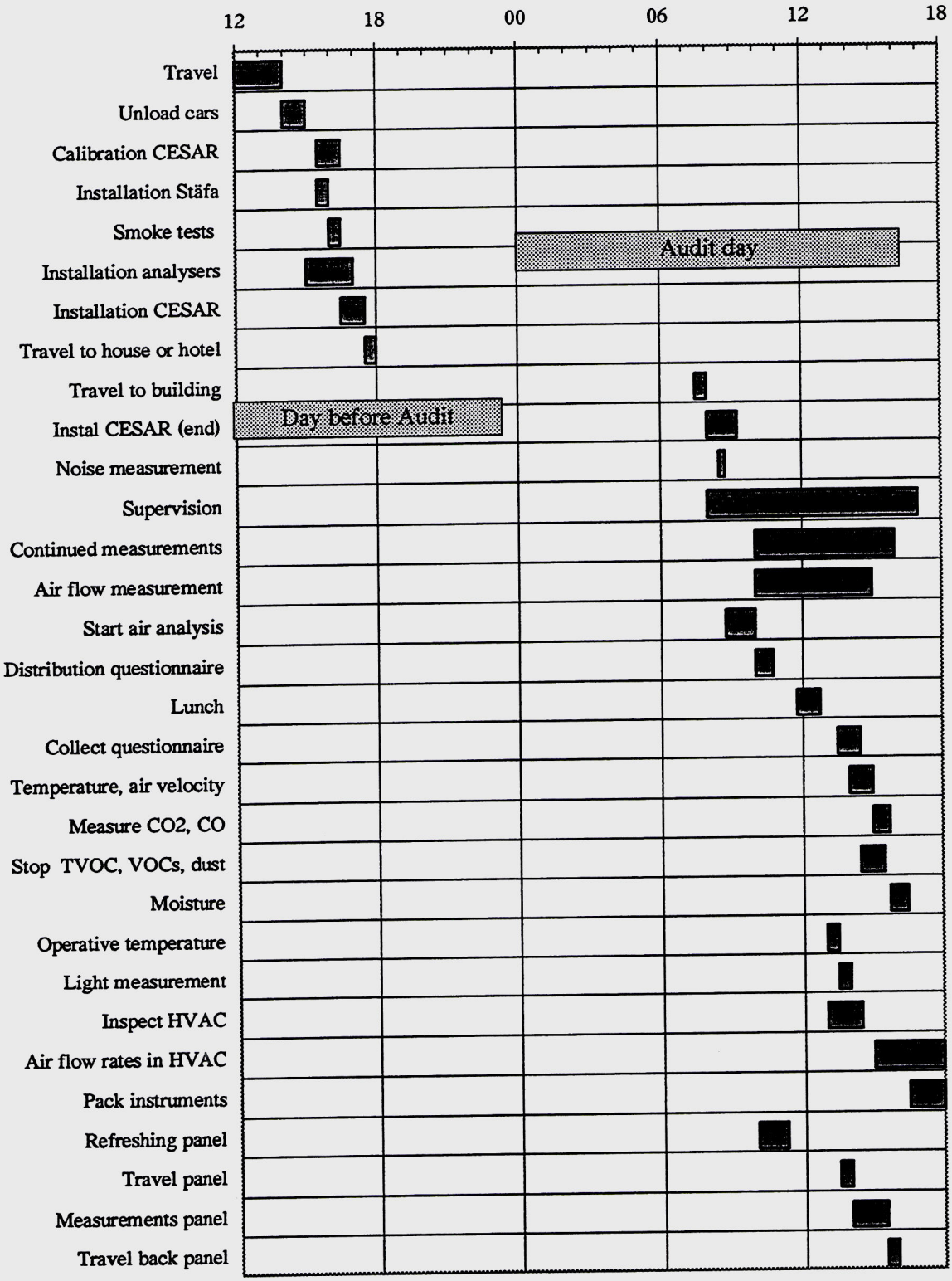

Figure 17: Typical time schedule followed during the audit of a building.

4. RESULTS

Main results are presented below, while detailed results are in appendices corresponding to each building.

4.1 Questionnaire

The collected questionnaires were interpreted using an EXCEL worksheet prepared for this purpose.

4.1.1 Population

Table 17: Building investigated population, per building

Occupants	A	B	C	D	E	F	G	H	μ	σ
Total number	240	750	1'200	223	200	800	800	240	557	380
Questionnaires distributed	80	150	120	140	100	135	130	130	123	23
Questionnaires returned	77	141	108	119	94	115	101	126	110	20
Mean Age	44	38	36	39	40	43	42	39	40	3
Stdev. of mean age	10	10	13	9	10	12	14	12	11	2
Female occupants	21%	40%	53%	43%	53%	35%	53%	51%	44%	12%
Male occupants	79%	60%	47%	57%	47%	65%	47%	49%	56%	12%
Time at desk before filling questionnaire	2.7	2.9	3.7	2.9	2.8	2.8	2.6	2.7	2.9	0.3
Managerial work	19%	16%	13%	41%	33%	12%	16%	18%	21%	10%
Specialist skill	57%	18%	1%	26%	18%	45%	31%	3%	25%	19%
Clerical	22%	49%	72%	23%	44%	30%	48%	72%	45%	20%
Other	1%	17%	13%	10%	5%	12%	5%	7%	9%	5%
Time spent in the building [years]	10.0	5.4	2.7	1.8	5.2	10.1	8.0	7.8	6.4	3.1
Time spent in the room [years]	2.9	3.0	2.3	1.4	2.1	4.5	4.4	5.5	3.3	1.4
Hours per day at the desk	6.9	7.5	8.2	7.7	7.5	9.2	7.8	8.2	7.9	0.7
Paid hours per week	42	41	40	42	44	41	41	39	41	2
Hours at VDU per week	14	26	24	22	24	19	16	16	20	5
Days per month in the building	17	20	16	16	15	21	22	21	18	3
Number of people in the room	8	66	44	0	1	2	2	4	16	25
Asthma	10%	6%	10%	14%	10%	10%	6%	12%	10%	3%
Eczema	24%	29%	28%	21%	26%	13%	17%	19%	22%	6%
Hay fever	19%	27%	29%	28%	27%	22%	19%	26%	25%	4%
Smoking neighbors	21%	81%	11%	29%	29%	37%	25%	52%	36%	22%
Smokers	16%	42%	41%	31%	19%	20%	21%	36%	28%	10%
Ancient smokers	16%	28%	26%	33%	31%	33%	36%	44%	31%	8%

In building A, the pilot study, there were not enough occupants to collect 100 questionnaires.

The average age of occupants is about 40 years, but it is 36 years in building C, which is a new banking centre, and more than 44 in A, hosting a long established government office.

Sex are more or less equally represented in most buildings, with a slight advantage to men. Buildings A and F, which host many managers or specialists, contain a large majority of men.

Smoking is allowed in separate rooms in every building. In building B it is even allowed to smoke everywhere, except is siome spaces in the cafeteria. The percentage of smokers, however, varies strongly between buildings. Bank and insurance show a percentage slightly higher than the Swiss average, while there are less smokers in public and food industry offices. Interesting is the comparison between buildings B and C, which are both open offices and which show the same percentage of smokers. In principle, in building B, it is allowed to smoke in some area of the open offices, while in building C it is not allowed to smoke in offices between 8 and 16 hours. The percentage of smoking neighbours (a cause of complaints often mentioned) is 81% in B while only 11% in C!.

4.1.2 Building symptom indices

These indices are calculated from the number of symptoms presented by each individual, which disappear when this person is out of building. These are defined in the Audit Manual. Basically, the larger is the BSI, the greater is the number of building related symptoms.

Tableau 18: Definition of symbols used for Building Symptom Indices.

Symbol	Signification	List of symptoms	Correction
BSI fs	Based on frequency scale,	Short (max 6)	
BSI ff	used for symptoms present	Long (max. 11)	
BSI fsc	during the month preceding	Short	Yes
BSI ffc	the audit day.	Long	Yes
BSI ss	Based on sensitivity scale	Short	
BSI sf	used for symptoms present	Long	
BSI ssc	the audit day.	Short	Yes
BSI sfc		Long	Yes

It is well known that women generally present more symptoms than men, and that managers complain less than clerical employees. To take account of the difference in populations between buildings, correction factors were defined in Audit Manual. These were based on male managers, since it is likely that these show the smallest symptom index.

Unfortunately, the number of male managers filling the questionnaire is often quite low, and sometime lower than 2. The related information has then no meaning. It was hence decided that the correction factor should be calculated on the base of female clerical, which are well represented in any office building. The factors shown in Table 19 are calculated on this base. Therefore, the correction factor for each building is 1 for female clerical.

It appears that the number of symptoms presented depends in average much more on sex than on the type of job

Table 19: Correction factors, based on a value of 1 for female clerical.

	Correction factors	A	B	C	D	E	F	G	H	μ	σ
PSI fs	Male Managers	0.77	0.60	0.75	1.13	0.43	0.03	0.26	0.93	0.61	0.36
	Male Specialists	0.34	0.50		0.88	0.37	0.37	0.43	0.55	0.49	0.19
	Male Clerical	0.42	1.06	0.60	0.00	0.86	0.51	0.76	0.73	0.62	0.32
	Male Others	1.35	0.10	0.64	0.47	0.19	0.08	0.38	1.10	0.54	0.47
	Male	0.45	0.66	0.64	0.93	0.42	0.30	0.41	0.82	0.58	0.22
	Female Managers	1.08	1.33	0.90	1.64	0.86	0.18		1.47	1.07	0.49
	Female Specialists	0.74	0.82	1.93	0.33	1.14	0.50	1.19		0.95	0.53
	Female Clerical	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
	Female Others		0.58	1.22	1.10	1.29	0.98	1.42	1.66	1.18	0.34
	Female	0.95	0.95	1.05	1.03	1.01	0.87	1.05	1.10	1.00	0.07
PSI ff	Male Managers	0.75	0.50	0.69	0.87	0.42	0.02	0.25	0.92	0.55	0.31
	Male Specialists	0.32	0.46		0.74	0.32	0.30	0.39	0.57	0.44	0.16
	Male Clerical	0.38	0.96	0.55	0.00	0.93	0.45	0.63	0.70	0.58	0.31
	Male Others	0.96	0.07	0.43	0.59	0.14	0.08	0.27	1.51	0.51	0.51
	Male	0.43	0.58	0.58	0.76	0.39	0.25	0.37	0.82	0.52	0.20
	Female Managers	0.87	1.33	0.82	1.51	0.78	0.12		1.26	0.96	0.46
	Female Specialists	0.82	0.54	2.37	0.25	0.98	0.52	1.00		0.92	0.69
	Female Clerical	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
	Female Others		0.63	1.22	1.85	1.03	1.16	1.28	1.51	1.24	0.38
	Female	0.94	0.94	1.06	1.04	0.98	0.89	1.02	1.07	0.99	0.07
PSI ss	Male Managers	0.92	0.47	0.37	0.95	0.52	0.34	0.31	0.60	0.56	0.25
	Male Specialists	0.67	0.47		0.70	0.47	0.46	0.44	0.31	0.50	0.14
	Male Clerical	0.57	0.89	0.52	0.00	1.08	0.68	0.73	0.94	0.68	0.33
	Male Others	1.50	0.10	0.39	0.18	0.58	0.11	0.00	1.57	0.55	0.63
	Male	0.72	0.56	0.46	0.75	0.53	0.43	0.42	0.85	0.59	0.16
	Female Managers	1.25	1.11	0.73	1.70	1.30	0.00		1.05	1.02	0.54
	Female Specialists	1.25	0.45	1.95	0.89	1.08	0.87	1.06		1.08	0.46
	Female Clerical	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
	Female Others		0.53	1.03	0.64	1.30	1.33	1.83	1.26	1.13	0.44
	Female	1.09	0.89	1.05	1.12	1.04	0.97	1.07	1.03	1.03	0.07
PSI sf	Male Managers	0.97	0.42	0.47	0.70	0.52	0.30	0.39	0.54	0.54	0.21
	Male Specialists	0.74	0.45		0.62	0.41	0.42	0.48	0.32	0.49	0.14
	Male Clerical	0.62	0.89	0.43	0.00	1.32	0.52	1.05	0.83	0.71	0.41
	Male Others	1.30	0.07	0.31	0.23	0.77	0.08	0.00	1.70	0.56	0.64
	Male	0.78	0.54	0.41	0.59	0.54	0.37	0.51	0.77	0.56	0.15
	Female Managers	2.17	1.09	0.55	1.44	1.19	0.18		0.99	1.09	0.64
	Female Specialists	1.52	0.49	2.51	0.74	0.99	0.93	0.92		1.16	0.67
	Female Clerical	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
	Female Others		0.62	0.91	0.82	0.99	1.23	1.67	1.15	1.06	0.34
	Female	1.28	0.91	1.02	1.04	1.02	0.98	1.04	1.02	1.04	0.11
	Managers	1.03	0.73	0.93	1.18	0.48	0.04	0.26	1.09	0.72	0.42
	Specialists	0.48	0.48	2.98	0.65	0.48	0.38	0.55	0.64	0.83	0.87
	Clerical	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
	Others	1.29	0.31	1.18	1.13	0.50	0.54	1.11	1.72	0.97	0.48

Table 20 shows the building symptom indices for the 8 buildings. Strong differences are obvious: buildings A, B, C and H show the highest values, while D, F and G are below average.

Table 20: Building Symptom Indices

	Building	A	B	C	D	E	F	G	H	μ	σ
BSI fs	Last month, short list	1.59	3.03	3.07	1.17	2.60	1.66	2.09	2.43	2.21	0.69
BSI ff	Last month, full list	2.12	4.21	4.43	1.43	3.45	2.33	2.79	3.44	3.02	1.05
BSI fsc	Last month, short list, corrected	2.89	4.79	4.43	1.88	2.65	1.87	2.06	3.79	3.04	1.16
BSI ffc	Last month, full list, corrected	4.23	7.07	6.73	2.40	3.78	2.55	2.97	6.04	4.47	1.89
BSI ss	Today, short list	1.34	2.05	1.94	0.74	1.87	1.26	1.57	1.57	1.54	0.43
BSI sf	Today, full list	1.74	2.77	2.77	1.00	2.40	1.66	2.02	2.16	2.07	0.60
BSI ssc	Today, short list, corrected	2.45	3.21	2.53	0.99	2.09	1.54	1.47	2.39	2.09	0.71
BSI sfc	Today, full list, corrected	3.17	4.42	3.55	1.31	2.89	1.94	2.33	3.32	2.87	0.98

Questions were asked on environment, air quality, noise, lighting, etc., mostly on a 7 point scale. Table 21 shows the scales used.

Table 21: Evaluations of environmental conditions corresponding to evaluation scales.

Condition	Evaluation for minimum note	Notes Min	Best	Max	Evaluation for maximum note
Comfort	Cold	-3	0	+3	Hot
Temperature	Comfortable	1	1	7	Uncomfortable
Temp. variations	Not enough	1	4	7	Too variable
IAQ acceptability	Not acceptable	-5	0	+5	Acceptable
Air movement	Still	1	4	7	Draughty
Air moisture	Dry	1	4	7	Humid
Air stuffiness	Fresh	1	1	7	Stuffy
Odours in air	Odourless	1	1	7	Smelly
Lightness	Too dark	1	4	7	Too bright
Light stability	Steady	1	1	7	Flickering
Glare	No glare at all	1	1	7	Too much glare
Light homogeneity	Very uniform	1	4	7	Very uneven
Light satisfactory	Satisfactory	1	1	7	Unsatisfactory
Noise from ventilation	No noise	1	1	7	Too much noise
Other noise	No other noise	1	1	7	Too much other noise
Noise in general	Satisfactory	1	1	7	Unsatisfactory

Table 22 shows the mean response rates with respect to IAQ, and allows the comparison between responses concerning the past month and the audit day.

Table 22: Mean response rates with respect to air quality. Best note is 5 for IAQ acceptability (from -5 to 5), 4 for air moisture (from 1 to 7) and 1 for air stuffiness and air odour (from 1 to 7).

	A	B	C	D	E	F	G	H
Environmental condition past month:								
indoor air acceptability	1.55	0.53	0.14	3.22	0.69	1.90	2.34	1.30
air humidity	2.54	2.59	2.45	3.17	2.09	2.68	2.58	2.56
air stuffyness	3.39	4.65	4.98	2.90	4.70	3.39	3.43	3.86
air odour	2.59	3.55	4.23	2.46	3.26	3.03	2.68	2.88
Environmental condition now:								
indoor air acc.	2.13	1.19	0.91	3.35	1.35	2.50	2.56	1.72
air humidity	2.71	2.93	2.93	3.13	2.54	2.76	2.80	2.64
air stuffyness	2.78	3.96	4.00	2.56	3.97	2.93	3.14	3.28
air odour	1.95	2.91	3.42	2.04	2.81	2.11	1.81	2.47
Control on ventilation	1.12	1.38	1.41	4.64	1.84	1.89	2.32	1.43

On Table 23, it can be seen that thermal comfort conditions, air movements, air moisture and odours are accepted in every building. IAQ is however judged just acceptable in most buildings, D being the exception.

Table 23: Judgement of comfort condition and IAQ on the audit day. Best notes are: 0 for thermal comfort (from -5 to 5), 1 for comfort temperature, air stuffiness and odour(from 1 to 7), 4 for air movement and humidity (from 1 to 7); and 5 for IAQ acceptability (from 1 to 7).

	A	B	C	D	E	F	G	H	μ	σ
Level of thermal comfort	-0.4	0.1	-0.4	0.0	-0.2	0.0	0.2	-0.1	-0.1	0.2
Indoor air acceptability	2.1	1.2	0.9	3.4	1.4	2.5	2.6	1.7	2.0	0.8
Comfort temperature	2.4	3.2	3.4	1.8	2.5	2.7	2.7	3.2	2.7	0.5
Air movement	4.3	4.3	4.4	3.6	3.8	3.7	4.0	3.6	4.0	0.3
Air humidity	2.7	2.9	2.9	3.1	2.5	2.8	2.8	2.6	2.8	0.2
Air stuffiness	2.8	4.0	4.0	2.6	4.0	2.9	3.1	3.3	3.3	0.6
Air odor	1.9	2.9	3.4	2.0	2.8	2.1	1.8	2.5	2.4	0.6

As shown on Table 24, lighting is found quite satisfactory everywhere. Ventilation system appears to be noisy in buildings B and G, but noise seem satisfactory in most buildings, A and B being the possible exceptions.

Table 24: Light and noise judgement on the audit day. Best notes are 1 for light flickering, glare, noise judgement and satisfaction; 4 for light brightness and homogeneity (all from 1 to 7).

Light and noise	A	B	C	D	E	F	G	H	μ	σ
Light brightness	3.9	3.7	4.1	4.1	3.9	3.8	4.1	4.1	4.0	0.1
Light flickering	1.5	2.0	2.0	1.5	1.8	1.6	1.6	2.0	1.7	0.2
Glare	1.8	2.5	2.3	2.3	2.4	2.1	2.5	3.0	2.4	0.4
Light uneven	4.1	4.1	4.2	4.1	4.0	4.0	4.0	4.0	4.1	0.1
Lighting satisfactory	1.9	2.7	2.4	1.8	2.4	2.3	2.4	3.0	2.4	0.4
Noise from ventilation	2.4	3.8	2.1	1.4	2.4	2.6	3.4	2.6	2.6	0.7
Other noise	3.6	3.9	2.6	2.7	3.1	3.5	3.2	2.9	3.2	0.4
Noise satisfactory	3.1	3.5	2.3	2.0	2.6	2.9	2.8	2.9	2.8	0.5

Except in buildings D and E, occupants feel they have no control on the temperature (Table 25). Control of occupants on ventilation appears to be possible only in building D, which is the only building having a part naturally ventilated. Even control on lighting is quite poor: only buildings A, D, E and G show some control possibilities overpassing the average value.

Most buildings are not dirty (all notes over 4) but building A, C, D and E are judged cleaner than the others.

Table 25: Judgement of occupants on environment control and cleanliness. Best note (full control and clean office) is 7

Control & cleanliness	A	B	C	D	E	F	G	H	μ	σ
Control on temperature	2.5	1.3	1.5	5.1	4.1	2.7	2.6	1.7	2.7	1.3
Control on ventilation	1.1	1.4	1.4	4.6	1.8	1.9	2.3	1.4	2.0	1.1
Control on lighting	4.9	2.0	2.6	5.3	4.1	3.3	3.7	2.9	3.6	1.1
Cleanliness	6.4	4.6	5.4	5.8	5.3	4.9	4.4	4.4	5.1	0.7

An important means of controlling temperature and ventilation is window opening. Table 26 shows the answers of occupants to several questions related to windows. It is allowed to open the windows only in buildings D, F and G. In building F, there is however some restriction. In building A and B, there are windows to every office room. Only conference rooms have no windows. Some occupants of this large open office buildings are however so far from the nearest window that they have the impression that their room has no windows.

Table 26: Relation of occupants with windows in the audited buildings.

Windows	A	B	C	D	E	F	G	H	μ	σ
Rooms without windows	5%	9%	3%	0%	3%	0%	0%	6%	0.03	0.03
Rooms with windows	95%	91%	97%	100%	97%	100%	100%	94%	0.97	0.03
Distance from the window	1.2	5.9	4.3	1.0	1.3	2.1	2.0	2.1	2.47	1.71
People opening the window	7%	0%	0%	94%	10%	62%	74%	3%	0.31	0.39
People not opening windows	93%	100%	100%	6%	90%	38%	26%	97%	0.69	0.39

4.2 Sensory evaluation

Perceived air quality as evaluated by the panels is given in Table 27. Outdoor air for building A was severely noted, because there were roadwork with asphalt vapours near the building.

In buildings F, G and H, fresh air was injected to the room through induction units. It was therefore not easily possible to judge the air coming from ventilation only, since this is already mixed with room air at inlet grids.

Table 27: Perceived air quality in decipol: mean values and standard deviation of votes. Last columns in the average of all buildings. δ is the confidence interval of the average vote for each building, calculated with 95% probability.

Sensory evalulation	A		B		C		D		E		F		G		H		
Decipol	μ	δ	μ	δ	μ	δ	μ	δ	μ	δ	μ	δ	μ	δ	μ	δ	μ
Outdoor air	4.3	2.3	2.1	2.1	1.8	0.8	1.4	0.6	1.4	0.6	0.5	0.7	0.9	0.9	1.1	0.8	1.7
Offices	8.0	2.9	6.1	1.8	4.7	1.5	6.9	1.9	5.7	1.9	6.4	2.5	6.1	1.7	4.3	1.6	6.0
Adjacent rooms	9.1	2.5	9.4	3.4	8.0	1.7	6.6	1.6	6.4	1.6	9.5	3.3	6.5	3.5	3.7	1.9	7.4
Supply air	2.7	3.0	3.6	1.3	3.4	1.3	4.1	2.0	3.0	1.1	3.3	1.9	2.3	1.3	3.0	2.0	3.2

4.3 General indoor air quality

Results of measurements on VOC, TVOC, CO, CO_2 and particles in selected offices of the buildings are given here. Note that CO and particle concentrations were everywhere close to or below the detection limits.

4.3.1 Volatile Organic Compounds (VOC)

One sample per building was evaluated beyond the overall TVOC index. Based on chromatographic retention times, a total of 215 organic compounds were detected in the FID mode in the 8 buildings. For 56 compounds, a tentative partial or complete identification was obtained from the mass spectra. Based on the toluene equivalent concentration index, the 15 most abundant VOC were identified in each sample. Thirty-nine compounds, of which 4 unidentified so far, were cited in the top-15 list.

Table 28 gives a compilation of the 15 volatile organic compounds which are most present in each specially investigated room of each building. These are sorted by GC retention time, in order to group similar compounds.

The highest concentration is for n-hexane, present in building H only. This is a solvent, but we did not notice any particular use of solvents in this building. Most presents VOC's are acetone, aliphatic C_7H_{16}, toluene, dichloro methane and m-xylene, which are all solvents. Some of these may also come from gasoline, and acetone may also be emitted by occupants.

In building F, a large quantity of VOC was emitted by freshly painted surfaces.

None of the identified VOC was present at suspectedly harmful concentrations, even accounting for their sensitivity ratios vs. toluene in the FID evaluation. Sensitivity ratios for the identified compounds will typically be within a 0.1 to 10 range, with a noticeable exception for halogenated hydrocarbons. Only for one compound (n-hexane in Building H) did the concentration index exceed 0.1 mg/m^3, while the TVOC index remained below 1 mg/m3 in all but 2 samples, the latter remaining below 2 mg/m^3 (Building F). N-hexane in Building H is a special case, with a comparatively high concentration index, while not being detected in any other sample.Compared with typical outdoor TVOC indices taken on the same

days, the increase in concentration was usually less than a factor of 3, with the exception of Building F (factor 4.5).

Table 28: Compilation of the 15 volatile organic compounds which are most present in investigated buildigns, sorted by GC retention time.

Retention time min.	VOC	Likely sources	Number of buildings where present
2.45	ethanol	cleaning agents	2
2.52	?		1
2.69	acetone	metabolism? General purpose solvent, correction fluids, outdoor oxidized products	8
2.82	2-meth-1,3-butadiene	or isoprene: vegetal emissions? synthetic rubber	2
3.06	dichloro methane	general purpose solvent	7
3.4	2-methyl-pentane	gasoline, petroleum distillates (white spirit type solvents, incl. correction fluids)	6
3.53	3-methyl-pentane		1
3.75	acetic acid ?	silicone sealants	4
3.74	n-hexane	gasoline, petroleum distillates (white spirit type solvents)	1
3.94	acet.acid eth.ester	solvent (glues, sealants)	1
4.2	?		3
4.26	methyl-cyclopentane	gasoline, petroleum distillates (white spirit type solvents, incl. correction fluids)	1
4.57	1,1,1-trichlorethane	correction fluids, printing appliances	2
4.84	1-butanol	VDU's, electronic equipment	2
4.87	aliphatic C7H16	gasoline, petroleum distillates (white spirit type solvents, incl. correction fluids)	8
5.01			4
5.28	dimethyl-cyclopentan		1
5.47	n-heptane		6
5.66	C5H2O8 ester	or methyl-methacrylate: plastics, glues, photocopier supplies.	6
6.16	methyl-cyclohexane	gasoline, petroleum distillates (white spirit type solvents, incl. correction fluids)	3
6.26	methyl-cyclohexane		1
6.4	C? alcohol		2
6.51	?		1
7.06	toluene	solvents, glues (carpets!), gasoline	8
9.3	p-xylene	solvents, glues (carpets!), gasoline	3
9.5	m-xylene	solvents, glues (carpets!), gasoline	7
10.04	?		1
10.09	o-xylene	solvents, glues (carpets!), gasoline	4
11.49	aliphat. C9H20 ?	gasoline, diesel fuel	1
11.79	benzaldehyde		4
12.41	decane C10H22	gasoline, diesel fuel	1
12.53	trimethyl-benzene	gasoline?	6
13.36	L-Limonene	scented cleansing agents, perfumes	4
14.71	undecane C11H24	diesel fuel?	1
15.86	benzoic acid ?		1
16.86	dodecane C12H26	diesel fuel	1
18.51	Si-compound		1
23.43	dodecanoic acid ?		2

The observed concentrations are all 2 or more orders of magnitude lower than the maximum allowable workplace concentrations applicable in Switzerland and in most Western countries. Whether such limit values should also apply to non-industrial chemicals to which personnel may be exposed without proper instructions is still an open debate. The relationship between such values and the annoyance caused by unexpected chemicals in office workplaces has already been discussed (E.Fellay-Bosco, "Gêne sensorielle provoquée par dix substances pilotes", IUMHT, Lausanne 1988).

Table 29: Most common volatile organic compounds found in the audited buildings.

Compounds	Nb of buildings where detected (max. 8)	Nb of citations in top-15 list	Avg. conc. index per cit. µg/m3	Maximum conc. index µg/m3
toluene	8	8	27	57
acetone	8	8	25	83
aliphatic C_7H_{16}	8	8	16	39
m-xylene	8	7	15	33
dichloro methane	8	7	11	25
n-heptane	8	6	26	81
$C_5H_2O_8$ ester	8	6	10	18
2-methyl-pentane	8	6	9	26
trimethyl-benzene	8	6	6	12
aliphatic C_7H_{16}	8	4	23	81
methyl-cyclohexane	8	4	17	99
L-Limonene	8	4	13	62
o-xylene	8	4	5	11
benzaldehyde	8	4	5	10
p-xylene	8	3	5	10
unknown Z09	8	3	4	7
1-butanol	8	2	17	84
ethanol	8	2	4	21
undecane $C_{11}H_{24}$	8	1	4	8
unknown Z02	8	1	3	12
unknown Z46	8	1	3	8
Si-compound	8	1	3	12
dodecane $C_{12}H_{26}$	8	1	2	6
acetic acid ?	7	4	6	12
C? alcohol	7	2	3	8
2-methyl-1,3-butadiene	7	2	3	8
3-methyl-pentane	7	1	6	25
dimethyl-cyclopentane	7	1	6	28
decane C10H22	7	1	4	12
1,1,1-trichlorethane	6	2	3	10
dimethyl-cyclopentan	5	1	6	19
dodecanoic acid ?	4	2	7	11
methyl-cyclopentane	4	1	11	32
acetic acid ethyl ester	4	1	3	6
benzoic acid ?	4	1	3	4
unknown Z22	3	1	2	3
aliph C_9H_{20}?	2	1	15	21
n-hexane	1	1	201	201

Most identified compounds are hydrocarbons. Other interesting compounds are methyl methacrylate ($C_5H_2O_8$ ester) and chlorinated solvents (dichloromethane, trichloroethane) observed in all or most samples. Among hydrocarbons, some are typical "outdoor substances", e.g. benzene, toluene and xylenes, as well as many lighter alkanes. Others, in turn, are considered typical "indoor substances", such as heavier alkanes ($^3C_{10}$) and terpene compounds like limonene and the pinenes. Oxidized VOC, like alcohols, aldehydes, ketones or fatty acids may originate in both compartments. In all cases, if any compound was found at significantly higher concentration indoors than outdoors, an indoor source would have to be present. The outdoor air samples were however not evaluated in full detail during this audit.

Another methodological limit must be stressed: the Tenax TA sampling process followed by thermal desorption does not provide a good insight at polar or moderately volatile compounds, nor at very light hydrocarbons ($^2C_5$). The latter may not be very relevant to indoor air quality, but the former comprise a large array of odorous substances, including amines, sulfur compounds, fatty acids and other oxidized compounds. Oxidized compounds appear to make up the greatest amount of indoor airborne organic pollutants. Some of the polar compounds are also of much greater significance to health than hydrocarbons.

4.3.2 Dust

Measurements of suspended dust were taken every minute with a straylight dust meter (Grimm Dust Monitor 1.102) integrating all particles greater than 0.5 µm. All profiles remained below 30 µg/m^3 on average. Some records show scattered very fast peaks largely above the baseline noise, but no peak even approaches the mg/m^3 range.

Table 30: Continuous dust measurements

Building/ location	Average µg/m^3	Std. dev. µg/m^3	Median µg/m^3	Geom. mean µg/m^3	Geom. std. dev.	Max. µg/m^3
A/4	28	21	25	22	2.2	174
B/5	15	10	14	13	1.8	118
B/2	9	5	8	7	1.9	36
C/4	8	7	7	6	1.7	117
D/4	16	8	15	14	1.6	56
D/2	29	13	28	27	1.6	170
E/4	13	13	10	9	2.5	181
F/3	7	6	5	5	2.5	34
G/2	8	6	7	7	1.9	40

4.3.3 Carbon dioxide

Diagrams of continuous records of CO_2 concentrations are provided in the annexes related to each building. In traditional production settings, continuous measurements of variables related to work processes yield lognormally distributed results, reflecting a finite probability of excursions to elevated levels with respect to the median of all measurements and, at the same time, a limiting zero level. In the presence of a continuous background, the distribution tends more and more to appear gaussian as the background increases relative to possible excursions. In such cases, tha average and the geometric mean will be very similar. A third typical situation arises when randomly distributed events are superimposed upon an essentially low, constant background. The particular events will appearas as outliers on the high side of the distribution.

Continuous carbon dioxide records reflect many influences, including presence or absence of mechanical ventilation, density of people present, and the daily course of the outdoor carbon

dioxide concentration. The latter may vary by more than 100 ppm, normally with a maximum in the morning time and a minimum at the end of the daylight period, due to plant photosynthesis. This variation will therefore also be influenced by weather conditions, wind, nearby sources (heating, traffic) and plant photosynthetic activity (plant density, seasonal cycles). The audits in this project were all conducted in the winter season, so that plant photosynthetic activity was generally low.

Table 31: Average value of CO, CO_2 ,TVOC and dust measurements in the buildings

Contaminant / Location	CO_2 [ppm] Contin.	Spot	CO [ppm]	TVOC [mg/m³] Toluene	Dust [mg/m³]
A: offices	775	833	<1	0.16	0.30
supply air		895		0.20	
outside air		420	<1		
adjacent		800		0.58	0.30
B: offices	723	622		0.19	0.25
supply air		440		0.16	
outside air		375	<1	0.06	<0.1
adjacent		620			
C: offices	642	564	<1	0.32	<0.1
supply air		360	<1	0.31	<0.1
outside air		350	<1	0.36	<0.1
adjacent		500	<1	0.39	<0.1
D: offices	781	904	<1	0.45	<0.1
supply air		400		0.17	
outside air		360		0.36	
adjacent		900		0.32	
E: offices	703	689	1	0.16	<0.1
supply air		360		0.17	
outside air		360	0	0.19	
adjacent		530		0.22	
F: offices	652	828	<1	1.82	0.24
supply air		700	<1	0.58	
outside air		400	<1	0.42	
adjacent		890	<1	1.98	0.28
G: offices	703	799		0.12	0.26
supply air		650		0.07	
outside air		400	<1	0.03	
adjacent		700		0.11	0.300
H: offices	711	712	<1	0.92	<0.1
supply air		380		0.82	
outside air		392		0.34	
adjacent		700		0.39	<0.1

For the purpose of the present audit project, carbon dioxide monitoring is also used for assessing the efficiency of the ventilation in controlling metabolic emissions from the persons in the offices. Therefore, the data must be validated with respect to variation with time incorporating predictable influences like presence or absence of personnel, but also external

influences from outdoors or particular indoor episodes. Levels exceeding 1500 ppm would also be expected to cause reversible annoyance symptoms like tiredness or headaches.

In naturally ventilated buildings, more fluctuation during the day is expected. In the present audit, this was only the case of building A, showing a clear drop of the concentration during lunch break. No single particular departure from a smooth variation was noted in the investigated Swiss buildings.

4.3.4 Global averages

Average values of contaminant concentrations are given on Table 31. Spot and average of continuous measurements do not provide the same CO_2 concentration, because this concentration varies with time. The average of continuous measurements is also influenced by the peak caused sometimes by the sensory panel. The two instruments used for these measurements where calibrated and give the same result for the same air.

For source intensity calculation, we have taken spot measurements, which were performed in the absence of the panel, and all with the same instrument.

Table 32: Air and mean radiant temperatures, air velocity relative humidity and noise level averaged over the investigated rooms in buildings.

	Location	Tair [°C]	Tmrt [°C]	Vair [m/s]	RH [%]	Noise [dB(A)]
A:	offices 1.1 m	22.3	19.8	0.16	34	46
	supply air					
	outside air	11.5			65	
B:	offices 1.1 m	23.0	19.9	0.14	50	45
	supply air					
	outside air				72	53
C:	offices 1.1 m	23.1	18.9	0.09	47	45
	supply air					
	outside air	8.6			70	
D:	offices 1.1 m	23.0	21.1	0.11	36	47
	supply air					
	outside air	5.5			61	53
E:	offices 1.1 m	23.6	17.6	0.09	28	49
	supply air					
	outside air					53
F:	offices 1.1 m	22.1	20.1	0.10	40	45
	supply air					
	outside air	5.0				
G:	offices 1.1 m	23.2	20.6	0.15	33	43
	supply air					
	outside air	5.4			62	55
H:	offices 1.1 m	22.9	19.9	0.11	42	41
	supply air					
	outside air				75	63

4.4 General indoor climate

Results of thermal and noise measurements in selected offices of the buildings are given on Table 32. It can be seen that air temperature is everywhere higher than the mean radiant temperature, even in large open office buildings. These are well within the comfort limits for office work with winter indoor clothing.

Air velocity may cause draft complaints in buildings A, B and G. In fact, the air movement is judged on the average slightly higher than the best note in buildings A, B, C, and G (see Table 23).

Noise level is within accepted limits everywhere. In most case, the noise comes from conversations and computer keyboards. The instruments brought by the audit team generated much more noise tan the ambient one, therefore noise level measurement were performed before switching the instruments on.

4.5 Ventilation

4.5.1 Building ventilation system

The audited buildings have various ventilation systems, as shown on Table 4. Note that the office rooms in external part of building D have only natural ventilation.

It is clearly shown on Table 33 that ventilation systems not always runs as planned. Large differences between planned and measured values were often found. Not surprising is that buildings B and D, where a careful planning and commissioning have been performed, present the smallest differences. Planned air flow rates are not known in building E.

Nevertheless, the fresh air flow rate per person is everywhere large enough to eliminate the contaminants generated by occupants. This is confirmed by CO_2 concentrations always below 1000 ppm as shown on Table 31). Value of building D seems very low, but a large part of ventilation, not taken into account in Table 33, is natural ventilation.

Table 33: Planned and measured air flow rates in ventilation systems of audited buildings. Note that more fresh air enters building D by natural ventilation.

Air flow rates	A	B	C	D	E	F	G	H
Fresh air, planned [m³/h]	34800	60000	134500	8800		75000	100000	58000
do, per person [l/s]	40	22	31	11		26	35	67
Fresh air, measured	32000	54000	52000	8500	36000	85000	66000	38000
do, per person [l/s]	37	20	12	11	50	30	23	44
Planned pulsed air [m³/h]	87000	180000	134500	8800		300000	100000	67400
Measured pulsed [m³/h]	39000	130000		8500	46000	170000	66000	40000
Planned recirculation rate	60%	66%	0%	0%		75%	0%	36%
Measured recirc. rate	18%	63%	> 0	0%	22%	50%	0%	11%

To compare the ventilation in buildings, it may be useful to compute the specific air flow rate, per m² heated floor area, as shown on Table 34. This comparison is discussed in 5.2 Ventilation performance.

Table 34: Specific air flow rates (in l/(s·m²) floor area) in audited buildings. Natural air flow rates are not taken into account in building D.

Air flow rates [l/(s·m²)]	A	B	C	D	E	F	G	H	μ	σ
Fresh air, planned	1.3	0.8	1.0	0.2		0.6	0.7	1.4	0.8	0.4
Fresh air, measured	1.2	0.7	0.4	0.2	1.1	0.7	0.4	0.9	0.7	0.4
Planned pulsed air	3.3	2.4	1.0	0.2		2.4	0.7	1.7	1.6	1.1
Measured pulsed	1.5	1.7	0.4	0.2	1.4	1.3	0.4	1.0	1.0	0.6

4.5.2 Ventilation in audited offices

Tracer gas were used to measure the air flow entering the audited zones. Average results, taken on all the monitored location considered as a whole, are presented on Table 35. Note that these air flow rates are not necessarily representative of the building. The standard deviations are those of the values in the different rooms.

Accuracy for decay measurements is determined as follows: The total error in air exchange rate is a result oferror in concentration measurement of tracer gas SF_6 (±0.5 ppm) and error in recording time (±0.1 sec). This leads to a total relative error of ± 5-10% in the air exchange rate of a space. The volume of a space is calculated with a relative error of 2.5%.

Accuracy for Cesar measurement at contant concentration is determined as follows: The total error is calculated with a bayesian method taking account of error in concentration measurement of the tracers used (±0.3 ppm for SF_6 and R1301 and ±3 ppm for N_2O), of error in inside & outside temperatures (± 1°C), of error in the volume (2.5%) and of error in the injection rate of the tracer gas. The total relative error depends on many parametersw but it ranges anyway between 5 and 15 %.

Table 35: Specific air flow rates (per m² floor area) in audited zones of the 8 buildings. μ is the average over the investigated offices, while σ is the standard deviation between these office rooms..

Building	Floor area [m²]		Supply [l/(s.m²)]		Infiltration [l/(s.m²)]		Adjacent [l/(s.m²)]	
	μ	σ	μ	σ	μ	σ	μ	σ
A	396		0.00	0.00	0.03	0.02	0.06	0.03
B	729	327	1.70	0.17	0.00	0.00	0.00	0.00
C	1'240	622	0.55	0.03	0.00	0.00	0.02	0.01
D	17	10	1.20	0.33	0.00	0.02	2.71	1.32
E	19	4	2.58	0.07	0.00	0.01	1.04	0.04
F	36	13	3.85	0.15	0.00	0.01	1.27	0.13
G	25	0	2.86	0.34	0.00	0.01	1.27	0.58
H	48	31	10.11	0.28	0.00	0.01	0.04	0.00

4.6 Weather conditions

As shown on Table 36, weather was overcast during most audits. It was cold but sunny for building D, and variable (overcast with some sun) for building E. Except for buildings A and C, the wind speed was low, and therefore no wind direction can be given.

Table 36: Weather conditions during the audit day.

Weather conditions	A	B	C	D	E	F	G	H
Description	Cloudy, windy	Overcast	Overcast	Sunny	Variable	Overcast	Overcast	Rainy
Weather station	Bern	Zürich SMA		Wädenswil		Pully		LESO
Temperature (°C)								
0600-1200	10.1	7.1	4.0	-0.2	2.4	0.3	0.6	7.6
1200-1800	9.3	8.3	4.3	4.0	4.5	1.6	2.9	8.9
Relative humidity(%)								
0600-1200	69	92	85	89	70	84	77	94
1200-1800	62	89	66	72	69	80	72	86
Wind speed (m/s)	9.3	2.3	7.4	0.8	0.6	0.6	1.6	0.1
Wind direction (from)	West		West					

4.7 Energy consumption

Tableau 37 energy consumption of investigated buildings

Annual energy use	A	B	C	D	E	F	G	H	μ	σ
Heating index [MJ/m²]	1'238	318	1'001	385	508	1'009	791	879	766	330
Electric index [MJ/m²]	612	567	949	448	622	491	409	121	527	234
Energy Index [MJ/m²]	1'850	885	1'950	833	1'130	1'500	1'200	1'000	1'294	428

Note that most recent buildings, i.e. buildings B and D, use much less energy than older ones. This is the effect of new, energy conscious design knowledge and regulations. These two buildings only comply with Swiss SIA 380/1 recommendation which, for office buildings, limits the heating energy index to about 385 MJ/m². The average heating index for the existing Swiss building stock is 700 MJ/m².

4.8 Miscellaneous

4.8.1 Multigas sensor

Three semiconductor multigas sensors were placed a few days before and removed a few days after the audit day, in order to record some information on the indoor air during about a week.

These recordings, which are shown in the appendices for each building, were very useful to ensure that the audit day was a normal working day. In all audited buildings, the temperature, humidity and multigas sensor recordings followed similar schedules on the audit day and on neighbouring days.

4.8.2 Ion concentration

Average ion concentrations in audited buildings are given on Table 38. Measurements were not performed in building A. Effects of ions on health is not yet well known. It is however

sometimes argued that a ration for negative ions concentration to positive ions concentration equal to 3:1 is required for well-being.

Table 38: Ion concentrations in audited buildings. Measurements were performed in several locations.

	+ Ions/cm³			- Ions/cm³		
Building	Average	Max.	Min.	Average	Max.	Min.
B	233	537	66	226	423	84
C	481	933	174	526	743	136
D	572	1'010	197	543	979	162
E	183	321	60	128	284	29
F	288	445	62	152	261	30
G	170	441	14	52	167	7
H	221	3'472	54	69	171	9

What was noticed is that ion concentration is generally very low and much unstable. In most buildings, most buildings, average concentration in positive and negative ions are about the same. The 3:1 ratio is observed only in buildings G and H, but the absolute values of concentrations are low anyway.

In building B, one of the two audited zones is equipped with Bentax ionisers. Measurement have shown that the so-called ionised zone does not present a higher concentration than the non ionised zone. Moreover, the ionised zone presented an excess of positive ions during the measurements, while the other zone was neutral.

5. DISCUSSION

This chapter summarises the deductions which can be obtained from data measured in Switzerland. Several of them are not country-dependent, and safer conclusions will be drawn from the whole European Database.

5.1 Questionnaire - sensory measurements

The main output from questionnaire is the Building Symptom Index. As shown in 6.1.1, there is not much difference between the various ways of determining the BSI (severity or frequency scale, audit day or last month period). Therefore, in the following considerations, only the BSI_{fsc} will be used.

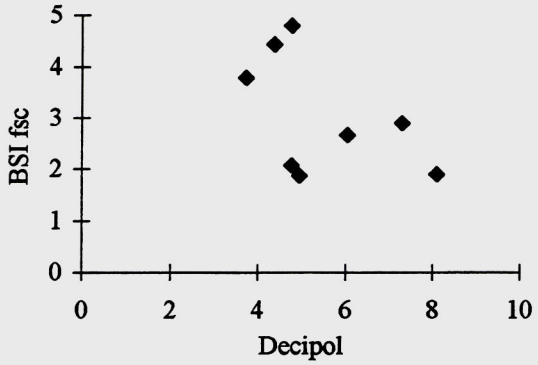

Figure 18: Comparison between Building Symptom Index and sensory pollution load.

Figure 18 shows that there is no obvious relationship between sensory pollution load as judged by the trained panel and building related symptoms of occupants. Figure 19 also shows no relation between sensory pollution load and subjective opinions of the occupants on indoor air acceptability, air freshness-stuffiness or presence of odour.

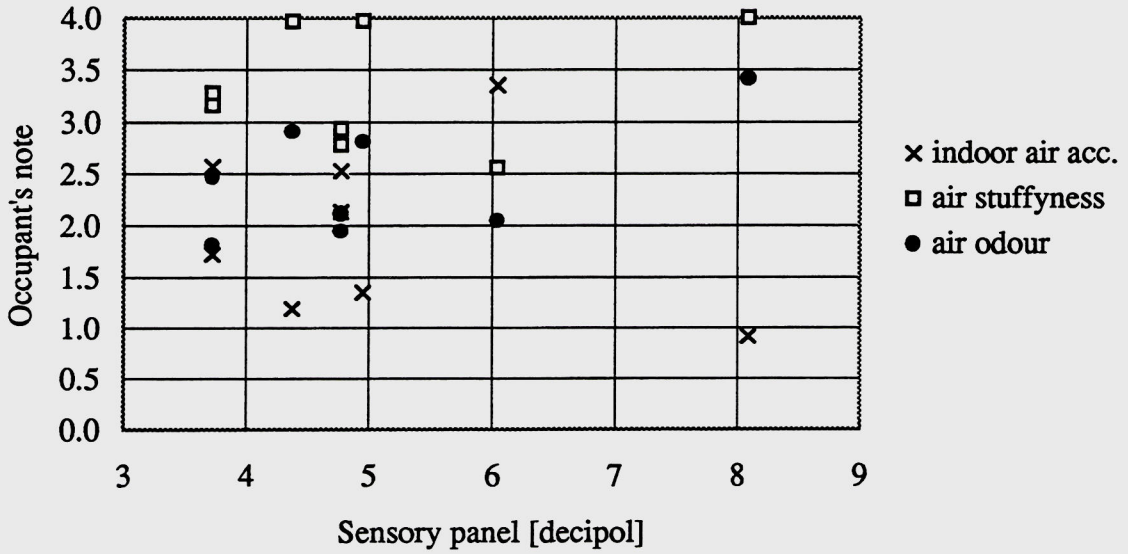

Figure 19: Comparison of occupant's opinion on indoor air quality and sensory evaluation of the trained panel.

5.2 Ventilation performance

Since there is no other CO_2 source than occupants in the audited buildings, CO_2 concentration is a good measure of the fresh air flow rate per person: the lower the concentration, the higher the fresh air flow rate. Figure 20 compares BSI to carbon gas concentration and to fresh air flow rate per working place (whole building). From this figure, it could be deduced that occupants feel better when they are less ventilated!. However, the apparent correlation is not statistically significant, and this is surely not true. However, it can be deduced that:

- the CO_2 concentration does not overpass the limits usually accepted in office buildings, hence the fresh air flow rate per person is everywhere sufficient to eliminate CO_2
- high ventilation levels do not make people feel healthier.

In other words, perceived health does not depend only on ventilation rate per person, and it is certainly possible to save energy by lowering the ventilation rate, provided that other conditions to make occupant healthy are fulfilled.

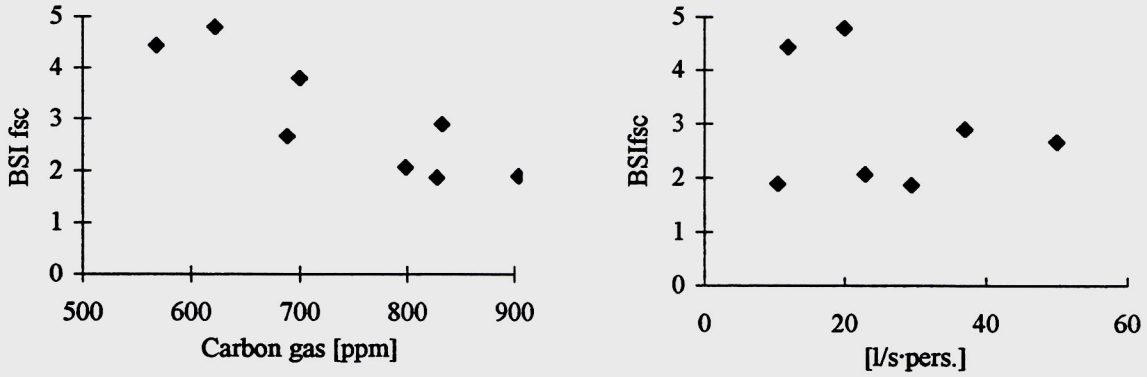

Figure 20: Building symptom index compared to carbon gas concentration and to fresh air supply per person.

It is interesting to compare planned and measured air flow rates in ventilation systems. Measurements in ventilation systems were not in the minimum requirements of the project, and were performed in second priority. Therefore, some air handling units were not measured (in buildings B, C, F and G), and in some cases, there was not enough time to check doubtful results (building C). However, it results clearly from these measurements that air handling units seldom functions as planned.

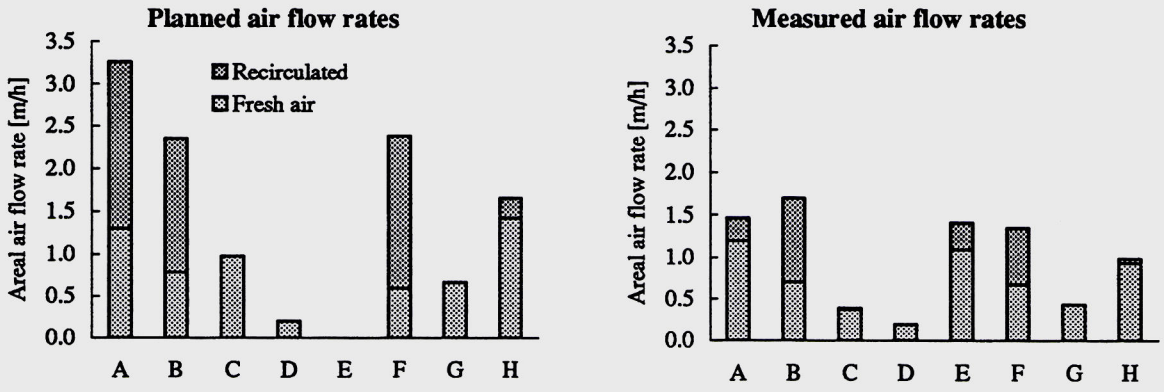

Figure 21: Air flow rates per square meter in 8 buildings, as planned and as measured in the ventilation systems.

Figure 21 shows the comparison. The fit is good for fresh air flow rates in buildings A, B, D and F, but it should be said that except for building D, this good fit results from a compensation of two mismatches: effective lower pulsed air flow rate and lower recirculation rate than planned. This results confirms that a careful commissioning cannot be avoided.

5.3 Sensory/chemical pollution load

Since many volatile organic compounds have an odour, there could be a correlation between the chemical pollution load measured by total VOC concentration, and perceived air quality. Figure 22 shows this comparison, and a possible correlation could be seen. The correlation coefficient does however not significantly differ from zero. It is however possible that the same diagram, based on all the buildings audited in Europe, could provide a somewhat different result.

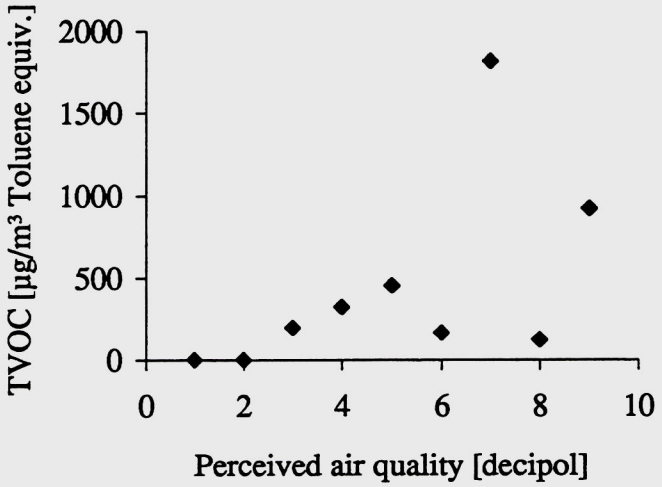

Figure 22: Comparison between total volatile organic compounds, as measured by adsorption and GC-FID analysis, and sensory load as judged by the panel. High TVOC value is for building F, in which some offices (not taken in the audit) were fresh painted a day before audit.

Pollution load can be calculated by using contaminant conservation equations together with contaminant concentrations and air flow rate measurements to determine the zone in which the sources are (see Audit Manual). Table 39 is the result of such a calculation applied to sensory pollution. An attempt is made to distinguish between sources in supply air, from tobacco smoke and occupants. The latter two can be estimated with a reasonable accuracy when the number of occupants and the percentage of smokers is known. We have noted that most CO analysers are not sensitive enough to obtain the trace CO concentration with a good accuracy. Therefore, the number of smoked cigarettes/hour cannot be determined this way.

Source from ventilation and source intensity in the room present very large confidence intervals. This results not only from uncertainties in decipol values and air flow rates, which are reasonable, but from the system of equations, which are ill-conditioned. In particular, there are, in these equations, small differences of relatively large concentrations. For all these reasons, interpretations of the following results should be taken with care.

The source intensity in offices varies considerably from one building to another. Buildings D, F,. G and H have their values over the average, but the figure does not differ significantly from zero in buildings A, C, E, F and H. Remember that, in building A, ventilation was switched off (by mistake) during the audit.

In buildings with recirculation, that is in buildings B, E, and F, as well as in offices equipped with induction units (E, F, G and H) it is difficult to distinguish between pollution generated in offices from that coming from ventilation system. This is because the air supplied to the office is a mixture of fresh and of recirculated air.

Table 39: Sensory pollution load in offices, computed from sensory evaluation and measured air flow rates.

Pollution load [olf/m²]	A	B	C	D	E	F	G	H	μ	σ
Area of audited offices	396	4'376	2'480	86	112	181	149	285		
In offices	-0.02	0.42	0.11	0.81	0.36	0.91	0.84	0.65	0.51	0.35
uncertainty	0.16	0.20	0.15	0.60	0.38	1.08	0.52	1.29	0.55	0.43
From supply air	0.00	-0.18	0.20	0.33	0.16	-0.07	0.34	1.29	0.26	0.46
uncertainty	0.00	0.17	0.13	0.19	0.17	0.58	0.25	1.14	0.33	0.37
From smokers	0.04	0.15	0.00	0.15	0.06	0.09	0.09	0.11	0.09	0.05
uncertainty	0.00	0.02	0.00	0.07	0.01	0.02	0.04	0.06	0.03	0.03
Occupants	0.05	0.06	0.04	0.08	0.05	0.08	0.07	0.05	0.06	0.02
uncertainty	0.00	0.01	0.00	0.04	0.01	0.02	0.03	0.03	0.02	0.01
Other sources	-0.11	0.21	0.07	0.58	0.25	0.74	0.67	0.50	0.36	0.30
uncertainty	0.16	0.20	0.15	0.61	0.38	1.08	0.52	1.29	0.55	0.43

As shown in Table 40, there is in most case a good fit between number of working places and Carbon dioxide concentrations. The misfits in building A comes from the fact that most employees were out of office on the audit day. In building E, the recirculation of air and the fact that a part of the audited zone was open to the rest of the building introduces some confusion in the identity of CO_2 sources. Obviously, CO_2 for occupants out of the audited zone was entering it. Misfit in building H is not explained yet.

Table 40: CO_2 source intensity compared with number of working places.

Pollution load l/(h·m²)]	A	B	C	D	E	F	G	H	μ	σ
Carbon dioxide	0.10	1.10	0.82	2.01	3.24	1.60	1.61	9.10	2.45	2.84
uncertainty	0.05	0.16	0.08	0.72	0.16	0.36	0.50	0.49	0.31	0.24
corresponding to	0.01	0.06	0.05	0.11	0.18	0.09	0.09	0.51	0.14	0.16
uncertainty	0.00	0.01	0.00	0.04	0.01	0.02	0.03	0.03	0.02	0.01
Working places/m²	0.05	0.06	0.04	0.08	0.05	0.08	0.07	0.05	0.06	0.02

5.4 Identification Pollution sources

Several ways can be used to identify pollution sources. The effectiveness of each method depends on the contaminant itself and on the possible sources.

We already have seen that it is difficult, from ventilation measurements and chemical or sensory analysis, to locate the sources. In this case, the cheapest way to localise some sources are the check list and the comments from panel and occupants.

Occupants were everywhere the smallest source of odours. Smokers are without doubt a large source of odours in buildings where it is allowed to smoke. Tobacco smoke alone can however not explain the sensory load in offices.

In building C, it was allowed to smoke only in the atrium or in the office rooms after 16:30 h. Since smoke spreads trough doors into office rooms and odours adsorbs in furniture and carpets, the pollution was finally not very different in office rooms (officially non smoking)

and atrium. This shows that no smoking policy should be applied very strictly to obtain positive results.

Other sources identified from comments are:

- a "new" carpet (2 years old) installed in building A, which was still emitting odours;
- unidentifiable mixture of many odours in the large open office in building B;
- cafeteria and corridor smokers in building C;
- new paintings in building F, even with work stopped for the audit day;
- cooking odours in building G.

5.5 Energy consumption

It was already said that the energy consumption of recent buildings, built according to new standards, use much less heating energy, and a little less electric energy, than older buildings. An interesting question is to relate energy consumption to ventilation and to occupants health.

On Figure 23 and Figure 24, one can hardly see any relationship between air flow rates and energy index. This does not mean that ventilation does not use energy, but that the noise, coming from the many other ways to spill energy, is much larger than the energy required for ventilation. A careful energetic analysis of each building, to determine the energy used for ventilation, could provide a better image. This was however not planned within this project.

The conclusion which could be drawn is that it is possible to ventilate buildings without a significant increase of energy consumption of the building.

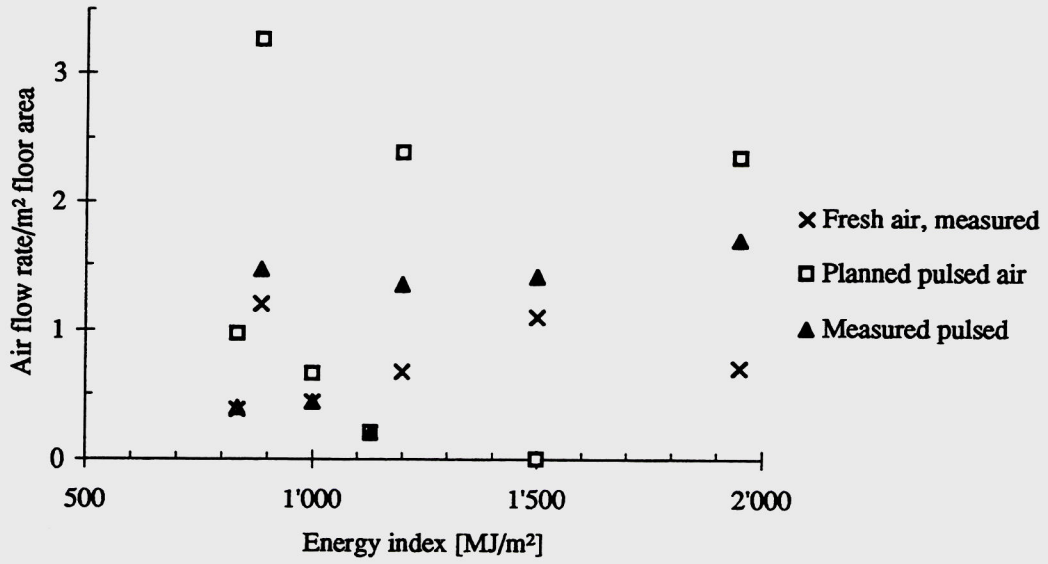

Figure 23: Energy index and air flow rates per square meter floor area.

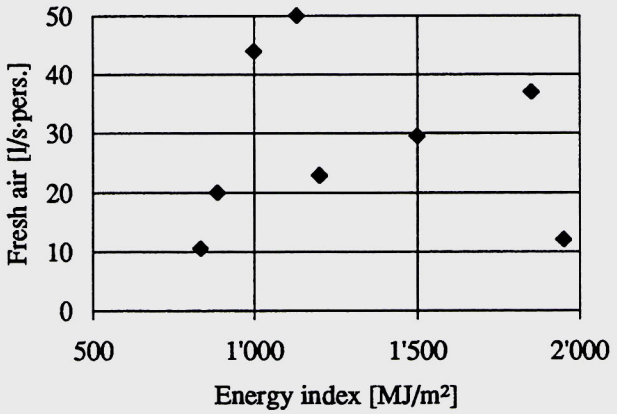

Figure 24: Relation between energy index and fresh air flow rate per person. No obvious correlation appears.

Figure 25 compares the BSI with the energy index. The absence of any correlation is not surprising. It confirms that it is not necessary to use energy consuming equipment to make occupants healthy.

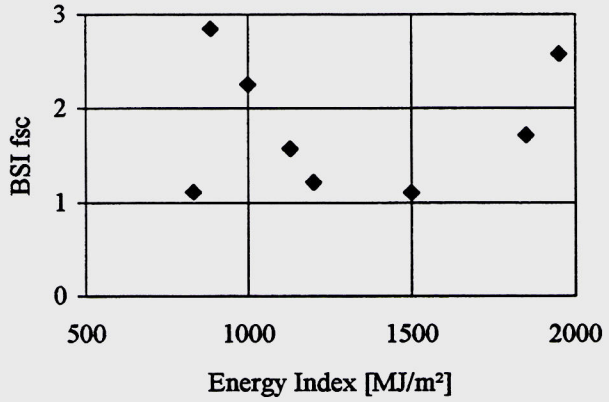

Figure 25: Relation between Building Symptom Index and energy index.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 IAQ assessment procedures

The applied IAQ assessment procedures are discussed for Switzerland and recommendations are given with respect to adjustment of the procedures or other procedures to be used.

6.1.1 Questionnaire

The questionnaire is without doubt a powerful tool for building analysis. Since buildings are (or at least should) first being built for the occupants, their opinion and health is of prime interest.

It seems however, after this first experiment, that the questionnaire can be shortened. The interpretation of data can also be greatly simplified by using only two correction factors and one type of BSI.

In the manual, correction factors are proposed for each population group, when this population is divided in occupation type and sex. With 4 occupation types, we get this way 8 correction factors per BSI, hence 32 correction factors per building.. On Figure 26, it can be seen that these factors depend much more on sex than on occupation type. Moreover, they do not depend much on the base used to compute the BSI's. It is hence proposed to limit the correction to the sexual effects.

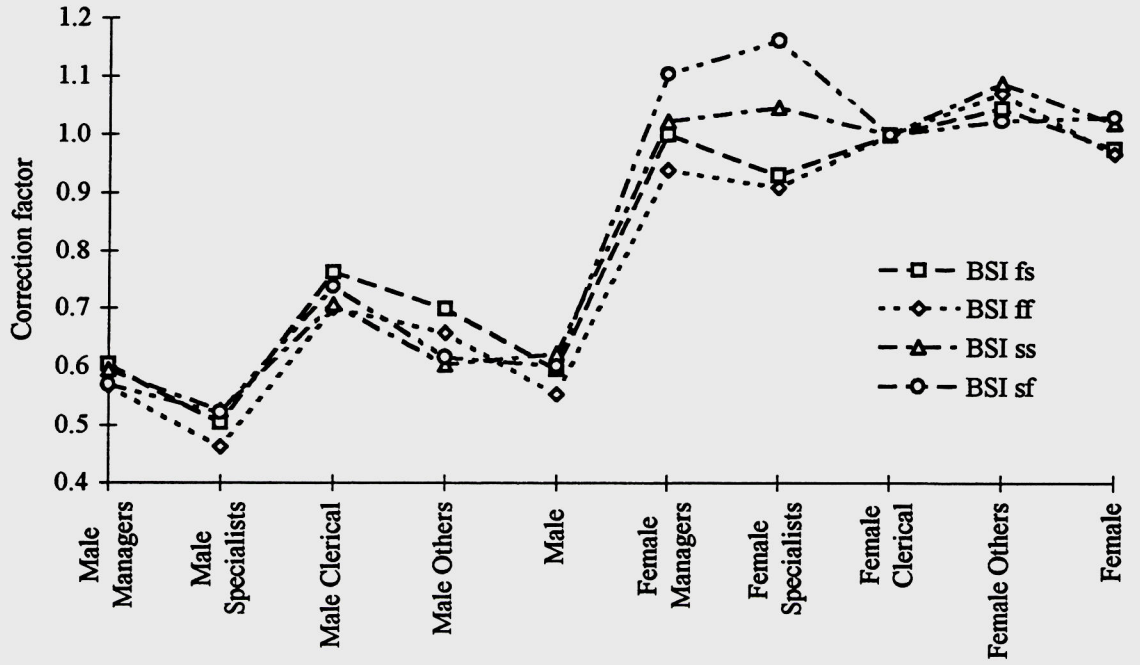

Figure 26: Correction factors referring to female clerical, for each fraction of occupants, sorted by sex and occupation.

Figure 27 compares the four BSI's (full and short symptom list, severity and frequency scale). There are obvious correlations between them. It seems therefore possible to shorten the questionnaire by eliminating one list of questions (either concerning last month or today), and possibly to retain only a short list of questions. Several persons and one building management complained for the length of the questionnaire.

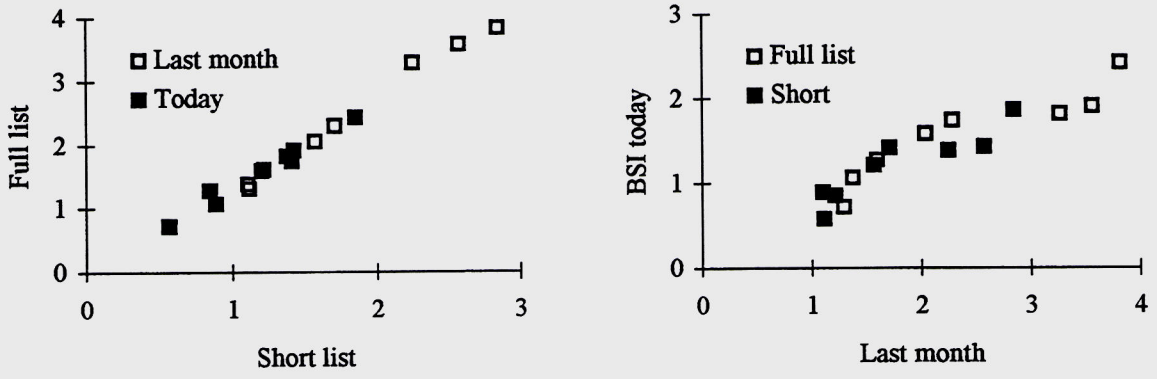

Figure 27: Comparison between the four corrected Building Symptom Indexes.

Since this study showed no relation between BSI and ventilation rates or energy, but, for example , a clear relation with environmental aspects (see 6.4, Ventilation and occupants health) questions concerning the work environment (E.G. are you satisfied with your job?) would be of great interest, in particular to separate the effects of such dissatisfactions from other energetic or ventilation effects. Such a question was planned, but deleted on request of some participants. We think that this was a mistake.

In test runs with students, we have eventually chosen to place the questionnaires in envelopes, with a sticker to be filled in by the investigating team containig survey and building ID, date, questionnaire #, floor, room and orientation of outside wall. Respondents were asked to seal the filled questionnaire in the envelope and leave the latter in a conspicuous place at their desk to be collected by members of the investigating team.

In order to save reading time, questions B1 through B12 and D1 through D12 could be stated once each only and the answers laid out in table format (legends as column headings, 1 line per question/answer cluster). Sections B and D can then both be compacted on only 1 page each, making the questionnaire look less considerable.

It is desirable to instruct respondents to fill in or tick appropriate boxes throughout and to avoid writing "yes" or "no" in answer boxes, ambiguous yes/no answers may result if people bar the inappropriate answer.

6.1.2 Measurement of ventilation rates

Figure 28 compares the number of persons calculated from ventilation rates and carbon gas concentrations to number of working places. For buildings B, C, D, F, and G, there is a good fit. That means that when the number of occupants in a well defined zone is known, fresh air flow rate can be deduced from CO_2 concentration. This is valid in any building without other CO_2 source (no fire, no other aerobic digestion). Misfits for other buildings come either from the absence of occupants (building A) or uncertainties in ventilated zone definition (building E). Misfit in building H is however not explained.

This means that the global fresh air flow rate of an office building can be assessed by measuring CO_2 concentrations in air handling units, at air inlets and exhaust, provided that the number of person in the building is known. In office buildings, the difference in CO_2 concentration between building air exhaust and building air inlet can provide a good estimate of the average fresh air flow rate per person, as far as a quasi-setady state is reached.

Except the PFT technique, tracer gas measurement of air flow rates are complex and expensive. Since they seldom allowed to assess the local contaminant source strengths with a

good enough confidence, it is propsed to replace them, in the audit procedure, by the CO_2 method.

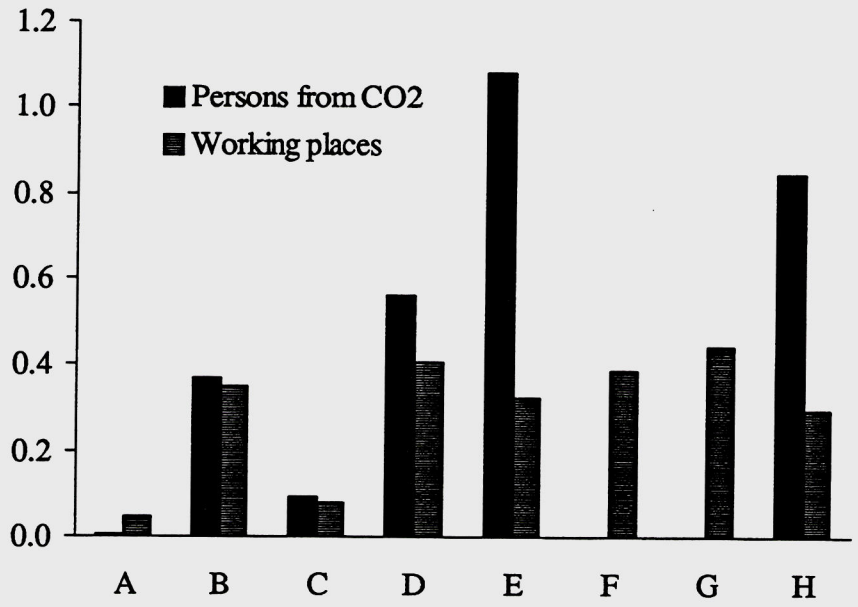

Figure 28: Comparisons of the number of persons per m² floor area obtained from air flow rates and CO_2 concentrations with the number of working places.

6.1.3 Air flow rates in air handling units

The use of tracer gas with constant injection rate in AHU allows the determination of all air flow rates in these units, including recirculation ratio and detection of unexpected shortcuts (see Roulet and Foradini, 1994). These measurements are relatively simple and also provide indication of ventilation rate and efficiency for the whole building. It is therefore proposed tio add such measurements to the audit procedure.

6.2 Ventilation and Source control

The intensities of odour sources in buildings was surprisingly high, and only a small part of these sources comes from the occupants. However, not much can be said on the sources themselves, because first source identification is a huge work, and second, the audit method chosen provides the sources intensities (with however very large confidence intervals) but does not allow a clear identification of sources.

From a statistical point of view, the largest contaminant concentrations are not found in buildings with small fresh air flow rates, and, at the contrary, the smallest concentration are not found in highly ventilated offices. This confirms that ventilation rate is not the good way to control sources.

6.3 Ventilation and Energy consumption

It was already said in 5.5, Energy consumption, that no obvious relation is found between energy consumption and ventilation rate. This does not mean that ventilation does use no energy, but that it is not necessary to use much energy to ventilate a building properly.

The example of building D, which present the lowest BSI, the lowest energy index, a low mechanical air flow rate added to natural ventilation shows that is possible to plan and build office space where people feel happy, without using much energy. It should be said, however,

that the ventilation engineer is a smart and skilled man, who took great care to integrate a good system in co-ordination with the architect and the owner.

6.4 Ventilation and occupants health

A fine relation is shown on Figure 29, where it can be seen that people allowed to open the windows feel much better that occupants of sealed buildings. If this relation is confirmed in other countries, and in order to improve productivity at work and to cut down health costs, we recommend to allow window openings wherever it is possible. The only reason to close windows in most mechanically ventilated buildings is that the planning work is made simpler. It does not seem to us that this is a good reason.

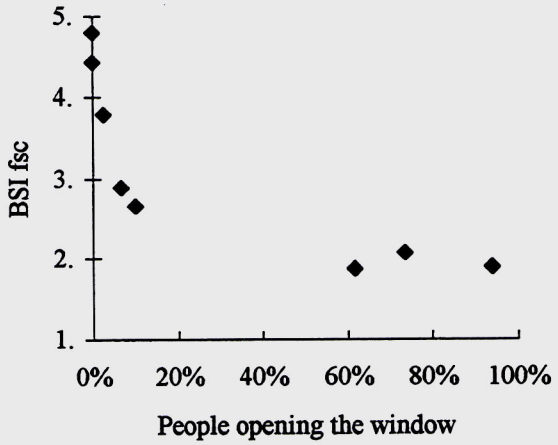

Figure 29: Relation between BSI and the possibility of opening windows.

7. LIST OF SYMBOLS

Symbol	Designation	Units	
C	concentration	kg/kg	m^3/m^3
S	source strength	kg/s	m^3/s
Q	air flow rate	kg/s	m^3/s
ϵ	measurement error on a variable		
μ	average value of a variable in a population		
σ	standard deviation of a variable in a population		

Indices

1, 2, ,.	Measurement location in a building or in a ventilation system
A, B,..	Building number or injection location in a ventilation system
C	related to concentration
e	extract air
ex	exhaust air
i	infiltration
o	outdoor, reference value
p	pulsed air
Q	related to air flow rate
r	recirculation
S	related to source strenght
x	exfiltration

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8.2 Swiss Publications related to the project

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9. APPENDICES

Checklist and other documents

The checklist provided in Audit manual was used by the audit team only and was therefore not translated.

However, several documents have been prepared for this audit, which are given in this annex. These are:

- Letters sent to the building management to prepare the audit
- Program presentation prepared for the building management, in French, German and English.
- Explanations on the way data were handled in Switzerland using EXCEL worksheets
- Standard EXCEL worksheet ccbDAT.XLS - Instructions for use

Questionnaires

in English, French and German

Detailed building data

for buildings A to H.

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Affaire traitée par **Claude-Alain Roulet**

Monsieur
«PrénomContact» «Contact»
«AdrrContact»

«NPIContact» «VilleContact»

Lausanne, le 5 août 1994

Concerne: **Bâtiments tests pour un projet de recherche**

Monsieur «Nomcontact»,

La Suisse participe au projet de recherche de la Commission des Communautés Européennes nommé *Joule II - Enquête sur la qualité de l'air intérieur*. Ce projet a pour but d'examiner cinq bâtiments de bureau dans 10 pays différents d'Europe, afin d'obtenir des données sur l'état actuel de la qualité de l'air et de la ventilation, en liaison avec la consommation d'énergie dans ce type de bâtiments.

Les organisations Suisses suivantes participent à ce projet:

- EPFL, LESO-PB, qui coordonne les travaux
- Université de Lausanne, Institut de Médecine et d'Hygiène du Travail
- ETH Zurich, Institut d'Hygiène et de Physiologie du Travail
- Sulzer-Infra

Dans ce cadre, nous cherchons donc 5 bâtiments situés en Suisse, qui devraient avoir les propriétés suivantes:

- bâtiment de bureaux
- au moins 200 employés
- ventilation naturelle ou mécanique
- installations accessibles
- consommation d'énergie des dernières années connue
- la (ou des) société occupant les bureaux doivent accepter les perturbations causées par les mesures et une visite préliminaire avec discussion, notamment avec les responsables des installations techniques.

L'examen a lieu pendant un jour ouvrable, et éventuellement pendant une période sans occupation. Il sera effectué par une équipe de 12 à 15 personnes. Il comprend notamment les mesures suivantes:

- examen du bâtiment et de son installation de ventilation (check-list),
- relevé des consommations d'énergie,
- questionnaire distribué au personnel concernant le confort et la qualité de l'air ressentis,
- mesures des débits d'air dans l'installation de ventilation,
- mesure, dans 5 bureaux ordinaires ou 2 bureaux paysage, de la concentration de l'air en gaz carbonique, en vapeur d'eau, et en composés organiques volatils, ainsi que mesure de la qualité olfactive de l'air, du confort thermique, du niveau de bruit et de l'éclairage.

Les résultats seront traités de manière confidentielle, et seront publiés de manière que le propriétaire et l'occupant du bâtiment ne puissent pas être reconnus. Le propriétaire du bâtiment et la direction de la société qui l'occupent auront droit en primeur aux résultats. Ils pourront utiliser ces résultats pour améliorer, si besoin est, les performances du bâtiment. Nous serons à leur disposition pour les aider dans l'interprétation de ces résultats.

En espérant que vous disposez d'un bâtiment susceptible de faire l'objet d'une telle étude, et dans l'attente de vos nouvelles, je vous prie d'agréer, Messieurs, mes salutations les meilleures.

Dr. Claude-Alain Roulet

EUROPEAN AUDIT PROJECT TO OPTIMISE INDOOR AIR QUALITY AND ENERGY CONSUMPTION OFFICE BUILDINGS

SHORT PRESENTATION

General objectives of the project

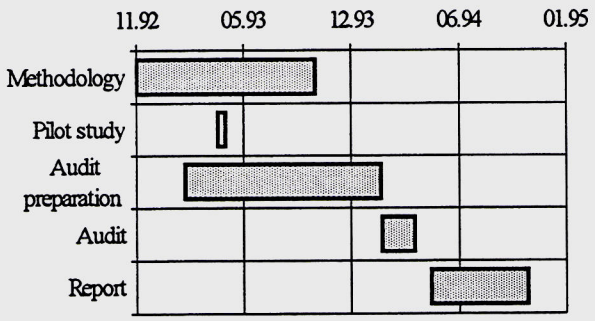
The research project was initiated by the Commission of European Communities. Its general objective is to improve the knowledge on indoor air quality in relationship with energy consumption in large office buildings. Seven countries of the European Community and three EFTA countries participate to this project. To gain knowledge, it is planned to investigate 6 buildings in each country, that is a total of about 54 buildings in Europe. The audited buildings should represent, as well as possible, the office building stock in each country. They are in any case not selected because they have problems.

The following results are expected from that research project:

- a common European method to investigate indoor air quality in office buildings ;
- a database containing measurement results and statistical interpretation, and which will present an image of the present state of indoor air quality and comfort conditions in office buildings;
- guidance for planning and maintenance of ventilation systems and buildings, for obtaining an efficient ventilation and a good control of contaminant sources.

Project planning.

In a first step, the audit methods and planning, to be followed by each participating institution, was established. A pilot study, which was performed in Denmark, allowed the participants to test and to improve the audit method. Then, a multi disciplinary audit team, comprising specialist of measurement techniques and a panel judging the olfactive quality of air is prepared and trained. The audits will be performed in February and March 1993. Finally the results will be interpreted and reported.



What will be examined?

The audit will concern the building itself and its technical equipment, in particular its ventilation system, the option of the occupants on the comfort and health condition, the thermal comfort, the lighting and noise level in some office rooms. The indoor air quality will be examined as well for its olfactive or sensory aspect as for its chemical composition. All this audit will be performed in less than a day, in order to obtain synchronous information all concerning the same working conditions, without perturbing too much the work in the visited firm.

General overview of the building and its equipment.

Important characteristics of each building will be assessed during a technical survey using a check list. A part of these data are obtained during a preliminary visit. Important data are, for example, the yearly energy consumption (oil, electricity, gas, district heat, etc.) or the date of the last maintenance of the ventilation system.

Questionnaire to officers

A questionnaire is distributed to about 150 officers, at a given time, and collected back one hour later. This anonymous questionnaire contains questions on the well-being of the employees, on possible physiological symptoms he feels now and during the last month, and on some characteristics of his working place. This questionnaire should be filled up in less than 15 minutes. They will be interpreted in a confidential way, and only statistical results will be published.

Working conditions in some office rooms.

Some office rooms, or only one large open office, are selected during the preliminary visit for more measurements, which are described below. These office rooms should be representative of the rooms occupied by the employees answering the questionnaire, and should not present major measurement difficulties.

- **Thermal comfort:** Air and radiant temperatures are measured, as well as air moisture and air speed at some working places. These data will be compared to the opinion on comfort conditions the employees may have.
- **Illuminance and noise level** : simple measurements at working places will be performed. Illuminance will be measured at table level from the window to the opposite wall.
- **Sensory assessment of air quality:** A trained panel of 10 to 12 "noses" judge the concentration of bad odours in the air and express it directly in Pol. This unit corresponds to the odour load of one average person diluted in an air flow of one litre per second. During this measurement, the panel should be allowed to refresh by inhaling outdoor air either by going out, or in a neighbouring room with open windows.
- **Chemical analysis:** Concentrations in carbon gas (normally generated by occupants), in carbon monoxide (coming from tobacco smoke) and volatile organic compounds (paint or glue solvents) are measured at some points. Dust concentration will be also assessed. The scope of these measurements is to check a possible relation between the well being of the occupants and the absence of such chemicals.
- **Ventilation measurements:** In order to obtain the contaminant source strength form the contaminant concentration, it is necessary to determine the rate at which fresh air is introduced in each room. These air flow rates are measured either with air flow meters or with harmless and odourless tracer gases at very low concentrations.

What is expected form the staff and from the employees?

Measurements are made possible only if the measuring team, about 20 people, can invade the building at about 8 AM and walk through freely during one day. Most of the measurements will be performed between 2 and 4 AM, and the team will leave the building before 6 AM.

The support of the Direction and the collaboration of the personal are necessary for the correct filling of the questionnaires. This will require between 10 and 20 minutes of the time of about 150 people.

An interview of one to two hours with the technical staff allows one to get answers concerning the energy consumption and the characteristics of the HVAC systems.

What does the company get back from such a survey?

The results of each visit are presented first to the company, as soon as they are interpreted. However, nobody, except the interpreting staff, will see the individual questionnaires.

The project management is ready to help the company to understand the results and could give to improve the working conditions if necessary. The results could also demonstrate that the measured conditions comply with the presently accepted standards.

Results will be published in an anonymous way. However, if it is the wish of the company, its name can be associated with the results.

June 1st, 1993 C.-A. Roulet

PROJET EUROPÉEN DE RECHERCHES JOULE II
QUALITÉ DE L'AIR INTÉRIEUR
BRÈVE PRÉSENTATION

But général du projet

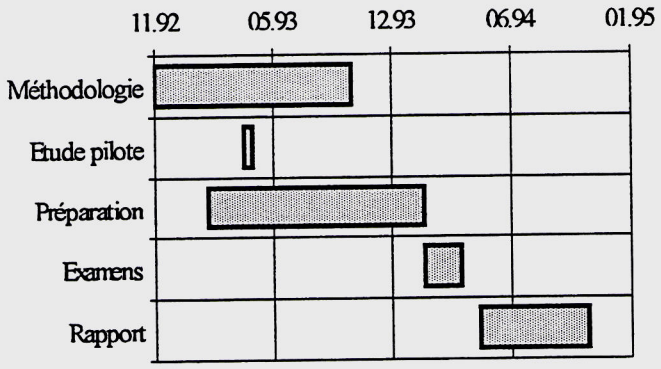
Le projet, initié par la Commission des Communautés Européennes, a pour objet d'améliorer les connaissances concernant la qualité de l'air en relation avec la consommation d'énergie dans les grands bâtiments administratifs. Sept pays de la communauté européenne et trois pays de l'OCDE, dont la Suisse, participent à ce projet. Dans ce but, il est prévu d'examiner une demi-douzaine de bâtiments par pays, soit un total de 54 bâtiments en Europe. Les bâtiments examinés doivent autant que possible être représentatifs de l'ensemble des immeubles de bureaux. Ils ne sont en aucun cas sélectionnés parce qu'ils présentent des problèmes.

On attend de ce projet de recherche les résultats suivants:

- une procédure européenne commune pour l'examen de la qualité de l'air intérieur dans les bâtiments de bureaux;
- une banque de données contenant les mesures effectuées et des interprétations statistiques présentant une image de l'état actuel de la qualité de l'air et des conditions de confort dans les bureaux;
- des conseils pour la planification et l'entretien des installations de ventilation et des bâtiments, pour une ventilation efficace et un bon contrôle des sources de pollution que l'on aura pu tirer des connaissances acquises.

Déroulement du projet.

En premier lieu, une méthodologie et un plan de mesures, qui sera suivi dans chaque pays participant, sont établis. Une étude pilote, qui a été effectuée au Danemark, a permis de tester la méthode d'examen. Ensuite, L'équipe multidisciplinaire d'examen, qui comprend des spécialistes de la mesure et une équipe de qualification olfactive de l'air est préparée et entraînée. L'examen des bâtiments aura lieu entre février et mars 1994. Enfin, les résultats seront interprétés et publiés.



Qu'est-ce qui sera examiné?

Les points examinés concernent le bâtiment et ses installations techniques, le bien être ressenti par le personnel de bureau, le confort thermique, l'éclairage et le niveau de bruit dans quelques bureaux. La qualité de l'air est examinée tant du point de vue olfactif que du point de vue chimique. Tous ces examens sont effectués durant un seul jour, pour obtenir des informations qui concernent des conditions de travail données sans toutefois trop perturber le fonctionnement de l'entreprise visitée.

Inspection générale du bâtiment et de ses installations.

Les données caractérisant chaque bâtiment seront acquises par une inspection en utilisant une liste de contrôle. Une partie de ces données est acquise lors de la visite préliminaire. Parmi les questions importantes, notons la date du dernier entretien de l'installation de ventilation (lavage, changement des filtres) et la consommation annuelle de vecteurs énergétiques (mazout, gaz, chaleur à distance, électricité, etc.)

Questionnaire au personnel

Un questionnaire est distribué à 150 employés au moins à une heure donnée, et récupéré une heure après. Ce questionnaire anonyme porte sur le bien être subjectif ressenti par l'employé, sur des symptômes physiologiques qu'il pourrait ressentir ou avoir ressenti pendant le dernier mois, et sur les caractéristiques de sa place de travail. Ce questionnaire est étudié pour pouvoir être remploi en moins de 15 minutes. Les questionnaires individuels seront traités de façon confidentielle et seuls les résultats statistiques seront publiés.

Conditions de travail dans quelques bureaux.

Quelques bureaux, éventuellement un seul bureau paysage, sont sélectionnés pendant la visite préliminaire pour des examens plus approfondis, qui sont décrits ci-dessous. Ces bureaux devraient être représentatifs des bureaux occupés par les personnes interrogées et ne pas présenter de difficultés majeures pour les mesures.

- **Mesures concernant le confort:** On mesure la température de l'air, la température radiante, l'humidité et la vitesse de l'air à quelques places de travail. Ces données peuvent être comparées à l'opinion que les employés ont de leur confort.
- Des mesures sommaires sont prévues pour quantifier l'éclairement et le niveau de bruit à la place de travail. L'éclairement est mesuré à hauteur de table le long d'une ligne allant d'une fenêtre au mur opposé.
- **Evaluation olfactive de la qualité de l'air:** Une équipe de 10 à 12 "nez", entraînés, jugent la charge de l'air en odeurs désagréables et l'expriment directement en Pol. Le Pol correspond à la charge odorante de une personne moyenne diluée dans courant d'air de 1 litre par seconde. Pendant les mesures, cette équipe doit pouvoir se régénérer en respirant de l'air extérieur au bâtiment, soit en sortant, soit en rejoignant un local avec fenêtres ouvertes.
- **Composés chimiques divers:** Les concentrations en gaz carbonique (normalement généré par les occupants), en monoxyde de carbone (provenant notamment de la fumée de tabac) et en composés organiques volatils (solvants de peinture, de colles) seront mesurées en certains points. On mesurera aussi la quantité de poussières présentes. On désire examiner s'il y a une relation entre le bien être des occupants et l'absence de ces composés.
- **Mesures concernant la ventilation:** Afin de déduire l'importance des sources de pollution à partir des concentrations mesurées, il est nécessaire de déterminer le débit d'air frais amené dans chaque bureau. Ces débits sont mesurés en utilisant des gaz traceurs totalement inodores et inoffensifs aux concentrations utilisées.

Quelle participation attend-on de la direction et du personnel?

Les mesures ne sont possibles que si l'équipe de mesure, comprenant environ 20 personnes, peut pénétrer dans le bâtiment vers 8 h du matin et s'y déplacer librement pendant un jour. L'essentiel des mesures est effectué l'après midi, entre 14 et 16 heures et les lieux sont totalement libérés avant 18 heures.

L'approbation de la direction et la collaboration du personnel sont nécessaires au remplissage correct des questionnaires. Celui-ci nécessite entre 10 et 20 minutes du temps d'environ 150 employés.

Une entrevue d'une heure ou deux avec les responsables techniques permet en général de répondre aux questions concernant la consommation d'énergie, les installations de ventilation et l'entretien.

L'équipe de "nez" a besoin d'un endroit bien aéré naturellement pour régénérer l'odorat. Cet endroit doit se trouver près des locaux examinés (moins de 30 mètres, au même étage). De plus, le matériel de mesure peut occuper un peu de place dans les bureaux ou les couloirs.

L'organisation du travail est grandement simplifiée si l'équipe de mesure peut utiliser le restaurant d'entreprise pour le lunch.

Que peut retirer l'entreprise d'un tel examen?

Les résultats de chaque visite sont présentés en primeur à l'entreprise, dès qu'ils sont interprétés. Par contre, aucune personne en dehors du personnel interprétant les questionnaires n'aura accès aux questionnaires individuels.

La direction de projet est prête à aider l'entreprise à comprendre les résultats obtenus et à en tirer des renseignements utiles à l'amélioration des conditions de travail si besoin est. Ces résultats peuvent aussi démonter que les conditions mesurées sont conformes aux normes actuellement admises.

Les résultats sont publiés de manière anonyme. Toutefois, si l'entreprise le désire, son nom sera associé aux résultats qui la concernent.

17 mai 1993

C.-A. Roulet

Europäisches Wissenschaftsprojekt - Joule II - Luftqualität in Innenräumen
Eine kurze Vorstellung

Ziel des Projektes

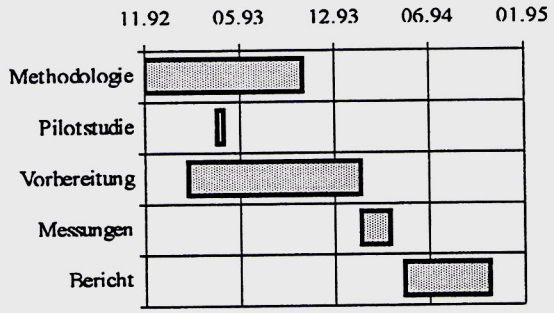
Dieses Projekt wurde durch die Europäische Gemeinschaft iniziiert. Das Ziel wird folgendermassen beschrieben: Es sollen bessere Kenntnisse betreffend Luftqualität und Energieverbrauch von grossen Bürogebäuden (v.a. administrativer Sektor) erlangt werden. Sieben Länder der Europäischen Gemeinschaft und drei OECD Länder, u.a. die Schweiz, nehmen am Projekt teil. Es ist vorgesehen, in jedem Land an die sechs Bürogebäude zu untersuchen was zu einem europäischen Total von etwa 54 gebäuden führt. Die dazu ausgesuchten Gebäude sollten im jeweiligen Land so gut als möglich einen räpresentativen Durchschnitt der im Land vorhandenen Bürotypen ergeben. Es sollen keine Gebäude aufgrund vorhandener Luftqualitätsprobleme ausgewählt werden.

Folgende Resultate werden von diesem Forschungsprojekt erwartet:

- Das Vorgehen bei Luftqualitätsbestimmungen in Büroinnenräumen soll innerhalb Europa vereinheitlicht werden.
- Eine Datenbank soll mittels den durchzuführenden Messungen und statistischen Auswertungen erstellt werden. Eine aktuelle Beschreibung der Luftqualität und des Konforts in Büroräumen wird daraus ermöglicht.
- Richtlinien für die Planung und den Unterhalt von Klimaanlagen und Gebäuden, mit dem Ziel einer wirkungsvollen Belüftung und einer guten Kontrolle von Innenraumschadstoffquellen, sollen anhand der erhaltenen Daten erarbeitet werden.

Ablauf des Projektes.

An erster Stelle wurde ein Messkonzept erstellt. Dieses gilt für alle Teilnahmeländer und enthält Messgrössen, Methoden und einen Zeitplan. Eine Pilotstudie wurde in Dänemark durchgeführt und ermöglichte eine überprüfung der Methoden. Eine Multidisziplinäre Untersuchungsequippe, welche sowohl Messspezalisten wie auch Personen zur olfaktometrischen Luftqualitätsbestimmung enthält (subiektive Geruchsmessung), wird nun zusammengestellt und trainiert. Die eigentlichen Messungen in den ausgewählten Bürogebäuden werden in den Monaten Februar und März 1994 stattfinden. Danach werden die Resultate interpretiert und publiziert.



Was wird untersucht

Die Untersuchungen betreffen das Gebäude selber, die technischen Einrichtungen, das subjektive Wohlempfinden des Büropersonals, den thermische Komfort, die Belichtungsverhältnisse (Lichtintensität) und die Schallstärke. Zusätzlich werden Luftqualitätsfaktoren sowohl durch ein olfaktometrisches Verfahren (subiektiver Störungsgrad) als auch durch chemische und physikalische Messverfahren bestimmt.

Sämtliche Messungen finden an einem einzigen Tag statt und erlauben so die Beschreibung und Beurteilung eines Arbeitstages ohne den normalen Arbeitsablauf im untersuchten Gebäude erheblich zu stören.

Generelle Inspektion von Gebäude und Einrichtung.

Eine frühzeitige Inspektion vor Ort und das Ausfüllen einer Check-Liste erlauben die Aufnahme grundsätzlicher Informationen die das Gebäude charakterisieren. Ein Teil davon geschieht während des ersten vororientierenden Besuches. Zu den wichtigsten Informationen gehören die Daten der letzten Unterhaltsarbeiten an der Klimaanlage (Wäscher, Filter etc.) und der Jährliche Energieverbrauch (Erdöl, Gas, Fernwärme, Elektrizität etc.).

Fragebögen für das Personal

Ein Fragebogen wird zu einer bestimmten Zeit während des Untersuchungstages an mindestens 150 MitarbeiterInnen verteilt. Es sollte gut möglich sein diesen Bogen innerhalb von 15 Minuten auszufüllen. Eine Stunde nach Verteilung wird der Fragebogen wieder eingesammelt. Erörtert werden hiermit vor allem das subjektive Wohlempfinden am Arbeitsplatz, mögliche physische Symptome im Zeitpunkt des Ausfüllens und während des letzten Monats und die Charakterisierung (Beschreibung) des eigenen Arbeitsplatzes bzw. der Arbeitstätigkeiten. Die Bögen werden anonym eingesammelt und streng vertraulich behandelt. Nur statistische Resultate werden publiziert.

Arbeitsplatzqualität einiger Büroräume.

In füunf einzelnen Büros, oder nur in einem Grossraumbüro pro Gebäude, sind weiterführende Untersuchungen geplant die im folgenden beschrieben werden. Diese Büroräume werden bereits beim vororientierenden Besuch ausgewählt. Sie sollten räpresentativ sein für die Arbeitsstätte der 150 MitarbeiterInnen welche den Fragebogen ausfüllen.

- Behaglichkeitsmessungen: Gemessen werden die Lufttemperatur, die Strahlungstemperatur, die Luftfeuchtigkeit und die Luftgeschwindigkeit an einigen Arbeitsplätzen. Diesen Grössen werden verglichen mit der subiektiven Einschätzung der MitarbeiterInnen bezüglich des Komforts am Arbeitsplatz.
- Punktuelle Messungen werden für die Belichtungsintensität und den Schallpegel durchgeführt.
- Bewertung der olfaktometrischen Qualität der Luft: Eine Gruppe von 10 bis 12 trainierten "Nasen" werden die Raumluft in Bezug auf unangenehme Gerüche einschätzen und dies direkt in der Einheit "Pol" ausdrücken. Ein Pol entspricht der durchschnittlich abgegebenen Geruchsmenge (Geruchspotenz) einer Person bei Verdünnung mit einer Luftströmung von einem Liter pro Sekunde.
- Chemische und physikalische Grössen: Gemessen werden an einigen Standorten das Kohlendioxid (v.a. durch Atmen verursacht), das Kohlenmonoxid (v.a. durch Tabakrauchen verursacht) und flüchtige organische Verbindungen (Kohlenwasserstoffe, aus Lösungsmittel von Leimen und Farbanstrichen etc.). Als physikalische Grösse wird der Schwebestaubgehalt der Luft quantitativ bestimmt. Es soll aufgezeigt werden ob ein Zusammenhang besteht zwischen dem Wohlergehen der Raumbenützer und der Konzentration solcher Stoffe in der Raumluft.
- Ventilationsmessungen: Um die Wichtigkeit einzelner Schadstoffquellen in Bezug auf deren Innenraumkonzentration festzustellen, muss die Frischluftzufuhr pro Zeiteinheit für die untersuchten Büroräume bestimmt werden. Dazu verwendet man Tracergas-Methoden. Die Tracergase die in die Luft gegeben werden sind in den verwendeten Konzentrationen absolut geruchsneutral und gesundheitlich unbedenklich.

Mitbeteiligung der Personalleitung (Direktion)

Die ganze Messkampagne ist nur realisierbar, wenn es der Messequippe von ca. 20 Personen ermöglicht wird, an einem festgesetzten Tag um 8 Uhr morgens ins Gebäude einzudringen und sich in den abgesprochenen Räumen frei zu bewegen. Die Hauptuntersuchungen finden ca. von 14 bis 16 Uhr statt. Um ca. 18 Uhr wird die gesamte Messequippe mitsamt Messgeräten das Gebäude verlassen.

Die Zustimmung der Direktion ist erforderlich, um den korrekten Ablauf bei der Verteilung und dem Ausfüllen der Fragebögen sicherzustellen. Für das Ausfüllen der Fragebögen sind 10 bis 20 Minuten pro Person zu rechnen, dies während der offiziellen Arbeitszeit und von insgesamt 150 MitarbeiterInnen.

Für das Ausfüllen der Gebäude-Checkliste, das Besichtigen der Klimaanlagen und das erarbeiten der Energieverbrauchsdaten ist in der Regel ein einstündiges Zusammentreffen mit den Verantwortlichen des technischen Dienstes vorzusehen.

Die Mitglider der Geruchsequippe (die Nasen) sollten immer wieder an einen Reinluftort zurückgehen, um ihr Geruchsempfinden zu regenerieren. Als Reinluftorte gelten Räume ohne Eigengerüche, deren Fenster für ca. eine Stunde offen gehalten werden. Falls solche Räume im Gebäude nicht vorhanden sind sollte es den "Nasen" jeweils ermöglicht werden nach Aussen zu treten (Balkon, Veranda etc.). Dies sollte auf demselben Stockwerk und nicht weiter als 30 Meter vom untersuchten Büro entfernt sein. Die Messgeräte beanspruchen in den entsprechenden Messräumen etwas Platz, werden aber so aufgestellt, dass sie den Büroalltag nicht erheblich stören.

Die Planung des Messtages wäre um einiges einfacher wenn es der Messequippe ermöglicht würde in der Kantine/Restaurant der Unternehmung zu Mittag zu Essen.

Gewinn für die untersuchte Unternehmung

Die Daten und Resultate werden zuallererst der untersuchten Unternehmung präsentiert. Niemand, ausser der Auswertungsgruppe der beteiligten Hochschulen, hat Zugang zu den individuellen Fragebögen oder zu deren Daten. Die Resultate werden anonym publiziert (kein Firmenname), ausser die Unternehmung würde eine Verbindung der Resultate mit dem Firmennamen begrüssen.

Die Projektleitung wird der Unternehmung beim Verstehen und Interpretieren der Resultate behilflich sein. Es wird auch beratende Hilfe zur Verbesserung gewisser Aspekte des Arbeitsumfeldes angeboten, falls dies nötig sein sollte (Lüftung, Klima, Luftschadstoffe). Anderenfalls können die Resultate aufzeigen, dass die gemessenen Parameter den erlaubten Normen entsprechen.

3. Juni 1993

C.-A. Roulet

STANDARD FILE MANAGEMENT FOR IAQ AUDIT PROJECT

This documents presents the policy used in Switzerland for such management and proposes more efficient ways not only to fill-up the standard EXCEL sheet, but also to use this worksheet to prepare reports semi-automatically. For that purpose, some files should have standard formats and standard names.

Standard name: ccbtyp.* with the following interpretation:

cc code for country, that is B for Belgium, NL for the Netherlands and CH for Switzerland

b letter (in principle A to E) designing the measured building

typ type of file, according to the list below

* usual DOS extension (DOC for Word files, XLS for EXCEL worksheets, DRW for DESIGNER files, etc.)

The empty files are provided with IAQ as ccb letters (e.g. IAQDAT.XLS)

Standard files

Basic files

Basic files are the standard data sheet and the files which take the information from this file. The only file really required for each building is ccbDAT.XLS. The other are provided for your convenience, and you could use them or not.

IAQMACRO.XLM: EXCEL macro-sheet containing formulas for calculating the PSI and BSI, for saturation water vapour pressure and many routines to translate back the codes in ccbDAT.XLS files. This macro-sheet shall be open when using a cbDAT.XLS, ccbAPP.XLS or ccbQST.XLS file.

ccbDAT.XLS Standard data sheet as agreed in Paris meeting. These files (one per building) contain all the minimum data required form each country. They can be linked to ccbQST.XLS by using the instruction File/Links of the EXCEL menu bar. Other links are possible to ccbMET.XLS, ccbOLF.XLS, or any other national data file providing data for ccbDAT.XLS. Since these files will provide the information for the European Data Base (EDB), their structure **shall not be changed at all** (neither add or delete a column or a line). However, their links to other files can be changed, since only the numerical values (not the formulas) will be picked up for the EDB.

ccbREP.XLS EXCEL worksheet preparing the appendix for the national report. This file is linked to ccbDAT.XLS by simply writing the actual name ccbDAT.XLS in cell A1 of ccbAPP.XLS and pressing the F9 taste. ccbDAT.XLS shall be open at this time. ccbAPP.XLS uses macros from file IAQMACRO.XLM, which should also be open preferably before opening a ccbAPP.XLS file.

ccbAPP.DOC a WINWORD version of appendix for national report (not ready now).

Optional, secondary files

These are files providing data to ccbDAT.XLS file. You may use them or not, and you may add, change or delete links between these files and ccbDAT.XLS files, as far as the location of each information in ccbDAT.XLS is not modified.

ccbMET.XLS EXCEL worksheet with meteorological data provided by meteorological station, and calculating the average data required for ccbDAT.XLS

ccbOLF.XLS EXCEL worksheet with all sensory measurements from each panel member, calculating the average data required for ccbDAT.XLS

ccbVOC.XLS EXCEL worksheet with VOC results, calculating the data required for ccbDAT.XLS

ccbCNT.XLS EXCEL worksheet with continuous measurements, calculating the data required for ccbDAT.XLS and drawing the diagrams.

ccbMAP.DRW DESIGNER drawing of the building and measured floors, which can be embedded in ccbDAT.XLS.

ccbVNT.DRW DESIGNER drawing of the ventilation system.

ccCOMPIL.XLS EXCEL worksheet compiling the national results. There are in particular the BSI's from all buildings and the calcualtion of the correction factors. It is planned to extend this file in order to prepare the tables for the national report

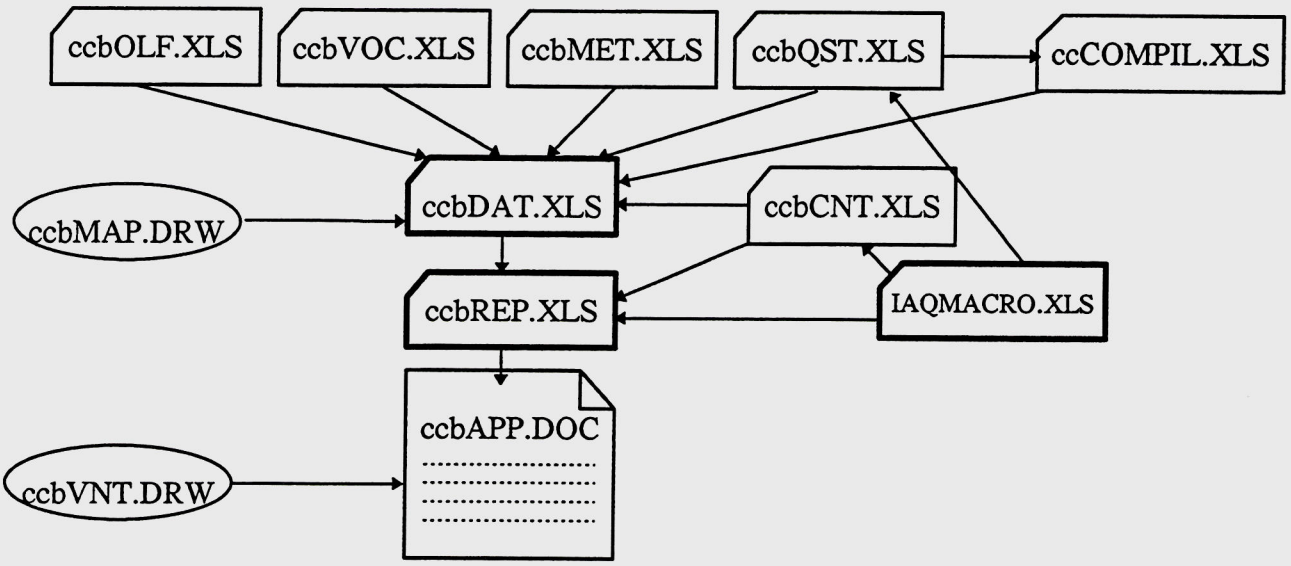


Figure 1: Relations between the ccbtyp.* files

EXCEL STANDARD DATA FILE - INSTRUCTIONS FOR USE

Purpose of the file

The research project should provide a database of data measured in all participating countries, and interpret these data to provide guidance on ventilation source control.

The file IAQDAT.XLS is designed in order to make this tasks easier. It should be filled up with data measured in one building, and delivered to the project management. Individual files for each building will then be merged into the European database, and standard procedures can be used to extract from all these files the information needed for various purposes.

Description of IAQDAT.XLS file

The file is a Microsoft EXCEL spreadsheet. It is divided into three main parts, from top to bottom:

Part I	Building check list
Part II	Questionnaire
Part III	Measurements
Part IV	Additional data

The second column describes the required data, in a similar way and in the same order as that of check list, questionnaire, or national report layout respectively. Column one contains the corresponding number, if any.

Coloured (or grey) cells are those to be filled with data. Cells F3 to J3 show the colours corresponding to cells which should contain a coded entry (red), those which will receive text or numerical data from keyboard (yellow) and those which are linked to other data files (blue) and can then be automatically filled.

Cells showing a little square on top right corner contain a note. This note can be seen by double-clicking on this cell. The note generally provide the code or some comments on the required entry. These notes are annexed to this document.

In order to avoid any change in the file, which would made it impractical, the file is protected. Only coloured cells and white cells at right of these can be changed. There is no password for that protection, so you could modify the file for your personal use. However, **only standard files should be given to the project management.**

How to use the file IAQDAT.XLS

Load IAQDAT.XLS and just fill in the coloured cells with the corresponding data.

If you want to use the linking procedure, first open the file in which the data are (e.g. ccbOLF.XLS file for sensory data. If this file has the data at exactly the same place as in IAQOLF.XLS file, simply change the link by using the LINK command in the FILES menu. If this is not the case, or for data taken in any other non standard file, select the data in the origin file, copy these (Alt+Ins), then select the destination cell(s) in ccbDAT.XLS and use PAST LINK command in EDIT menu.

Then save it under **a new name** related to the corresponding country and building (e.g. NLADAT.XLS, or DKBDAT.XLS). Always keep a blank copy of IAQDAT.XLS.

There is one file, with a different name, for each building. The file corresponding to any building can be filled in several sessions, by loading each time the proper file.

B8 Embed a sketch using DRAW or DESIGNER

C16 Code Situation:
1 Industrial area
2 Downtown
3 Suburb
4 Country side
5 Other (specify)

C17 Code Traffic within 200 m
1 Motorway
2 Busy through road
3 Busy cross road
4 Moderate busy road
5 Quiet road

C18 Code pollution source
(which could have an influence on IAQ)
Several answers possible
0 None
1 Parking garage
2 Power plant
3 Industry
4 Cooling tower
5 Other (specify)

C19 Code activities
0 Only office work
1 Industry
2 Shops
3 Laboratory
4 Garage
5 Other (specify)

C29 Code shadings
0 No solar protection
1 Outside
2 Between glazing
3 Inside

C30 Code for shading movement
1 Automatically controlled
2 Central down, individually up
3 Individual
4 Fixed

C31 Number of glazing
1 single pane
2 double pane
3 triple pane
4 other (specify)

C32 Glazing type
(several possible answers)
1 Clear
2 Heat reflecting
3 Light reflecting
4 Light absorbing
5 Other (specify)

C33 to 39: Modifications
If there were no modification, type 0

C40 Furniture made of
1 Mainly solid wood
2 Veneered chip board
3 Metal
4 Other (specify)

C41 Age of furniture
1 3 years or less
2 More than three years

C42 Green plants
0 No large green plants
1 Flowering green plants
2 Green leafed plants

C43 Plant treatment
0 No treatment
1 "Chlorophyll" treatment
2 Pesticide treatments

C44 Smoking is
1 not allowed
2 Allowed in separate rooms
3 Generally allowed

C46 Solvents used
Type name and type of solvent.
If no solvents used, type 0 (zero)

C47 Other chemicals used
Type name and type of chemical.
If no chemical used, type 0 (zero)

C48 Copying machines in office
0 = no
1 = yes

C49 Number of persons per visual display unit
0 No VDU
1 1-2 persons per VDU
2 2-10 persons per VDU
3 10-20 persons per VDU

C50 Laser printers in office
0 = no
1 = yes

C51 Carbonless paper in extensive use
0 = no
1 = yes

C53 to C61 Cleaning frequency
0 Less than once a month
1 1 to 3 times a month
2 Once a week
3 2 - 4 times a week
4 Daily

C62 Dirtiness of floors
1 floors does not look dirty
2 floors look dirty

B63 to F68: Code for cleaning agents
1 Polish or wax
2 Leaves a film
3 Does not leave a film

C70 Type of heating
0 No heating
1 Hot water heating
2 Air heating
3 Direct electric heating
4 Other (specify)

C71 Location of heating
1 Radiators
2 Floor heating
3 Ceiling heating
4 Fan coil units
5 Other (specify)

C72 Room cooling
0 No specific cooling
1 Supply of cooled air
2 Local fan coil units
3 Cooled ceiling
4 Cooling convectors
5 Other (specify)

C73 Temperature control
1 Manual (e.g. radiator valve)
2 Adjustable thermostat on radiator or unit
3 Adjustable wall thermostat
4 Central temperature control
5 Other (specify)

C74 Temperature or heating reduced centrally outside g hours?
0 = No
1 = Yes

C75 How are rooms ventilated?
1 Windows or natural ventilation
2 Exhaust system
3 Supply system
4 Balanced VAV system
5 Dual ducts balanced system
6 Induction units balanced system
8 Other

C76 Window opening
0 Window cannot be opened
1 Windows can, but may not be opened
2 Windows can be opened

C77 Design air change rate
1 less than 0,5 per hour
2 0,5 to 1 per hour
3 1 to 3 per hour
4 more than 3 per hour

C78 Lowest outdoor air supply
Provide the lowest design value together with the umber or designation.

C79 Position of ventilation system intake
0 No air intake
1 On the roof
2 In the facade
3 Close to the ground
4 Other location (specify)

C84 Recirculation:
Indicate the approximate percentage of recirculation.
If no recirculation, type 0

C85 Humidification system
0 No humidification
1 Evaporation
2 Spray
3 Steam

C86 Water purification
0 None
1 Ozone
2 Biocides
3 High voltage
4 UV lamp
5 Other (specify)

C87 Cooling
0 no cooling
1 there is a cooling system
Indicate type in cell at right

C88 Heat recovery type
0 None
1 Rotating wheel
2 Plate exchanger
3 Other (specify)

C89 Ventilation system is set on and off
1 manually
2 automatic by a clock

C90 Demand controlled ventilation
0 no such control
1 Temperature sensors
2 CO_2 sensors
3 Humidity sensors
4 Multi-gas (SnO_2) sensors
5 Other (specify)

C97 Duct material
1 Asbestos cement
2 Fabric
3 PVC
4 Galvanised steel
5 Other (specify)

C98 Duct insulation
0 No thermal insulation
1 External insulation
2 Internal insulation
3 Both

C99 Indicate dates in format yy.mm.dd or yy.mm

E99 to D112 Components needs service
0 No
1 Yes

C113 Location of air supply inlets
1 In the floor
2 At windowsill
3 In the ceiling
4 High on wall
5 Low on wall

C114 Location of air outlets
1 High
2 Low

C115 Planned ventilation principle
0 No designed principle
1 Displacement ventilation
2 Mixing ventilation

C119 to H119 Inside wall material
1 Brick
2 Chipboard
3 Plaster board
4 Concrete
5 Metal
6 Glass
7 Other (specify)

C120 to H 120 Insulation material
0 No specific insulation
1 Fiberglas
2 Mineral wool
3 Glass foam
4 Polystyrene
5 Polyurethane
6 Urea formaldehyde
7 Other (specify)

C121 to H 121 Insulation thickness
Type 0 (zero) if there is no insulation

C129 to H 129 Wall surface covering
1 Wallpaper
2 Enamel paint
3 Dispersion paint
4 Wood
5 Unpainted textiles
6 PVC
7 Other (specify)

C130 to H 130 Ceiling material (inside surface)
1 Concrete
2 Plaster board
3 Wood
4 Plaster ceiling
5 Acoustic panes (specify material)
6 Other (specify)

C131 to H 131 Airspace above acoustic panes?
0 No
1 Yes

C132 to H 132 Is some dust above acoustic panes?
0 No
1 Yes

C133 to H 133 Do acoustic baffles hang below ceiling
0 No
1 Yes

C134 to H 134 Type ceiling type

C135 to H 135 Room lighting
1 Artificial
2 Daylight
3 Both

C136 to H 136 Lighting location
1 Ceiling
2 Individual
3 Both

C 137 to H137 Artificial lighting
0 No individual lighting
1 Fluorescent
2 Incandescent lamps
3 Halogen lamps
4 Other (specify)

C138 to H138 Lighting control
0 No control
1 Automatic
2 Automatic with manual end control
3 Manual

C139 to H139 Visible mould growth?
0 No
1 Yes

C140 to H140 Are there damp spots?
0 No damp spots
1 Yes

C141 to H141 Mould odour?
0 No
1 Yes

C152 to H152 Access for cleaning
0 no, bad access
1 yes, acceptable access

C153 to H153 Door often open
0 no, door closed
1 yes, door often open

B180 Put the total number of answers in each box below.

C198 Indicate the average vote (PMV) on the -3 +3 scale)

C199 Indicate average acceptability on the -5 to +5

C200 to C 207 Indicate average note on the 1 to 7 scale.

B209 Indicate numbers of answers.

C223 Indicate the average vote (PMV) on the -3 +3 scale)

C224 Indicate average acceptability on the -5 to +5

C225 to C237 Indicate average note on the 1 to 7 scale.

B252 BSI: Average and standard deviation are obtained according to Annex B of manual.

B363 to E 369 Either mean radiant or operative temperature should be given, depending on the instrument used. The other will be calculated according to ISO 7730.

C415 Weather station: Name of weather station from which the data come.
Note "on site" if measured near the building that day.

C417 Weather description
Not if sunny, overcast, rainy, etc.

I426 The lower heating value is indicated here to facilitate the conversions.

B444 Energy index is the annual energy use divided by the gross heating floor area (C20*C21)

B446 Power index is the energy index divided by degree-days and 86'400 [s/d]

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

OFFICE ENVIRONMENT SURVEY

Within the frame of an European research programme, a survey concerning your office environment is being performed in your building. The annexed questionnaire is an essential element of this survey.

Your opinion is essential. Please attempt to answer all the questions.

Do not take too much time over your answers, just give your initial response.

You will probably need about 15 minutes. However, if you really do not want to fill in the questionnaire, just write below "Refused" and, briefly, the reason (e.g. no time, I never fill up questionnaires, etc.)

This questionnaire will be used by the Solar Energy and Building Physics Research Laboratory of the EPFL (Swiss Federal Institute of Technology, Lausanne) as part of an evaluation of your working environment. Neither this questionnaire nor any information from it will be passed to your employer or any other party except as averaged and anonymous data.

It is important that you record your own views, without talking to colleagues.

Once terminated, let the questionnaire on your desk or in your "out" mail box, when available. We will pick it up.

If you have any queries about this questionnaire, please contact the survey staff.

THANK YOU FOR PARTICIPATING IN THIS SURVEY.

(A) # OFFICE ENVIRONMENT QUESTIONNAIRE

Survey Number ☐☐☐☐☐☐

Time ☐☐ ☐☐ *(24 Hour clock)*

Age ☐☐ Sex ☐1 Male ☐2 Female

[Location] *Please write in* -

1 Approximately how long were you sitting at your desk before you started this questionnaire (excluding short breaks)? ☐ Hours

2 What is the biggest part of the work you do? *Please tick a box*

- Managing people or resources ☐1
- Using specialist skills (e.g. legal, medical, engineering, scientific) ☐2
- Doing clerical, secretarial or administrative work ☐3
- Other ☐4 *Please write in* -

	Years	Months*
3 How long have you been working in this building?	☐	☐
4 How long have you been working in this room?	☐	☐

**Months not needed if more than two years*

On average, during the **past month** -

5 How long did you spend at your desk per **working day**? ☐ Hours

6 How many hours did you spend doing paid work per **week?** ☐ Hours
(Include any time you may have spent working away from this building)

7 How many hours per **week** did you operate a VDU at work? ☐ Hours

8 And how many days did you come to this building? ☐ Days

9 How many other people normally share the room where you normally work? ☐ People

10 Is there a window in your room? ☐ Yes 1 ☐ No 2 **If no: please go to next page**
Please tick

11 Approximately how far is your desk from the nearest window? ☐ Metres
Please write in, to the nearest metre.

12 Do you ever open a window in your room? ☐ Yes 1 ☐ No 2
Please tick.

 (Continued overleaf)

(B) YOUR HEALTH DURING THE PAST MONTH

1a During the past month, on **how many days** did you experience DRY EYES when you were at work in this building? None [1] 1 to 5 [2] 6 to 10 [3] More than 10 [4]

1b If symptom experienced: was this better on days away from the office? Yes [1] No [2]

2a During the past month, on **how many days** did you experience WATERING EYES when you were at work in this building? None [1] 1 to 5 [2] 6 to 10 [3] More than 10 [4]

2b If symptom experienced: was this better on days away from the office? Yes [1] No [2]

3a During the past month, on **how many days** did you experience a BLOCKED OR STUFFY NOSE when you were at work in this building? None [1] 1 to 5 [2] 6 to 10 [3] More than 10 [4]

3b If symptom experienced: was this better on days away from the office? Yes [1] No [2]

4a During the past month, on **how many days** did you experience a RUNNY NOSE when you were at work in this building? None [1] 1 to 5 [2] 6 to 10 [3] More than 10 [4]

4b If symptom experienced: was this better on days away from the office? Yes [1] No [2]

5a During the past month, on **how many days** did you experience a DRY/IRRITATED THROAT when you were at work in this building? None [1] 1 to 5 [2] 6 to 10 [3] More than 10 [4]

5b If symptom experienced: was this better on days away from the office? Yes [1] No [2]

6a During the past month, on **how many days** did you experience CHEST TIGHTNESS OR BREATHING DIFFICULTY when you were at work in this building? None [1] 1 to 5 [2] 6 to 10 [3] More than 10 [4]

6b If symptom experienced: was this better on days away from the office? Yes [1] No [2]

7a During the past month, on **how many days** did you experience FLU-LIKE SYMPTOMS when you were at work in this building? None [1] 1 to 5 [2] 6 to 10 [3] More than 10 [4]

7b If symptom experienced: was this better on days away from the office? Yes [1] No [2]

(Continued overleaf)

(B)

YOUR HEALTH DURING THE PAST MONTH

8a During the past month, on **how many days** did you experience DRY SKIN when you were at work in this building? None 1 | 1 to 5 2 | 6 to 10 3 | More than 10 4

8b If symptom experienced: was this better on days away from the office? Yes 1 | No 2

9a During the past month, on **how many days** did you experience a RASH OR IRRITATED SKIN when you were at work in this building?

None 1 | 1 to 5 2 | 6 to 10 3 | More than 10 4

9b If symptom experienced: was this better on days away from the office? Yes 1 | No 2

10a During the past month, on **how many days** did you experience HEADACHES when you were at work in this building? None 1 | 1 to 5 2 | 6 to 10 3 | More than 10 4

10b If symptom experienced: was this better on days away from the office? Yes 1 | No 2

11a During the past month, on **how many days** did you experience LETHARGY OR TIREDNESS when you were at work in this building?

None 1 | 1 to 5 2 | 6 to 10 3 | More than 10 4

11b If symptom experienced: was this better on days away from the office? Yes 1 | No 2

12a During the past month, on **how many days** did you experience ANY OTHER SYMPTOMS when you were at work in this building?

None 1 | 1 to 5 2 | 6 to 10 3 | More than 10 4

12b If any experienced: was this better on days away from the office? Yes 1 | No 2

Please describe symptoms. -

Consider any symptoms which you have experienced at work (but only those that are better when you are away from the office).

13 In which season do such symptoms tend to be at their worst? Spring 1 | Summer 2 | Autumn 3 | Winter 4 | No particular season 5

Please tick one box only.

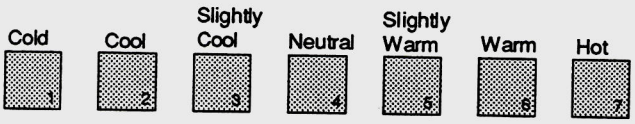
14 And during which part of the day do such symptoms tend to be at their worst? Morning 1 | Afternoon 2 | Evening 3 | No particular time 4

Please tick one box only.

(Continued overleaf)

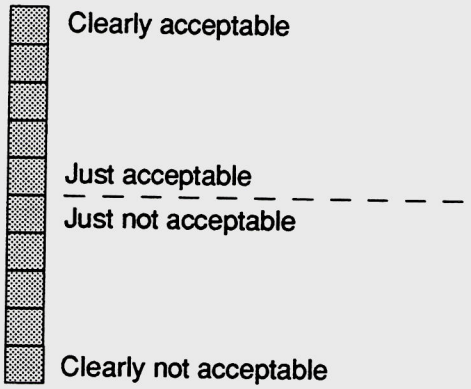
(C) ENVIRONMENTAL CONDITIONS DURING THE PAST MONTH

1 How would you describe your typical level of thermal comfort in this office during the past month? *Please tick one box*



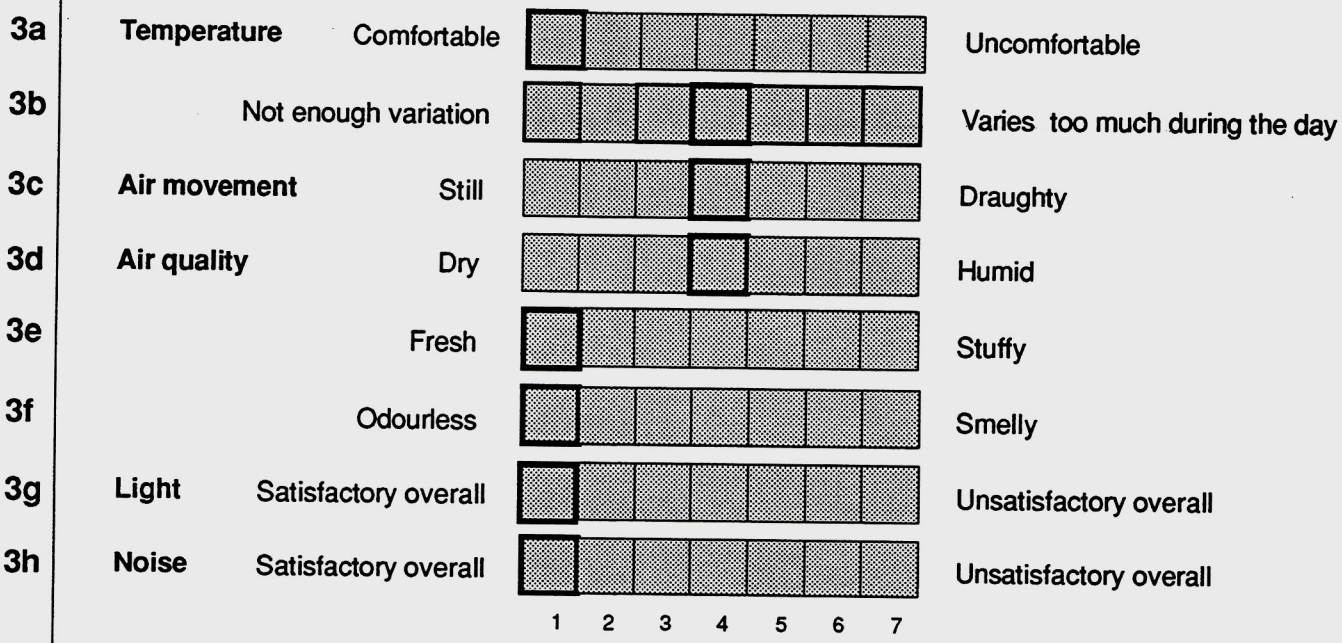
2 How would you rate the typical overall acceptability of the indoor air quality in this office during the past month?

Please tick one box



How would you describe the typical indoor conditions in this office during the past month? *Please tick one box per scale*

The boxes with bold edges represent the ideal point on each scale



(Continued overleaf)

(D)

YOUR HEALTH AT THIS POINT IN TIME

1a At this moment, are you experiencing DRY EYES at all? Yes 1 No 2

1b If yes: has this symptom got better or worse since you arrived in this building today? Better 1 No Change 2 Worse 3

1c How severe is this symptom at this moment? *Please tick one box on the scale.* Very mild 1 2 3 4 5 6 7 Very severe

2a At this moment, are you experiencing WATERING EYES at all? Yes 1 No 2

2b If yes: has this symptom got better or worse since you arrived in this building today ? Better 1 No Change 2 Worse 3

2c How severe is this symptom at this moment? *Please tick one box on the scale.* Very mild 1 2 3 4 5 6 7 Very severe

3a At this moment, are you experiencing a BLOCKED OR STUFFY NOSE at all? Yes 1 No 2

3b If yes: has this symptom got better or worse since you arrived in this building today? Better 1 No Change 2 Worse 3

3c How severe is this symptom at this moment? *Please tick one box on the scale.* Very mild 1 2 3 4 5 6 7 Very severe

4a At this moment, are you experiencing a RUNNY NOSE at all? Yes 1 No 2

4b If yes: has this symptom got better or worse since you arrived in this building today? Better 1 No Change 2 Worse 3

4c How severe is this symptom at this moment? *Please tick one box on the scale.* Very mild 1 2 3 4 5 6 7 Very severe

5a At this moment, are you experiencing a DRY or IRRITATEDTHROAT at all? Yes 1 No 2

5b If yes: has this symptom got better or worse since you arrived in this building today? Better 1 No Change 2 Worse 3

5c How severe is this symptom at this moment? *Please tick one box on the scale.* Very mild 1 2 3 4 5 6 7 Very severe

6a At this moment, are you experiencing CHEST TIGHTNESS OR BREATHING DIFFICULTY at all? Yes 1 No 2

6b If yes: has this symptom got better or worse since you arrived in this building today? Better 1 No Change 2 Worse 3

6c How severe is this symptom at this moment? *Please tick one box on the scale.* Very mild 1 2 3 4 5 6 7 Very severe

(Continued overleaf)

(D) YOUR HEALTH AT THIS POINT IN TIME

7a At this moment, are you experiencing FLU-LIKE SYMPTOMS at all? Yes 1 No 2

7b If yes: has this symptom got better or worse since you arrived in this building today? Better 1 No Change 2 Worse 3

7c How severe is this symptom at this moment? *Please tick one box on the scale.* Very mild 1 2 3 4 5 6 7 Very severe

8a At this moment, are you experiencing DRY SKIN at all? Yes 1 No 2

8b If yes: has this symptom got better or worse since you arrived in this building today? Better 1 No Change 2 Worse 3

8c How severe is this symptom at this moment? *Please tick one box on the scale.* Very mild 1 2 3 4 5 6 7 Very severe

9a At this moment, are you experiencing a RASH OR IRRITATED SKIN at all? Yes 1 No 2

9b If yes: has this symptom got better or worse since you arrived in this building today? Better 1 No Change 2 Worse 3

9c How severe is this symptom at this moment? *Please tick one box on the scale.* Very mild 1 2 3 4 5 6 7 Very severe

10a At this moment, are you experiencing HEADACHES at all? Yes 1 No 2

10b If yes: has this symptom got better or worse since you arrived in this building today? Better 1 No Change 2 Worse 3

10c How severe is the symptom at this moment *Please tick one box on the scale.* Very mild 1 2 3 4 5 6 7 Very severe

11a At this moment, are you experiencing LETHARGY OR TIREDNESS at all? Yes 1 No 2

11b If yes: has this symptom got better or worse since you arrived in this building today? Better 1 No Change 2 Worse 3

11c How severe is this symptom at this moment? *Please tick one box on the scale.* Very mild 1 2 3 4 5 6 7 Very severe

12a At this moment, are you experiencing ANY OTHER SYMPTOMS at all? *Please describe symptoms.* Yes 1 No 2

12b ---

12c If yes: have these symptoms got better or worse since you arrived in this building today ? Better 1 No Change 2 Worse 3

12d How severe are these symptoms at this moment? *Please tick one box on the scale.* Very mild 1 2 3 4 5 6 7 Very severe

(Continued overleaf)

(E) ENVIRONMENTAL CONDITIONS AT THIS POINT IN TIME

1 How would you describe your level of thermal comfort at this moment? *Please tick one box*

Cold	Cool	Slightly Cool	Neutral	Slightly Warm	Warm	Hot
1	2	3	4	5	6	7

2 How would you rate the overall acceptability of the indoor air quality in this office at this moment?

Please tick one box

- Clearly acceptable
- Just acceptable
- Just not acceptable
- Clearly not acceptable

How would you describe the indoor conditions in this office at this moment?

Please tick one box per scale

The boxes with bold edges represent the ideal point on each scale

3a	**Temperature**	Comfortable	Uncomfortable
3b	**Air movement**	Still	Draughty
3c	**Air quality**	Dry	Humid
3d		Fresh	Stuffy
3e		Odourless	Smelly
3f	**Light**	Too dark	Too bright
3g		Steady	Flickering
3h		No glare at all	Too much glare
3i		Very uniform	Very uneven
3j		Satisfactory overall	Unsatisfactory overall
3k	**Noise**	No noise from ventilation system	Too much noise from ventilation system
3l		No other noise	Too much other noise
3m		Satisfactory overall	Unsatisfactory overall

1 2 3 4 5 6 7

(Continued overleaf)

(F) OTHER ASPECTS OF YOUR OFFICE ENVIRONMENT

In your office, how much control do you have over the following?

Please tick one box per scale.

1	**Temperature**	None at all	1	2	3	4	5	6	7	Full control
2	**Ventilation**	None at all	1	2	3	4	5	6	7	Full control
3	**Lighting**	None at all	1	2	3	4	5	6	7	Full control

4 How would you describe the cleanliness of your office ?

Please tick one box on scale.

Unsatisfactory 1 2 3 4 5 6 7 Satisfactory

5 Do other people smoke in your immediate working environment at work? Yes 1 No 2

6 Is there any other aspect of your office environment you would like to comment on? Yes 1 No 2 *If yes, please describe below*

- -

- -

- -

- -

- -

- -

- -

- -

- -

(G) ABOUT YOURSELF

1 Have you ever had asthmatic problems? Yes 1 No 2

2 Have you ever suffered from eczema? Yes 1 No 2

3 Have you ever suffered with hay fever? Yes 1 No 2

4a Are you currently a smoker?

4b Yes 1 → Do you smoke in this room? Yes 1 No 2

4c No 2 → Did you ever smoke regularly in the past? Yes 1 No 2

Name -

It is optional to enter your name but it would help us to keep track of which questionnaires have been collected and to follow up any important comments.

THAT IS THE END OF THE QUESTIONNAIRE THANK YOU FOR YOUR TIME

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

ENQUÊTE SUR LA QUALITÉ DE L'AIR DANS LES BÂTIMENTS DE BUREAUX

Dans le cadre d'un programme de recherches européen, une analyse scientifique de l'environnement de travail dans votre bâtiment est en cours. Vous avez reçu récemment une lettre vous expliquant la but de cette analyse. Le questionnaire qui suit est un élément essentiel de cette analyse.

Vous êtes priés de répondre à toutes les questions de manière spontanée.
Donnez simplement votre première opinion.

Il vous faudra approximativement 15 minutes pour remplir ce questionnaire.

Ce questionnaire sera utilisé par le Laboratoire d'Energie Solaire et de Physique du Bâtiment de l'Ecole Polytechnique Fédérale de Lausanne pour évaluer votre environnement de travail. Les informations contenues dans ce questionnaire seront traitées confidentiellement. Le contenu de ce questionnaire ne sera transmis ni à votre employeur, ni à des tierces personnes. Les renseignements que l'on pourra en tirer ne seront publiés que sous forme de statistiques et de manière totalement anonyme.

Il est important que vous notiez vos opinions personnelles,
sans en référer à vos collègues.

N'hésitez pas à contacter le personnel de l'EPFL si vous avez des questions concernant ce document ou l'enquête en cours.

L'ÉQUIPE DE RECHERCHE VOUS REMERCIE VIVEMENT POUR VOTRE COLLABORATION

Questionnaire No ☐☐☐☐☐☐☐☐

Heure ☐☐ ☐☐ (Horloge 24 Heures)

Age ☐☐ Homme ☐ Femme ☐

Position de votre place de travail: Etage ☐ No de pièce ☐☐☐

Orientation de la façade principale (fenêtre) Nord | Est | Sud | Ouest

1 Depuis combien de temps, approximativement, étiez vous assis(e) à ce bureau avant de commencer à remplir ce questionnaire? ☐☐ heures
Ne tenez pas compte des interruptions de courte durée.

2 A quoi consacrez vous la majeure partie de votre travail? *(cochez une case)*
Tâches de direction, d'organisation ☐
Tâche de spécialiste (telle que ingénieur, médecin, juriste, informaticien) ☐
Tâches de secrétariat et d'administration ☐
Autre tâche ☐ (précisez)

	Années	Mois*
3 Depuis combien de temps travaillez vous dans ce bâtiment?	☐☐	☐☐
4 Depuis combien de temps travaillez vous dans cette pièce?	☐☐	☐☐

*Ne notez pas les mois si plus de 2 ans

En moyenne, sur la base des derniers 30 jours:

5 combien de temps passez vous à votre bureau, par jour ouvrable? ☐☐ heures

6 Combien d'heures par semaine effectuez vous un travail rémunéré? ☐☐ heures
(y compris le temps passé en dehors de ce bâtiment)

7 Combien d'heures par semaine passez vous devant un écran ? ☐☐ heures

8 Durant les derniers 30 jours, combien de jours avez vous passé dans ce bâtiment? ☐☐ jours

9 Pendant votre travail, combien de personnes occupent votre bureau? ☐☐ personnes

10 Il y a-t-il une fenêtre dans votre bureau? Oui Non Si NON, passez à la page suivante

11 A quelle distance, approximativement, est la plus proche fenêtre? ☐☐ mètres

12 Ouvrez vous parfois une fenêtre de votre bureau? Oui Non

1 Pendant combien de jours, le mois passé, avez vous eu **des yeux secs** pendant que vous travailliez dans ce bâtiment?

Jamais ☐ 1 à 5 ☐ 5 à 10 ☐ plus de 10 ☐ jours

Avez vous observé une amélioration pendant les jours d'absence? Oui Non

2 Pendant combien de jours, le mois passé, avez vous eu **des yeux larmoyants** pendant que vous travailliez dans ce bâtiment?

Jamais ☐ 1 à 5 ☐ 5 à 10 ☐ plus de 10 ☐ jours

Avez vous observé une amélioration pendant les jours d'absence? Oui Non

3 Pendant combien de jours, le mois passé, avez vous eu **le nez bouché** pendant que vous travailliez dans ce bâtiment?

Jamais ☐ 1 à 5 ☐ 5 à 10 ☐ plus de 10 ☐ jours

Avez vous observé une amélioration pendant les jours d'absence? Oui Non

4 Pendant combien de jours, le mois passé, avez vous eu **le nez qui coule** pendant que vous travailliez dans ce bâtiment?

Jamais ☐ 1 à 5 ☐ 5 à 10 ☐ plus de 10 ☐ jours

Avez vous observé une amélioration pendant les jours d'absence? Oui Non

5 Pendant combien de jours, le mois passé, avez vous eu **la gorge sèche ou irritée** pendant que vous travailliez dans ce bâtiment?

Jamais ☐ 1 à 5 ☐ 5 à 10 ☐ plus de 10 ☐ jours

Avez vous observé une amélioration pendant les jours d'absence? Oui Non

6 Pendant combien de jours, le mois passé, avez vous eu la **poitrine oppressée ou des difficultés respiratoires** pendant que vous travailliez dans ce bâtiment?

Jamais ☐ 1 à 5 ☐ 5 à 10 ☐ plus de 10 ☐ jours

Avez vous observé une amélioration pendant les jours d'absence? Oui Non

7 Pendant combien de jours, le mois passé, avez vous eu des **symptômes grippaux** pendant que vous travailliez dans ce bâtiment?

Jamais ☐ 1 à 5 ☐ 5 à 10 ☐ plus de 10 ☐ jours

Avez vous observé une amélioration pendant les jours d'absence? Oui Non

8 Pendant combien de jours, le mois passé, avez vous eu **la peau sèche** pendant que vous travailliez dans ce bâtiment?

Jamais ☐ 1 à 5 ☐ 5 à 10 ☐ plus de 10 ☐ jours

Avez vous observé une amélioration pendant les jours d'absence? Oui Non

9 Pendant combien de jours, le mois passé, avez vous eu **la peau irritée ou des éruptions** pendant que vous travailliez dans ce bâtiment?

Jamais ☐ 1 à 5 ☐ 5 à 10 ☐ plus de 10 ☐ jours

Avez vous observé une amélioration pendant les jours d'absence? Oui Non

10 Pendant combien de jours, le mois passé, avez vous eu **des maux de tête** pendant que vous travailliez dans ce bâtiment?

Jamais ☐ 1 à 5 ☐ 5 à 10 ☐ plus de 10 ☐ jours

Avez vous observé une amélioration pendant les jours d'absence? Oui Non

11 Pendant combien de jours, le mois passé, avez vous ressenti **de la fatigue ou** une certaine **apathie** pendant que vous travailliez dans ce bâtiment?

Jamais ☐ 1 à 5 ☐ 5 à 10 ☐ plus de 10 ☐ jours

Avez vous observé une amélioration pendant les jours d'absence? Oui Non

12 Pendant combien de jours, le mois passé, avez vous eu **d'autres symptômes** pendant que vous travailliez dans ce bâtiment?

Jamais ☐ 1 à 5 ☐ 5 à 10 ☐ plus de 10 ☐ jours

Avez vous observé une amélioration pendant les jours d'absence? Oui Non

Décrivez brièvement ces symptômes .....

.....

Pour les deux questions suivantes, ne considérez que les symptômes que vous ressentez au travail et qui s'améliorent pendant les jours d'absence.
S'il vous plaît, ne cochez qu'une case par ligne.

		Printemps	Eté	Automne	Hiver	N'importe quand
13	En quelle saison ces symptômes sont-ils les plus sévères?	☐	☐	☐	☐	☐

		Matin	Après-midi	Soir	N'importe quand
14	Et quand, pendant la journée, ces symptômes sont-ils les plus sévères?	☐	☐	☐	☐

C VOTRE ENVIRONNEMENT DE TRAVAIL DURANT LE MOIS PASSÉ

1 Comment qualifiez-vous le confort thermique de votre bureau pendant le mois passé?

Froid	Frais	A peine frais	Neutre	A peine chaud	Chaud	Trop chaud
1	2	3	4	5	6	7

2 Comment jugez vous la qualité de l'air dans votre bureau pendant le mois passé?
Veuillez cochez une case

3	Tout à fait acceptable
1	Juste acceptable
-1	Juste inacceptable
-3	Tout à fait inacceptable

3 Comment qualifiez vous le climat intérieur et les conditions de travail régnant dans votre bureau pendant le mois passé?
Veuillez cocher une case par ligne.
Les cases encadrées représentent, sur chaque échelle, la valeur idéale.

Température	Confortable	**1**	2	3	4	5	6	7	Inconfortable
Température	Trop stable	1	2	3	**4**	5	6	7	Trop variable
Mouvements d'air	Air stagnant	1	2	3	**4**	5	6	7	Courants d'air
Sécheresse, humidité de l'air	Sec	1	2	3	**4**	5	6	7	Humide
Qualité de l'air	Frais	**1**	2	3	4	5	6	7	Etouffant
Odeur dans l'air	Insignifiante	**1**	2	3	4	5	6	7	Horrible
Eclairage	Satisfaisant	**1**	2	3	4	5	6	7	Insatisfaisant
Bruit	Satisfaisant	**1**	2	3	4	5	6	7	Insatisfaisant

Remarques éventuelles concernant les questions ci-dessus .....

.....

.....

.....

1 En cet instant précis, avez-vous **les yeux secs**? Oui Non
Si oui, ce symptôme a-t-il diminué ou empiré depuis que vous êtes dans ce bâtiment? Diminué 1 Inchangé 2 Empiré 3

Cochez la case correspondant à la sévérité de ce symptôme — Très faible 1 2 3 4 5 6 7 Très sévère

2 En cet instant précis, avez-vous **les yeux larmoyants**? Oui Non
Si oui, ce symptôme a-t-il diminué ou empiré depuis que vous êtes dans ce bâtiment? Diminué 1 Inchangé 2 Empiré 3

Cochez la case correspondant à la sévérité de ce symptôme — Très faible 1 2 3 4 5 6 7 Très sévère

3 En cet instant précis, avez-vous **le nez bouché**? Oui Non
Si oui, ce symptôme a-t-il diminué ou empiré depuis que vous êtes dans ce bâtiment? Diminué 1 Inchangé 2 Empiré 3

Cochez la case correspondant à la sévérité de ce symptôme — Très faible 1 2 3 4 5 6 7 Très sévère

4 En cet instant précis, avez-vous le **nez qui coule?** Oui Non
Cochez la case correspondant à la sévérité de ce symptôme — Très faible 1 2 3 4 5 6 7 Très sévère
Si oui, ce symptôme a-t-il diminué ou empiré depuis que vous êtes dans ce bâtiment? Diminué 1 Inchangé 2 Empiré 3

Cochez la case correspondant à la sévérité de ce symptôme — Très faible 1 2 3 4 5 6 7 Très sévère

5 En cet instant précis, avez-vous **la gorge sèche ou irritée**? Oui Non
Si oui, ce symptôme a-t-il diminué ou empiré depuis que vous êtes dans ce bâtiment? Diminué 1 Inchangé 2 Empiré 3

Cochez la case correspondant à la sévérité de ce symptôme — Très faible 1 2 3 4 5 6 7 Très sévère

6 En cet instant précis, avez-vous **la poitrine oppressée ou des difficultés respiratoires**? Oui Non
Si oui, ce symptôme a-t-il diminué ou empiré depuis que vous êtes dans ce bâtiment? Diminué 1 Inchangé 2 Empiré 3

Cochez la case correspondant à la sévérité de ce symptôme — Très faible 1 2 3 4 5 6 7 Très sévère

7 En cet instant précis, avez-vous **des symptômes grippaux**? Oui Non
Si oui, ce symptôme a-t-il diminué ou empiré depuis que vous êtes dans ce bâtiment? Diminué 1 Inchangé 2 Empiré 3

Cochez la case correspondant à la sévérité de ce symptôme Très faible 1 2 3 4 5 6 7 Très sévère

8 En cet instant précis, avez-vous **la peau sèche**? Oui Non
Si oui, ce symptôme a-t-il diminué ou empiré depuis que vous êtes dans ce bâtiment? Diminué 1 Inchangé 2 Empiré 3

Cochez la case correspondant à la sévérité de ce symptôme Très faible 1 2 3 4 5 6 7 Très sévère

9 En cet instant précis, avez-vous **la peau irritée ou des éruptions**? Oui Non
Si oui, ce symptôme a-t-il diminué ou empiré depuis que vous êtes dans ce bâtiment? Diminué 1 Inchangé 2 Empiré 3

Cochez la case correspondant à la sévérité de ce symptôme Très faible 1 2 3 4 5 6 7 Très sévère

10 En cet instant précis, avez-vous **mal à la tête**? Oui Non
Si oui, ce symptôme a-t-il diminué ou empiré depuis que vous êtes dans ce bâtiment? Diminué 1 Inchangé 2 Empiré 3

Cochez la case correspondant à la sévérité de ce symptôme Très faible 1 2 3 4 5 6 7 Très sévère

11 En cet instant précis, êtes vous **fatigué ou apathique**? Oui Non
Si oui, ce symptôme a-t-il diminué ou empiré depuis que vous êtes dans ce bâtiment? Diminué 1 Inchangé 2 Empiré 3

Cochez la case correspondant à la sévérité de ce symptôme Très faible 1 2 3 4 5 6 7 Très sévère

12 En cet instant précis, ressentez vous un **symptôme non mentionné** ci-dessus? Oui Non

Si oui, décrivez le: .....

.....

Si oui, ce symptôme a-t-il diminué ou empiré depuis que vous êtes dans ce bâtiment? Diminué 1 Inchangé 2 Empiré 3

Cochez la case correspondant à la sévérité de ce symptôme Très faible 1 2 3 4 5 6 7 Très sévère

1 Comment qualifiez-vous le confort thermique dans votre bureau en ce moment?

Froid	Frais	A peine frais	Neutre	A peine chaud	Chaud	Trop chaud
1	2	3	4	5	6	7

2 Comment jugez vous la qualité de l'air dans votre bureau en ce moment?
Veuillez cochez une case

5	Tout à fait acceptable
1	Juste acceptable
-1	Juste inacceptable
-5	Tout à fait inacceptable

3 Comment qualifiez vous le climat intérieur et les conditions de travail régnant actuellement dans votre bureau?

Veuillez cocher une case par ligne.
Les cases encadrées représentent, sur chaque échelle, la valeur idéale.

Température	Confortable	**1**	2	3	4	5	6	7	Inconfortable
Température	Trop stable	1	2	3	**4**	5	6	7	Trop variable
Mouvements d'air	Air stagnant	1	2	3	**4**	5	6	7	Courants d'air
Sécheresse, humidité de l'air	Sec	1	2	3	**4**	5	6	7	Humide
Qualité de l'air	Frais	**1**	2	3	4	5	6	7	Etouffant
Odeur dans l'air	Insignifiante	**1**	2	3	4	5	6	7	Horrible
Eclairage	Trop sombre	1	2	3	**4**	5	6	7	Trop clair
Eclairage	Stable	**1**	2	3	4	5	6	7	Clignotant
Eclairage	Sans éblouissement	**1**	2	3	4	5	6	7	Eblouissant
Eclairage	Trop uniforme	1	2	3	**4**	5	6	7	Trop irrégulier
Eclairage, en général	Satisfaisant	**1**	2	3	4	5	6	7	Insatisfaisant
Bruit de la ventilation	Aucun bruit	**1**	2	3	4	5	6	7	Trop de bruit
Autres bruits	Pas d'autres bruits	**1**	2	3	4	5	6	7	Trop de bruits
Bruit en général	Satisfaisant	**1**	2	3	4	5	6	7	Insatisfaisant

F AUTRES ASPECTS DE VOTRE ENVIRONNEMENT DE TRAVAIL

Dans votre bureau, dans quelle mesure pouvez vous influencer les fonctions suivantes?
Cochez une case par ligne

1 Température	Aucune influence	1	2	3	4	5	6	7	Contrôle total
2 Ventilation, aération	Aucune influence	1	2	3	4	5	6	7	Contrôle total
3 Eclairage	Aucune influence	1	2	3	4	5	6	7	Contrôle total

4 Comment qualifiez-vous la propreté dans votre bureau? Insatisfaisante | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Satisfaisante

5 Il y a-t-il des fumeurs dans votre environnement immédiat? Oui Non

6 Il y a-t-il d'autres aspects de votre environnement de travail que vous désireriez commenter? Oui Non

Si oui, faites le ci-dessous

.....

.....

.....

.....

.....

.....

G QUELQUES QUESTIONS PERSONNELLES

1 Avez vous souffert d'asthme? Oui Non

2 Avez vous souffert d'eczéma? Oui Non

3 Avez vous souffert du rhume des foins? Oui Non

4 Etes vous fumeur, maintenant? Oui — Fumez-vous dans cette pièce? Oui Non

Non — Fumiez vous régulièrement par le passé? Oui Non

Nom (facultatif)

.....

Votre nom n'est pas indispensable, et vous êtes libre de le mettre ou non. Il nous aiderait à mieux tenir compte des remarques importantes.

VOICI LA FIN DU QUESTIONNAIRE. MERCI POUR VOTRE PEINE ET VOTRE TEMPS.

Fragebogen zu den Innenraum-Bedingungen im Büro

Studie über Luftqualität und Klimabedingungen in Büroräumen

Durch das Ausfüllen dieses Fragebogens werden Sie zur TeilnehmerIn einer wissenschaftlichen EG-Studie. Insgesamt 10 europäische Länder sind daran beteiligt. Wir begrüssen Sie dazu ganz herzlich!

Wir führen verschiedene Messungen in diesem Gebäude durch. Nun möchten wir wissen, wie die gemessenen Faktoren auf Sie einwirken. Dabei fragen wir bewusst nach Ihrem subjektiven Empfinden. Weiter fragen wir nach Auswirkungen dieser Faktoren auf Ihre Gesundheit. Ihre ganz persönliche Meinung interessiert uns!

Bitte beantworten Sie alle Fragen. Überlegen Sie nicht zu lange. Antworten sie spontan! Der Fragebogen sollte nicht mehr als eine Viertelstunde Ihrer Zeit in Anspruch nehmen.

Ihre Antworten werden vertraulich behandelt und an niemanden in Ihrer Firma weitergeleitet.

Einsammeln des Fragebogens:

Legen Sie den ausgefüllten Fragebogen gut sichtbar an Ihren Arbeitsplatz (z.B auf PC ...). Falls Sie den Bogen nicht ausfüllen, so notieren Sie bitte eine kurze Begründung auf die Rückseite dieses Schreibens.
Sämtliche Bögen werden ca. um 14:30 von uns eingesammelt. Kontaktieren Sie uns bitte, falls Sie Fragen haben.

Ganz herzlichen Dank für Ihre Mitarbeit,

mit freundlichen Grüssen, die Messteams der

ETH-Zürich
ETH-Lausanne
UNI-Lausanne

Fragebogen zu den Innenraum-Bedingungen im Büro

Fragebogen-Nummer ☐☐☐☐☐☐

jetzige Uhrzeit ☐☐ ☐☐ (in 24-Stundenangabe)

Alter ☐ Geschlecht ☐ männlich ☐ weiblich

Gebäude und Raum .....

1. Wie lange sind Sie heute ungefähr an ihrem Schreibtisch gesessen, bevor Sie mit dem Ausfüllen des Fragebogens begonnen haben? (ohne kurze Pausen) ☐ Stunden

2. Mit welcher Art von Arbeit beschäftigen Sie sich vor allem?
   Bitte kreuzen Sie ein oder mehrere Felder an

   -Mit der Arbeitsorganisation oder mit Finanzen ☐

   -Mit der Anwendung von Fachwissen (z.Bsp. im Bereich der Justiz, Medizin, Wissenschaft oder des Ingenieurwesens) ☐

   -Mit der Ausführung von administrativen Arbeiten (Büro- oder Sekretariatsarbeiten) ☐

   -Mit anderen Arbeiten, wie..... ☐

	Jahre	Monate
3. Seit wie langer Zeit arbeiten Sie schon in diesem Gebäude?	☐	☐
	Monatsangabe ist überflüssig, falls länger als 2 Jahre	
4. Seit wie langer Zeit arbeiten Sie schon in diesem Raum?	☐	☐

5. Die folgenden Fragen beziehen sich auf den **vergangenen Monat** - durchschnittliche Angaben genügen:

- Wieviel Zeit verbrachten Sie an Ihrem Schreibtisch während eines Arbeitstages? ☐ Stunden

- Wieviele bezahlte Arbeitsstunden leisteten Sie pro Woche? (schliessen Sie auch die Zeit mit ein, in welcher Sie ausserhalb dieses Gebäudes gearbeitet haben) ☐ Stunden

- Wieviele Stunden pro Woche haben Sie an einem Bildschirm gearbeitet? ☐ Stunden

- Wieviele Tage haben Sie in diesem Gebäude gearbeitet? ☐ Tage

6. Wieviele andere Personen arbeiten normalerweise im gleichen Raum wie Sie? ☐ Personen

7. Gibt es in Ihrem Raum ein Fenster?

Ja ☐

Nein ☐ → **fahren Sie bitte mit Frage 10 fort**

8. Wie weit ist Ihr Schreibtisch ungefähr vom nächsten Fenster entfernt? (Auf Meter genau auf- bzw. abrunden) ☐ Meter

9. Öffnen Sie in Ihrem Raum je ein Fenster? ☐ Ja ☐ Nein

Ihre Gesundheit während des letzten Monats

10. An wievielen Tagen während des letzten Monats hatten Sie während der Arbeit in diesem Gebäude **gereizte** oder **brennende Augen**?

keinem ☐ 1 bis 5 ☐ 6 bis 10 ☐ mehr als 10 ☐

Falls Sie dieses Symptom hatten: verspürten Sie eine Besserung an Tagen, an denen Sie nicht im Büro waren? Ja ☐ Nein ☐

11. An wievielen Tagen während des letzten Monats hatten Sie während der Arbeit in diesem Gebäude **tränende Augen**?

keinem ☐ 1 bis 5 ☐ 6 bis 10 ☐ mehr als 10 ☐

Falls Sie dieses Symptom hatten: verspürten Sie eine Besserung an Tagen, an denen Sie nicht im Büro waren? Ja ☐ Nein ☐

12. An wievielen Tagen während des letzten Monats hatten Sie während der Arbeit in diesem Gebäude eine **leicht verstopfte oder blockierte Nase**?

keinem ☐ 1 bis 5 ☐ 6 bis 10 ☐ mehr als 10 ☐

Falls Sie dieses Symptom hatten: verspürten Sie eine Besserung an Tagen, an denen Sie nicht im Büro waren? Ja ☐ Nein ☐

13. An wievielen Tagen während des letzten Monats hatten Sie während der Arbeit in diesem Gebäude eine **laufende Nase**?

keinem ☐ 1 bis 5 ☐ 6 bis 10 ☐ mehr als 10 ☐

Falls Sie dieses Symptom hatten: verspürten Sie eine Besserung an Tagen, an denen Sie nicht im Büro waren? Ja ☐ Nein ☐

14. An wievielen Tagen während des letzten Monats hatten Sie während der Arbeit in diesem Gebäude einen **trockenen oder gereizten Hals**?

keinem ☐ 1 bis 5 ☐ 6 bis 10 ☐ mehr als 10 ☐

Falls Sie dieses Symptom hatten: verspürten Sie eine Besserung an Tagen, an denen Sie nicht im Büro waren? Ja ☐ Nein ☐

15. An wievielen Tagen während des letzten Monats hatten Sie während der Arbeit in diesem Gebäude ein **beengendes Gefühl in der Brustgegend** oder **Atmungsbeschwerden**?

keinem ☐ 1 bis 5 ☐ 6 bis 10 ☐ mehr als 10 ☐

Falls Sie dieses Symptom hatten: verspürten Sie eine Besserung an Tagen, an denen Sie nicht im Büro waren? Ja ☐ Nein ☐

16. An wievielen Tagen während des letzten Monats hatten Sie während der Arbeit in diesem Gebäude **erkältungsähnliche Symptome** ?

keinem ☐ 1 bis 5 ☐ 6 bis 10 ☐ mehr als 10 ☐

Falls Sie dieses Symptom hatten: verspürten Sie eine Besserung an Tagen, an denen Sie nicht im Büro waren? Ja ☐ Nein ☐

17. An wievielen Tagen während des letzten Monats hatten Sie während der Arbeit in diesem Gebäude **trockene Haut** ?

keinem ☐ 1 bis 5 ☐ 6 bis 10 ☐ mehr als 10 ☐

Falls Sie dieses Symptom hatten: verspürten Sie eine Besserung an Tagen, an denen Sie nicht im Büro waren? Ja ☐ Nein ☐

18. An wievielen Tagen während des letzten Monats hatten Sie während der Arbeit in diesem Gebäude einen **Hautausschlag** oder eine **gerötete bzw. gereizte Haut**?

keinem ☐ 1 bis 5 ☐ 6 bis 10 ☐ mehr als 10 ☐

Falls Sie dieses Symptom hatten: verspürten Sie eine Besserung an Tagen, an denen Sie nicht im Büro waren? Ja ☐ Nein ☐

19. An wievielen Tagen während des letzten Monats hatten Sie während der Arbeit in diesem Gebäude **Kopfschmerzen** ?

keinem ☐ 1 bis 5 ☐ 6 bis 10 ☐ mehr als 10 ☐

Falls Sie dieses Symptom hatten: verspürten Sie eine Besserung an Tagen, an denen Sie nicht im Büro waren? Ja ☐ Nein ☐

20. An wievielen Tagen während des letzten Monats litten Sie während der Arbeit in diesem Gebäude an **Müdigkeit oder Abgespanntheit**?

keinem ☐ 1 bis 5 ☐ 6 bis 10 ☐ mehr als 10 ☐

Falls Sie dieses Symptom hatten: verspürten Sie eine Besserung an Tagen, an denen Sie nicht im Büro waren? Ja ☐ Nein ☐

21. An wievielen Tagen während des letzten Monats litten Sie während der Arbeit in diesem Gebäude unter irgendwelchen **anderen Symptomen**?

keinem ☐ 1 bis 5 ☐ 6 bis 10 ☐ mehr als 10 ☐

Bitte beschreiben Sie die Symptome:.....

.....

.....

Falls Sie solche Symptome hatten: verspürten Sie eine Besserung an Tagen, an denen Sie nicht im Büro waren? Ja ☐ Nein ☐

Berücksichtigen Sie für die folgenden zwei Fragen alle Symptome, unter welchen Sie während der Arbeit leiden (nur diejenigen, die sich bessern, wenn Sie nicht im Büro sind).

22. In welcher Jahreszeit scheinen die Symptome am schlimmsten zu sein?
Kreuzen Sie bitte nur ein Feld an.

Frühling ☐ Sommer ☐ Herbst ☐ Winter ☐ keine bestimmte Jahreszeit ☐

23. Und während welcher Tageszeit scheinen die Symptome am schlimmsten zu sein?
Kreuzen Sie bitte nur ein Feld an.

Morgen ☐ Nachmittag ☐ Abend ☐ keine bestimmte Zeit ☐

Raum- und Klimabedingungen während des letzten Monats

24. Wie würden Sie die Temperatur in Ihrem Büro während des letzten Monats bezeichnen? Bitte kreuzen Sie ein Feld an

sehr kalt	etwas kalt	kühl	angenehm	warm	etwas heiss	sehr heiss
☐	☐	☐	☐	☐	☐	☐

25. Wie würden Sie die Innenraumluftqualität in Ihrem Büro während des letzten Monats beurteilen?

Bitte kreuzen Sie ein Feld an

klar akzeptabel

gerade noch akzeptabel

gerade nicht mehr akzeptabel

klar nicht akzeptabel

26. Wie würden Sie die typischen Innenraumbedingungen in Ihrem Büro während des letzten Monats bezeichnen? Bitte ein Feld pro Skala ankreuzen

Die fett umrahmten Felder markieren den Idealzustand

		1	2	3	4	5	6	7	
Temperatur	angenehm	☐	☐	☐	☐	☐	☐	☐	unangenehm
	ungenügende Schwankungen innerhalb eines Tages	☐	☐	☐	☐	☐	☐	☐	zu starke Schwankungen innerhalb eines Tages
Luftbewegung	zu ruhig	☐	☐	☐	☐	☐	☐	☐	zu starker Luftzug
Luftqualität	trocken	☐	☐	☐	☐	☐	☐	☐	feucht
	frisch	☐	☐	☐	☐	☐	☐	☐	abgestanden
	geruchlos	☐	☐	☐	☐	☐	☐	☐	übelriechend
Licht	allgemein befriedigend	☐	☐	☐	☐	☐	☐	☐	allgemein unbefriedigend
Lärm	allgemein befriedigend	☐	☐	☐	☐	☐	☐	☐	allgemein unbefriedigend

Ihre momentane Gesundheit

27. Verspüren Sie im Moment **gereizte** oder **brennene Augen** ? Ja ☐ Nein ☐

Falls ja: hat sich dieses Symptom verbessert oder verschlimmert seit Sie heute in dieses Gebäude gekommen sind?

☐ verbessert
☐ keine Veränderung
☐ verschlimmert

Wie stark ist dieses Symptom im Moment?

bitte kreuzen Sie nur ein Feld an

sehr schwach 1 2 3 4 5 6 7 sehr stark

28. Haben Sie im Moment **tränende Augen** ? Ja ☐ Nein ☐

Falls ja: hat sich dieses Symptom verbessert oder verschlimmert seit Sie heute in dieses Gebäude gekommen sind?

☐ verbessert
☐ keine Veränderung
☐ verschlimmert

Wie stark ist dieses Symptom im Moment?

sehr schwach 1 2 3 4 5 6 7 sehr stark

29. Verspüren Sie im Moment eine **leicht verstopfte** oder **blockierte Nase**? Ja ☐ Nein ☐

Falls ja: hat sich dieses Symptom verbessert oder verschlimmert seit Sie heute in dieses Gebäude gekommen sind?

☐ verbessert
☐ keine Veränderung
☐ verschlimmert

Wie stark ist dieses Symptom im Moment?

sehr schwach 1 2 3 4 5 6 7 sehr stark

30. Haben Sie im Moment eine **laufende Nase**? Ja ☐ Nein ☐

Falls ja: hat sich dieses Symptom verbessert oder verschlimmert seit Sie heute in dieses Gebäude gekommen sind?

☐ verbessert
☐ keine Veränderung
☐ verschlimmert

Wie stark ist dieses Symptom im Moment?

sehr schwach 1 2 3 4 5 6 7 sehr stark

31. Verspüren Sie im Moment einen **trockenen oder gereizten Hals** ?

Ja ☐ Nein ☐

Falls ja: hat sich dieses Symptom verbessert oder verschlimmert seit Sie heute in dieses Gebäude gekommen sind?

verbessert ☐
keine Veränderung ☐
verschlimmert ☐

Wie stark ist dieses Symptom im Moment?

1 2 3 4 5 6 7

sehr schwach ☐☐☐☐☐☐☐ sehr stark

32. Verspüren Sie im Moment **beengende Gefühle in der Brustgegend** oder **Atmungsbeschwerden** ?

Ja ☐ Nein ☐

Falls ja: hat sich dieses Symptom verbessert oder verschlimmert seit Sie heute in dieses Gebäude gekommen sind?

verbessert ☐
keine Veränderung ☐
verschlimmert ☐

Wie stark ist dieses Symptom im Moment?

1 2 3 4 5 6 7

sehr schwach ☐☐☐☐☐☐☐ sehr stark

33. Haben Sie im Moment **erkältungsähnliche Symptome** ?

Ja ☐ Nein ☐

Falls ja: hat sich dieses Symptom verbessert oder verschlimmert seit Sie heute in dieses Gebäude gekommen sind?

verbessert ☐
keine Veränderung ☐
verschlimmert ☐

Wie stark ist dieses Symptom im Moment?

1 2 3 4 5 6 7

sehr schwach ☐☐☐☐☐☐☐ sehr stark

34. Haben Sie im Moment **trockene Haut** ?

Ja ☐ Nein ☐

Falls ja: hat sich dieses Symptom verbessert oder verschlimmert seit Sie heute in dieses Gebäude gekommen sind?

verbessert ☐
keine Veränderung ☐
verschlimmert ☐

Wie stark ist dieses Symptom im Moment?

1 2 3 4 5 6 7

sehr schwach ☐☐☐☐☐☐☐ sehr stark

35. Haben Sie im Moment einen **Hautausschlag** oder eine **gerötete bzw. gereizte Haut** ?

Ja ☐ Nein ☐

Falls ja: hat sich dieses Symptom verbessert oder verschlimmert seit Sie heute in dieses Gebäude gekommen sind?

verbessert ☐
keine Veränderung ☐
verschlimmert ☐

Wie stark ist dieses Symptom im Moment?

1 2 3 4 5 6 7

sehr schwach ☐☐☐☐☐☐☐ sehr stark

36. Verspüren Sie im Moment **Kopfschmerzen** ?

Ja ☐ Nein ☐

Falls ja: hat sich dieses Symptom verbessert oder verschlimmert seit Sie heute in dieses Gebäude gekommen sind?

verbessert ☐
keine Veränderung ☐
verschlimmert ☐

Wie stark ist dieses Symptom im Moment?

sehr schwach 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ sehr stark

37. Verspüren Sie im Moment **Müdigkeit oder Schlaffheit** ?

Ja ☐ Nein ☐

Falls ja: hat sich dieses Symptom verbessert oder verschlimmert seit Sie heute in dieses Gebäude gekommen sind?

verbessert ☐
keine Veränderung ☐
verschlimmert ☐

Wie stark ist dieses Symptom im Moment?

sehr schwach 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ sehr stark

38. Verspüren Sie im Moment irgendwelche **andere Symptome**? Beschreiben Sie diese Symptome bitte:

Ja ☐ Nein ☐

.....

Falls ja: hat sich dieses Symptom verbessert oder verschlimmert seit Sie heute in dieses Gebäude gekommen sind?

verbessert ☐
keine Veränderung ☐
verschlimmert ☐

Wie stark ist dieses Symptom im Moment?

sehr schwach 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ sehr stark

Momentane Raum- und Klimabedingungen

39. Wie würden Sie die Temperatur in Ihrem Büro zum jetzigen Zeitpunkt bezeichnen? Bitte kreuzen Sie ein Feld an

sehr kalt	etwas kalt	kühl	angenehm	warm	etwas heiss	sehr heiss
☐	☐	☐	☐	☐	☐	☐

40. Wie würden Sie die Innenraumluftqualität in Ihrem Büro zum jetzigen Zeitpunkt beurteilen?
Bitte kreuzen Sie ein Feld an

- klar akzeptabel
- gerade noch akzeptabel
- gerade nicht mehr akzeptabel
- klar nicht akzeptabel

41. Wie würden Sie die Innenraumbedingungen in Ihrem Büro zum jetzigen Zeitpunkt bezeichnen? Bitte ein Feld pro Skala ankreuzen

Die fett umrahmten Felder markieren den Idealzustand

		1	2	3	4	5	6	7	
Temperatur	angenehm	■	☐	☐	☐	☐	☐	☐	unangenehm
Luftbewegung	zu ruhig	☐	☐	☐	■	☐	☐	☐	zu starker Luftzug
Luftqualität	trocken	☐	☐	☐	■	☐	☐	☐	feucht
	frisch	■	☐	☐	☐	☐	☐	☐	abgestanden
	geruchlos	■	☐	☐	☐	☐	☐	☐	übelriechend
Licht	zu dunkel	☐	☐	☐	■	☐	☐	☐	zu hell
	konstant	■	☐	☐	☐	☐	☐	☐	flimmernd
	nicht grell	■	☐	☐	☐	☐	☐	☐	viel zu grell
	sehr einheitlich	☐	☐	☐	■	☐	☐	☐	sehr unterschiedlich
	allgemein befriedigend	■	☐	☐	☐	☐	☐	☐	allgemein unbefriedigend

Lärm keine Ventilationsgeräusche ☐☐☐☐☐☐☐ zuviele Ventilationsgeräusche

kein anderer Lärm ☐☐☐☐☐☐☐ zuviel anderer Lärm

allgemein befriedigend ☐☐☐☐☐☐☐ allgemein unbefriedigend

Andere Aspekte Ihrer Büro-Umwelt

42. Können Sie in Ihrem Büro Einfluss nehmen auf folgende Faktoren?

Bitte kreuzen Sie jeweils ein Feld an

		1 2 3 4 5 6 7	
Temperatur	überhaupt keinen	☐☐☐☐☐☐☐	beliebigen Einfluss
Luftbewegung	überhaupt keinen	☐☐☐☐☐☐☐	beliebigen Einfluss
Licht	überhaupt keinen	☐☐☐☐☐☐☐	beliebigen Einfluss

43. Wie würden Sie die Sauberkeit in Ihrem Büro bewerten?

Bitte kreuzen Sie ein Feld an

1 2 3 4 5 6 7

unbefriedigend ☐☐☐☐☐☐☐ befriedigend

44. Rauchen andere Leute in Ihrer unmittelbaren Umgebung während der Arbeit? Ja ☐ Nein ☐

45. Gibt es andere Raum- oder Klimabedingungen Ihres Büros über die Sie sich äussern möchten? Ja ☐ Nein ☐

Falls ja, beschreiben Sie sie bitte:

.....

.....

.....

.....

Fragen zu Ihrer Person

46. Hatten Sie schon einmal Asthma?	Ja ☐	Nein ☐
47. Hatten Sie schon einmal Ekzeme?	Ja ☐	Nein ☐
48. Hatten Sie schon einmal Heuschnupfen?	Ja ☐	Nein ☐
50. Rauchen Sie?	Ja ☐ → Rauchen Sie in diesem Zimmer?	Ja ☐ Nein ☐
	Nein ☐ → Haben Sie früher regelmässig geraucht?	Ja ☐ Nein ☐

Name: .....

Es steht Ihnen frei, keinen Namen anzugeben. Ihr Name würde uns jedoch ermöglichen festzustellen, ob alle Fragebogen zurückgekommen sind. Wir könnten ausserdem auf allfällige Kommentare Ihrerseits näher eingehen. Auf jeden Fall werden Ihre Informationen vertraulich behandelt und an keine Drittperson weitergegeben.

Sie sind am Ende des Fragebogens angelangt. Wir danken Ihnen für Ihre Bemühungen.

BUILDING A

General information

1. Building identification.	AFB		
3. Situation	Downtown.	7. Number of floors	14
4. Traffic within 200 m.	Busy through road.	area of each floor (m2)	529
		number of offices	60
5. Near sources of pollution	Parking garage.	number of employees	240
	Industry.	8. Year of building completion	1'972
	0	Year of total renovation	1'972
6. Activities besides office work	Only office work.	Year when present user entered	1'972
9. No. of floors beneath ground	4	10. Position of solar shadings	No solar protection.
Roof tilt angle	Flat roof	Solar shadings: movement	0
11. Number of glazing	Double pane.	12. Modification of?	
Glazing type	Clear.	Flooring	fev.92
13. Furniture made of	Mainly solid wood.	Insulation	None
Age of furniture	More than three years.	Wall or ceiling lining	None
14. Large green plants	Green leafed plants.	Windows	None
Plants treatment	No treatement.	Heating system	None
		Ventilation system	None
15. Smoking	Allowed in separate rooms.	16. Office activities and machines	
		solvents	Tipex
		other chemicals	Markers
		copying machines	Yes.
17. Cleaning frequency		laser printers	Yes.
Tables	1 to 3 times a month.	person per VDU	1-2 persons per VDU.
Walls	1 to 3 times a month.	carbonless paper use	No.
Washing floors	1 to 3 times a month.		
Vacuum cleaning	1 to 3 times a month.		
Mopping	Less than once a month.		
Sweeping	Less than once a month.		
Waxing	Less than once a month.		
Spring cleaning	Less than once a year.		
Time since last spring cleaning			
Look of the floors			
18. Detergent for cleaning	type/name	content pH	
cleaning agent linoleum	Taski TR 103	Surfactants, solvents, soap, citrate, perfume	Does not leave a film.
cleaning agent carpet	Taski TR 104	Isopropyl alcool	Polish or wax.
cleaning agent tables	Taski Trik	Unknown	Does not leave a film.
cleaning agent sanitary	Taski Crystal	Surfactants, NTA, soap, colors, perfume	

Installation

1. Installation identification			
2. Room heating Location of heating	Hot water heating. Radiators.	3. Room cooling	Supply of cooled air.
4. Temperature control Night set back	Adjustable thermostat on radiator or unit. No.	5.Ventilation of rooms Windows	Dual ducts balanced system. Windows can be opened.
6. Design outdoor air change Lowest outdoor air supply	More than 3 per hour. 37 l/s·pers	7. Position air intake height above ground distance from exhaust distance from cooling towers	On the roof. 40 vert. 0 hor. 10 vert. 0 hor. 10
8. Equipment vent. system Recirculation [%] Humidification system Water purification Cooling type Heat recovery	 20 No humidification. None. 0 None.		
9. Ventilation system on/off Sensors for demand control	Automatically by a clock. No such control.		
Operating at:	From	to	days per week
full performance reduced performance stopped	06:00 18:30	18:30 06:00	5 7
100% recirculation			
Partial recirculation	06:00	18:30	20 %return air
10. Duct material Duct insulation	Galvanised steel. External insulation.		
11. Service Air intake filter Recirculation duct filter Central unit filter Supply filter Induction / fan coil filter	Class	Last replacement 1-08-90 1-08-90	Needing service No. No. 0
	Last cleaning	Needing service	
Heating batteries	1-09-93	No.	
Cooling batteries	1-09-93	No.	
Heat exchanger		0	
Humidifier	1-04-93	No.	
Ducts		0	
Air outlets in rooms		0	
Air inlet in rooms		0	
12. Location air supply inlets Location air outlets Designed ventilation principle	In the ceiling. High. Mixing ventilation.		

Ventilation was switched off by mistake during the measurements.

Investigated room

The investigated room is a large open office building, in which measurements were performed at 5 locations, it is conmnected to a small office in the northern part and to outdoor for the rest.

Summary Room name	 Office
Wall materials inside insulation Insulation material Thickness of insulation [cm]	Metal. Fiberglas. 3
Felt carpet (needle) [%area] Nap carpet [%area] Lacquered wood [%area] Vinyl (PVC) [%area] Linoleum [%area] Tiles [%area] Other (type here) [%area]	100
Wall covering / treatments Ceiling material (inside surface) Space above acoustic tiles [cm] Dust above acoustic panes? Acoustic baffles below ceiling? Any other ceiling type?	Dispersion paint. Acoustic panes. 10 Yes. No.
Room lighting Lighting location Type of artificial lighting Control of lighting	Artificial. Ceiling. Fluorescent. Manual.
Visible mould growth in rooms Damp spots Mould odor in room	 No damp spots. No.
Area [m²] Height [m] Nb of work places Fleecy material [m²] Shelf length [m] Window area [m²] Office depth [m]	396 2.5 18 440 25 400 5
Nb. of laser printers Nb. of photocopiers Nb. of VDUs Acceptable access for cleaning? Door to corridor open? Nb. of VDU with reflection Nb of VDU with glare	6 1 23 Yes Open 1 22

Questionnaire

General	Total/Nr	Mean	Stdev	Percentage
Questionnaires distributed	80			
Questionnaires returned	77			96%
Age	77	44.23	9.75	
Number of female occupants	61			79%
Number of male occupants	16			21%
Time at desk before filling questionnaire	75	2.73	2.30	
Managerial work	15			19%
Specialist skill	44			57%
Clerical	17			22%
Other	1			1%
Time spent in the building [years]	77	10.01	7.62	
Time spent in the room [years]	76	2.86	3.79	
Hours per day at the desk	74	6.93	1.53	
Paid hours per week	76	41.93	6.05	
Hours at VDU per week	75	13.77	10.55	
Days per month in the building	72	16.56	4.57	
Number of people in the room	76	8.16	6.96	
Rooms without windows	4			5%
Rooms with windows	74			95%
Distance from the window	75	1.23	0.54	
People opening the window	5			7%
People not opening the window	70			93%

All windows in this room were closed.

Health

Health during past month		Symptom present for			Better away	
	Answers	1-5 Days	6-10 Days	>10 days	yes	no
Dry eyes	78	25	4	8	34	2
Watering eyes	78	12	1	1	11	6
Stuffy nose	77	29	13	13	29	22
Runny nose	78	21	3	4	9	18
Dry throat	78	31	16	7	35	14
Chest tightness	78	7	3	2	10	2
Flu-like symptoms	78	35	7	4	22	18
Dry skin	78	11	5	18	17	14
Rash or irritated skin	77	3	3	1	3	4
Headaches	78	33	4	1	23	10
Lethargy	78	29	7	6	20	15
Other symptoms	71	3	1	4	5	3
Season when worst		Spring	Summer	Autumn	Winter	Any
(numbers of answers)	65	1	3	9	28	24
Part of the day when worst		Morning	Afternoon	Evening	Any	
(numbers of answers)	66	9	10	10	37	

Health now	Symptom present		In building			Severity	
	Total/Nr	Nb of yes	Better	Same	Worst	Mean	Stdev
Dry eyes	78	19	0	12	12	3.14	1.46
Watering eyes	78	2	0	4	0	2.40	0.16
Stuffy nose	78	33	0	19	15	3.33	0.00
Runny nose	78	7	0	8	1	2.78	0.89
Dry throat	78	37	0	14	20	3.52	0.50
Chest tightness	78	9	0	5	2	3.22	0.50
Flu-like symptoms	77	14	0	8	4	3.23	1.63
Dry skin	78	27	0	17	8	3.52	0.29
Rash or irritated skin	78	5	0	4	1	3.00	0.33
Headaches	78	9	1	4	3	3.63	1.39
Lethargy	78	15	0	5	6	3.64	0.50
Other symptoms	75	4	0	1	3	5.25	0.50

Frequency of building related symptoms

Only symptoms which disappear out of building are taken into account in this table. For each symptom, the frequency is the ratio of the number of person presenting the symptom to the total number of answers..

Symptom	Last month	Now
Dry eyes	[illegible]	23%
Watering eyes	14%	3%
Stuffy nose	[illegible]	[illegible]
Runny nose	12%	9%
Dry throat	[illegible]	[illegible]
Chest tightness	13%	9%
Flu-like symptoms	30%	16%
Dry skin	23%	32%
Rash or irritated skin	4%	6%
Headaches	32%	9%
Lethargy	29%	15%
Other symptoms	7%	5%

Average air humidity on the audit day was 34%. This may explain the symptoms related to dryness. 22 displays out of 23 have glare, and this may explain dry eyes.

Environmental conditions

Environmental conditions past month	Total/Nr	Mean	Stdev
Level of thermal comfort	77	-0.35	1.02
Indoor air acceptability	78	1.55	2.24
Comfort temperature	77	2.82	1.55
Temperature variation	76	4.24	1.12
Air movement	77	4.53	1.21
Air humidity	76	2.54	1.17
Air stuffiness	76	3.39	1.68
Air odor	74	2.59	1.64
Lighting	77	2.12	1.66
Noise	77	3.12	2.26

Level of thermal comfort are on a -3 to+3 scale, Indoor air acceptability is on a -5 to+5 scale, while other votes are on a 1 to 7 scale.

Environmental conditions now	Total/Nr	Mean	Stdev
Level of thermal comfort	78	-0.42	0.71
Indoor air acceptability	77	2.13	2.22
Comfort temperature	77	2.39	1.46
Air movement	77	4.29	1.23
Air humidity	76	2.71	1.09
Air stuffiness	77	2.78	1.75
Air odor	76	1.95	1.24
Light brightness	77	3.94	0.57
Light flickering	77	1.48	1.03
Glare	77	1.78	1.32
Light uneven	77	4.13	0.91
Lighting satisfactory	77	1.95	1.46
Noise from ventilation	77	2.42	1.54
Other noise	77	3.57	1.92
Noise satisfactory	77	3.10	1.87

Environmental conditions: evaluation

Criterion	Past month μ	Past month σ	Now μ	Now σ	Conclusions
Thermal Comfort	-0.4	1.0	-0.4	0.7	Comfortable
Termperature	2.8	1.5	2.4	1.5	Comfortable
Termperature variations	4.2	1.1			Nice
IAQ acceptability	1.6	2.2	2.1	2.2	Unacceptable
Air movement	4.2	1.1	4.3	1.2	Nice
Air humidity	4.5	1.2	2.7	1.1	Nice
Air stuffiness	2.5	1.2	2.8	1.8	Acceptable
Air odor	3.4	1.7	1.9	1.2	Faint smell
Light brightness			3.9	0.6	Fine
Light flickering			1.5	1.0	Very stable
Glare			1.8	1.3	No glare
Light uneven			4.1	0.9	Nice
Lighting satisfactory	2.1	1.7	1.9	1.5	Excellent
Noise from ventilation			2.4	1.5	No noise
Other noise			3.6	1.9	No noise
Noise satisfactory	3.1	2.3	3.1	1.9	Good

Unacceptable IAQ now may result from from the absence of mechanical ventilation.

Health and direct environment

	Total/Nr	Nb yes	Percent
I have smoking neighbors	75	16	21%
I bring comments on my environment	71	26	37%
I had asthmatic problems	78	8	10%
I have suffered from eczema	78	19	24%
I have suffered with hay fever	77	15	19%
Do you smoke?	67	11	16%
Do you smoke in this room?	23	5	22%
Did you ever smoke?	64	10	16%

Estimation of occupant's influence on indoor conditions

μ is the average vote on a 1 (no influence, unsatisfactory) to 7 (total influence, satisfactory) scale. σ is the standard deviation of the votes within the population.

Influence on	μ	σ	Conclusions
-temperature	2.5	1.7	Weak influence
-ventilation	1.1	0.6	No influence
-lighting	4.9	2.0	Acceptable influence
Cleanliness	6.4	1.2	Very clean

Building symptom indices

Uncorrected	BSI's	Number	Past month Short list	Past month Full list	Today Short list	Today Full list
Women	All women	16	3.8	4.9	2.2	3.3
	Managers	2	4.0	4.5	2.5	5.0
	Specialists	4	2.8	4.3	2.5	3.5
	Clerical	10	3.7	5.2	2.0	2.3
	Others	0	0.0	0.0	0.0	0.0
Men	All men	60	2.7	3.7	1.8	2.2
	Managers	13	2.8	3.9	1.8	2.2
	Specialists	39	1.3	1.7	1.3	1.7
	Clerical	7	1.6	2.0	1.1	1.4
	Others	1	5.0	5.0	3.0	3.0

Global building symptom indices		Number	Value
Last month, short list	BSI fs	76	1.59
Last month, full list	BSI ff	76	2.12
Last month, short list, corrected	BSI fsc	76	2.89
Last month, full list, corrected	BSI ffc	76	4.23
Today, short list	BSI ss	76	1.34
Today, full list	BSI sf	76	1.74
Today, short list, corrected	BSI ssc	76	2.45
Today, full list, corrected	BSI sfc	76	3.17

Correction factors are based on female clerical.

Sensory measurements

Sensory evaluation	Offices μ	Offices σ	Supply air μ	Supply air σ	Adjacent 1 μ	Adjacent 1 σ	Adjacent 2 μ	Adjacent 2 σ
Perceived air quality								
Location 1	7.3	3.5	2.7	3.0				
Location 2	9.7	2.6	2.7	3.0				
Location 3	9.7	3.2	2.7	3.0				
Location 4	7.3	3.3	2.7	3.0				
Location 5	6.2	2.1	2.7	3.0				
(Location 6)					9.1	2.5	2.7	0.9
Average	8.0	2.9	2.7	3.0	9.1	2.5	2.7	0.9
Outdoor air	4.3	2.3						

General Indoor Air Quality Measurements

Chemical analysis of air	Offices		Supply	air	Adjacent	1	Adjacent	2
Carbon dioxide [ppm]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	890	30	895	30				
Location 2	960	30	895	30				
Location 3	760	30	895	30				
Location 4	775	30	895	30				
Location 5	780	30	895	30				
(Location 6)								
Average	833	30	895	30	800			
Outdoor air	420	30						
Carbon monoxide [ppm]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	<1		<1					
Location 2	<1							
Location 3	<1							
Location 4	<1							
Location 5	<1							
(Location 6)					<1			
Average	<1							
Outdoor air	<1							
Particulate matter [mg/m3]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	0.3	0.2						
Location 2	0.3	0.2						
Location 3	0.3	0.2						
Location 4	0.3	0.2						
Location 5	0.3	0.2						
(Location 6)					0.3	0.2		
Average	0.3	0.2			0.3	0.2		
Outdoor air								
TVOC[mg/m3] Toluene equiv	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	0.18	0.02	0.20	0.02				
Location 2	0.15	0.01						
Location 3	0.13	0.01						
Location 4	0.15	0.01						
Location 5	0.17	0.01						
(Location 6)					0.58	0.02		
Average	0.16	0.01	0.20	0.02	0.58	0.02		
Outdoor air								

The mechanical ventilation was inadvertently turned off during inspection in the morning of the audit day. The time profile shows considerable variation, with a morning low close to outside air concentrations, followed by a rise to about 800 ppm over 1 hour. The concentraion drops to 600 ppm over lunchtime and rises again rapidly in the afternoon, reaching a steadily

increasing pattern going from 800 ppm to 1000 ppm over ca.3 h. A small peak in the early afternoon could be due to the presence of the "sniffing" panel.
The entire set of data fits a normal or a lognormal distribution equally well (or bad). Rejecting the morning rise and the lunchbreak depression as being nonrepresentative of the usual conditions causes a more than 10 % rise in the average concentration.The resulting average of about 860±80 ppm slightly exceeds the 800 ppm (time-weighted average) upper comfort limit recommended by some organisms for control of body odors. The remaining values are however poorly represented in either a normal or a lognormal distribution, considering that the standard deviation still represents 9% of the average. This may partly be explained by the upward trend of ca. 100 ppm/h observed over the working periods.

Building CH-A Carbon dioxide cont. meas.	Average ppm	SD ppm	Geomean ppm	GSD	Median ppm	Max. ppm
All data points, location 4	773	140	760	05:02	782	1013
Reject 10:30-11:12 (morning rise) & 12:06-13:30 (lunch break)						
Selected data	862	77	859	1.09	843	1013

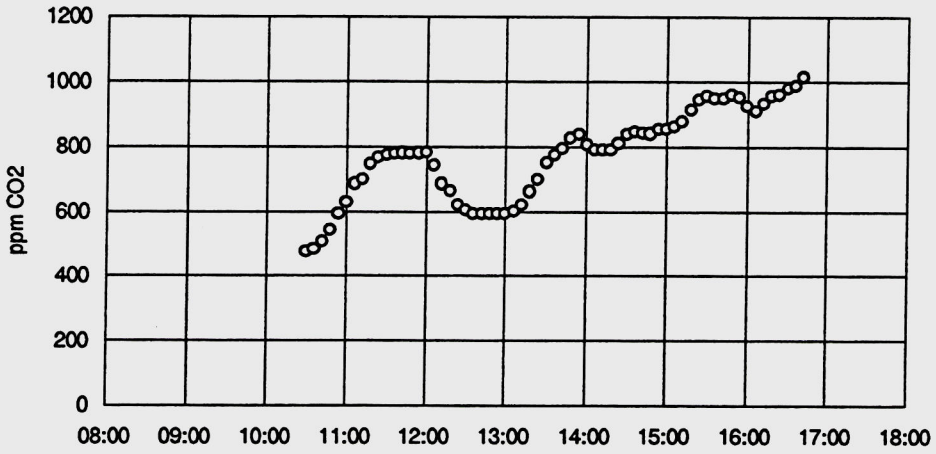


Figure A1: CO_2 concentration versus time. Morning coffee break and lunch time result in clear decrease of concentration. The CO_2 concentration increases during the day because the ventilation was off and the window were closed.

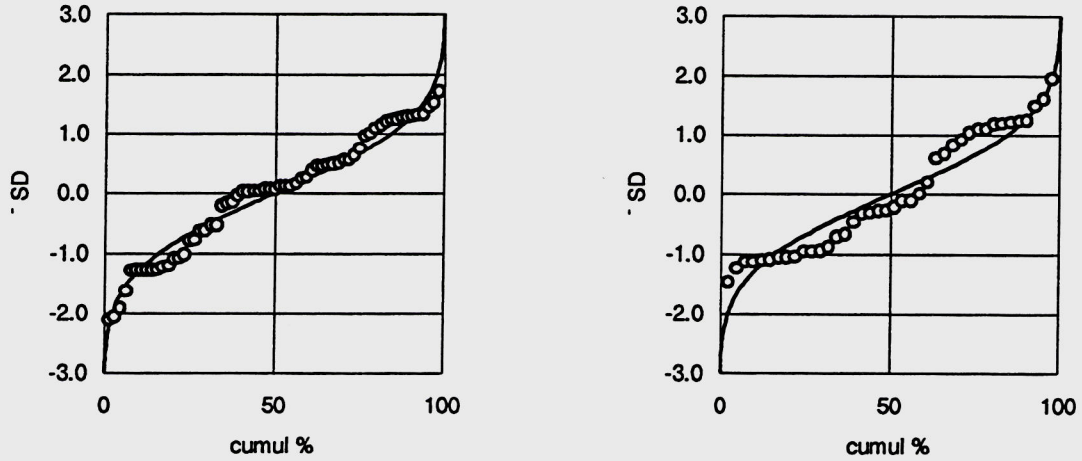


Figure A2: Cumulated frequencies of CO_2 concentrations. Left: all values. Right: selected values.

VOC: compound	Concentration [µg/m3]
ethanol	21
acetone	19
dichloro methane	16
toluene	14
m-xylene	9
acetic acid ?	6
C? alcohol	6
aliphatic C7H16	5
n-heptane	4
methyl-cyclohexane	4
trimethyl-benzene	4
benzaldehyde	4
2-methyl-pentane	3
C5H2O8 ester	3
?	3

General Indooor Climate Measurements

Continuous measurements	Location Nr.	4				
	Start time	Stop time	µ	σ	Min	Max.
Air temperature 0,1 m [°C]	11:00	17:00				
Air temperature 0,6 m [°C]	11:00	17:00				
Air temperature 1,1 m [°C]	11:00	17:00				
Operative temperature [°C]	11:00	17:00	22.9	0.1	22.6	23.2
Relative humidity [%]	11:00	17:00	36	2	33	40
Carbon dioxide [ppm]	11:00	17:00	775	138	474	1'013

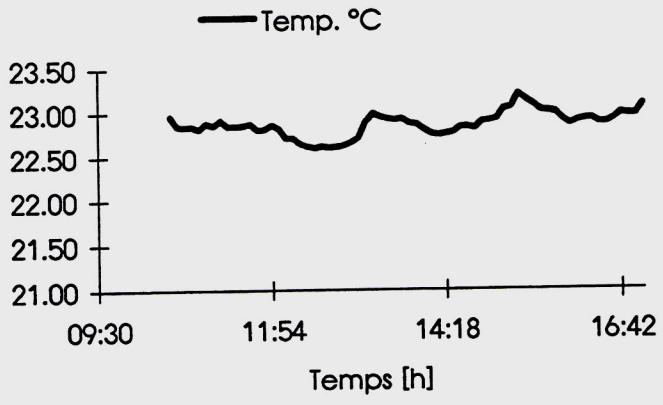


Figure A3: Indoor air temperature during the audit day.

Air velocity [m/s] at	0,1 m		0,6m		1,1m	
	μ	σ	μ	σ	μ	σ
Location 1						
Location 2	0.14					
Location 3	0.10		0.09		0.16	
Location 4	0.10		0.23			
Location 5						
(Location 6)						
Average	0.11		0.16		0.16	

Air temperatures at	0,1 m	0,6m	1,1m	Supply air
Location 1			23.0	
Location 2			22.3	
Location 3			22.0	
Location 4			22.9	
Location 5			21.5	
(Location 6)				
Average			22.3	
Outside air	11.5			

Mean radiant temperature	At 1,1 m	Calculated	Operative temperature Measured	Calculated
Location 1		21.6	22.3	
Location 2		19.7	21.0	
Location 3		19.8	21.0	
Location 4		18.6	20.7	
Location 5		19.5	20.5	
(Location 6)				
Average		19.8	21.1	

In our cases, mean radiant temperature was always calculated from air and operative temperatures.

Relative Humidity	1,1 m	Supply air	Adj. room
Location 1	33		
Location 2	33		
Location 3	34		
Location 4	36		
Location 5	35		
(Location 6)			
Average	34		
Outdoor air	65		

Noise [dB (A)]	Office	Adjacent
Location 1	44	
Location 2	48	
Location 3	47	
Location 4	47	
Location 5	48	
(Location 6)	40	
Average	46	
Outdoor noise		

Light	Lux ext	Lux int	DLF
Location 1	2400	1000	0.42
Location 2	1600	110	0.07
Location 3	1800	550	0.31
Location 4	2200	500	0.23
Location 5	2600	300	0.12
(Location 6)			
Average	2120	492	0.23

DLF= Day Light Factor

Ventilation measurements

Air flow rates in ventilation system [m³/h]	Planned	Measured	±
Total air flow rate into building	87'000	36'000	4'000
Fresh air flow rate into building	34'800	29'000	
Recirculated air flow rate	52'200	7'000	900
Recirculation rate	60%	19%	
Estimated air change rate [/h]	1.88		0.00
Estimated fresh air per person [l/(s·pers.)]	40		0

Mesure at location Nr	Total
Air flow rate from ventilation	0
uncertainty	0
Air flow rate from hall	500
uncertainty	200
Air flow rate from other space	0
uncertainty	0
Infiltration	200
uncertainty	100

Air flow rates in m³/h. Total is total air flow rate into monitored area.

Pollution load

Source intensity	Total	
Total olfactive load	16	Olf
incertitude	18	Olf
Olfactive office load	-10	Olf
uncertainty	60	Olf
Load from ventilation	0	Olf
uncertainty	0	Olf
Load from smokers	18	Olf
uncertainty	1	Olf
Load from occupants	18	Olf
uncertainty	1	Olf
Load from other sources	-40	Olf
uncertainty	60	Olf
Carbon dioxide	40	l/h
uncertainty	20	l/h
corresponding to	2	persons
uncertainty	1	persons
Number of working places	18	persons

Total is total pollution load in monitored zone.

Weather conditions on audit day

Weather station	Bern		
Date	9-12-93		
Description	Cloudy, windy		
Weather data	Average	Maximum	Minimum
Temperature 0600-1200	10.1	10.7	9.2
Temperature 1200-1800	9.3	10.8	8.1
Relative humidity 0600-1200	69	79	63
Relative humidity 1200-1800	62	68	58
Wind speed 0600-1200	9.3	10.0	7.6

Energy consumption

Annual energy use [MJ]	in 1992	1'991	1'990	1'989	Uncertainty
Extra light oil					
Heavy oil					
Diesel oil					
Gas for cars					
Natural gas					
Propane, butane					
Electricity	4'625'712	4'443'876	4'770'972	4'798'044	239'902
Anthracite, coke					
Coal bricks					
Lignite					
Dry wood					
Chopped wood 30 % moisture					
Dry chopped wood					
Dry wood, deciduous trees					
Dry pine wood					
District heat	9'394'236	8'960'710	7'548'599	7'848'202	392'410
Total	14'019'948	13'404'586	12'319'571	12'646'246	632'312
Energy index [MJ/m²]	1'900	1'800	1'700	1'700	100
Heating degree days	3'274	3'378	3'025	3'052	50
Power index [W/m²K]	7	6	7	7	6
Heating index	1'268	1'210	1'019	1'060	53
Electric index	625	600	644	648	32

Note that most digits, resulting from transformation of liters, kg, kWh, etc into MJ, are not significant.
The energy index of that building is very high. A retrofit of this building was planned to start immediately after the audit.

BUILDING B

General information

1. Building identification.	B		
3. Situation	Downtown.	7. Number of floors	6
4. Traffic within 200 m.	Busy through road.	area of each floor (m2)	3'546
		number of offices	19
5. Near sources of pollution	Parking garage.	number of employees	750
	Industry.	8. Year of building completion	1'980
	0	Year of total renovation	1'980
6. Activities besides office work	Only office work.	Year when present user entered	1'980
9. No. of floors beneath ground	1	10. Position of solar shadings	Inside.
Roof tilt angle	Flat roof	Solar shadings: movement	Individual.
11. Number of glazing	Double pane.	12. Modification of?	
Glazing type	Light absorbing.	Flooring	None
13. Furniture made of	Metal.	Insulation	None
Age of furniture	More than three years.	Wall or ceiling lining	None
14. Large green plants	Green leafed plants.	Windows	None
Plants treatment	0	Heating system	None
		Ventilation system	None
15. Smoking	Allowed in separate rooms.	16. Office activities and machines	
		solvents	No solvents
		other chemicals	None
17. Cleaning frequency		copying machines	Yes.
Tables	2-4 times a week.	laser printers	Yes.
Walls	Less than once a month.	person per VDU	1-2.
Washing floors	Once a week.	carbonless paper use	No.
Vacuum cleaning	1 to 3 times a month.		
Mopping	0		
Sweeping	0		
Waxing	0		
Spring cleaning	Less than once a year.		
Time since last spring cleaning			
Look of the floors	Clean floors.		

18. Detergent for cleaning	type/name	content	
cleaning agent linoleum	Wetrok-Karpfom	aromatic substance, not mineral water, propan,	Does not leave a film.
cleaning agent carpet	Wetrok-Safe	natursoap, not mineral water, slipping protection	Does not leave a film.
cleaning agent tables	Wetrok-Brilant	high alcohol, glycol, odors,colour, water	Does not leave a film.
cleaning agent sanitary	Wetroc-Reocid 2000	Alcoholhoxilate, citron, alcohol, colour, water, inibitor of calcareous	Does not leave a film.

Installation

1. Installation identification			
2. Room heating Location of heating	Hot water heating. Radiators.	3. Room cooling	Supply of cooled air.
4. Temperature control Night set back	Adjustable wall thermostat. 0	5.Ventilation of rooms Windows	Dual ducts balanced system. Windows cannot be opened.
6. Design outdoor air change Lowest outdoor air supply	1 to 3 per hour. 25 l/s·pers	7. Position air intake height above ground distance from exhaust distance from cooling towers	Close to the ground. 1 vert. 24 hor. 70 vert. 24 hor. 0
8. Equipment vent. system Recirculation [%] Humidification system Water purification Cooling type Heat recovery	 33 Spray. UV lamp. Mixing boxes Plate exchanger.		
9. Ventilation system on/off Sensors for demand control	Automatically by a clock. No such control.		
Operating at:	From	to	days per week
full performance reduced performance stopped	05:00 18:00	18:00 05:00	5 5
100% recirculation			
Partial recirculation			
10. Duct material Duct insulation	Galvanised steel. External insulation.		
11. Service Air intake filter Recirculation duct filter Central unit filter Supply filter Induction / fan coil filter	Class EU3 EU8	Last replacement 11-03-93 26-03-92	Needing service No. 0 No.
 Heating batteries Cooling batteries Heat exchanger Humidifier Ducts Air outlets in rooms Air inlet in rooms	Last cleaning 1-10-93 1-10-93 1-10-93 1-11-93	Needing service No. No. No. No. No. Yes. No.	
12. Location air supply inlets Location air outlets Designed ventilation principle	In the ceiling. High. Mixing ventilation.		

Investigated rooms

These are two large zones, furnished the same manner, separated by a hall. Bentax zone is equipped with Bentax ionisers in the air handling unit, while normal zone is not.

Summary Room name	1 Bentax N	2 Bentax C	3 Normal S	4 Normal C	5 Normal N	6 Hall
Wall materials inside insulation	Other.					
Insulation material	Mineral wool.					
Thickness of insulation [cm]	4					
Felt carpet (needle) [%area]	100					100
Nap carpet [%area]						
Lacquered wood [%area]						
Vinyl (PVC) [%area]						
Linoleum [%area]						
Tiles [%area]						
Other (type here) [%area]						
Wall covering / treatments	Unpainted textiles.					Enamel paint.
Ceiling material (inside surface)	Acoustic panes.					Acoustic panes.
Space above acoustic tiles [cm]	70					70
Dust above acoustic panes?	Yes.					Yes.
Acoustic baffles below ceiling?	No.					No.
Any other ceiling type?						
Room lighting	Artificial and Daylight.					Artificial and Daylight.
Lighting location	Ceiling.					Ceiling.
Type of artificial lighting	Fluorescent.					Fluorescent.
Control of lighting	Automatic with manual end control.					Manual.
Visible mould growth	No.					No.
Damp spots	No damp spots.					None
Mould odor in room	No.					No.
Area [m²]	630	627	880	875	1164	200
Height [m]	3	3	3	3	3	3
Nb of work places	49	22	54	55	76	0
Fleecy material [m²]	214	201.6	135	140	237.6	0
Shelf length [m]	300	225	440	430	763	0
Window area [m²]	98	84	75.6	70	143	0
Office depth [m]	20	20	20	20	12	0
Nb. of laser printers	12	7	14	14	17	0
Nb. of photocopiers	1	1	2	1	2	0
Nb. of VDUs	56	29	50	51	86	0
Acceptable access for cleaning?	Yes	Yes	Yes	Yes	Yes	Yes
Door to corridor open?	Open	Open	Open	Open	Open	
VDUs with reflection	16	8	3	3	16	0
Nb of VDU with glare	6	7	5	5	25	0

Questionnaire

General	Total/Nr	Mean	Stdev	Percentage
Questionnaires distributed	150			
Questionnaires returned	141			94%
Age	141	38.04	9.86	
Number of female occupants	84			60%
Number of male occupants	57			40%
Time at desk before filling questionnaire	141	2.95	1.55	
Managerial work	23			16%
Specialist skill	25			18%
Clerical	68			49%
Other	24			17%
Time spent in the building [years]	140	5.42	3.80	
Time spent in the room [years]	137	2.97	2.06	
Hours per day at the desk	141	7.52	2.12	
Paid hours per week	139	41.27	4.38	
Hours at VDU per week	139	26.47	11.71	
Days per month in the building	126	19.79	2.43	
Number of people in the room	131	66.02	37.61	
Rooms without windows	13			9%
Rooms with windows	128			91%
Distance from the window	124	5.86	6.45	
People opening the window	0			0%
People not opening the window	125			100%

The number of people in the room does not have the same meaning in large open offices than in cells offices.

Health

Health during past month		Symptom present for			Better away	
	Answers	1-5 Days	6-10 Days	>10 days	yes	no
Dry eyes	141	55	18	22	87	7
Watering eyes	140	25	4	5	33	1
Stuffy nose	141	41	25	35	70	29
Runny nose	139	46	10	4	30	32
Dry throat	141	45	19	28	73	18
Chest tightness	141	19	14	9	34	9
Flu-like symptoms	141	60	23	13	55	38
Dry skin	141	12	12	35	43	14
Rash or irritated skin	140	19	6	11	18	19
Headaches	141	68	14	10	66	21
Lethargy	141	63	20	31	87	18
Other symptoms	117	11	12	7	31	4
Season when worst		Spring	Summer	Autumn	Winter	Any
(numbers of answers)	131	3	2	1	47	78
Part of the day when worst		Morning	Afternoon	Evening	Any	
(numbers of answers)	130	13	37	21	59	

Health now	Symptom present		In building			Severity	
	Total/Nr	Nb of yes	Better	Same	Worst	Mean	Stdev
Dry eyes	141	44	0	15	29	3.64	1.38
Watering eyes	141	7	0	2	5	3.00	0.25
Stuffy nose	141	68	0	31	29	3.45	0.52
Runny nose	140	13	1	6	4	2.92	1.60
Dry throat	141	64	1	28	31	3.76	0.50
Chest tightness	140	24	0	8	11	3.48	0.50
Flu-like symptoms	141	47	0	33	12	3.02	1.55
Dry skin	140	50	1	31	15	3.43	0.32
Rash or irritated skin	140	21	0	14	6	3.57	0.67
Headaches	141	30	0	7	22	3.32	1.25
Lethargy	141	52	1	21	28	3.62	0.50
Other symptoms	122	15	1	4	8	4.00	0.55

Frequency of building related symptoms

Only symptoms which disappear out of building are taken into account in this table. For each symptom, the frequency is the ratio of the number of person presenting the symptom to the total number of answers..

Symptom	Last month	Now
Dry eyes	62%	31%
Watering eyes	24%	5%
Stuffy nose	51%	45%
Runny nose	21%	7%
Dry throat	53%	43%
Chest tightness	24%	14%
Flu-like symptoms	40%	32%
Dry skin	31%	34%
Rash or irritated skin	13%	14%
Headaches	49%	21%
Lethargy	66%	35%
Other symptoms	25%	10%

The symptoms related to air dryness are surprising, since relative air humidity is more than 40%.

Environmental conditions

Environmental conditions past month	Total/Nr	Mean	Stdev
Level of thermal comfort	136	0.20	1.18
Indoor air acceptability	140	0.53	2.28
Comfort temperature	139	3.31	1.60
Temperature variation	134	4.33	1.35
Air movement	139	4.41	1.54
Air humidity	138	2.59	1.20
Air stuffiness	139	4.65	1.64
Air odor	139	3.55	1.76
Lighting	140	3.32	2.00
Noise	140	3.88	1.98

Level of thermal comfort are on a -3 to+3 scale, Indoor air acceptability is on a -5 to+5 scale, while other votes are on a 1 to 7 scale.

Environmental conditions now	Total/Nr	Mean	Stdev
Level of thermal comfort	140	0.06	1.08
Indoor air acceptability	140	1.19	2.32
Comfort temperature	139	3.15	1.67
Air movement	139	4.25	1.40
Air humidity	139	2.93	1.26
Air stuffiness	139	3.96	1.68
Air odor	137	2.91	1.67
Light brightness	138	3.72	0.93
Light flickering	134	1.96	1.38
Glare	134	2.48	1.81
Light uneven	133	4.12	1.10
Lighting satisfactory	138	2.70	1.80
Noise from ventilation	140	3.77	1.89
Other noise	137	3.92	1.79
Noise satisfactory	139	3.55	1.81

Environmental conditions: evaluation

Criterion	Past month μ	Past month σ	Now μ	Now σ	Conclusions
Thermal Comfort	0.2	1.2	0.1	1.1	Comfortable
Termperature	3.3	1.6	3.2	1.7	Comfortable
Termperature variations	4.3	1.3			Nice
IAQ accaptability	0.5	2.3	1.2	2.3	Unacceptable
Air movement	4.3	1.3	4.3	1.4	Nice
Air humidity	4.4	1.5	2.9	1.3	Nice
Air stuffiness	2.6	1.2	4.0	1.7	Acceptable
Air odor	4.6	1.6	2.9	1.7	Smelly
Light brightness			3.7	0.9	Fine
Light flickering			2.0	1.4	Very stable
Glare			2.5	1.8	Faint glare
Light uneven			4.1	1.1	Nice
Lighting satisfactory	3.3	2.0	2.7	1.8	Good
Noise from ventilation			3.8	1.9	No noise
Other noise			3.9	1.8	No noise
Noise satisfactory	3.9	2.0	3.5	1.8	Acceptable

The indoor air quality is not well judged by occupants. Other parameters are OK.

Health and direct environment

	Total/Nr	Nb yes	Percent
I have smoking neighbors	140	113	81%
I bring comments on my environment	135	43	32%
I had asthmatic problems	141	8	6%
I have suffered from eczema	141	41	29%
I have suffered with hay fever	141	38	27%
Do you smoke?	132	55	42%
Do you smoke in this room?	78	48	62%
Did you ever smoke?	86	24	28%

Percentage of smokers is higher than the national average. Many non smokers complained about smoking neighbors.

Estimation of occupant's influence on indoor conditions

μ is the average vote on a 1 (no influence, unsatisfactory) to 7 (total influence, satisfactory) scale. σ is the standard deviation of the votes within the population.

Influence on	μ	σ	Conclusions
-temperature	1.3	1.0	No influence
-ventilation	1.4	1.0	No influence
-lighting	2.0	1.4	No influence
Cleanliness	4.6	2.1	Clean

Many occupants complain about the lack of influence on their environment.

Building symptom indices

Uncorrected BSI's			Past month		Today	
		Number	Short list	Full list	Short list	Full list
Women	All women	57	3.5	5.2	2.3	3.2
	Managers	6	3.7	5.5	2.5	3.3
	Specialists	4	2.5	2.5	1.3	2.5
	Clerical	37	3.6	5.4	2.6	3.5
	Others	10	2.9	4.2	1.3	2.0
Men	All men	83	2.9	3.8	1.8	2.4
	Managers	17	2.8	3.7	1.5	1.9
	Specialists	21	2.5	3.1	1.9	2.5
	Clerical	31	3.1	4.2	2.3	3.0
	Others	14	2.5	3.4	1.6	2.2

Building symptom index is fairly high in this building.

Global building symptom indices		Number	Value
Last month, short list	BSI fs	140	3.03
Last month, full list	BSI ff	140	4.21
Last month, short list, corrected	BSI fsc	140	4.79
Last month, full list, corrected	BSI ffc	140	7.07
Today, short list	BSI ss	140	2.05
Today, full list	BSI sf	140	2.77
Today, short list, corrected	BSI ssc	140	3.21
Today, full list, corrected	BSI sfc	140	4.42

Correction factors are based on female clerical.

Sensory measurements

Sensory evaluation	Offices		Supply air		Adjacent 1		Adjacent 2	
Perceived air quality	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	4.8	1.3	3.6	1.3				
Location 2	6.1	1.7	3.6	1.3				
Location 3	6.5	2.1	3.6	1.3				
Location 4	6.7	1.6	3.6	1.3				
Location 5	6.6	2.2	3.6	1.3				
(Location 6)					9.4	3.4		
Average	6.1	1.8	3.6	1.3	9.4	3.4		
Outdoor air	2.1	2.1						

General Indoor Air Quality Measurements

Chemical analysis of air	Offices		Supply	air	Adjacent	1	Adjacent	2
Carbon dioxide [ppm]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	570	30	440	30				
Location 2	620	30	440	30				
Location 3	630	30	440	30				
Location 4	670	30	440	30				
Location 5	620	30	440	30				
(Location 6)					620	30		
Average	622	30	440	30	620	30		
Outdoor air	375	10						
Carbon monoxide [ppm]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	<1		<1					
Location 2	<1		<1					
Location 3	<1		<1					
Location 4	<1		<1					
Location 5	<1		<1					
(Location 6)	<1		<1					
Average								
Outdoor air	<1							
Particulate matter [mg/m3]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	0	0.01						
Location 2	0.35	0.01						
Location 3	0	0.01						
Location 4	0	0.01						
Location 5	0.9	0.01						
(Location 6)								
Average	0.25	0.01						
Outdoor air	0	0.01						
TVOC[mg/m3] Toluene equiv	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	0.19	0.01						
Location 2	0.23	0.02	0.18	0.02				
Location 3	0.16	0.01						
Location 4	0.16	0.02	0.15	0.02				
Location 5	0.23	0.01						
(Location 6)								
Average	0.19	0.01	0.16	0.02				
Outdoor air	0.06	0.01						

CO_2 level is low, and CO, dust and VOC levels are negligible.

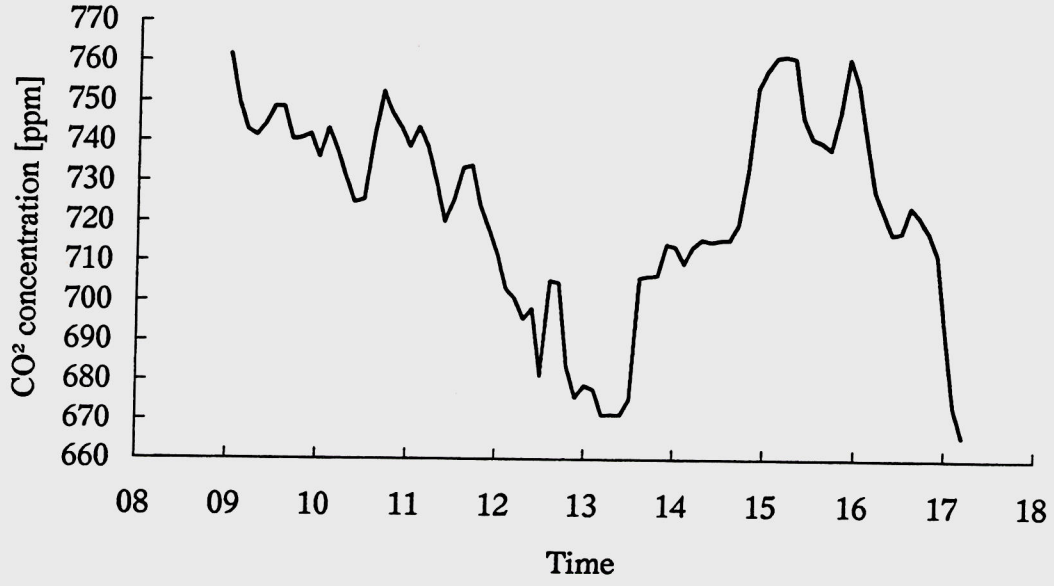


Figure 1: CO2 concentration at location 2.

Building CH-B Carbon dioxide cont. meas.	Average ppm	SD ppm	Geomean ppm	GSD	Median ppm	Max. ppm
Location 2 (full dots)	724	24	724	1.03	725	762
Location 4 (open circles)	649	19	649	1.03	652	690

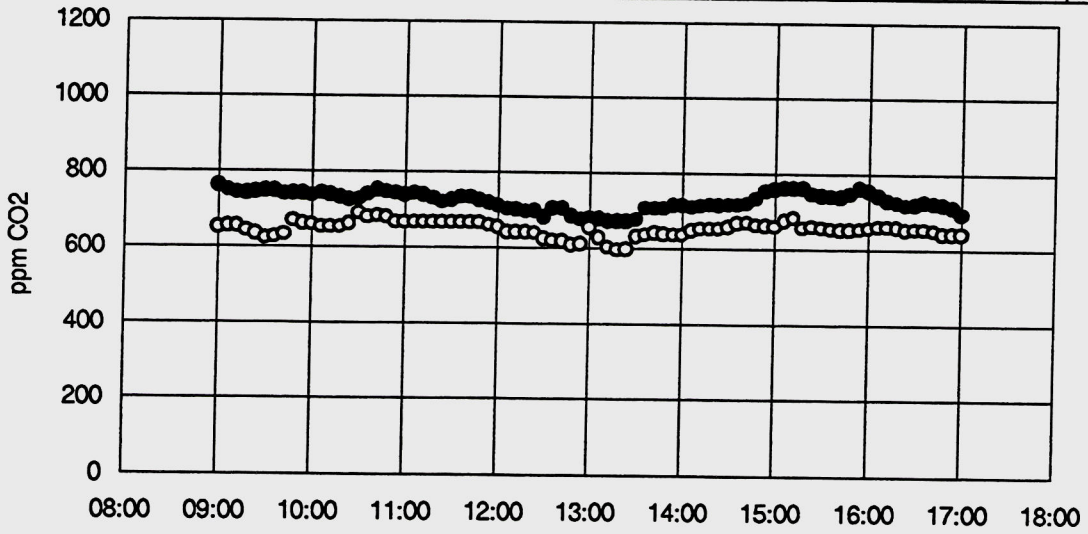


Figure B1: CO_2 concentration versus time. Dots for location 2 and circles for location 4.

Two locations were monitored (cf. building description, chap. 2.2.1), resulting in two very similar steady time profiles, possibly with a very slight downward trend over the day. The averages in both locations differ by about 80 ppm and are both well above the outdoors concentraion. The relative standard deviation is very low at both locations (3%), yet the data fit a normal distribution quite well. The observed pattern reflects a steady state produced by a strongly balanced source and ventilation system.

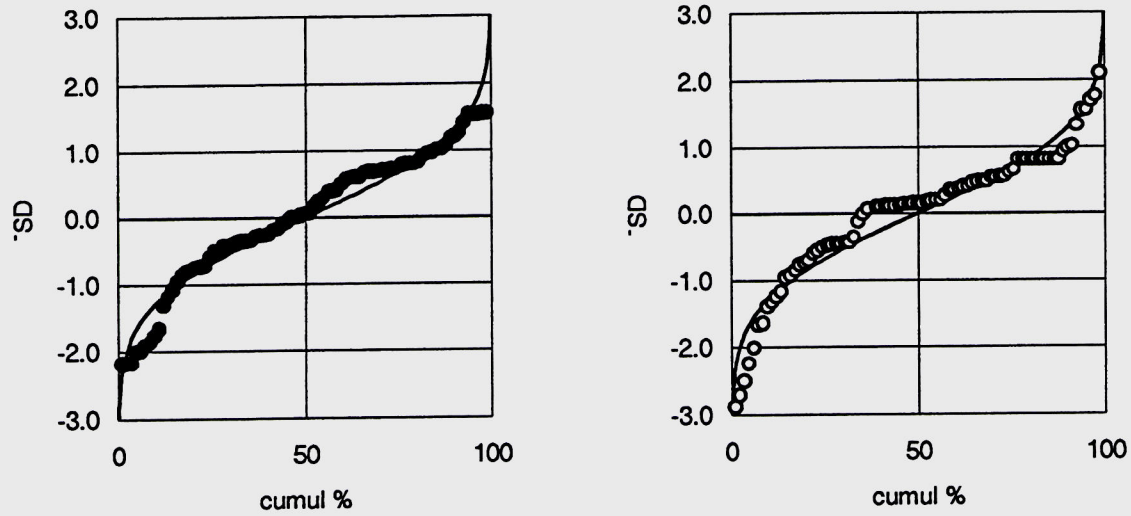


Figure B2: Cumulated frequencies of CO_2 concentrations. Left: all values. Right: selected values.

VOC: compound	Concentration [µg/m3]
toluene	14
dodecanoic acid ?	11
L-Limonene	8
acetone	8
C5H2O8 ester	6
m-xylene	5
aliphatic C7H16	5
2-meth-1,3-butadiene	5
1,1,1-trichlorethane	4
benzaldehyde	4
benzoic acid ?	4
?	3
trimethyl-benzene	3
dichloro methane	3
?	3

General Indooor Climate measurements

Continuous measurements	Location Nr.	5				
	Start time	Stop time	µ	σ	Min	Max.
Air temperature 0,1 m [°C]	09:00	17:12	21.6	0.2	21.2	21.9
Air temperature 0,6 m [°C]	09:00	17:12	22.0	0.2	21.6	22.3
Air temperature 1,1 m [°C]	09:00	17:12	22.6	0.2	22.2	23.0
Operative temperature [°C]	09:00	17:12	21.8	0.1	21.4	22.1
Relative humidity [%]	09:00	17:12	44	0	43	45
Carbon dioxide [ppm]	09:00	17:12	723	25	666	762

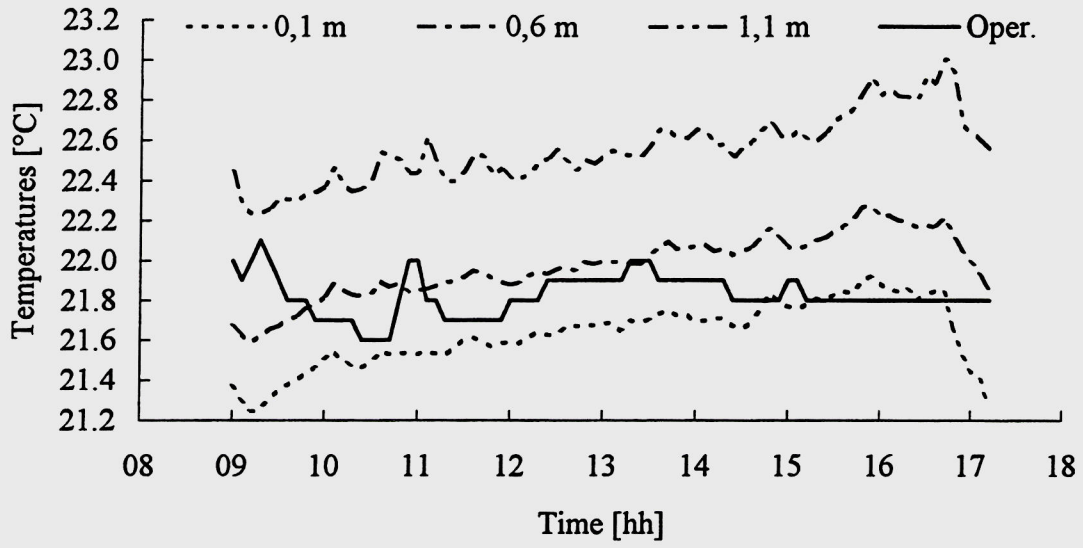


Figure 2: Temperatures versus time at location 2. Note a gradient of 1 K/m between head and ankles.

Air velocity [m/s] at	0,1 m		0,6m		1,1m	
	μ	σ	μ	σ	μ	σ
Location 1	0.21	0.02	0.13	0.02	0.12	0.02
Location 2	0.11	0.02	0.16	0.02	0.14	0.02
Location 3	0.14	0.02	0.16	0.02	0.15	0.02
Location 4	0.16	0.02	0.17	0.02	0.11	0.02
Location 5	0.22	0.02	0.10	0.02	0.16	0.02
(Location 6)						
Average	0.17	0.02	0.14	0.02	0.14	0.02

Air temperatures at	0,1 m	0,6m	1,1m	Supply air
Location 1			22.9	
Location 2			22.9	
Location 3			22.9	
Location 4			23.0	
Location 5			23.0	
(Location 6)			23.0	
Average			23.0	
Outside air				

Mean radiant temperature	At 1,1 m	Calculated	Operative temperature Measured	Calculated
Location 1		20.6	21.8	
Location 2		20.1	21.6	
Location 3		19.9	21.5	
Location 4		19.0	21.1	
Location 5		20.2	21.7	
(Location 6)				
Average		19.9	21.5	

In our cases, mean radiant temperature was always calculated from air and operative temperatures.

Relative Humidity	1,1 m	Supply air	Adj. room
Location 1	46		
Location 2	47		
Location 3	51		
Location 4	52		
Location 5	51		
(Location 6)	52		
Average	50		
Outdoor air	72		

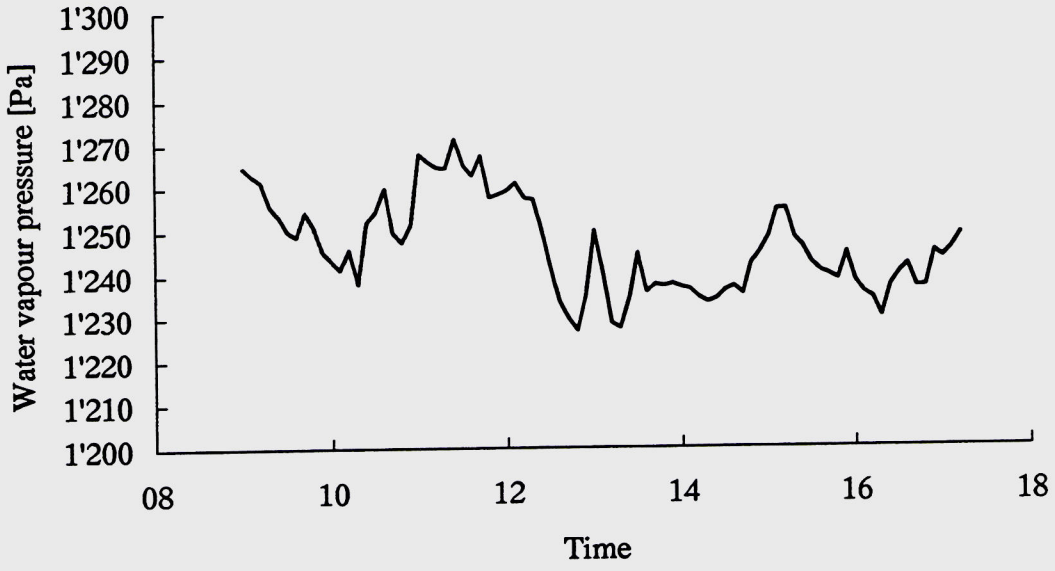


Figure 3: Water vapour pressure versus time at location 2.

Noise [dB (A)]	Office	Adjacent
Location 1	48	
Location 2	42	
Location 3	42	
Location 4	45	
Location 5	47	
(Location 6)		
Average	45	
Outdoor noise	53	

Light	Lux	DLF
Location 1	400	
Location 2	420	
Location 3	400	
Location 4	380	
Location 5	420	
(Location 6)		
Average	404	

DLF= Day Light Factor

Ventilation measurements

Air flow rates in ventilation system [m³/h]	Planned	Measured	±	
Total air flow rate into building	109'500	82'500	28'500	m³/h
Fresh air flow rate into building	36'500	36'000	31'000	
Exhaust from building	98'500	58'500	3'500	
Extracted to outdoor	26'000	11'500	8'000	
Recirculated air flow rate	73'000	46'500	7'000	m³/h
Recirculation rate	0.7	0.6	0.2	
Estimated air change rate	0.7	0.7		/h
Estimated fresh air per person	13.5	13.3		l/s·person

Air flow rates measured with tracer gas are large enough, but slightly smaller than planned and than measured with velocity traverses using Pitot tubes.

Mesure at location Nr	Bentax	Normal	Total
Air flow rate from ventilation	6'300	16'000	22'000
uncertainty	600	2'000	2'000
Air flow rate from hall	0	0	0
uncertainty	0	0	0
Air flow rate from other space	0	0	0
uncertainty	0	0	0
Infiltration	0	0	0
uncertainty	1	0	2

Air flow rates in m^3/h. Total is total air flow rate into monitored area.

Pollution load

Source intensity	Bentax	Normal	Total	
Olfactive total load	306	894	1'200	Olf
uncertainty	148	384	533	Olf
Olfactive load	400	1'400	1'800	Olf
uncertainty	200	600	900	Olf
Load from ventilation	-100	-500	-600	Olf
uncertainty	200	500	700	Olf
Load from smokers	60	140	640	Olf
uncertainty	20	70	100	Olf
Load from occupants	22	60	260	Olf
uncertainty	10	30	40	Olf
Load from other sources	400	1'200	900	Olf
uncertainty	200	600	900	Olf
Carbon dioxide	1'100	3'700	4'800	l/h
uncertainty	200	500	700	l/h
corresponding to	63	210	270	persons
uncertainty	10	30	40	persons
Number of working places	22	55	256	persons

Total is total pollution load in monitored zone.
Load from ventilation looks negative. In fact, it is not significantly different from zero.

Weather conditions on audit day

Weather station	Zürich SMA		
Date	25-01-94		
Description	Overcast		
Weather data	Average	Maximum	Minimum
Temperature 0600-1200	7.1	7.8	6.6
Temperature 1200-1800	8.3	8.5	8.1
Relative humidity 0600-1200	92	95	89
Relative humidity 1200-1800	89	90	87
Wind speed 0600-1200	2.3	4.0	1.0

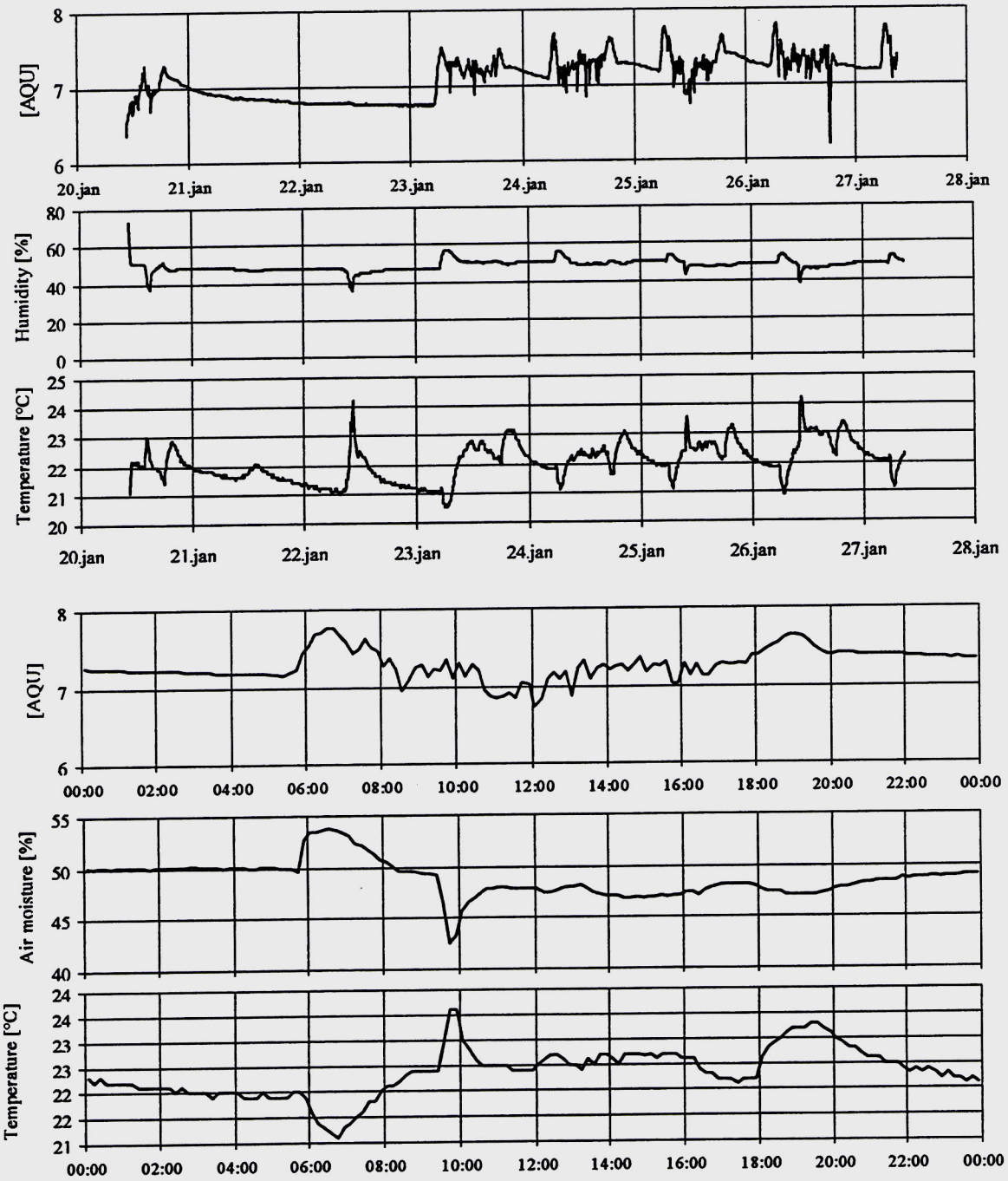
Energy consumption

Annual energy use [MJ]	in 1992	1'991	1'990	1'989	Uncertainty
Extra light oil	6'769'000	6'926'000	6'403'000		128'060
Heavy oil					
Diesel oil					
Gas for cars					
Natural gas					
Propane, butane					
Electricity	12'034'836	12'111'264	11'991'168		239'823
Anthracite, coke					
Coal bricks					
Lignite					
Dry wood					
Chopped wood 30 % moisture					
Dry chopped wood					
Dry wood, deciduous trees					
Dry pine wood					
District heat					
Total	18'803'836	19'037'264	18'394'168		367'883
Energy index [MJ/m²]	880	890	860		0
Heating degree days					
Power index [W/m²K]					
Heating index	314	321	296		0
Electric index	566	569	564		0

Note that most digits, resulting from transformation of liters, kg, kWh, etc into MJ, are not significant.
Energy index is within the national Swiss average, but electricity consumption is especially high.

IAQ Stäfa measurements

IAQ Stäfa	Day 8:00-18:00				Night 20:00-06:00			
	Mean	Stdev.	Mini	Maxi	Mean	Stdev.	Mini	Maxi
Location a	7.15	0.16	6.74	7.38	7.30	0.07	7.21	7.47
Location b	6.95	0.22	6.47	7.37	6.97	0.04	6.91	7.03
Location c	7.15	0.21	6.61	7.48	6.76	0.08	6.68	7.17
average	7.08	0.19	6.61	7.41	7.01	0.06	6.93	7.22



It can be seen that the audit day does not show any special event in temperature, air moisture or IAQ as measured by multigas sensor. Ventilation is on from 06:00 to 19:00

Ions and Radon:

Ions	Time		+ ions			- ions		
office	begin	end	Mean	Max.	Min	Mean	Max.	Min
Location 1	15:48	16:47	254	383	100	180	286	0
Location 2	14:41	15:46	276	741	101	176	330	28
Location 3	12:25	14:34	237	743	100	310	478	191
Location 4	10:00	11:27	189	353	0	244	538	123
Location 5 (Location 6)	16:52	17:50	207	463	30	222	485	80
Average			233	537	66	226	423	84
Outdoor								

Locations 1 and 2 are equipped with Bentax ionisers in the air handling unit. These locations present however less negative ions than the normal zone, while the difference in positive ions is not significant.

Radon	Bq/m3
Location 1	<15
Location 2	<15
Location 4	<15
inlet	<15
outlet	<15

BUILDING C

General information

1. Building identification.	C		
3. Situation	Downtown.	7. Number of floors	5
4. Traffic within 200 m.	Busy through road.	area of each floor (m2)	7'688
		number of offices	10
5. Near sources of pollution	Parking garage.	number of employees	1'200
	0	8. Year of building completion	1'990
6. Activities besides office work	Only office work.	Year of total renovation	1'990
9. No. of floors beneath ground	0	Year when user entered	1'990
Roof tilt angle	Flat roof	10. Position of solar shadings	Inside.
		Solar shadings: movement	Automatically controled.
11. Number of glazing	Triple pane.	12. Modification of?	
Glazing type	Clear.	Flooring	None
13. Furniture made of	Veneered chip board.	Insulation	None
Age of furniture	3 years or less.	Wall or ceiling lining	None
14. Large green plants	Green leafed plants.	Windows	None
Plants treatment	No treatement.	Heating system	None
		Ventilation system	None
15. Smoking	Not allowed.	16. Office activities	
		solvents	No solvents
		other chemicals	None
17. Cleaning frequency		copying machines	Yes.
Tables	Daily.	laser printers	Yes.
Walls	Less than once a month.	person per VDU	1-2
Washing floors	Daily.	carbonless paper use	No.
Vacuum cleaning	Daily.		
Mopping	0		
Sweeping	0		
Waxing	0		
Spring cleaning	Less than once a year.		
Look of the floors	Clean		

18. Detergent for cleaning	type/name	content	pH
cleaning agent linoleum	Taski Nof	1-5% Alkohol, 1-5% glycol, >10% lemon,<1% preservative,	Does not leave a film.
cleaning agent carpet	Enzler 1221	5-15% ethoxylate (FAO), <1% NTA, 1-5% phosphat	Does not leave a film.
cleaning agent tables	Clinex Superactiv Steinfels	<5% oilsoaps, <5%Na-Alkalbenzolsulphat, <5% phosphat, <1% preservative,< 1% parfum, <1% Dyestuff	Polish or wax.
cleaning agent sanitary	Johnson Wax 161730	5-30% acideamidosulphuric, <1%aromatic substance, >30% water	Does not leave a film.

Installation

1. Installation identification			
2. Room heating Location of heating	Air heating.	3. Room cooling	Supply of cooled air.
4. Temperature control Night set back	Adjustable thermostat on radiator or unit. Yes.	5.Ventilation of rooms Windows	Balanced VAV system. Windows cannot be opened.
6. Design outdoor air change Lowest outdoor air supply	More than 3 per hour.	7. Position air intake height above ground distance from exhaust distance from cooling towers	On the roof. 20 vert. 0 hor. 10 vert. 5 hor. 0
8. Equipment vent. system Recirculation [%] Humidification system Water purification Cooling type Heat recovery	 0 Spray. Biocides. Heat exchanger Rotating wheel.		
9. Ventilation system on/off Sensors for demand control	Automatically by a clock. 0		

Operating at:	From	to	days per week
full performance	06:00	17:30	5
reduced performance			
stopped	17:30	06:00	5
100% recirculation	06:00	06:10	5
Partial recirculation			%return air

10. Duct material Duct insulation	Galvanised steel. External insulation.		
11. Service	Class	Last replacement	Needing service
Air intake filter			0
Recirculation duct filter	Eu6	1-01-93	No.
Central unit filter	Eu6	1-01-93	No.
Supply filter			
Induction / fan coil filter			

	Last cleaning	Needing service	
Heating batteries	1-10-93	No.	
Cooling batteries	1-10-93	No.	
Heat exchanger	1-10-93	No.	
Humidifier	1-11-93	No.	
Ducts		0	
Air outlets in rooms		0	
Air inlet in rooms		0	
12. Location air supply inlets	In the ceiling.		
Location air outlets	High.		
Designed ventilation principle	Mixing ventilation.		

Investigated rooms

The investigated locations were all in an open office room adjacent to an atrium.

Summary Room name	Open office	Atrium
Wall materials inside insulation	Concrete.	Concrete.
Insulation material	Fiberglas.	No specific insulation.
Thickness of insulation [cm]	10	
Felt carpet (needle) [%area]	100	
Nap carpet [%area]		
Lacquered wood [%area]		
Vinyl (PVC) [%area]		
Linoleum [%area]		
Tiles [%area]		100
Other (type here) [%area]		
Wall covering / treatments	Dispersion paint.	Dispersion paint.
Ceiling material (inside surface)	Acoustic panes.	
Space above acoustic tiles [cm]	70	
Dust above acoustic panes?	No.	
Acoustic baffles below ceiling?	No.	
Any other ceiling type?		
Room lighting	Artificial and Daylight.	Artificial and Daylight.
Lighting location	Ceiling.	Ceiling.
Type of artificial lighting	Fluorescent.	Halogen lamps.
Control of lighting	Automatic with manual end control.	Automatic.
Visible mould growth in rooms	No.	No.
Damp spots	No damp spots.	No damp spots.
Mould odor in room	No.	No.
Area [m²]	1680	800
Height [m]	2.8	19
Nb of work places	99	0
Fleecy material [m²]	60	0
Shelf length [m]	86	0
Window area [m²]	180.32	1139.8
Office depth [m]	10	
Nb. of laser printers	3	0
Nb. of photocopiers	4	0
Nb. of VDUs	112	0
Acceptable access for cleaning?	Yes	Yes
Door to corridor open?	Closed	
Nb. of VDU with reflection	5	0
Nb of VDU with glare	17	0

Questionnaire

General	Total/Nr	Mean	Stdev	Percentage
Questionnaires distributed	120			
Questionnaires returned	108			90%
Age	108	35.91	12.61	
Number of female occupants	48			46%
Number of male occupants	57			54%
Time at desk before filling questionnaire	106	3.67	1.45	
Managerial work	14			13%
Specialist skill	1			1%
Clerical	75			72%
Other	14			13%
Time spent in the building [years]	104	2.75	2.55	
Time spent in the room [years]	98	2.26	1.02	
Hours per day at the desk	106	8.17	3.58	
Paid hours per week	99	40.07	11.81	
Hours at VDU per week	100	23.70	14.59	
Days per month in the building	78	15.74	8.21	
Number of people in the room	100	44.19	20.51	
Rooms without windows	3			3%
Rooms with windows	105			97%
Distance from the window	102	4.30	3.62	
People opening the window	0			0%
People not opening the window	105			100%

Health

Health during past month		Symptom present for			Better away	
	Answers	1-5 Days	6-10 Days	>10 days	yes	no
Dry eyes	107	33	23	18	62	9
Watering eyes	104	23	7	8	32	8
Stuffy nose	108	30	15	33	49	18
Runny nose	104	30	9	15	34	19
Dry throat	106	34	15	27	59	14
Chest tightness	102	12	10	10	27	4
Flu-like symptoms	104	34	19	19	49	21
Dry skin	105	12	13	31	39	18
Rash or irritated skin	102	10	1	14	16	11
Headaches	107	51	13	14	56	21
Lethargy	105	28	23	35	67	10
Other symptoms	82	11	5	5	21	4
Season when worst		Spring	Summer	Autumn	Winter	Any
(numbers of answers)	93	1	4	1	33	54
Part of the day when worst		Morning	Afternoon	Evening	Any	
(numbers of answers)	93	13	25	10	45	

Health now	Symptom present		In building			Severity	
	Total/Nr	Nb of yes	Better	Same	Worst	Mean	Stdev
Dry eyes	106	42	3	18	18	3.57	1.73
Watering eyes	104	12	0	10	6	3.53	0.33
Stuffy nose	106	56	2	20	27	3.72	0.49
Runny nose	105	22	3	14	6	3.64	1.94
Dry throat	103	44	2	14	25	3.91	0.50
Chest tightness	103	18	1	5	12	4.18	0.59
Flu-like symptoms	102	38	3	21	12	3.43	1.75
Dry skin	103	41	1	17	18	4.20	0.42
Rash or irritated skin	101	16	1	11	5	3.67	0.67
Headaches	106	20	2	10	12	3.58	1.97
Lethargy	103	46	2	21	23	4.08	0.49
Other symptoms	93	7	0	3	5	5.00	0.62

Frequency of building related symptoms

Only symptoms which disappear out of building are taken into account in this table. For each symptom, the frequency is the ratio of the number of person presenting the symptom to the total number of answers..

Symptom	Last month	Now
Dry eyes	60%	34%
Watering eyes	30%	12%
Stuffy nose	52%	46%
Runny nose	33%	17%
Dry throat	60%	38%
Chest tightness	27%	15%
Flu-like symptoms	48%	32%
Dry skin	37%	35%
Rash or irritated skin	14%	14%
Headaches	53%	17%
Lethargy	70%	41%
Other symptoms	25%	8%

Air moisture may not be the reason for symptoms realted to dryness, since relative air humidity was 47% in average on the audit day.

Environmental conditions

Environmental conditions past month	Total/Nr	Mean	Stdev
Level of thermal comfort	95	0.14	1.54
Indoor air acceptability	104	0.14	3.13
Comfort temperature	102	3.77	1.90
Temperature variation	91	4.48	1.43
Air movement	96	4.49	1.68
Air humidity	101	2.45	1.45
Air stuffiness	97	4.98	2.09
Air odor	97	4.23	2.25
Lighting	102	2.70	2.01
Noise	102	2.36	1.71

Level of thermal comfort are on a -3 to+3 scale, Indoor air acceptability is on a -5 to+5 scale, while other votes are on a 1 to 7 scale.

Environmental conditions now	Total/Nr	Mean	Stdev
Level of thermal comfort	105	-0.44	1.21
Indoor air acceptability	105	0.91	2.77
Comfort temperature	103	3.38	1.90
Air movement	102	4.37	1.58
Air humidity	104	2.93	1.39
Air stuffiness	97	4.00	2.05
Air odor	96	3.42	1.94
Light brightness	95	4.07	0.88
Light flickering	95	1.99	1.63
Glare	95	2.35	1.84
Light uneven	93	4.16	1.10
Lighting satisfactory	100	2.35	1.73
Noise from ventilation	93	2.13	1.83
Other noise	95	2.62	1.91
Noise satisfactory	100	2.26	1.80

Environmental conditions: evaluation

Criterion	Past month μ	Past month σ	Now μ	Now σ	Conclusions
Thermal Comfort	0.1	1.5	-0.4	1.2	Comfortable
Termperature	3.8	1.9	3.4	1.9	Acceptable
Termperature variations	4.5	1.4			Nice
IAQ accaptability	0.1	3.1	0.9	2.8	Just acceptable
Air movement	4.5	1.4	4.4	1.6	Nice
Air humidity	4.5	1.7	2.9	1.4	Nice
Air stuffiness	2.4	1.4	4.0	2.1	Acceptable
Air odor	5.0	2.1	3.4	1.9	Smelly
Light brightness			4.1	0.9	Fine
Light flickering			2.0	1.6	Very stable
Glare			2.3	1.8	Faint glare
Light uneven			4.2	1.1	Nice
Lighting satisfactory	2.7	2.0	2.4	1.7	Good
Noise from ventilation			2.1	1.8	No noise
Other noise			2.6	1.9	No noise
Noise satisfactory	2.4	1.7	2.3	1.8	Good

Health and direct environment

	Total/Nr	Nb yes	Percent
I have smoking neighbors	104	11	11%
I bring comments on my environment	91	16	18%
I had asthmatic problems	104	10	10%
I have suffered from eczema	105	29	28%
I have suffered with hay fever	103	30	29%
Do you smoke?	95	39	41%
Do you smoke in this room?	63	8	13%
Did you ever smoke?	65	17	26%

Estimation of occupant's influence on indoor conditions

μ is the average vote on a 1 (no influence, unsatisfactory) to 7 (total influence, satisfactory) scale. σ is the standard deviation of the votes within the population.

Influence on	μ	σ	Conclusions
-temperature	1.5	1.1	No influence
-ventilation	1.4	1.0	No influence
-lighting	2.6	1.9	Weak influence
Cleanliness	5.4	1.9	Clean

Building symptom indices

Uncorrected BSI's			Past month		Today	
		Number	Short list	Full list	Short list	Full list
Women	All women	54	3.5	5.2	2.2	3.3
	Managers	5	4.6	6.8	2.8	3.5
	Specialists	1	6.0	11.0	4.0	8.0
	Clerical	39	3.2	4.8	2.2	3.3
	Others	9	3.8	5.7	2.1	2.9
Men	All men	46	2.6	3.5	1.6	2.1
	Managers	9	3.0	4.3	1.4	2.1
	Specialists	0	0.0	0.0	0.0	0.0
	Clerical	32	2.5	3.4	1.7	2.3
	Others	5	2.0	2.0	0.8	1.0

Global building symptom indices		**Number**	**Value**
Last month, short list	BSI fs	100	3.07
Last month, full list	BSI ff	100	4.43
Last month, short list, corrected	BSI fsc	100	4.43
Last month, full list, corrected	BSI ffc	100	6.73
Today, short list	BSI ss	100	1.94
Today, full list	BSI sf	100	2.77
Today, short list, corrected	BSI ssc	100	2.53
Today, full list, corrected	BSI sfc	100	3.55

Correction factors are based on female clerical.

Sensory measurements

Sensory evaluation	**Offices**		**Supply air**		**Adjacent 1**		**Adjacent 2**	
Perceived air quality	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	4.4	1.1	3.4	1.3				
Location 2	4.3	1.7	3.4	1.3				
Location 3	4.8	1.8	3.4	1.3				
Location 4	4.9	1.8	3.4	1.3				
Location 5	5.4	1.3	3.4	1.3				
(Location 6)					8.0	1.7	11.0	3.9
Average	4.7	1.5	3.4	1.3	8.0	1.7	11.0	3.9
Outdoor air	1.8	0.8						

General Indoor Air Quality Measurements

Chemical analysis of air	Offices		Supply	air	Adjacent	1	Adjacent	2
Carbon dioxide [ppm]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	525	42	360	28.8	500	40		
Location 2	516	41.28	360	28.8	500	40		
Location 3	620	49.6	360	28.8	500	40		
Location 4	580	46.4	360	28.8	500	40		
Location 5	600	48	360	28.8	500	40		
(Location 6)	540	43.2	360	28.8	500	40		
Average	563.5	45.08	360	28.8	500	40		
Outdoor air	350	28						
Carbon monoxide [ppm]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	<1		<1		<1			
Location 2	<1		<1		<1			
Location 3	<1		<1		<1			
Location 4	<1		<1		<1			
Location 5	<1		<1		<1			
(Location 6)	<1		<1		<1			
Average	<1		<1		<1			
Outdoor air	<1							
Particulate matter [mg/m3]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	<0,1		<0,1		<0,1			
Location 2	<0,1		<0,1		<0,1			
Location 3	<0,1		<0,1		<0,1			
Location 4	<0,1		<0,1		<0,1			
Location 5	<0,1		<0,1		<0,1			
(Location 6)	<0,1		<0,1		<0,1			
Average	<0,1		<0,1		<0,1			
Outdoor air	<0,1							
TVOC[mg/m3] Toluene equiv	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	0.20	0.02	0.31	0.02				
Location 2	0.47	0.02						
Location 3	0.21	0.02						
Location 4	0.20	0.02						
Location 5	0.53	0.02						
(Location 6)					0.39	0.(		
Average	0.32	0.02	0.31	0.02	0.39	0.(		
Outdoor air	0.36	0.03						

Building CH-C Carbon dioxide cont. meas.	Average ppm	SD ppm	Geomean ppm	GSD	Median ppm	Max. ppm
Location 5	642	23	641	1.04	637	701

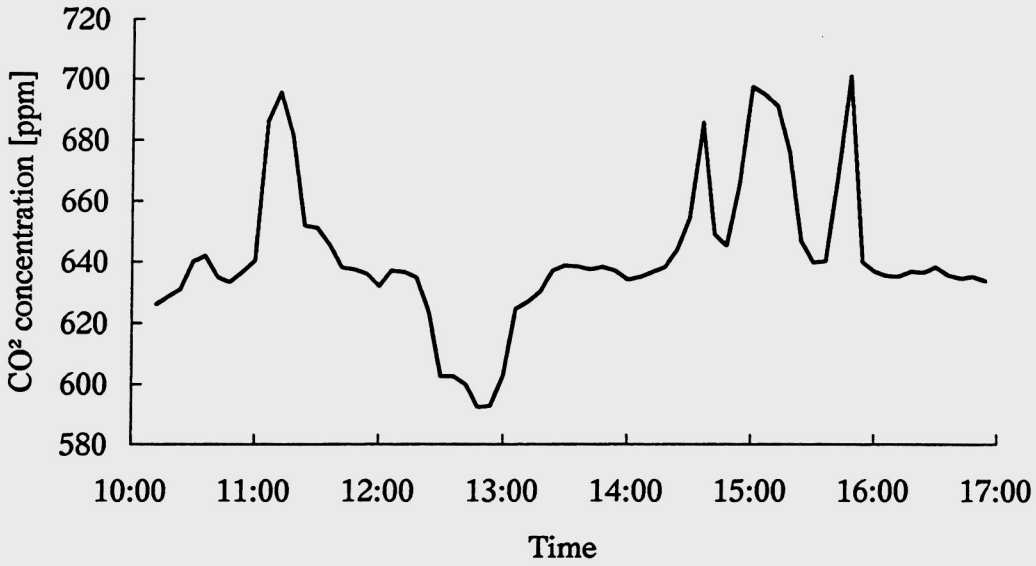


Figure C 1: CO_2 concentration versus time.

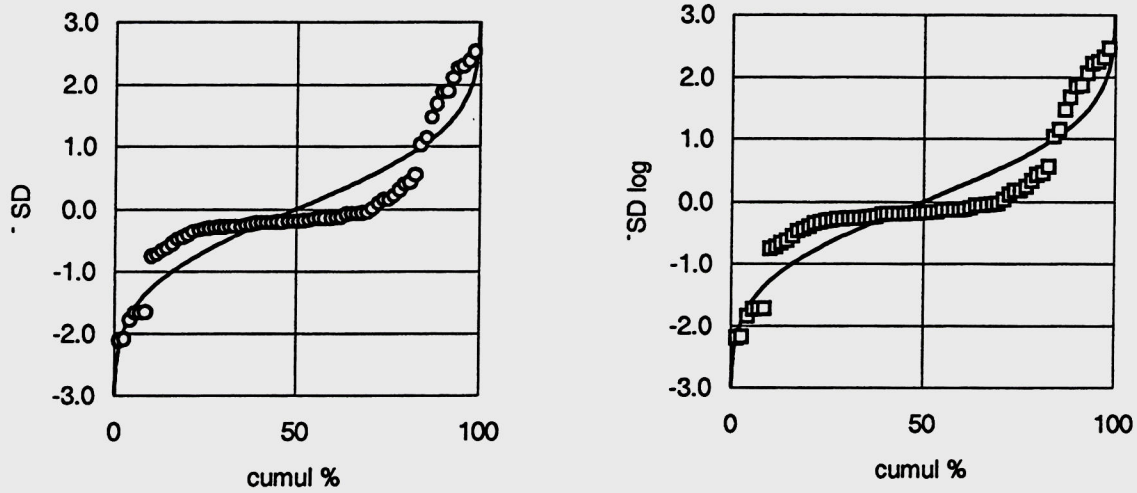


Figure C2: Cumulated frequencies of CO_2 concentrations. Left: all values. Right: selected values.

The time profile is steady in general, with a slight depression between 12h30 and 13h00 (lunchbreak?) and four short episodes of moderately elevated concentration. This departure from a completely flat profile is reflected in the poor fit with either a normal or a lognormal distribution, with both ends skewed and nearly no variation in the middle part. It is not large enough, however, to raise the relative standard deviation above a low 4%. The profile corresponds to a strongly balanced, rapidly relaxing, source and removal system.

VOC: compound	Concentration [µg/m3]
methyl-cyclohexane	99
acetone	83
n-heptane	77
aliphatic C7H16	62
1-butanol	41
aliphatic C7H16	33
dimethyl-cyclopentan	28
toluene	20
dichloro methane	19
dimethyl-cyclopentan	19
2-methyl-pentane	13
?	13
dodecanoic acid ?	11
L-Limonene	9
C? alcohol	8

General Indooor Climate measurements

Continuous measurements	Location Nr.	4				
	Start time	Stop time	µ	σ	Min	Max.
Air temperature 0,1 m [°C]	10:12	16:54	21.4	0.2	21.1	22.1
Air temperature 0,6 m [°C]	10:12	16:54	22.2	0.1	22.0	22.4
Air temperature 1,1 m [°C]	10:12	16:54	22.4	0.1	22.1	22.6
Operative temperature [°C]	10:12	16:54	23.0	0.1	22.6	23.1
Relative humidity [%]	10:12	16:54	41	1	39	42
Carbon dioxide [ppm]	10:12	16:54	642	23	592	701

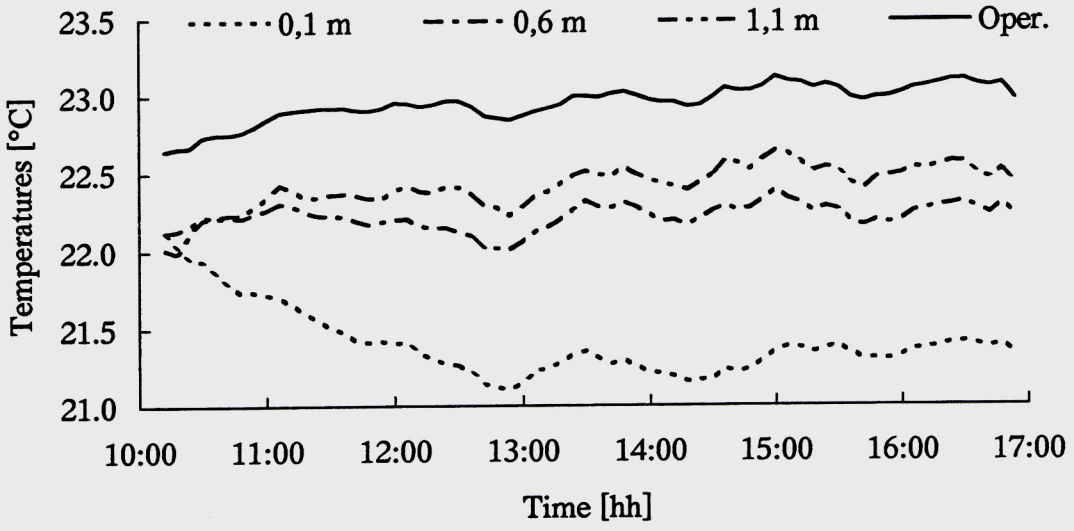


Figure C 2: Temperatures at location 5 during the audit day. Warm surfaces (ceiling) rise the operative temperature above the air tempeature at 1.1 m.

Air velocity [m/s] at	0,1 m		0,6m		1,1m	
	μ	σ	μ	σ	μ	σ
Location 1	0.08	0.02	0.14	0.02	0.09	0.02
Location 2	0.11	0.02	0.09	0.02	0.09	0.02
Location 3	0.14	0.02	0.17	0.02	0.09	0.02
Location 4	0.12	0.02	0.06	0.02	0.08	0.02
Location 5	0.15	0.02	0.13	0.02	0.12	0.02
(Location 6)						
Average	0.12	0.02	0.12	0.02	0.09	0.02

Air temperatures at	0,1 m	0,6m	1,1m	Supply air
Location 1			23.4	
Location 2			23.2	
Location 3			23.2	
Location 4			23.0	
Location 5			22.9	
(Location 6)				
Average			23.1	
Outside air	8.6			

Mean radiant temperature	At 1,1 m	Calculated	Operative temperature Measured	Calculated
Location 1		19.0	21.3	
Location 2		19.2	21.3	
Location 3		18.6	21.0	
Location 4		18.4	20.8	
Location 5		19.1	21.1	
(Location 6)				
Average		18.9	21.1	

In our cases, mean radiant temperature was always calculated from air and operative temperatures.

Relative Humidity	1,1 m	Supply air	Adj. room
Location 1	47		28
Location 2	48		28
Location 3	47		28
Location 4	47		27
Location 5	47		27
(Location 6)			27
Average	47		28
Outdoor air	70		

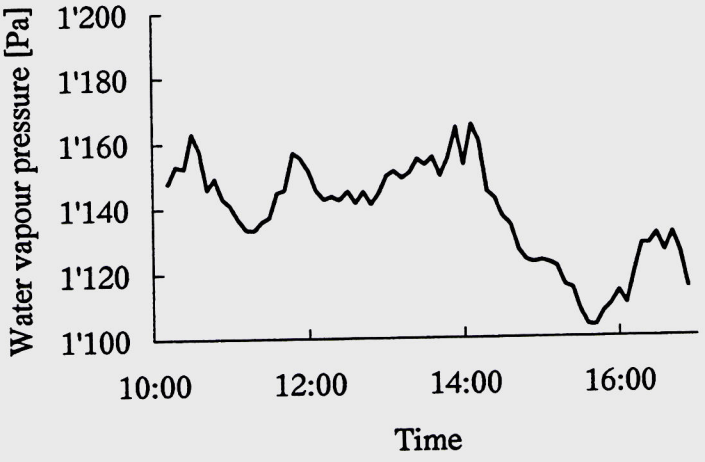


Figure 3: Water vapour pressure at location 5 during the audit day.

Noise [dB (A)]	Office	Adjacent
Location 1	48	
Location 2	42	
Location 3	42	
Location 4	45	
Location 5	47	
Average	45	
Outdoor noise		

Ventilation measurements

Air flow rates in ventilation system [m³/h]	Planned	Measured	±
Total air flow rate into building	134'500		
Fresh air flow rate into building	134'500	52'000	10'000
Exhaust from building	134'500		
Extracted to outdoor	134'500		
Recirculated air flow rate	0	2'000	2'000
Recirculation rate	0	4%	4%
Estimated air change rate [/h]	3	1	0.2
Estimated fresh air per person [l/(s·pers.)]	31		

Air flow rates	Value	±
Air flow rate from ventilation	12'200	600
Air flow rate from hall	600	200
Air flow rate from other space	0	0
Infiltration	0	1

Air flow rates in m³/h..

Pollution load

Source intensity	Total	
Total olfactive load	800	Olf
uncertainty	300	Olf
Olfactive load	300	Olf
uncertainty	400	Olf
Load from ventilation	500	Olf
uncertainty	300	Olf
Load from smokers	*	Olf
uncertainty	*	Olf
Load from occupants	100	Olf
uncertainty	10	Olf
Load from other sources	200	Olf
uncertainty	400	Olf
Carbon dioxide	2'000	l/h
uncertainty	200	l/h
corresponding to	110	persons
uncertainty	10	persons
Number of working places	99	persons

* Load from smokers cannot be exactly estimated. The proportion of smokers among occupants is large, but smoking is allowed in office rooms only from 16:30 on.
Total is total pollution load in monitored zone.

Weather conditions on audit day

Weather station	Zürich SMA		
Date	26-01-94		
Description	Overcast		
Weather data	Average	Maximum	Minimum
Temperature 0600-1200	4.0	4.9	2.8
Temperature 1200-1800	4.3	5.2	3.3
Relative humidity 0600-1200	85	90	78
Relative humidity 1200-1800	66	73	61
Wind speed 0600-1200	7.4	8.8	6.5

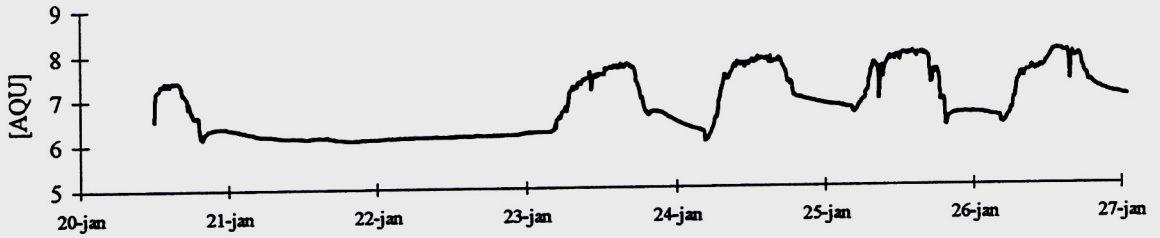
Energy consumption

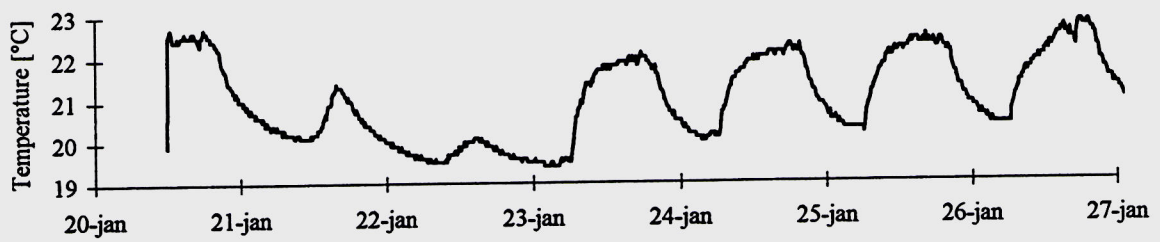
Annual energy use [MJ]	in 1993	1'992	1'990	1'989	Uncertainty
Extra light oil	2'874'391	4'446'159			143'720
Natural gas	28'054'800	40'964'400			1'402'740
Electricity	37'828'800	35'157'600			1'891'440
Total	68'757'991	80'568'159			3'437'900
Energy index [MJ/m²]	1'800	2'100			100
Heating degree days	3'616	3'616			289
Power index [W/m²K]	6	7			10
Heating index	816	1'185			150
Electric index	984	915			50

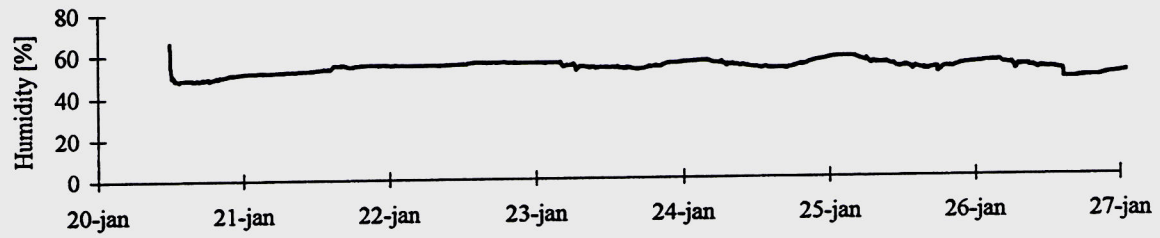
Note that most digits, resulting from transformation of liters, kg, kWh, etc into MJ, are not significant.
The energy consuption of this building is high when compared to modern Swiss standards.

Additional measurements

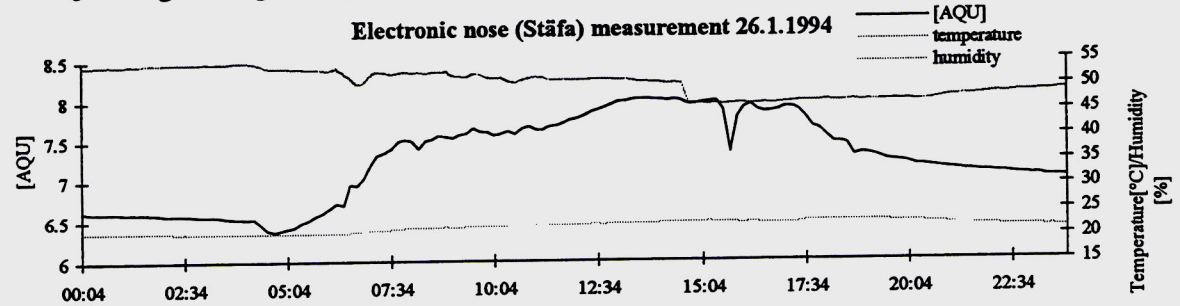
IAQ Stäfa	Day 8:00-18:00				Night 20:00-06:00			
	Mean	Stdev.	Min.	Max.	Mean	Stdev.	Min.	Max.
Location 1	7.78	0.19	7.34	8.02	6.96	0.15	6.58	7.21
Location 2	7.84	0.14	7.47	8.03	7.08	0.13	6.80	7.28
Location 3	7.82	0.17	7.45	8.06	7.12	0.10	6.92	7.33
Average	7.81	0.17	7.42	8.04	7.06	0.13	6.77	7.27







The diagrams above show taht the audit day was similar to any other working day. Decrease in IAQ during the night may be caused by desorption from fleecy materials.



Ions	Time	+ ions			- ions			
Office	Begin	End	Average	Max.	Min	Average	Max.	Min
Location 1	09:54	10:43	721	1'098	245	609	930	95
Location 2	10:46	11:56	543	888	268	718	961	463
Location 3	12:23	13:21	506	1'180	240	670	886	0
Location 4	13:25	14:33	265	950	50	182	318	65
Location 5	14:36	15:35	368	548	68	452	620	58
Average			481	933	174	526	743	136

Radon	**Bq/m3**
Location 1	50
Location 2	25
Location 3	25
Air inlet	15
Air outlet	40

BUILDING D

General information

1. Building identification.	D		
3. Situation	Countryside.	7. Number of floors	5
4. Traffic within 200 m.	Moderate busy road.	area of each floor (m2)	2'400
		number of offices	320
5. Near sources of pollution	Parking garage.	number of employees	223
	0	8. Year of building completion	1'991
6. Activities besides office work	Laboratory.	Year of total renovation	1'991
9. No. of floors beneath ground	1	Year when user entered	1'991
Roof tilt angle	Flat roof	10. Position of solar shadings	Outside.
11. Number of glazing	Double pane.	Solar shadings: movement	Individual.
Glazing type	Clear.	12. Modification of?	
13. Furniture made of	Mainly solid wood.	Flooring	None
Age of furniture	3 years or less.	Insulation	None
14. Large green plants	No large green plants.	Wall/ ceiling lining	None
Plants treatment	No treatement.	Windows	None
		Heating system	None
15. Smoking	Generally allowed.	Ventilation system	None
		16. Office activities	
		solvents	No solvents
		other chemicals	None
17. Cleaning frequency		copying machines	No.
Tables	Once a week.	laser printers	No.
Walls	Less than once a month.	person per VDU	1-2
Washing floors	Less than once a month.	carbonless paper use	No.
Vacuum cleaning	Once a week.		
Mopping	Less than once a month.		
Sweeping	Less than once a month.		
Waxing	Less than once a month.		
Spring cleaning	Less than once a year.		
Look of the floors	Clean floors.		
18. Detergent for cleaning	type/name	content pH	
cleaning agent linoleum	Johnson Tapi	tense anion solvent	Does not leave a film.
cleaning agent carpet			
cleaning agent tables	Neupol (universal detergent)		Does not leave a film.
cleaning agent sanitary	Taski NOF	1-5% Alkohol, 1-5% glycol, >10% lemon,<1% preservative,	Does not leave a film.

Installation

1. Installation identification			
2. Room heating Location of heating	Hot water heating. Radiators.	3. Room cooling	Cooled ceiling.
4. Temperature control Night set back	Adjustable thermostat on radiator or unit. No.	5.Ventilation of rooms Windows	Windows or natural ventilation. Windows can be opened.
6. Design outdoor air change Lowest outdoor air supply	1 to 3 per hour. 10 l/s·pers	7. Position air intake height above ground distance from exhaust distance from cooling towers	On the roof. 16 vert. 5 hor. 10 vert. 0 hor. 25
8. Equipment vent. system Recirculation [%] Humidification system Water purification Cooling type Heat recovery	 0 Spray. Other. Water cooling in concrete decks Rotating wheel.		
9. Ventilation system on/off Sensors for demand control	Automatically by a clock. No such control.		

Operating at:	From	to	days per week
full performance	07:00	17:00	5
reduced performance	17:00	07:00	5
stopped			
100% recirculation			
Partial recirculation			

10. Duct material Duct insulation	5 External insulation.		
11. Service	Class	Last replacement	Needing service
Air intake filter	Eu3	15-01-94	No.
Recirculation duct filter			0
Central unit filter	Eu7	15-01-94	No.
Supply filter			
Induction / fan coil filter			

	Last cleaning	Needing service	
Heating batteries	1-10-93	No.	
Cooling batteries	1-10-93	No.	
Heat exchanger			
Humidifier			
Ducts		No.	
Air outlets in rooms		No.	
Air inlet in rooms		No.	
12. Location air supply inlets	Under the ceiling.		
Location air outlets	High, in wall to corridor		
Designed ventilation principle	Displacement ventilation.		

Investigated rooms

Summary	1	2	3	4	5	6
Room name	220	221	223	237	236	Hall
Wall materials inside insulation	Plaster board.					
Insulation material	Fiberglas.					
Thickness of insulation [cm]	10	10	10	10	10	10
Felt carpet (needle) [%area]	0	0	0	0	0	0
Nap carpet [%area]	100	100	100	100	100	100
Lacquered wood [%area]	0	0	0	0	0	0
Vinyl (PVC) [%area]	0	0	0	0	0	0
Linoleum [%area]	0	0	0	0	0	0
Tiles [%area]	0	0	0	0	0	0
Other (type here) [%area]	0	0	0	0	0	0
Wall covering / treatments	Dispersion paint.					
Ceiling material (inside surface)	Concrete.					Acoustic panes.
Space above acoustic tiles [cm]						30
Dust above acoustic panes?						No.
Acoustic baffles below ceiling?						No.
Any other ceiling type?						
Room lighting	Artificial and Daylight.					
Lighting location	Ceiling.					
Type of artificial lighting	Fluorescent.					
Control of lighting	Manual.					
Visible mould growth in rooms	No.	No.	No.	No.	No.	No.
Damp spots	No damp spots.					
Mould odor in room	No.	No.	No.	No.	No.	No.
Area [m²]	12	12	12	35	15	
Height [m]	2.85	2.85	2.85	2.85	2.85	2.3
Nb of work places	1	1	1	3	1	0
Fleecy material [m²]	1	2	2	5	2	0
Shelf length [m]	15	3	7	15	3	0
Window area [m²]	5.4	5.4	5.4	5.4	12.6	0
Office depth [m]	4	4	4	5	5	
Nb. of laser printers	0	0	0	0	0	
Nb. of photocopiers	0	0	0	0	0	
Nb. of VDUs	1	1	1	1	3	
Acceptable access for cleaning?	Yes	Yes	Yes	Yes	Yes	Yes
Door to corridor open?	Closed	Open	Open	Open	Open	
Nb. of VDU with reflection	0	0	0	0	0	0
Nb of VDU with glare	1	0	0	0	0	0

Questionnaire

General	Total/Nr	Mean	Stdev	Percentage
Questionnaires distributed	135			
Questionnaires returned	119			88%
Age	119	38.88	9.32	
Number of female occupants	66			57%
Number of male occupants	49			43%
Time at desk before filling questionnaire	103	2.87	1.26	
Managerial work	49			41%
Specialist skill	31			26%
Clerical	27			23%
Other	12			10%
Time spent in the building [years]	117	1.79	0.68	
Time spent in the room [years]	119	1.38	0.74	
Hours per day at the desk	115	7.70	2.20	
Paid hours per week	115	42.07	11.38	
Hours at VDU per week	103	21.88	11.37	
Days per month in the building	102	15.66	6.68	
Number of people in the room	118	0.29	0.51	
Rooms without windows	0			0%
Rooms with windows	119			100%
Distance from the window	101	1.00	0.66	
People opening the window	110			94%
People not opening the window	7			6%

Health

Health during past month		Symptom present for			Better away	
	Answers	1-5 Days	6-10 Days	>10 days	yes	no
Dry eyes	117	34	6	4	29	14
Watering eyes	119	15	3	2	14	5
Stuffy nose	117	40	8	9	17	36
Runny nose	118	32	4	2	7	28
Dry throat	118	36	5	0	17	24
Chest tightness	118	6	1	1	3	5
Flu-like symptoms	119	43	5	2	5	39
Dry skin	118	27	6	14	14	29
Rash or irritated skin	118	7	1	4	0	12
Headaches	118	65	4	1	26	35
Lethargy	117	52	16	5	34	30
Other symptoms	114	2	0	6	7	1
Season when worst		Spring	Summer	Autumn	Winter	Any
(numbers of answers)	95	3	1	3	28	60
Part of the day when worst		Morning	Afternoon	Evening	Any	
(numbers of answers)	95	6	17	17	55	

Health now	Symptom present		In building			Severity	
	Total/Nr	Nb of yes	Better	Same	Worst	Mean	Stdev
Dry eyes	118	13	0	4	9	2.92	1.70
Watering eyes	117	6	0	3	3	3.17	0.21
Stuffy nose	118	21	2	15	3	3.15	0.50
Runny nose	118	11	1	6	4	3.67	1.00
Dry throat	118	15	0	10	4	2.87	0.39
Chest tightness	118	2	0	2	0	3.50	0.52
Flu-like symptoms	118	13	0	11	1	3.45	2.02
Dry skin	117	27	0	26	1	3.20	0.30
Rash or irritated skin	118	7	0	6	1	3.43	0.71
Headaches	118	10	0	6	3	2.50	1.94
Lethargy	117	23	0	15	7	2.90	0.32
Other symptoms	114	4	0	1	3	5.25	0.42

Frequency of building related symptoms

Only symptoms which disappear out of building are taken into account in this table. For each symptom, the frequency is the ratio of the number of person presenting the symptom to the total number of answers..

Symptom	Last month	Now
Dry eyes	25%	11%
Watering eyes	12%	5%
Stuffy nose	15%	15%
Runny nose	6%	9%
Dry throat	14%	11%
Chest tightness	3%	2%
Flu-like symptoms	4%	8%
Dry skin	12%	23%
Rash or irritated skin	0	8%
Headaches	24%	8%
Lethargy	31%	22%
Other symptoms	6%	3%

Environmental conditions

Environmental conditions past month	Total/Nr	Mean	Stdev
Level of thermal comfort	117	0.06	0.67
Indoor air acceptability	117	3.22	1.63
Comfort temperature	117	1.91	1.22
Temperature variation	115	3.94	0.78
Air movement	117	3.87	1.07
Air humidity	116	3.17	1.01
Air stuffiness	116	2.90	1.61
Air odor	116	2.46	1.53
Lighting	118	2.18	1.52
Noise	118	2.19	1.44

Level of thermal comfort are on a -3 to+3 scale, Indoor air acceptability is on a -5 to+5 scale, while other votes are on a 1 to 7 scale.

Environmental conditions now	Total/Nr	Mean	Stdev
Level of thermal comfort	117	0.02	0.68
Indoor air acceptability	117	3.35	1.59
Comfort temperature	118	1.80	1.19
Air movement	117	3.62	0.85
Air humidity	118	3.13	0.89
Air stuffiness	117	2.56	1.52
Air odor	116	2.04	1.36
Light brightness	118	4.08	0.68
Light flickering	114	1.51	1.11
Glare	112	2.26	1.62
Light uneven	111	4.10	0.96
Lighting satisfactory	114	1.82	1.24
Noise from ventilation	117	1.39	1.02
Other noise	117	2.74	1.65
Noise satisfactory	117	2.04	1.30

Environmental conditions: evaluation

Criterion	Past month μ	Past month σ	Now μ	Now σ	Conclusions
Thermal Comfort	0.1	0.7	0.0	0.7	Comfortable
Termperature	1.9	1.2	1.8	1.2	Very comfortable
Termperature variations	3.9	0.8			Nice
IAQ accaptability	3.2	1.6	3.4	1.6	Excellent
Air movement	3.9	0.8	3.6	0.8	Nice
Air humidity	3.9	1.1	3.1	0.9	Dry
Air stuffiness	3.2	1.0	2.6	1.5	Acceptable
Air odor	2.9	1.6	2.0	1.4	Faint smell
Light brightness			4.1	0.7	Fine
Light flickering			1.5	1.1	Very stable
Glare			2.3	1.6	Faint glare
Light uneven			4.1	1.0	Nice
Lighting satisfactory	2.2	1.5	1.8	1.2	Excellent
Noise from ventilation			1.4	1.0	No noise
Other noise			2.7	1.7	No noise
Noise satisfactory	2.2	1.4	2.0	1.3	Excellent

Health and direct environment

	Total/Nr	Nb yes	Percent
I have smoking neighbors	117	34	29%
I bring comments on my environment	115	34	30%
I had asthmatic problems	117	16	14%
I have suffered from eczema	117	25	21%
I have suffered with hay fever	118	33	28%
Do you smoke?	107	33	31%
Do you smoke in this room?	52	22	42%
Did you ever smoke?	88	29	33%

Estimation of occupant's influence on indoor conditions

μ is the average vote on a 1 (no influence, unsatisfactory) to 7 (total influence, satisfactory) scale. σ is the standard deviation of the votes within the population.

Influence on	μ	σ	Conclusions
-temperature	2.5	1.7	Weak influence
-ventilation	1.1	0.6	No influence
-lighting	4.9	2.0	Acceptable influence
Cleanliness	6.4	1.2	Very clean

Building symptom indices

Uncorrected BSI's			Past month		Today	
		Number	Short list	Full list	Short list	Full list
Women	All women	16	3.8	4.9	2.2	3.3
	Managers	2	4.0	4.5	2.5	5.0
	Specialists	4	2.8	4.3	2.5	3.5
	Clerical	10	3.7	5.2	2.0	2.3
	Others	0	0.0	0.0	0.0	0.0
Men	All men	60	2.7	3.7	1.8	2.2
	Managers	13	2.8	3.9	1.8	2.2
	Specialists	39	1.3	1.7	1.3	1.7
	Clerical	7	1.6	2.0	1.1	1.4
	Others	1	5.0	5.0	3.0	3.0

Global building symptom indices		**Number**	**Value**
Last month, short list	BSI fs	76	1.59
Last month, full list	BSI ff	76	2.12
Last month, short list, corrected	BSI fsc	76	2.89
Last month, full list, corrected	BSI ffc	76	4.23
Today, short list	BSI ss	76	1.34
Today, full list	BSI sf	76	1.74
Today, short list, corrected	BSI ssc	76	2.45
Today, full list, corrected	BSI sfc	76	3.17

Correction factors are based on female clerical.

Sensory measurements

Sensory evaluation	**Offices**		**Supply air**		**Adjacent 1**		**Adjacent 2**	
Perceived air quality	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	7.3	3.5	2.7	3.0				
Location 2	9.7	2.6	2.7	3.0				
Location 3	9.7	3.2	2.7	3.0				
Location 4	7.3	3.3	2.7	3.0				
Location 5	6.2	2.1	2.7	3.0				
(Location 6)					9.1	2.5	2.7	0.9
Average	8.0	2.9	2.7	3.0	9.1	2.5	2.7	0.9
Outdoor air	4.3	2.3						

General Indoor Air Quality Measurements

Chemical analysis of air	Offices		Supply air		Adjacent 1		Adjacent 2	
Carbon dioxide [ppm]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	870	69.6	400	32				
Location 2	900	72	400	32				
Location 3	950	76	400	32				
Location 4	900	72	400	32				
Location 5	900	72	400	32				
(Location 6)					900	72		
Average	904	72.32	400	32	900	72		
Outdoor air	360							
Carbon monoxide [ppm]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	<1							
Location 2	<1							
Location 3	<1							
Location 4	<1							
Location 5	<1							
(Location 6)	0							
Average	<1							
Outdoor air								
Particulate matter [mg/m3]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	0.07	0.02						
Location 2	0.1	0.02						
Location 3	0	0.02						
Location 4	0.08	0.02						
Location 5	0	0.02						
(Location 6)								
Average	0.05	0.02						
Outdoor air								
TVOC[mg/m3] Toluene equiv	μ		μ	σ	μ	σ	μ	σ
Location 1	0.31	0.02	0.17	0.02	0.32	0.02		
Location 2	0.50	0.02						
Location 3	0.30	0.02						
Location 4	0.30	0.02						
Location 5	0.85	0.03						
(Location 6)								
Average	0.45	0.02	0.17	0.02	0.32	0.02		
Outdoor air	0.36	0.05						

Building CH-D **Carbon dioxide cont. meas.**	Average ppm	SD ppm	Geomean ppm	GSD	Median ppm	Max. ppm
Location 2 (filled dots)	724	133	711	1.23	728	919
Location 4 (open circles)	795	57	793	1.08	808	902

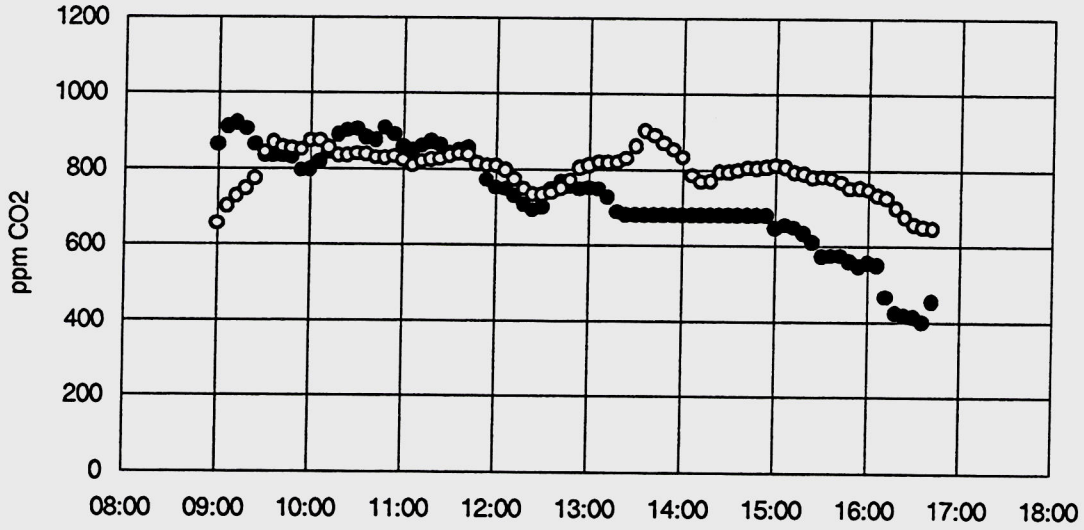


Figure D1: CO_2 concentration versus time..

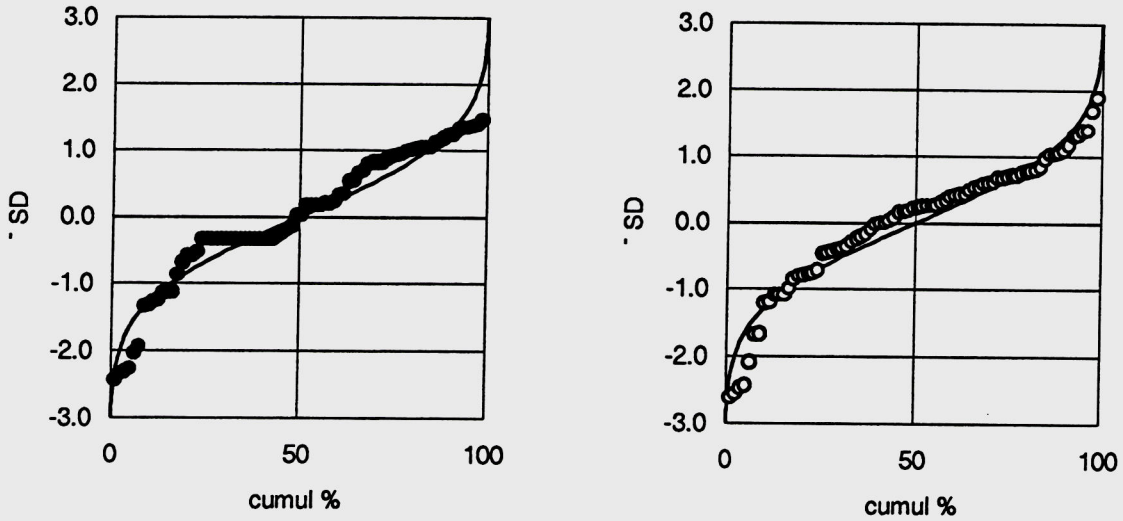


Figure D2: Cumulated frequencies of CO_2 concentrations. Left: all values. Right: selected values.

Two locations were monitored, one with mechanical and the other with natural ventilation (cf. building description, chap. 2.4.1). In both places, a slight but noticeable drop apprears at lunch time. At the naturally ventilated location 2, the profile shows a steady decrease to less than 600 ppm in the late afternoon, with a brisk unexplained drop to 400 ppm at the end of the series. Scatter around the general trend is much lower than what the 18% relative standard deviation suggests. The distribution is strongly biased by the downward trend. In the mechanically ventilated office 4, the time course is much steadier, with a morning rise to 850 ppm and again a slow, less pronounced decrease to 650 pm trough the day. A slight peak around 14h00 may be due to the presence of the "sniffing" panelists, as noted elsewhere. Apart from the morning rise, the distribution is essentially gaussian.

VOC: compound	Concentration [µg/m3]
L-Limonene	62
dichloro methane	25
toluene	22
acetone	15
aliphatic C7H16	11
C5H2O8 ester	11
m-xylene	10
2-meth-1,3-butadiene	8
?	7
n-heptane	7
acetic acid ?	6
undecane C11H24	6
dodecane C12H26	6
2-methyl-pentane	5
ethanol	5

General Indooor Climate measurements

Continuous measurements	Location Nr.	2				
	Start time	Stop time	µ	σ	Min	Max.
Air temperature 0,1 m [°C]	09:00	17:00	21.9	0.3	21.2	22.6
Air temperature 0,6 m [°C]	09:00	17:00	23.5	0.4	22.5	24.2
Air temperature 1,1 m [°C]	09:00	17:00	24.4	0.3	23.4	24.9
Operative temperature [°C]	09:00	17:00	22.9	2.6	0.5	23.8
Relative humidity [%]	09:00	17:00	27	3	1	30
Carbon dioxide [ppm]	09:00	17:00	781	100	61	902

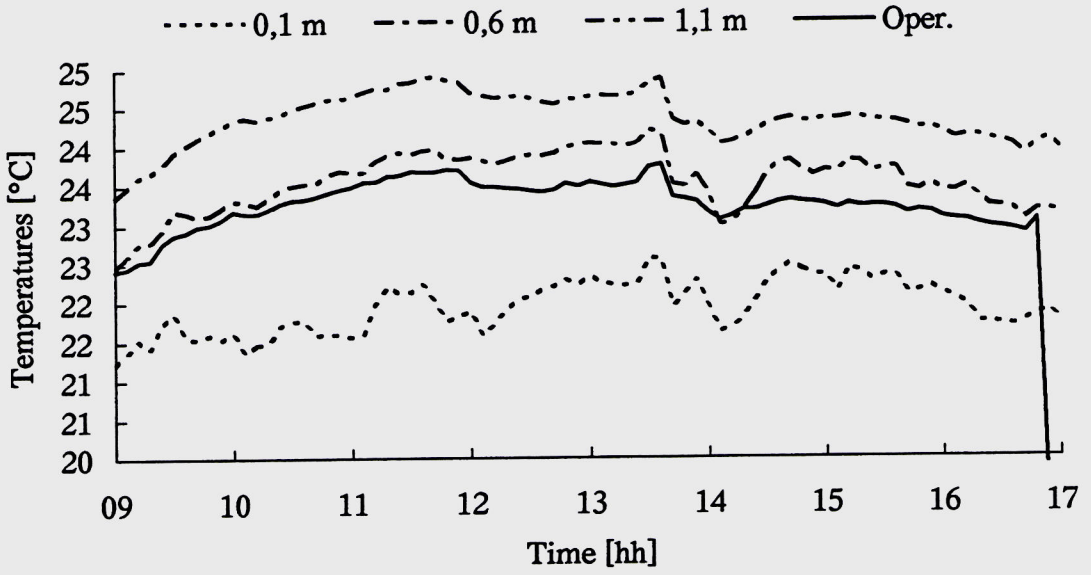


Figure D3: Temperatures at location 4.

Air velocity [m/s] at	0,1 m		0,6m		1,1m	
	μ	σ	μ	σ	μ	σ
Location 1	0.17	0.02	0.06	0.02	0.08	0.02
Location 2	0.10	0.02	0.14	0.02	0.14	0.02
Location 3	0.22	0.02	0.12	0.02	0.14	0.02
Location 4	0.13	0.02	0.06	0.02	0.07	0.02
Location 5	0.15	0.02	0.13	0.02	0.14	0.02
Average	0.15	0.02	0.10	0.02	0.11	0.02

Air temperatures at	0,1 m	0,6m	1,1m	Supply air
Location 1			22.8	
Location 2			23.1	
Location 3			22.7	
Location 4			22.7	
Location 5			23.6	
Average			23.0	
Outside air	5.5			

Mean radiant temperature	At 1,1 m	Calculated	Operative temperature Measured	Calculated
Location 1		23.2	23.0	
Location 2		20.7	22.0	
Location 3		19.7	21.3	
Location 4		22.9	22.8	
Location 5		18.9	21.4	
Average		21.1	22.1	

Mean radiant temperature was always calculated from air and operative temperatures.

Relative Humidity	1,1 m	Supply air	Adj. room
Location 1	39		
Location 2	34		
Location 3	38		
Location 4	35		
Location 5	36		
Average	36		
Outdoor air	61		

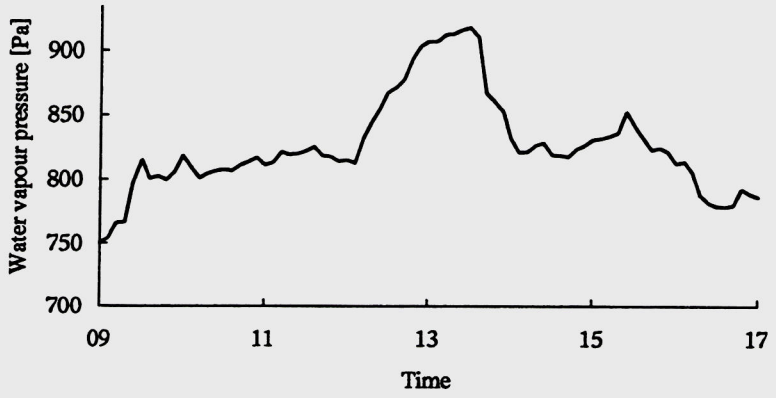


Figure D4: Water vapour pressure at location 4.

Ventilation measurements

Air flow rates in ventilation system [m³/h]	Planned	Measured	±
Pulsed air flow rate	8'800	8'257	800
Fresh air flow rate into building	>8'800*		0
Recirculation rate	0	0	
Estimated air change rate [/h]			
Estimated fresh air per person [l/(s·pers.)]	>11*	11	

* more with natural ventilation

Mesure at location Nr	1	2	3	4	5	Total
Air flow rate from ventilation	70	170	10	50	60	400
uncertainty	20	30	20	10	30	100
Air flow rate from hall	440	290	0	20	60	800
uncertainty	80	70	100	100	30	400
Air flow rate from other space	0	0	0	0	0	0
uncertainty	0	0	0	0	0	0
Infiltration	0	0	0	0	0	0
uncertainty	1	1	1	1	1	5

Air flow rates in m³/h. Total is total air flow rate into monitored area.

Pollution load

Source intensity	1	2	3	4	5	Total	
Total olfactive load	14	36	2	6	8	70	Olf
uncertainty	4	7	2	3	5	20	Olf
Olfactive load	30	40	0	2	1	70	Olf
uncertainty	20	20	3	4	6	50	Olf
Load from ventilation	6	13	1	4	5	30	Olf
uncertainty	3	7	1	2	3	20	Olf
Load from smokers	2	2	2	6	2	13	Olf
uncertainty	1	2	1	1	2	6	Olf
Load from occupants	1	1	1	3	1	7	Olf
uncertainty	1	1	1	0	1	3	Olf
Load from other sources	20	40	-3	-7	-2	50	Olf
uncertainty	20	20	3	4	6	50	Olf
Carbon dioxide	20	90	10	25	30	170	l/h
uncertainty	10	10	10	8	20	60	l/h
corresponding to	1	5	1	1	2	10	persons
uncertainty	1	1	1	0	1	3	persons
Number of working places	1	1	1	3	1	7	persons

Total is total pollution load in monitored zone.
Office Nr 3 was empty.

	Noise [dB (A)]		Light [Lux]
Location 1	38		420
Location 2	45		500
Location 3	43		1400
Location 4	60	Conversation	1000
Location 5	47		1000
(Location 6)	50		
Average	47		864
Outdoor noise	53		

Weather conditions on audit day

Weather station	Wädenswil		
Date	1-02-94		
Description	Sunny		
Weather data	Average	Maximum	Minimum
Temperature 0600-1200	-0.2	1.9	-1.5
Temperature 1200-1800	4.0	4.9	2.5
Relative humidity 0600-1200	89	92	82
Relative humidity 1200-1800	72	81	65
Wind speed 0600-1200	0.8	1.1	0.7

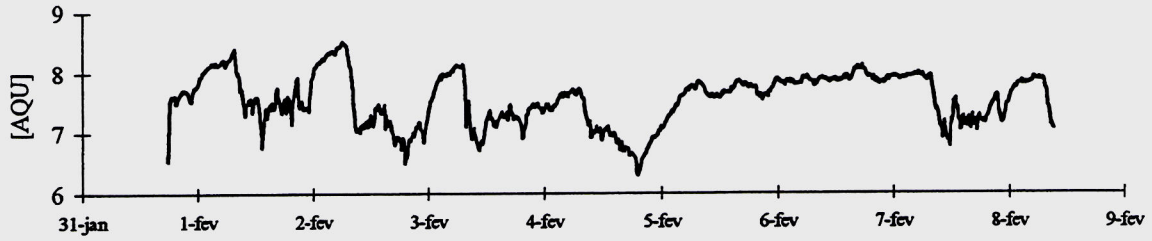
Energy consumption

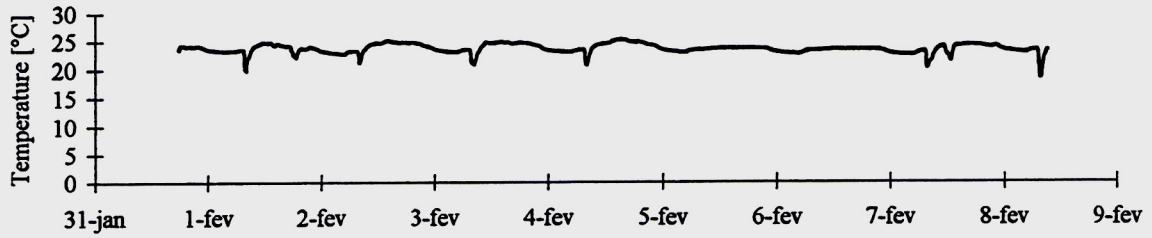
Annual energy use [MJ]	1'993	1'992	1'991	1'990	Uncertainty
Extra light oil	483'720	624'941	518'930	417'949	25'569
Electricity	5'007'948	5'828'737	5'306'712	4'934'794	105'391
District heat	3'756'564	4'040'215	3'744'135	2'993'836	181'684
Total	9'248'232	10'493'894	9'569'777	8'346'578	312'645
Energy index [MJ/m²]	800	900	800	700	0
Heating degree days					
Power index [W/m²K]					
Heating index	383	414	358	289	0
Electric index	417	486	442	411	0

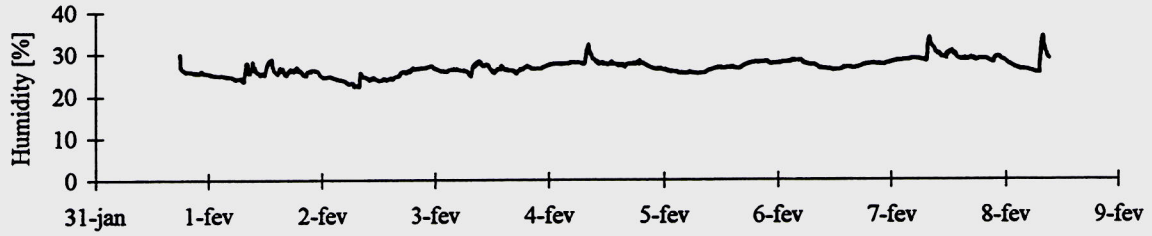
Note that most digits, resulting from transformation of liters, kg, kWh, etc into MJ, are not significant. This building presents the lowest energy indexes of the audited buildings. It is also low when compared to Swiss standards.

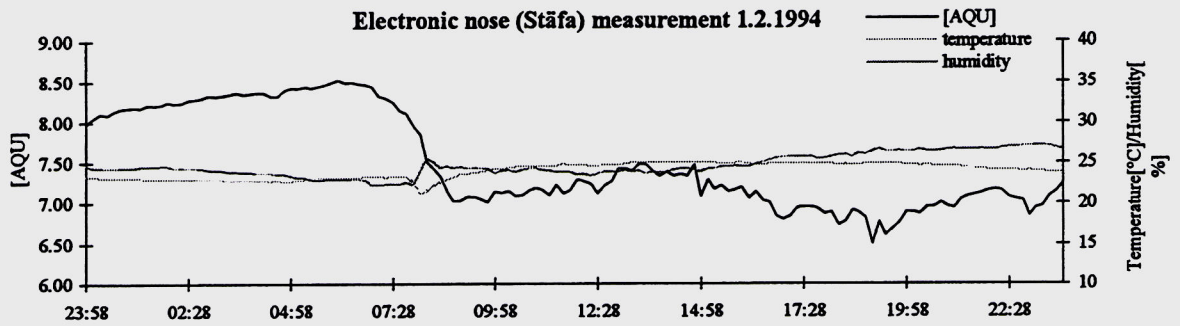
Additional measurements

IAQ Stäfa	Day 8:00-18:00				Night 20:00-06:00			
	Mean	Stdev.	Min.	Max.	Mean	Stdev.	Min.	Max.
Location a	6.43	0.62	5.25	7.28	6.92	0.07	6.66	7.01
Location b	7.01	0.13	6.83	7.34	7.16	0.21	6.73	7.44
Location c	7.18	0.19	6.80	7.84	7.55	0.44	6.85	8.14
Average	6.88	0.31	6.29	7.49	7.21	0.24	6.75	7.53









The audit day (1994.2.1) is similar to the following working days.

Ions	time		+ ions			- ions		
office	begin	end	Mean	Max.	Min	Mean	Max.	Min
Location 1	11:10	12:28	27	85	0	25	191	0
Location 2	12:30	13:10	83	161	20	42	258	1
Location 3	13:15	13:56	146	266	38	35	130	0
Location 4	14:02	14:57	1'521	2'738	366	1'540	2'633	296
Location 5	15:03	15:55	1'085	1'800	561	1'072	1'685	513
Average			572	1'010	197	543	979	162
Outdoor								

Mechanically ventilated locations have a higher ion concentration than naturally ventilated rooms. Some air molecules may be ionised by rubbing the ducts metallic surfaces. The atmospere remains anyway neutral.

Radon	Bq/m3
Location 1	19
Location 2	19
Location 3	30
inlet	19
outlet	19

BUILDING E

General information

1. Building identification.	E		
3. Situation	Countryside.	7. Number of floors	7
4. Traffic within 200 m.	Moderate busy road.	area of each floor (m2)	1'295
		number of offices	205
5. Near sources of pollution	Parking garage.	number of employees	200
	0	8. Year of building completion	1974
6. Activities besides office work	Laboratory.	Year of total renovation	1974
9. No. of floors beneath ground	1	Year when user entered	1974
Roof tilt angle	Flat roof	10. Position of solar shadings	No solar
11. Number of glazing	Double pane.	Solar shadings: movement	protection.
Glazing type	Light reflecting.	12. Modification of?	
13. Furniture made of	Mainly solid wood.	Flooring	None
Age of furniture	More than three years.	Insulation	None
14. Large green plants	No large green plants.	Wall or ceiling lining	None
Plants treatment	0	Windows	None
		Heating system	None
		Ventilation system	None
15. Smoking	Allowed in separate rooms.	16. Office activities	
		solvents	No solvents
		other chemicals	None
17. Cleaning frequency		copying machines	No.
Tables	Daily.	laser printers	No.
Walls	Less than once a month.	person per VDU	1-2
Washing floors	Less than once a month.	carbonless paper use	No.
Vacuum cleaning	Once a week.		
Mopping	0		
Sweeping	0		
Waxing	0		
Spring cleaning	Less than once a year.		
Look of the floors	Clean floors.		
18. Detergent for cleaning	type/name	content pH	
cleaning agent linoleum	Johnson Tapi	tense anion solvent	Does not leave a film.
cleaning agent carpet			
cleaning agent tables	Neupol (universal detergent)		Does not leave a film.
cleaning agent sanitary	Taski NOF	1-5% Alkohol, 1-5% glycol, >10% lemon,<1% preservative,	Does not leave a film.

Installation

1. Installation identification			
2. Room heating Location of heating	Hot water heating. Radiators.	3. Room cooling	Local fan coil units.
4. Temperature control Night set back	Adjustable thermostat on radiator or unit. No.	5.Ventilation of rooms Windows	Inductin units balanced system. Windows cannot be opened.
6. Design outdoor air change Lowest outdoor air supply	1 to 3 per hour. 52 l/s·pers	7. Position air intake height above ground distance from exhaust	0 0 vert. 17 hor. 30
8. Equipment vent. system Recirculation [%] Humidification system Water purification Cooling type Heat recovery	 14 Steam. None. Fan coil None.	distance from cooling towers	vert. 15 hor. 100
9. Ventilation system on/off Sensors for demand control	Automatically by a clock. No such control.		
Operating at:	From	to	days per week
full performance reduced performance stopped	06:15 17:00	17:00 06:15	5 7
100% recirculation			
Partial recirculation	06:15	17:00	30 %return air
10. Duct material Duct insulation	Galvanised steel. No thermal insulation.		
11. Service Air intake filter Recirculation duct filter Central unit filter Supply filter Induction / fan coil filter	Class Eu7 Eu3 Eu7	Last replacement 1-05-93 1-05-93 1-05-93	Needing service No. No. No.
 Heating batteries Cooling batteries Heat exchanger Humidifier Ducts Air outlets in rooms Air inlet in rooms	Last cleaning 1-10-93 1-10-93 1-10-93 1-10-93 1-10-93	Needing service No. No. No. No. No. No. No.	
12. Location air supply inlets Location air outlets Designed ventilation principle	At windowsill. High. Mixing ventilation.		

Investigated rooms

Summary	1	2	3	4	5	6
Room name	105	104	107	108	109	110
Wall materials inside insulation	Steel					
Insulation material	Polystyrene.					
Thickness of insulation [cm]	4	4	4	4	4	4
Felt carpet (needle) [%area]						
Nap carpet [%area]	100	100	100	100	100	100
Lacquered wood [%area]						
Vinyl (PVC) [%area]						
Linoleum [%area]						
Tiles [%area]						
Other (type here) [%area]						
Wall covering / treatments	Dispersion paint.					
Ceiling material (inside)	Acoustic panes					
Space above acoustic tiles [cm]	30	30	30	30	30	30
Dust above acoustic panes?	No.	No.	No.	No.	No.	No.
Acoustic baffles	No.	No.	No.	No.	No.	No.
Any other ceiling type?						
Room lighting	Artificial and Daylight.					
Lighting location	Ceiling					
Type of artificial lighting	Fluorescent. t					
Control of lighting	Manual					
Visible mould in rooms	No.	No.	No.	No.	No.	No.
Damp spots	No damp spots.					
Mould odor in room	No.	No.	No.	No.	No.	No.
Area [m²]	16	24	16	16	16	24
Height [m]	2.6	2.6	2.6	2.6	2.6	2.6
Nb of work places	1	2	1	1	1	2
Fleecy material [m²]	3	2	1	2	2	2
Shelf length [m]	7	5	4	3	1	1
Window area [m²]	12	12	6	6	12	6.8
Office depth [m]	4	4	4	4	4	4
Nb. of laser printers	0	0	0	0	0	1
Nb. of photocopiers	0	0	0	0	0	0
Nb. of VDUs	1	2	1	1	1	2
Acceptable access for cleaning?	Yes	Yes	Yes	Yes	Yes	Yes
Door to corridor open?	Open	Open	Closed	Open	Open	Open
VDU with reflection	0	0	0	0	0	1
Nb of VDU with glare	0	0	0	0	0	0

There are are two ventilation systems. Only fresh air is blown int the office rooms while in central room (without window) there is a recirculation of air coming from the office roms.

Questionnaire

General	Total/Nr	Mean	Stdev	Percentage
Questionnaires distributed	100			
Questionnaires returned	94			94%
Age	94	40.11	9.50	
Number of female occupants	49			53%
Number of male occupants	44			47%
Time at desk before filling questionnaire	93	2.85	1.23	
Managerial work	31			33%
Specialist skill	17			18%
Clerical	41			44%
Other	5			5%
Time spent in the building [years]	93	5.19	5.75	
Time spent in the room [years]	92	2.14	4.04	
Hours per day at the desk	93	7.54	1.86	
Paid hours per week	90	44.19	11.63	
Hours at VDU per week	82	24.05	12.67	
Days per month in the building	91	14.88	8.01	
Number of people in the room	91	0.75	1.65	
Rooms without windows	3			3%
Rooms with windows	91			97%
Distance from the window	87	1.28	1.30	
People opening the window	9			10%
People not opening the window	82			90%

Health

Health during past month		Symptom present for			Better away	
	Answers	1-5 Days	6-10 Days	>10 days	yes	no
Dry eyes	91	23	18	14	49	5
Watering eyes	88	15	3	4	19	4
Stuffy nose	91	37	14	16	40	26
Runny nose	90	21	5	8	17	18
Dry throat	93	31	20	8	43	14
Chest tightness	91	11	2	1	8	7
Flu-like symptoms	91	35	11	6	25	23
Dry skin	91	15	9	38	29	28
Rash or irritated skin	91	11	3	5	10	8
Headaches	93	42	15	4	40	21
Lethargy	91	42	16	10	42	25
Other symptoms	80	2	3	4	10	0
Season when worst		Spring	Summer	Autumn	Winter	Any
(numbers of answers)	81	2	1	1	30	47
Part of the day when worst		Morning	Afternoon	Evening	Any	
(numbers of answers)	81	6	19	10	46	

Health now	Symptom present		In building			Severity	
	Total/Nr	Nb of yes	Better	Same	Worst	Mean	Stdev
Dry eyes	93	28	0	12	16	3.11	1.64
Watering eyes	90	5	0	2	3	3.60	0.23
Stuffy nose	93	36	1	16	17	3.31	0.55
Runny nose	91	13	0	10	3	3.62	1.14
Dry throat	93	32	0	13	19	3.19	0.49
Chest tightness	90	7	0	3	5	3.13	0.56
Flu-like symptoms	92	17	1	12	4	3.35	1.24
Dry skin	93	47	0	33	13	3.70	0.35
Rash or irritated skin	90	9	1	6	2	3.11	0.44
Headaches	93	11	0	3	7	3.20	1.39
Lethargy	92	27	2	11	13	3.39	0.48
Other symptoms	84	6	0	3	4	4.57	0.50

Frequency of building related symptoms

Only symptoms which disappear out of building are taken into account in this table. For each symptom, the frequency is the ratio of the number of person presenting the symptom to the total number of answers..

Symptom	Last month	Now
Dry eyes	54%	30%
Watering eyes	21%	6%
Stuffy nose	44%	37%
Runny nose	19%	14%
Dry throat	47%	35%
Chest tightness	9%	9%
Flu-like symptoms	29%	18%
Dry skin	34%	51%
Rash or irritated skin	11%	9%
Headaches	43%	10%
Lethargy	47%	26%
Other symptoms	12%	7%

Measured relative humidity during the audit day was 28% on the average. This may explain the symptom realted to dryness.

Environmental conditions

Environmental conditions past month	Total/Nr	Mean	Stdev
Level of thermal comfort	88	-0.16	1.11
Indoor air acceptability	93	0.69	2.93
Comfort temperature	93	2.80	1.60
Temperature variation	86	4.16	1.16
Air movement	87	4.02	1.85
Air humidity	92	2.09	1.07
Air stuffiness	92	4.70	1.95
Air odor	92	3.26	1.97
Lighting	92	2.82	1.95
Noise	92	2.50	1.73

Level of thermal comfort are on a -3 to+3 scale, Indoor air acceptability is on a -5 to+5 scale, while other votes are on a 1 to 7 scale.

Environmental conditions now	Total/Nr	Mean	Stdev
Level of thermal comfort	92	-0.23	0.88
Indoor air acceptability	93	1.35	2.71
Comfort temperature	92	2.50	1.48
Air movement	89	3.82	1.62
Air humidity	89	2.54	1.06
Air stuffiness	91	3.97	1.80
Air odor	89	2.81	1.85
Light brightness	88	3.94	1.07
Light flickering	88	1.77	1.31
Glare	90	2.43	1.66
Light uneven	90	3.99	1.02
Lighting satisfactory	91	2.43	1.62
Noise from ventilation	88	2.43	1.78
Other noise	88	3.14	1.74
Noise satisfactory	90	2.63	1.72

As shown on next table, most environmental conditions were found acceptable, except IAQ, air dryness, air odour and glare. The recirculation is certainly one of the reason for a poor IAQ acceptability.

Environmental conditions: evaluation

Criterion	Past month μ	Past month σ	Now μ	Now σ	Conclusions
Thermal Comfort	-0.2	1.1	-0.2	0.9	Comfortable
Termperature	2.8	1.6	2.5	1.5	Comfortable
Termperature variations	4.2	1.2			Nice
IAQ acceptability	0.7	2.9	1.4	2.7	Unacceptable
Air movement	4.2	1.2	3.8	1.6	Nice
Air humidity	4.0	1.9	2.5	1.1	Dry
Air stuffiness	2.1	1.1	4.0	1.8	Acceptable
Air odor	4.7	1.9	2.8	1.9	Smelly
Light brightness			3.9	1.1	Fine
Light flickering			1.8	1.3	Very stable
Glare			2.4	1.7	Faint glare
Light uneven			4.0	1.0	Nice
Lighting satisfactory	2.8	2.0	2.4	1.6	Good
Noise from ventilation			2.4	1.8	No noise
Other noise			3.1	1.7	No noise
Noise satisfactory	2.5	1.7	2.6	1.7	Good

Health and direct environment

	Total/Nr	Nb yes	Percent
I have smoking neighbors	92	27	29%
I bring comments on my environment	84	38	45%
I had asthmatic problems	91	9	10%
I have suffered from eczema	91	24	26%
I have suffered with hay fever	91	25	27%
Do you smoke?	86	16	19%
Do you smoke in this room?	25	12	48%
Did you ever smoke?	68	21	31%

Estimation of occupant's influence on indoor conditions

μ is the average vote on a 1 (no influence, unsatisfactory) to 7 (total influence, satisfactory) scale. σ is the standard deviation of the votes within the population.

Influence on	μ	σ	Conclusions
-temperature	4.1	2.2	Some influence
-ventilation	1.8	1.7	No influence
-lighting	4.1	2.2	Some influence
Cleanliness	5.3	1.7	Clean

Building symptom indices

Uncorrected BSI's			Past month		Today	
		Number	Short list	Full list	Short list	Full list
Women	All women	49	3.4	4.7	2.5	3.1
	Managers	5	3.0	3.8	3.0	3.6
	Specialists	4	4.0	4.8	2.5	3.0
	Clerical	38	3.5	4.8	2.3	3.0
	Others	2	4.5	5.0	3.0	3.0
Men	All men	43	1.6	2.2	1.3	1.7
	Managers	25	1.6	2.2	1.2	1.6
	Specialists	13	1.3	1.5	1.1	1.2
	Clerical	2	3.0	4.5	2.5	4.0
	Others	3	0.7	0.7	1.3	2.3

The BSI are high for the women.

Global building symptom indices		Number	Value
Last month, short list	BSI fs	92	2.60
Last month, full list	BSI ff	92	3.45
Last month, short list, corrected	BSI fsc	92	2.65
Last month, full list, corrected	BSI ffc	92	3.78
Today, short list	BSI ss	92	1.87
Today, full list	BSI sf	92	2.40
Today, short list, corrected	BSI ssc	92	2.09
Today, full list, corrected	BSI sfc	92	2.89

Correction factors are based on female clerical.

Sensory measurements

Sensory evaluation	Offices		Supply air		Adjacent 1		Adjacent 2	
Perceived air quality	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	6.0	1.8	3.0	1.1				
Location 2	7.8	2.3	3.0	1.1				
Location 3	4.8	1.9	3.0	1.1				
Location 4	5.6	2.3	3.0	1.1				
Location 5	4.1	1.3	3.0	1.1				
(Location 6)					6.4	1.6	5.6	1.5
Average	5.7	1.9	3.0	1.1	6.4	1.6	5.6	1.5
Outdoor air	1.4	0.6						

General Indoor Air Quality Measurements

Chemical analysis of air	Offices		Supply	air	Adjacent	1	Adjacent	2
Carbon dioxide [ppm]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	736	58.	360	28.				
Location 2	680	54.						
Location 3	590	47.						
Location 4	701	56.						
Location 5	736	58.						
(Location 6)					530	42		
Average	688.6	55.0 88	360	28.	530	42.		
Outdoor air	360							
Carbon monoxide [ppm]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	<1							
Location 2	5							
Location 3	<1							
Location 4	<1							
Location 5	<1							
(Location 6)								
Average	1							
Outdoor air	0							
Particulate matter [mg/m3]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	0	0.02						
Location 2	0.17	0.02						
Location 3	0.09	0.02						
Location 4	0	0.02						
Location 5	0	0.02						
(Location 6)								
Average	0.052	0.02						
Outdoor air								
TVOC[mg/m3] Toluene equiv	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	0.14	0.01	0.17	0.02				
Location 2	0.18	0.02						
Location 3	0.17	0.02						
Location 4	0.18	0.02						
Location 5	0.14	0.02						
(Location 6)					0.22	0.02		
Average	0.16	0.02	0.17	0.02	0.22	0.02		
Outdoor air	0.19				0.05			

Building CH-E **Carbon dioxide cont. meas.**	Average ppm	SD ppm	Geomean ppm	GSD	Median ppm	Max. ppm
Location 4	701	81	697	1.12	693	864

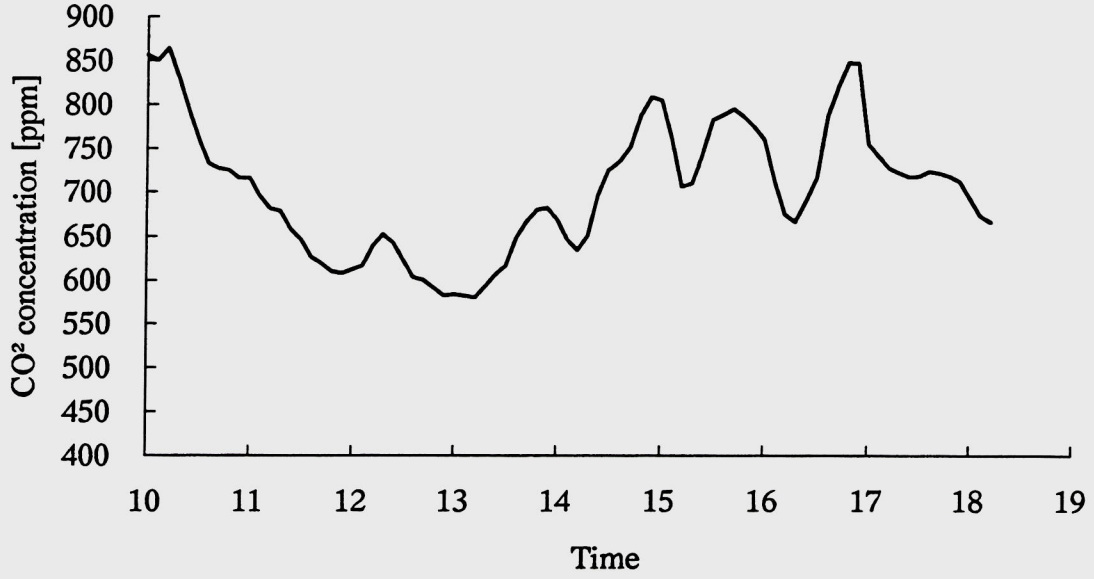


Figure E1: Carbon dioxide concentration at location 4 during the audit day.

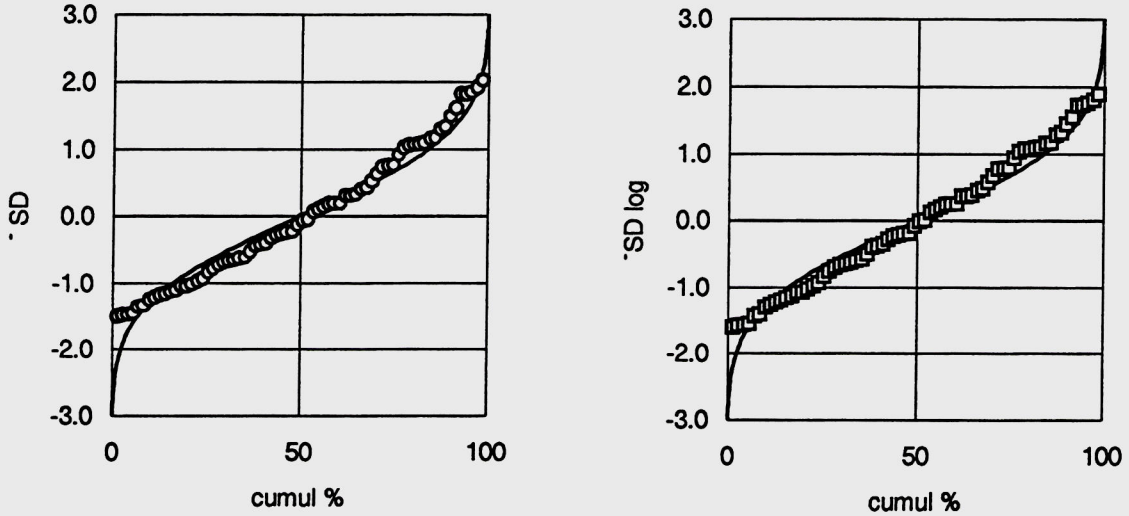


Figure E2: Cumulated frequencies of CO_2 concentrations. Left: all values. Right: selected values.

The variation is considerable, taking into account the fact that this is not a naturally ventilated building. The pattern is not randomly distributed, the distribution diagrams are trimmed at both ends. A morning high of 850 ppm at 10h00 is followed by a steady decrease to 600 ppm by lunchtime, while the afternoon is a sequence of rise and fall episodes with an amplitude of ca. 100 ppm superimposed on a steadily rising trend. The events in that sequence may occur with an apparent period of 40-60 min. No indication of a particular regulation of the air conditioning system could explain this behaviour.

VOC: compound	Concentration [µg/m3]
acetone	24
toluene	19
m-xylene	14
aliphatic C7H16	12
C5H2O8 ester	11
1,1,1-trichlorethane	10
acetic acid ?	9
acet.acid eth.ester	6
2-methyl-pentane	6
dichloro methane	5
o-xylene	5
trimethyl-benzene	5
p-xylene	4
benzaldehyde	4
?	4

This building presents low concentrations ov very common VOCs

General Indooor Climate measurements

Continuous measurements	Location Nr.	4				
	Start time	Stop time	µ	σ	Min	Max.
Air temperature 0,1 m [°C]	10:00	18:12	21.5	0.2	21.1	22.0
Air temperature 0,6 m [°C]	10:00	18:12	22.8	0.5	21.8	23.6
Air temperature 1,1 m [°C]	10:00	18:12	23.0	0.5	22.1	23.9
Operative temperature [°C]	10:00	18:12	22.3	0.5	21.3	23.3
Relative humidity [%]	10:00	18:12	40	2	37	44
Carbon dioxide [ppm]	10:00	18:12	703	75	580	864

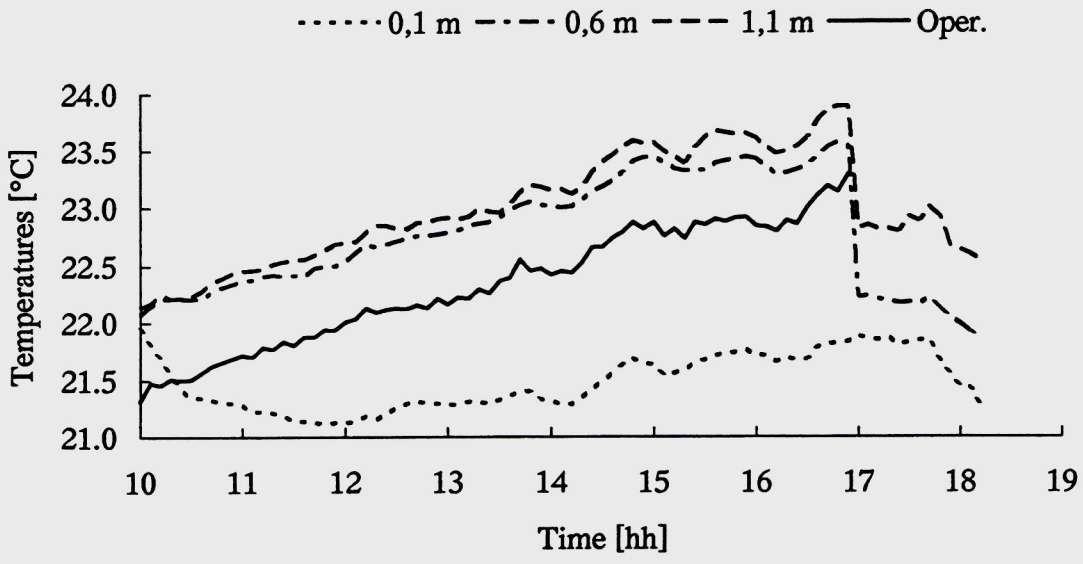


Figure E2: Temperatures at location 4 during the audit day. Ventilation is stopped a 17:00.

Air velocity [m/s] at	0,1 m		0,6m		1,1m	
	μ	σ	μ	σ	μ	σ
Location 1	0.10		0.10		0.11	
Location 2	0.08		0.08		0.10	
Location 3	0.07		0.07		0.07	
Location 4	0.14		0.11		0.06	
Location 5	0.07		0.08		0.14	
(Location 6)	0.12		0.12		0.08	
Average	0.10		0.09		0.09	

Air temperatures at	0,1 m	0,6m	1,1m	Supply air
Location 1			23.1	
Location 2			24.3	
Location 3			23.8	
Location 4	21.4	22.9	23.0	
Location 5			23.8	
(Location 6)			23.3	
Average	21.4	22.9	23.6	
Outside air				

Mean radiant temperature	At 1,1 m	Calculated	Operative temperature Measured	Calculated
Location 1		17.4	20.4	
Location 2		18.2	21.4	
Location 3		14.5	19.3	
Location 4		21.6	22.3	
Location 5		15.6	20.0	
(Location 6)		18.5	21.0	
Average		17.6	20.7	

In our cases, mean radiant temperature was always calculated from air and operative temperatures.

Relative Humidity	1,1 m	Supply air	Adj. room
Location 1	29		
Location 2	28		
Location 3	28		
Location 4	29		
Location 5	28		
(Location 6)	28		
Average	28		
Outdoor air			

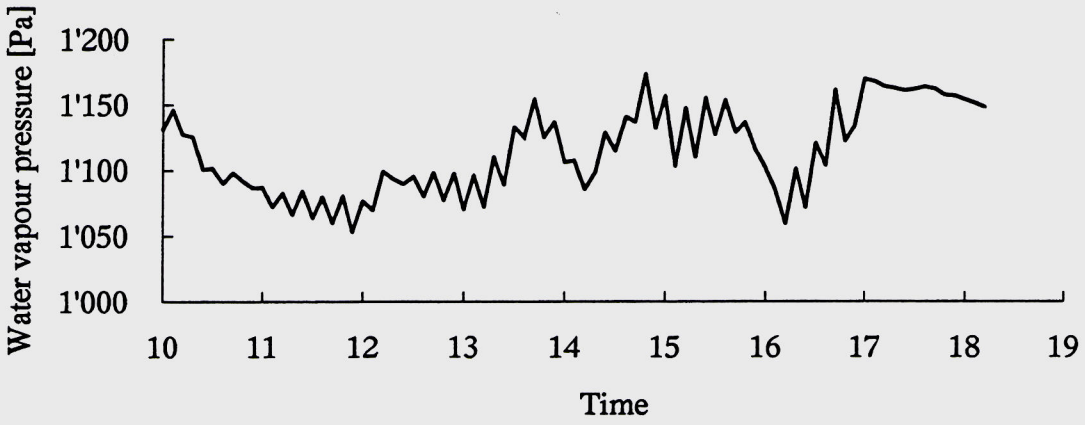


Figure E3: Water vapour pressure at location 4 during the audit day. This parameter is tightly controlled (±5%) by the air conditioning system.

Noise [dB (A)]	Office	Note
Location 1	40	
Location 2	55	
Location 3	35	Empty room
Location 4	55	
Location 5	55	
(Location 6)	55	
Average	49	
Outdoor noise	53	

Ventilation measurements
$

Air flow rates in ventilation system [m³/h]	Planned	Measured	±
Total air flow rate into building	64'000	44'000	4000
Fresh air flow rate into building		34'700	4000
Exhaust from building	62'000	10'000	2000
Recirculation rate		25%	5%
Estimated air change rate [/h]		2	
Estimated fresh air per person [l/(s·pers.)]		62	

Mesure at location Nr	1	2	3	4	5	Total
Air flow rate from ventilation	320		144	134	268	870
uncertainty	8		4	4	7	20
Air flow rate from hall	106		44	82	118	350
uncertainty	4		2	4	5	10
Air flow rate from other space	0		0	0	0	0
uncertainty	0		0	0	0	0
Infiltration	0		0	0	0	0
uncertainty	1		1	1	1	4

Air flow rates in m³/h. Total is total air flow rate into monitored area.

Pollution load

Source intensity	1	2	3	4	5	Total	
Olfactive load	30		5	8	0	40	Olf
uncertainty	20		7	9	10	40	Olf
Load from ventilation	5		3	2	7	20	Olf
uncertainty	7		3	3	6	20	Olf
Load from smokers	1		1	1	1	7	Olf
uncertainty	0		0	0	0	1	Olf
Load from occupants	1		1	1	1	6	Olf
uncertainty	0		0	0	0	1	Olf
Load from other sources	20		3	6	0	30	Olf
uncertainty	20		7	9	10	40	Olf
Carbon dioxide	142		36	60	125	360	l/h
uncertainty	6	0	3	3	6	20	l/h
corresponding to	8	0	2	3	7	20	persons
uncertainty	0	0	0	0	0	1	persons
Number of working places	1	2	1	1	1	6	persons

Total is total pollution load in monitored zone.

Weather conditions on audit day

Weather station	Wädenswil		
Date	2-02-94		
Description	Variable		
Weather data	Average	Maximum	Minimum
Temperature 0600-1200	2.4	3.7	1.4
Temperature 1200-1800	4.5	5.0	3.8
Relative humidity 0600-1200	70	72	68
Relative humidity 1200-1800	69	71	67
Wind speed 0600-1200	0.6	0.8	0.4

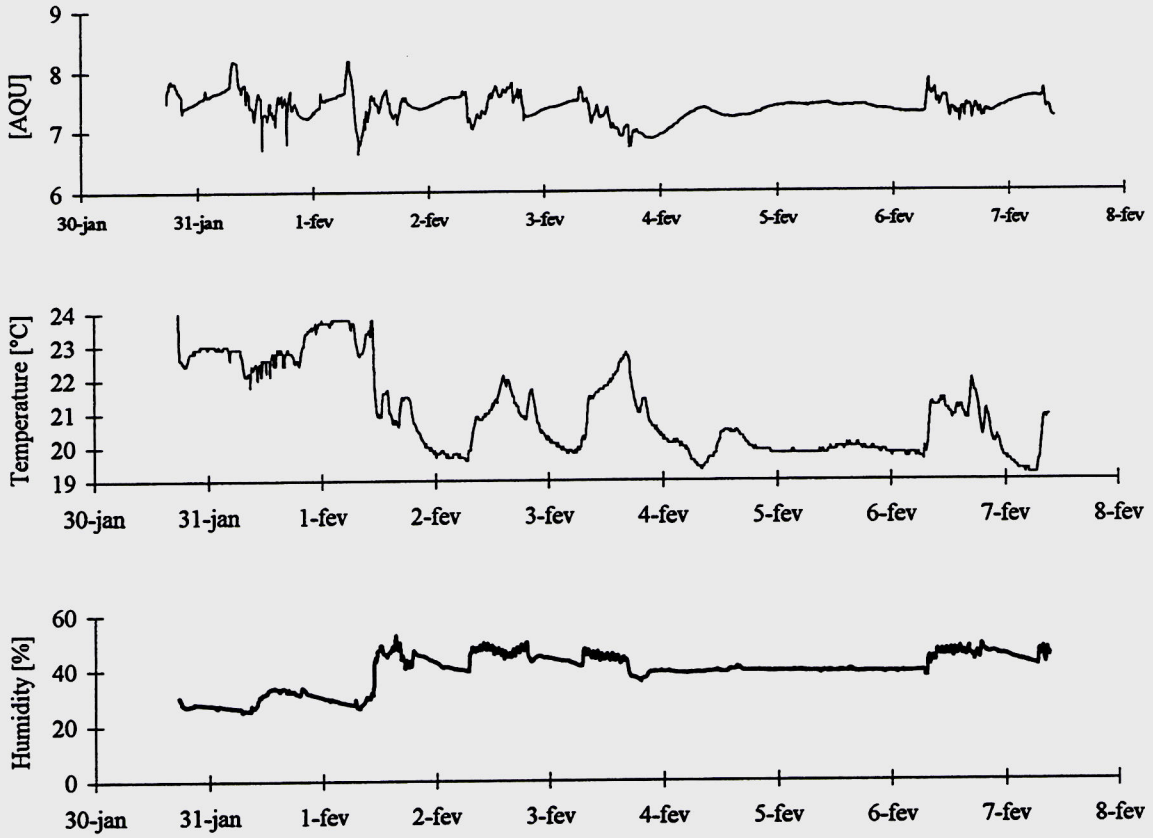
Energy consumption

Annual energy use [MJ]	1'993	1'992	1'991	1'990	Uncertainty
Extra light oil	506'754	654'700	543'641	437'851	26'787
Electricity	5'246'422	6'106'296	5'559'412	5'169'784	110'410
District heat	3'935'448	4'232'606	3'922'428	3'136'399	190'336
Total	9'688'624	10'993'603	10'025'481	8'744'034	327'532
Energy index [MJ/m²]	1'100	1'200	1'100	1'000	0
Heating index	521	527	487	430	0
Electric index	579	673	613	570	0

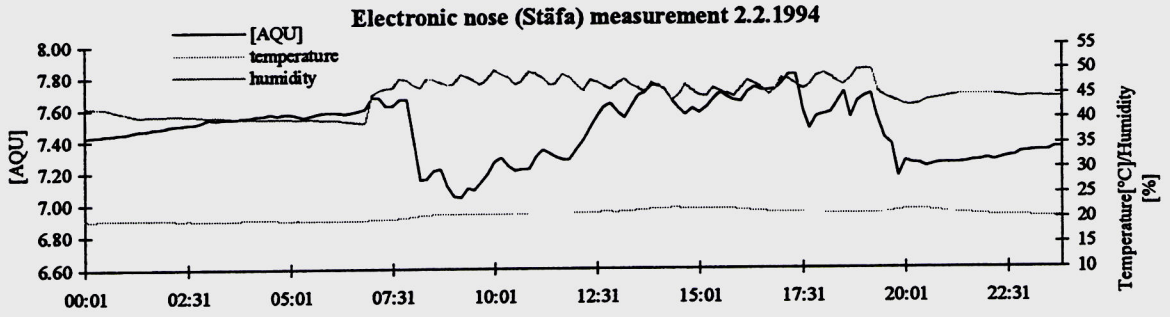
Note that most digits, resulting from transformation of liters, kg, kWh, etc into MJ, are not significant.

Additional measurements

IAQ Stäfa	Day 8:00-18:00				Night 20:00-06:00			
	Mean	Stdev.	Min.	Max.	Mean	Stdev.	Min.	Max.
Location e	7.34	0.29	6.56	7.79	7.72	0.15	7.50	7.93
Location f	7.34	0.26	6.63	7.87	7.47	0.07	7.36	7.58
Location d	7.29	0.24	6.61	7.83	7.62	0.13	7.44	7.82
Average	7.32	0.27	6.60	7.83	7.60	0.12	7.43	7.78



The audit day (Feb. 2) looks like any other week day. It is interessant to observe the automatic correction of humidity during the day.



The ventilation does not make the air better when it switches on at 7:30However, a part of the employees arrive at the office at this time.

Ions	time		+ ions			- ions		
office	begin	end	Mean	Max.	Min	Mean	Max.	Min
Location 1	11:05	12:32	208	315	51	137	245	11
Location 2	10:00	11:04	207	358	51	132	511	6
Location 3	12:34	13:43	210	341	105	135	220	31
Location 4	13:51	15:07	113	323	51	66	180	0
Location 5 (Location 6)	15:25	16:39	177	266	43	169	265	95
Average			183	321	60	128	284	29
Outdoor								

There is no largedifference of concentration between positive and negative ions.

Radon	Bq/m3
corridor	20
Location 2	19
Location 4	15
inlet	20
outlet	19

Radon concentration is very small.

BUILDING F

General information

1. Building identification.	F		
3. Situation	Downtown.	7. Number of floors	6
4. Traffic within 200 m.	Busy through road.	area of each floor (m2)	5'830
		number of offices	1'500
5. Near sources of pollution	Parking garage.	number of employees	800
	0	8. Year of building completion	1'958
6. Activities besides office work	Laboratory.	Year of total renovation	
9. No. of floors beneath ground	2	Year when user entered	1'958
		10. Position of solar shadings	Between glazing.
Roof tilt angle	Flat roof	Solar shadings: movement	Individual.
11. Number of glazing	Triple pane.	12. Modification of?	
Glazing type	Light reflecting.	Flooring	None
13. Furniture made of	Veneered chip board.	Insulation	None
Age of furniture	More than three years.	Wall or ceiling lining	None
14. Large green plants	No large green plants.	Windows	None
Plants treatment	No treatement.	Heating system	None
		Ventilation system	None
15. Smoking	Allowed in separate rooms.	16. Office activities	
17. Cleaning frequency		solvents	No solvents
Tables	Daily.	other chemicals	None
Walls	Less than once a month.	copying machines	Yes.
Washing floors	Less than once a month.	laser printers	Yes.
Vacuum cleaning	Daily.	person per VDU	1-2.
Mopping	0	carbonless paper use	No.
Sweeping	0		
Waxing	0		
Spring cleaning	Less than once a year.		
Look of the floors	Not so clean		
18. Detergent for cleaning	type/name	content pH	
cleaning agent linoleum	Shampoo Wetrox	carpet cleaner	Does not leave a film.
cleaning agent carpet	Antiwax Wetrox	wax	Polish or wax.
cleaning agent tables	Swipe	alcool	Leaves a film.
cleaning agent sanitary	Caletin		Does not leave a film.

Installation

1. Installation identification			
2. Room heating Location of heating	Air heating. Supply of warm air	3. Room cooling	Supply of cooled air
4. Temperature control Night set back	Adjustable wall thermostat. No.	5.Ventilation of rooms Windows	Simple balanced system. Windows can, but may not be opened.
6. Design outdoor air change Lowest outdoor air supply 8. Equipment vent. system Recirculation [%] Humidification system	0,5 to 1 per hour. l/s·pers <75 Spray.	7. Position air intake height above ground distance from exhaust distance from cooling towers	On the roof. 30 vert. 5 hor. 20 vert. 5 hor. 15
Water purification Cooling type	None. Lake water		
Heat recovery	None.		
9. Ventilation system on/off Sensors for demand control	Manually. No such control.		
Operating at: full performance 100% recirculation Partial recirculation	From 00:00 00:00	to 23:59 23:59	days per week 7 Variable %return air
10. Duct material Duct insulation	Galvanised steel. Internal insulation.		
11. Service Air intake filter Recirculation duct filter	Class Eu1	Last replacement 1-11-93 1-10-91	Needing service No. No.
Central unit filter Supply filter Induction / fan coil filter	Eu4	1-10-93	No.
Heating batteries Cooling batteries Heat exchanger Humidifier	Last cleaning 1-10-93 1-10-93 1-10-93 1-10-93	Needing service No. No. No. No.	
Ducts Air outlets in rooms Air inlet in rooms		No. No. Yes.	
12. Location air supply inlets Location air outlets Designed ventilation principle	At windowsill. High. Mixing ventilation.		

Investigated rooms

Summary	1	2	3	4	5	6
Room name	301	302	305/6	307	308	Hall
Wall materials inside	Glass.					
Insulation material	Mineral wool.					
Thickness of insulation [cm]	4	4	4	4	4	
Felt carpet (needle) [%area]	100	100	100	100	100	100
Nap carpet [%area]						
Lacquered wood [%area]						
Vinyl (PVC) [%area]						
Linoleum [%area]						
Tiles [%area]						
Other (type here) [%area]						
Wall covering / treatments	Enamel paint.					
Ceiling material (inside surface)	Acoustic panes.					
Space above acoustic tiles [cm]	40	40	40	40	40	40
Dust above acoustic panes?	Yes.	Yes.	Yes.	Yes.	Yes.	Yes.
Acoustic baffles below ceiling?	No.	No.	No.	No.	No.	No.
Any other ceiling type?						
Room lighting	Artificial and Daylight.					
Lighting location	Ceiling and individual.					
Type of artificial lighting	Fluorescent.					
Control of lighting	Manual.					
Visible mould growth in rooms	No.	No.	No.	No.	No.	No.
Damp spots	No damp spots.					
Mould odor in room	No.	No.	No.	No.	No.	No.
Area [m²]	27	26.64	53.28	26.64	47.73	
Height [m]	2.9	2.9	2.9	2.9	2.9	2.9
Nb of work places	2	2	4	2	4	0
Fleecy material [m²]	0	0	0	0	0	0
Shelf length [m]	1.6		25.2	5.6	14.3	0
Window area [m²]	5.92	5.92	11.84	5.92	11.84	0
Office depth [m]	7	7	7	7	7	0
Nb. of laser printers	2	1	1	1	2	0
Nb. of photocopiers	0	0	0	0	1	0
Nb. of VDUs	2	2	5	2	3	0
Acceptable access for cleaning?	Yes	Yes	Yes	Yes	Yes	Yes
Door to corridor open?	Closed	Closed	Open	Open	Open	
Nb. of VDU with reflection	0	0	0	0	0	0
Nb of VDU with glare	0	0	4	2	1	0

All the air is extracted from the room to the corridor and later in the central staircase. At the top of the staircase is an exhaust fan. A part of this air is recirculated.

The 5 offices are separated by walls. Room 308 has only air coming from ventilation and infiltration. The other offices also get some air from the corridor.

Questionnaire

General	Total/Nr	Mean	Stdev	Percentage
Questionnaires distributed	135			
Questionnaires returned	115			85%
Age	115	42.76	12.39	
Number of female occupants	40			35%
Number of male occupants	75			65%
Time at desk before filling questionnaire	109	2.77	3.47	
Managerial work	14			12%
Specialist skill	52			45%
Clerical	35			30%
Other	14			12%
Time spent in the building [years]	113	10.13	9.94	
Time spent in the room [years]	114	4.52	6.63	
Hours per day at the desk	113	9.17	14.74	
Paid hours per week	112	41.29	6.54	
Hours at VDU per week	114	19.40	14.62	
Days per month in the building	115	21.17	5.47	
Number of people in the room	113	2.24	2.66	
Rooms without windows	0			0%
Rooms with windows	115			100%
Distance from the window	113	2.07	1.16	
People opening the window	70			61%
People not opening the window	45			39%

Health

Health during past month		Symptom present for			Better away	
	Answers	1-5 Days	6-10 Days	>10 days	yes	no
Dry eyes	113	29	7	13	38	15
Watering eyes	115	26	5	2	23	14
Stuffy nose	114	30	9	15	26	27
Runny nose	115	34	6	8	19	25
Dry throat	115	36	11	13	28	29
Chest tightness	115	13	4	1	17	7
Flu-like symptoms	115	44	8	1	12	36
Dry skin	114	14	9	26	26	25
Rash or irritated skin	114	8	4	7	7	16
Headaches	115	48	8	4	30	29
Lethargy	114	46	15	9	43	22
Other symptoms	106	8	4	11	15	7
Season when worst		Spring	Summer	Autumn	Winter	Any
(numbers of answers)	83	4	2	2	34	41
Part of the day when worst		Morning	Afternoon	Evening	Any	
(numbers of answers)	85	10	25	17	33	

Health now	Symptom present		In building			Severity	
	Total/Nr	Nb of yes	Better	Same	Worst	Mean	Stdev
Dry eyes	115	28	0	14	17	3.70	1.59
Watering eyes	115	5	1	7	2	2.33	0.23
Stuffy nose	115	35	3	19	16	3.54	0.57
Runny nose	114	17	3	8	8	3.79	1.12
Dry throat	115	38	0	23	17	3.30	0.47
Chest tightness	115	9	0	7	5	2.91	0.65
Flu-like symptoms	115	12	3	8	5	2.94	1.54
Dry skin	114	40	0	28	13	3.68	0.38
Rash or irritated skin	115	13	0	9	6	3.43	0.69
Headaches	115	11	0	8	7	3.73	2.01
Lethargy	115	20	0	10	10	3.10	0.48
Other symptoms	104	11	1	2	9	5.09	0.51

Frequency of building related symptoms

Only symptoms which disappear out of building are taken into account in this table. For each symptom, the frequency is the ratio of the number of person presenting the symptom to the total number of answers..

Symptom	Last month	Now
Dry eyes	34%	24%
Watering eyes	19%	4%
Stuffy nose	23%	30%
Runny nose	17%	16%
Dry throat	26%	34%
Chest tightness	15%	8%
Flu-like symptoms	11%	11%
Dry skin	23%	33%
Rash or irritated skin	6%	10%
Headaches	27%	12%
Lethargy	40%	18%
Other symptoms	15%	12%

Environmental conditions

Environmental conditions past month	Total/Nr	Mean	Stdev
Level of thermal comfort	108	0.05	1.72
Indoor air acceptability	114	1.90	2.32
Comfort temperature	114	3.37	1.81
Temperature variation	112	4.63	1.51
Air movement	111	3.96	1.70
Air humidity	114	2.68	1.15
Air stuffiness	114	3.39	1.59
Air odor	115	3.03	1.84
Lighting	115	2.42	1.86
Noise	114	2.75	1.68

Level of thermal comfort are on a -3 to+3 scale, Indoor air acceptability is on a -5 to+5 scale, while other votes are on a 1 to 7 scale.

Environmental conditions now	Total/Nr	Mean	Stdev
Level of thermal comfort	115	0.00	1.44
Indoor air acceptability	115	2.50	2.44
Comfort temperature	115	2.69	1.58
Air movement	114	3.73	1.44
Air humidity	114	2.76	1.10
Air stuffiness	115	2.93	1.53
Air odor	114	2.11	1.52
Light brightness	113	3.81	0.90
Light flickering	111	1.61	1.16
Glare	114	2.11	1.56
Light uneven	112	3.99	0.93
Lighting satisfactory	114	2.27	1.72
Noise from ventilation	114	2.55	1.66
Other noise	114	3.49	1.65
Noise satisfactory	113	2.94	1.69

As shown on next table, most environmental conditions are found acceptable, except IAQ, air dryness, air odour and glare. The air problem probably comes from recirculation and tobacco smoke.

Environmental conditions: evaluation

Criterion	Past month μ	Past month σ	Now μ	Now σ	Conclusions
Thermal Comfort	-0.2	1.1	-0.2	0.9	Comfortable
Termperature	2.8	1.6	2.5	1.5	Comfortable
Termperature variations	4.2	1.2			Nice
IAQ acceptability	0.7	2.9	1.4	2.7	Just acceptable
Air movement	4.2	1.2	3.8	1.6	Nice
Air humidity	4.0	1.9	2.5	1.1	Dry
Air stuffiness	2.1	1.1	4.0	1.8	Acceptable
Air odour	4.7	1.9	2.8	1.9	Smelly
Light brightness			3.9	1.1	Fine
Light flickering			1.8	1.3	Very stable
Glare			2.4	1.7	Faint glare
Light uneven			4.0	1.0	Nice
Lighting satisfactory	2.8	2.0	2.4	1.6	Good
Noise from ventilation			2.4	1.8	No noise
Other noise			3.1	1.7	No noise
Noise satisfactory	2.5	1.7	2.6	1.7	Good

Health and direct environment

	Total/Nr	Nb yes	Percent
I have smoking neighbors	92	27	29%
I bring comments on my environment	84	38	45%
I had asthmatic problems	91	9	10%
I have suffered from eczema	91	24	26%
I have suffered with hay fever	91	25	27%
Do you smoke?	86	16	19%
Do you smoke in this room?	25	12	48%
Did you ever smoke?	68	21	31%

Estimation of occupant's influence on indoor conditions

μ is the average vote on a 1 (no influence, unsatisfactory) to 7 (total influence, satisfactory) scale. σ is the standard deviation of the votes within the population.

Influence on	μ	σ	Conclusions
-temperature	4.1	2.2	Some influence
-ventilation	1.8	1.7	No influence
-lighting	4.1	2.2	Some influence
Cleanliness	5.3	1.7	Clean

Despite the fact that ocupants can open the windows, they feel that they have no influence on ventilation, because window opening is not recommended. This building is also felt cleaner than G, but does not seem to the audit team that F is really cleaner.

Building symptom indices

Uncorrected BSI's		Number	Past month Short list	Past month Full list	Today Short list	Today Full list
Women	All women	49	3.4	4.7	2.5	3.1
	Managers	5	3.0	3.8	3.0	3.6
	Specialists	4	4.0	4.8	2.5	3.0
	Clerical	38	3.5	4.8	2.3	3.0
	Others	2	4.5	5.0	3.0	3.0
Men	All men	43	1.6	2.2	1.3	1.7
	Managers	25	1.6	2.2	1.2	1.6
	Specialists	13	1.3	1.5	1.1	1.2
	Clerical	2	3.0	4.5	2.5	4.0
	Others	3	0.7	0.7	1.3	2.3

Global building symptom indices		**Number**	**Value**
Last month, short list	BSI fs	92	2.60
Last month, full list	BSI ff	92	3.45
Last month, short list, corrected	BSI fsc	92	2.65
Last month, full list, corrected	BSI ffc	92	3.78
Today, short list	BSI ss	92	1.87
Today, full list	BSI sf	92	2.40
Today, short list, corrected	BSI ssc	92	2.09
Today, full list, corrected	BSI sfc	92	2.89

Correction factors are based on female clerical.

Sensory measurements

Sensory evaluation	**Offices**		**Supply air**		**Adjacent 1**		**Adjacent 2**	
Perceived air quality	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	5.0	1.6	3.3	1.9				
Location 2	6.0	1.9	3.3	1.9				
Location 3	7.8	3.3	3.3	1.9				
Location 4	6.5	2.5	3.3	1.9				
Location 5	6.9	3.2	3.3	1.9				
(Location 6)					9.5	3.3		
Average	6.4	2.5	3.3	1.9	9.5	3.3		
Outdoor air	0.5	0.7						

General Indoor Air Quality Measurements

Chemical analysis of air	Offices		Supply air		Adjacent 1		Adjacent 2	
Carbon dioxide [ppm]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	770	61.			890	71.2		
Location 2	800	64			890	71.2		
Location 3	880	70.			890	71.2		
Location 4	880	70.			890	71.2		
Location 5	810	64.			890	71.2		
(Location 6)								
Average	828	66.24	700	56	890	71.2		
Outdoor air	400	32						
Carbon monoxide [ppm]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	<1		<1		<1			
Location 2	<1		<1		<1			
Location 3	<1		<1		<1			
Location 4	<1		<1		<1			
Location 5	<1		<1		<1			
(Location 6)								
Average	<1		<1		<1			
Outdoor air	<1							
Particulate matter [mg/m3]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	0.34	0.02	<1		0.28	0.02		
Location 2	0.21	0.02	<1		0.28	0.02		
Location 3	<1		<1		0.28	0.02		
Location 4	0.25	0.02	<1		0.28	0.02		
Location 5	0.15	0.02	<1		0.28	0.02		
(Location 6)								
Average	0.24	0.02			0.28	0.02		
Outdoor air								
TVOC[mg/m3] Toluene equiv	μ		μ		μ		μ	σ
Location 1	0.53	0.02	0.58	0.02	1.98	0.06		
Location 2	0.97	0.03						
Location 3	0.71	0.02						
Location 4	2.30	0.06						
Location 5	4.58	0.12						
(Location 6)								
Average	1.82	0.05	0.58	0.02	1.98	0.06		
Outdoor air	0.42	0.03						

Building CH-F CO_2 continuous meas.	Average ppm	SD ppm	Geomean ppm	GSD	Median ppm	Max. ppm
Location 3	645	45	643	1.07	643	747

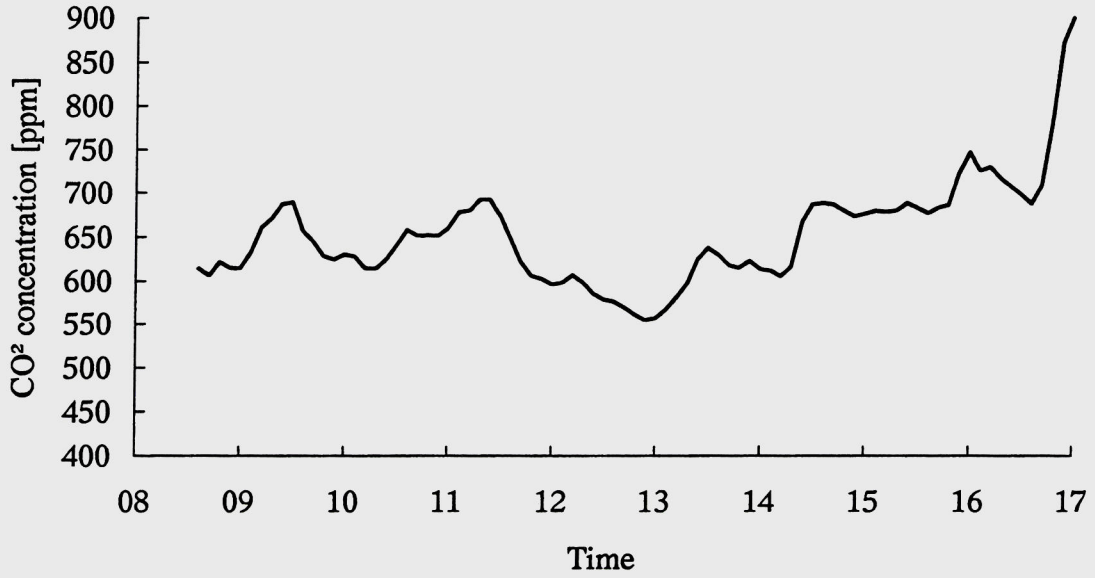


Figure F1: Carbon dioxide concentration at location 3 during the audit day. Strong increase at 17 h may be caused by auditing staff when dismantling the instruments.

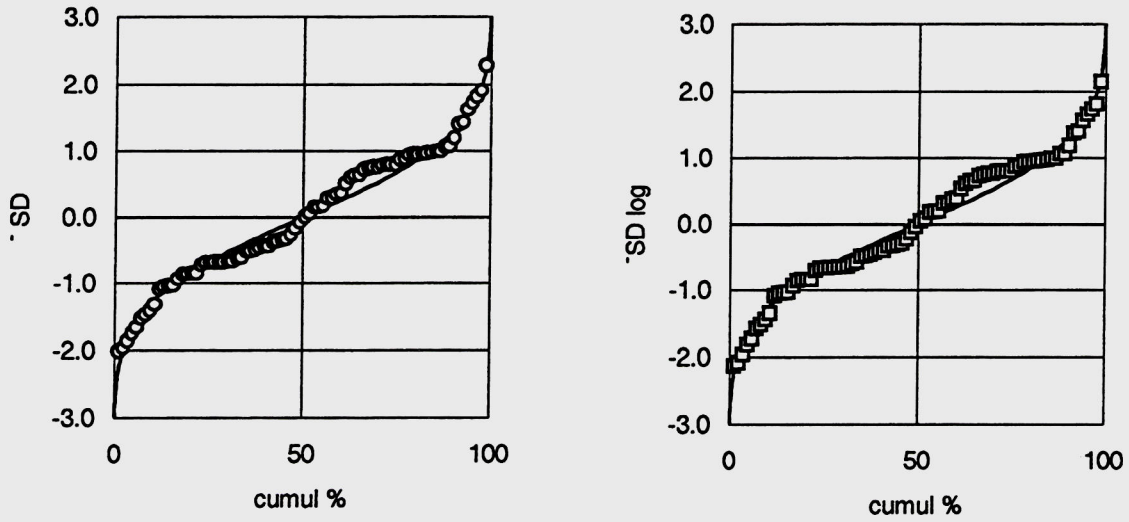


Figure F2: Cumulated frequencies of CO_2 concentrations. Left: all values. Right: selected values.

The concentration fluctuates moderately around a very slowly upward drifting line. The distribution fits the normal curve correctly, with the possible exception that two comparably abundant data populations seem to be present, centered about ±0.7 standard deviations away from the mean.

VOC: compound	Concentration [µg/m3]
1-butanol	84
n-heptane	81
aliphatic C7H16	81
toluene	57
m-xylene	33
acetone	28
C5H2O8 ester	18
methyl-cyclohexane	14
L-Limonene	13
decane C10H22	12
acetic acid ?	12
trimethyl-benzene	11
aliphatic C7H16	10
o-xylene	10
p-xylene	10

The first three compounds are also found in relatively large concentration in building C. 1-Butanol is found only in F and C. These solvents come likely from fresh painting work performed in the building.

General Indooor Climate measurements

Continuous measurements	Location Nr.	3				
	Start time	Stop time	µ	σ	Min	Max.
Air temperature 0,1 m [°C]	08:36	17:00	21.0	0.2	20.6	21.3
Air temperature 0,6 m [°C]	08:36	17:00	22.2	0.2	21.8	22.7
Air temperature 1,1 m [°C]	08:36	17:00	23.1	0.2	22.5	23.5
Operative temperature [°C]	08:36	17:00	22.2	0.2	21.7	22.6
Relative humidity [%]	08:36	17:00	35	1	34	38
Carbon dioxide [ppm]	08:36	17:00	652	59	555	900

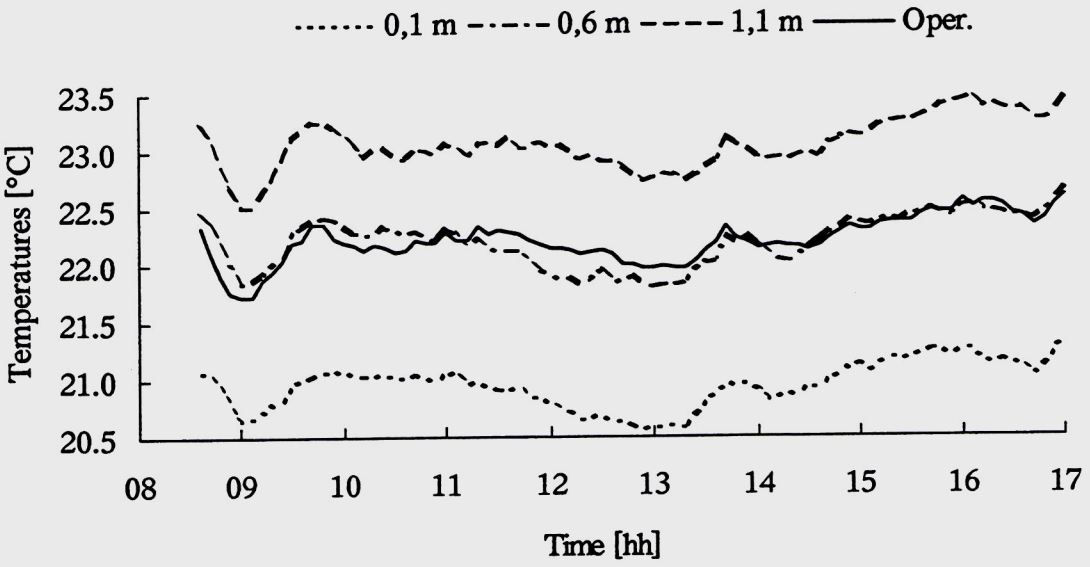


Figure F2: Temperatures at location 3 during the audit day.

Air velocity [m/s] at	0,1 m		0,6m		1,1m	
	μ	σ	μ	σ	μ	σ
Location 1	0.20	0.02	0.07	0.02	0.06	0.02
Location 2	0.08	0.02	0.05	0.02	0.07	0.02
Location 3	0.11	0.02	0.14	0.02	0.08	0.02
Location 4	0.33	0.02	0.25	0.02	0.09	0.02
Location 5	0.16	0.02	0.16	0.02	0.15	0.02
(Location 6)	0.15	0.02	0.32	0.02	0.17	0.02
Average	0.17	0.02	0.17	0.02	0.10	0.02

Air temperatures at	0,1 m	0,6m	1,1m	Supply air
Location 1			21.1	
Location 2			22.5	
Location 3			21.6	
Location 4			22.0	
Location 5			22.9	
(Location 6)			22.5	
Average			22.1	
Outside air	5			

Mean radiant temperature	At 1,1 m	Calculated	Operative temperature Measured	Calculated
Location 1		21.5	21.3	
Location 2		20.0	21.3	
Location 3		20.4	21.0	
Location 4		19.5	20.8	
Location 5		19.0	21.1	
(Location 6)				
Average		20.1	21.1	

In our cases, mean radiant temperature was always calculated from air and operative temperatures.

Relative Humidity	1,1 m	Supply air	Adj. room
Location 1	41		39
Location 2	45		39
Location 3	37		39
Location 4	41		39
Location 5	38		39
(Location 6)			
Average	40		39
Outdoor air			

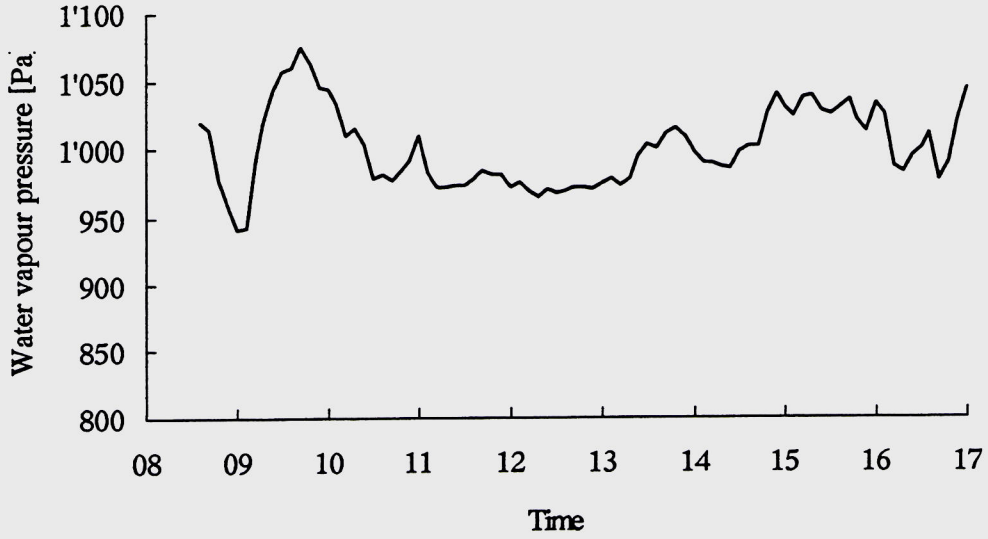


Figure F3: Water vapour pressure at location 3 during the audit day.

Noise [dB (A)]	Office	Adjacent
Location 1	48	
Location 2	42	
Location 3	42	
Location 4	45	
Location 5	47	
Average	45	
Outdoor noise		

Ventilation measurements

Air flow rates in ventilation system	Planned	Measured*	±	
Total air flow rate into building	300'000	170'000	15'000	m³/h
Fresh air flow rate into building	225'000	87'000	17'000	
Recirculated air flow rate	225'000	84'000	9'000	m³/h
Recirculation rate	75%	49%	10%	
Estimated air change rate [/h]	0.9	0.3		/h
Estimated fresh air per person [l/(s·pers.)]	26	30		l/s·person

* Three times the air flow rate measured on one of the three units. The system is very old (30 years), then is possible that the planned air flow rates were not so well defined.

Measure at location Nr	513	385	631	189	791	Total
Air flow rate from ventilation	510	385	630	190	790	2'510
uncertainty	10	9	20	40	20	100
Air flow rate from hall	43	33	144	560	47	830
uncertainty	1	2	4	70	5	90
Air flow rate from other space	0	0	0	0	0	0
uncertainty	0	0	0	0	0	0
Infiltration	0	0	0	0	0	0
uncertainty	1	1	1	1	1	5

Air flow rates in m³/h. Total is total air flow rate into monitored area. In the first two rooms the doors were closed all the time (air flow rate from hall are very small).

Pollution load

Source intensity	1	2	3	4	5	Total	
Olfactive total load	33	30	70	16	70	220	Olf
uncertainty	8	7	20	8	20	70	Olf
Olfactive load	20	30	70	-30	80	200	Olf
uncertainty	20	20	50	50	60	200	Olf
Load from ventilation	10	0	-10	-1	-10	0	Olf
uncertainty	20	10	30	8	40	100	Olf
Load from smokers	2	2	5	2	5	17	Olf
uncertainty	1	1	1	1	1	4	Olf
Load from occupants	2	2	4	2	4	14	Olf
uncertainty	1	1	1	1	1	4	Olf
Load from other sources	10	20	60	-30	70	100	Olf
uncertainty	20	20	50	50	60	200	Olf

Total is total pollution load in monitored zone.
In room 5 was much old paper.

Weather conditions on audit day

Weather station	Pully		
Date	15-02-94		
Description	Overcast		
Weather data	Average	Maximum	Minimum
Temperature 0600-1200	0.3	1.0	-0.1
Temperature 1200-1800	1.6	1.9	1.2
Relative humidity 0600-1200	84	87	83
Relative humidity 1200-1800	80	84	78
Wind speed 0600-1200	0.6	0.7	0.4

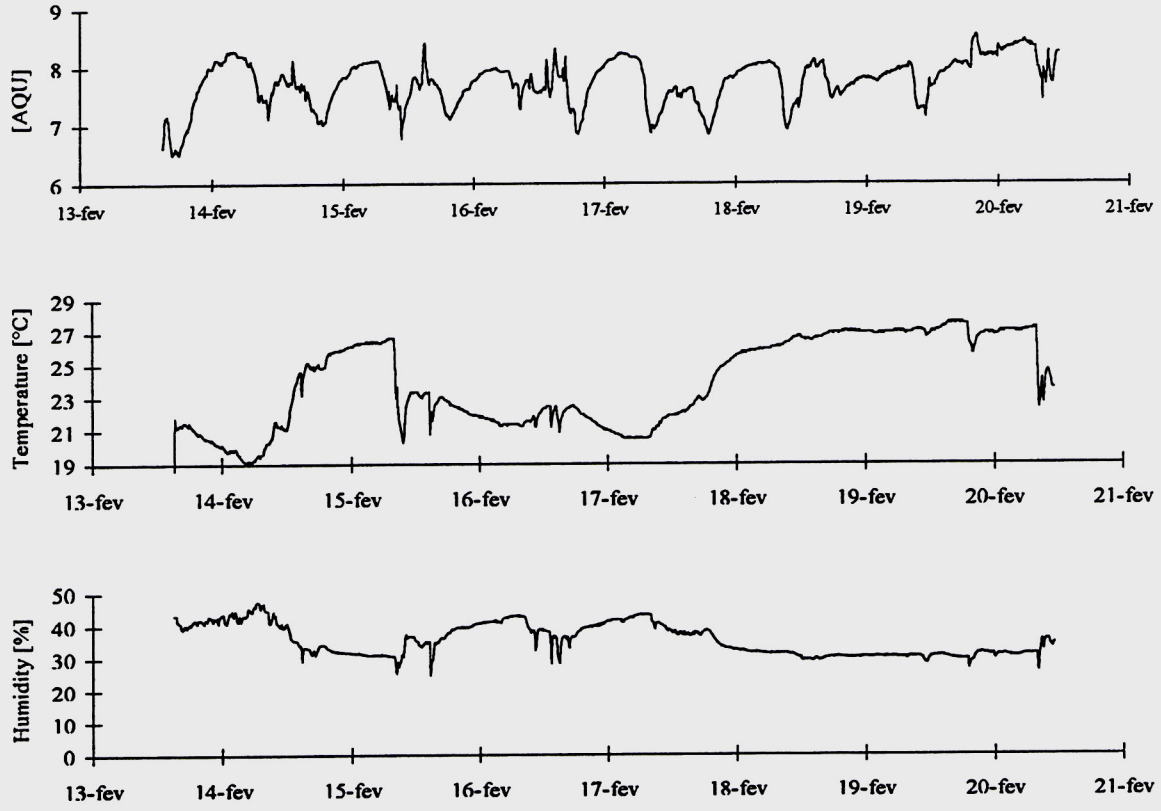
Energy consumption

Annual energy use [MJ]	in 1992	1'991	1'990	1'989	Uncertainty
Natural gas	32'717'763	36'204'566	33'709'765	33'632'696	1'703'310
Electricity	18'345'096	15'979'104	16'717'212	16'267'104	841'356
Total	51'062'859	52'183'670	50'426'977	49'899'800	2'544'666
Energy index [MJ/m²]	1'500	1'500	1'400	1'400	100
Heating index	976	1'043	922	935	100
Electric index	524	457	478	465	0

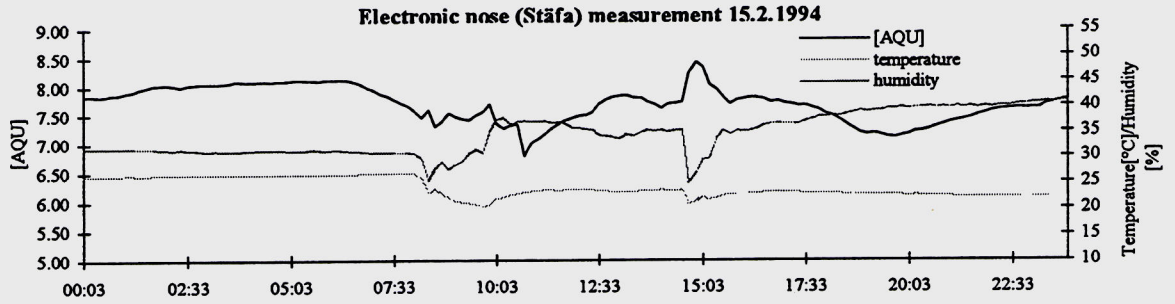
Note that most digits, resulting from transformation of liters, kg, kWh, etc into MJ, are not significant.

Additional measurements

IAQ Stäfa	Day 8:00-18:00				Night 20:00-06:00			
	Mean	Stdev.	Min.	Max	Mean	Stdev.	Min.	Max
Location a	7.61	0.29	6.78	8.42	7.74	0.24	7.16	8.00
Location b	7.26	0.28	6.74	7.62	7.68	0.21	7.15	7.89
Location c	7.52	0.48	6.54	8.53	8.10	0.29	7.36	8.37
Average	7.47	0.35	6.69	8.19	7.84	0.25	7.22	8.09



The audit day, 1994-02-15, looks more like a week-end day (Feb. 19 and 20) than like a normal working day.



Ions	time		+ ions			- ions		
office	begin	end	Mean	Max.	Min	Mean	Max.	Min
Location 1	09:49	10:45	278	401	5	210	378	85
Location 2	10:47	11:40	360	503	68	138	228	3
Location 3	11:46	12:39	300	376	190	141	225	31
Location 4	12:47	14:14	277	561	48	148	260	0
Location 5	14:20	15:31	225	383	1	125	215	33
Average			288	445	62	152	261	30

Radon	**Bq/m3**
Location 1	20
Location 6	15
Location 3	20
inlet	20
outlet	20

Very low radon concentration

BUILDING G

General information

1. Building identification.	G		
3. Situation	Downtown.	7. Number of floors	9
4. Traffic within 200 m.	Busy through road.	area of each floor (m2)	4'667
		number of offices	680
5. Near sources of pollution	Parking garage.	number of employees	800
	0	8. Year of building completion	1'976
6. Activities besides office work	Other.	Year of total renovation	
9. No. of floors beneath ground	2	Year when user entered	1'976
Roof tilt angle	Flat roof	10. Position of solar shadings	Inside.
		Solar shadings: movement	Central down, individually up.
11. Number of glazing	Double pane.	12. Modification of?	
Glazing type	Light reflecting.	Flooring	None
13. Furniture made of	Metal.	Insulation	None
Age of furniture	3 years or less.	Lining	None
14. Large green plants	Green leafed plants.	Windows	None
Plants treatment	No treatement.	Heating system	None
		Ventilation system	None
15. Smoking	Allowed in separate rooms.	16. Office activities	
		solvents	No solvents
		other chemicals	None
		copying machines	No.
17. Cleaning frequency		laser printers	Yes.
Tables	Once a week.	person per VDU	1-2
Walls	Less than once a month.	carbonless paper use	No.
Washing floors	Less than once a month.		
Vacuum cleaning	1 to 3 times a month.		
Mopping	Less than once a month.		
Sweeping	0		
Waxing	0		
Spring cleaning	Once a year.		
Time since last spring cleaning		10 months	
Look of the floors			
18. Detergent for cleaning	type/name	content pH	
cleaning agent linoleum	Shampoo Wetrok		Does not leave a film.
cleaning agent carpet	Antiwax Wetrox		Polish or wax.
cleaning agent tables	Swipe		Leaves a film.
cleaning agent sanitary	Caletin		Does not leave a film.

Installation

1. Installation identification			
2. Room heating Location of heating	Hot water heating. Fan coil units.	3. Room cooling	Local fan coil units.
4. Temperature control Night set back	Adjustable wall thermostat. Yes.	5.Ventilation of rooms Windows	Supply system. Windows can be opened.
6. Design outdoor air change Lowest outdoor air supply	More than 3 per hour. l/s·pers	7. Position air intake height above ground distance from exhaust distance from cooling towers	In the facade. 0 vert. 27 hor. 50 vert. hor.
8. Equipment vent. system Recirculation [%] Humidification system Water purification Cooling type Heat recovery	 0 Spray. UV lamp. Lake water Other.		
9. Ventilation system on/off Sensors for demand control	Automatically by a clock. No such control.		
Operating at:	From	to	days per week
full performance reduced performance stopped	04:00 00:00	20:00 04:00	5 5
100% recirculation			
Partial recirculation			
10. Duct material Duct insulation	Galvanised steel. Internal insulation.		
11. Service Air intake filter Recirculation duct filter Central unit filter Supply filter Induction / fan coil filter	Class Eu3 Eu7	Last replacement 1-10-93 1-10-93	Needing service No. No. No. No. No.
 Heating batteries Cooling batteries Heat exchanger Humidifier Ducts Air outlets in rooms Air inlet in rooms	Last cleaning 1-10-93 1-10-93 1-09-93	Needing service No. No. No. No. No. No. Yes.	
12. Location air supply inlets Location air outlets Designed ventilation principle	In the ceiling. Low. Displacement ventilation.		

After the audit, the building management decided to improve IAQ in this building and inspected the 17 year old fan coil units. They were so dirty that it was decided to dismount, clean and reinstall them.

Investigated rooms

Summary	1	2	3	4	5	6
Room name	575	576	577	578	579	Hall
Wall materials inside insulation	Metal.	Metal.	Metal.	Metal.	Metal.	
Insulation material	Fiberglas.	Fiberglas.	Fiberglas.	Fiberglas.	Fiberglas.	
Thickness of insulation [cm]	8	8	8	8	8	
Felt carpet (needle) [%area]	100	100	100	100	100	
Nap carpet [%area]						
Lacquered wood [%area]						
Vinyl (PVC) [%area]						
Linoleum [%area]						
Tiles [%area]						
Other (type here) [%area]						
Wall covering / treatments	Enamel paint.					
Ceiling material	Acoustic panes.					
Space above acoustic tiles [cm]	17	17	17	17	17	17
Dust above acoustic panes?	No.	No.	No.	No.	No.	No.
Acoustic baffles below ceiling?	No.	No.	No.	No.	No.	No.
Any other ceiling type?						
Room lighting	Artificial and Daylight.					
Lighting location	Ceiling and individual.				Ceiling.	
Type of artificial lighting	Fluorescent.					
Control of lighting	Manual.	Manual.	Manual.	Manual.	Manual.	Automatic.
Visible mould growth in rooms	No.	No.	No.	No.	No.	No.
Damp spots	No damp spots.					
Mould odor in room	No.	No.	No.	No.	No.	No.
Area [m²]	24.832	24.832	24.832	24.832	24.832	24.832
Height [m]	2.7	2.7	2.7	2.7	2.7	2.7
Nb of work places	2	2	2	2	3	0
Fleecy material [m²]	3	3	3	3	3	0
Shelf length [m]	13	12	12	12	12	0
Window area [m²]	7.2	7.2	7.2	7.2	7.2	0
Office depth [m]	6.4	6.4	6.4	6.4	6.4	0
Nb. of laser printers	2	1	0	0	1	0
Nb. of photocopiers	0	0	0	0	0	0
Nb. of VDUs	2	2	2	2	2	0
Acceptable access for cleaning?	Yes	Yes	Yes	Yes	Yes	Yes
Door to corridor open?	Closed	Closed	Closed	Closed	Closed	Closed
VDU with reflection	0	1	0	0	0	0
Nb of VDU with glare	0	0	0	0	0	0

The five locations are closed office rooms, separated by walls. All doors go to the corridor and are allways closed. The tracer gas measurement did not show important connection between rooms.

Questionnaire

General	Total/Nr	Mean	Stdev	Percentage
Questionnaires distributed	130			
Questionnaires returned	102			78%
Age	102	42.20	13.49	
Number of female occupants	47			47%
Number of male occupants	54			53%
Time at desk before filling questionnaire	98	2.59	2.03	
Managerial work	16			16%
Specialist skill	31			31%
Clerical	49			49%
Other	5			5%
Time spent in the building [years]	102	8.11	6.87	
Time spent in the room [years]	102	4.49	5.51	
Hours per day at the desk	101	7.76	1.43	
Paid hours per week	95	40.60	7.43	
Hours at VDU per week	97	16.21	12.48	
Days per month in the building	99	21.93	4.33	
Number of people in the room	101	1.85	2.65	
Rooms without windows	0			0%
Rooms with windows	101			100%
Distance from the window	100	1.97	1.20	
People opening the window	75			74%
People not opening the window	27			26%

Health

Health during past month		Symptom present for			Better away	
	Answers	1-5 Days	6-10 Days	>10 days	yes	no
Dry eyes	101	21	9	16	37	3
Watering eyes	101	17	4	7	20	7
Stuffy nose	101	31	9	19	37	18
Runny nose	101	22	3	10	14	20
Dry throat	101	39	9	15	34	21
Chest tightness	101	12	1	5	12	5
Flu-like symptoms	102	38	5	4	21	18
Dry skin	100	14	8	19	24	12
Rash or irritated skin	100	9	1	6	7	7
Headaches	102	47	4	3	37	14
Lethargy	101	36	20	9	45	13
Other symptoms	85	6	1	6	7	2
Season when worst		Spring	Summer	Autumn	Winter	Any
(numbers of answers)	73	0	1	0	27	45
Part of the day when worst		Morning	Afternoon	Evening	Any	
(numbers of answers)	75	8	26	3	38	

Health now	Symptom present		In building			Severity	
	Total/Nr	Nb of yes	Better	Same	Worst	Mean	Stdev
Dry eyes	99	32	0	11	20	3.57	1.40
Watering eyes	99	9	0	2	8	3.33	0.28
Stuffy nose	99	38	1	20	14	3.38	0.44
Runny nose	98	12	1	7	4	3.42	1.41
Dry throat	99	34	0	13	20	3.74	0.49
Chest tightness	98	9	0	3	7	2.89	0.55
Flu-like symptoms	99	12	1	9	3	3.20	1.40
Dry skin	101	33	0	18	14	3.53	0.34
Rash or irritated skin	101	9	0	3	4	3.33	0.50
Headaches	101	15	0	4	11	2.73	1.31
Lethargy	100	25	1	10	13	2.63	0.48
Other symptoms	77	7	0	1	6	3.71	0.49

Frequency of building related symptoms

Only symptoms which disappear out of building are taken into account in this table. For each symptom, the frequency is the ratio of the number of person presenting the symptom to the total number of answers..

Symptom	Last month	Now
Dry eyes	39%	32%
Watering eyes	20%	9%
Stuffy nose	38%	36%
Runny nose	14%	12%
Dry throat	37%	33%
Chest tightness	12%	10%
Flu-like symptoms	22%	13%
Dry skin	25%	32%
Rash or irritated skin	7%	8%
Headaches	37%	15%
Lethargy	48%	22%
Other symptoms	9%	10%

Environmental conditions

Environmental conditions past month	Total/Nr	Mean	Stdev
Level of thermal comfort	92	0.50	1.53
Indoor air acceptability	102	2.34	2.28
Comfort temperature	99	2.98	1.71
Temperature variation	98	4.66	1.29
Air movement	101	4.51	1.50
Air humidity	99	2.58	1.33
Air stuffiness	95	3.43	1.58
Air odor	100	2.68	1.74
Lighting	100	2.80	2.00
Noise	100	2.74	1.79

Level of thermal comfort are on a -3 to+3 scale, Indoor air acceptability is on a -5 to+5 scale, while other votes are on a 1 to 7 scale.

Environmental conditions now	Total/Nr	Mean	Stdev
Level of thermal comfort	101	0.19	1.43
Indoor air acceptability	98	2.56	2.37
Comfort temperature	100	2.72	1.73
Air movement	100	4.03	1.15
Air humidity	100	2.80	1.17
Air stuffiness	100	3.14	1.61
Air odor	100	1.81	1.27
Light brightness	100	4.06	0.67
Light flickering	100	1.55	1.12
Glare	100	2.53	1.94
Light uneven	99	4.02	0.92
Lighting satisfactory	100	2.36	1.87
Noise from ventilation	101	3.38	1.91
Other noise	99	3.17	1.92
Noise satisfactory	101	2.84	1.61

As shown on next table most environmental conditions are found acceptable or good, except variable temperature, indoor air quality, odour and glare.

Environmental conditions: evaluation

Criterion	Past month μ	Past month σ	Now μ	Now σ	Conclusions
Thermal Comfort	0.5	1.5	0.2	1.4	Comfortable
Termperature	3.0	1.7	2.7	1.7	Comfortable
Termperature variations	4.7	1.3			Variable
IAQ acceptability	2.3	2.3	2.6	2.4	Acceptable
Air movement	4.7	1.3	4.0	1.2	Nice
Air humidity	4.5	1.5	2.8	1.2	Nice
Air stuffiness	2.6	1.3	3.2	1.6	Acceptable
Air odor	3.4	1.6	1.8	1.3	Faint smell
Light brightness			4.1	0.7	Fine
Light flickering			1.6	1.1	Very stable
Glare			2.5	1.9	Faint glare
Light uneven			4.0	0.9	Nice
Lighting satisfactory	2.8	2.0	2.4	1.9	Good
Noise from ventilation			3.4	1.9	No noise
Other noise			3.1	1.9	No noise
Noise satisfactory	2.7	1.7	2.8	1.6	Good

Health and direct environment

	Total/Nr	Nb yes	Percent
I have smoking neighbors	101	26	26%
I bring comments on my environment	102	30	29%
I had asthmatic problems	102	7	7%
I have suffered from eczema	102	17	17%
I have suffered with hay fever	100	19	19%
Do you smoke?	95	20	21%
Do you smoke in this room?	82	14	17%
Did you ever smoke?	85	30	35%

Estimation of occupant's influence on indoor conditions

μ is the average vote on a 1 (no influence, unsatisfactory) to 7 (total influence, satisfactory) scale. σ is the standard deviation of the votes within the population.

Influence on	μ	σ	Conclusions
-temperature	2.6	1.9	Weak influence
-ventilation	2.3	1.7	Weak influence
-lighting	3.7	2.0	Some influence
Cleanliness	4.4	2.1	Just acceptable

Building symptom indices

Uncorrected BSI's			Past month		Today	
		Number	Short list	Full list	Short list	Full list
Women	All women	53	2.4	3.3	1.9	2.3
	Managers	0	0.0	0.0	0.0	0.0
	Specialists	7	3.7	4.3	2.2	2.3
	Clerical	42	2.7	3.7	2.0	2.5
	Others	4	3.8	4.8	3.8	4.3
Men	All men	47	0.9	1.2	0.7	1.2
	Managers	16	0.7	1.0	0.6	1.0
	Specialists	24	1.3	1.7	0.9	1.2
	Clerical	6	2.3	2.7	1.5	2.7
	Others	1	1.0	1.0	0.0	0.0

Global building symptom indices		**Number**	**Value**
Last month, short list	BSI fs	100	2.09
Last month, full list	BSI ff	100	2.79
Last month, short list, corrected	BSI fsc	100	2.06
Last month, full list, corrected	BSI ffc	100	2.97
Today, short list	BSI ss	100	1.57
Today, full list	BSI sf	100	2.02
Today, short list, corrected	BSI ssc	100	1.47
Today, full list, corrected	BSI sfc	100	2.33

Correction factors are based on female clerical.

Sensory measurements

Sensory evaluation	**Offices**		**Supply air**		**Adjacent 1**		**Adjacent 2**	
Perceived air quality	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	4.8	1.4	2.3	1.3				
Location 2	8.2	2.4	2.3	1.3				
Location 3	4.2	1.0	2.3	1.3				
Location 4	6.8	1.6	2.3	1.3				
Location 5	6.7	2.2	2.3	1.3				
(Location 6)					6.5	3.5		
Average	6.1	1.7	2.3	1.3	6.5	3.5		
Outdoor air	0.9	0.9						

Location 2 contains smokers. Adjacent 1 is the corridor.

General Indoor Air Quality Measurements

Chemical analysis of air	Offices		Supply	air	Adjacent	1	Adjacent	2
Carbon dioxide [ppm]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	763	61.04.			700	56		
Location 2	840	67.2			700	56		
Location 3	800	64			700	56		
Location 4	820	65.6			700	56		
Location 5	770	61.6			700	56		
(Location 6)								
Average	798.6	63.88	650	52	700	56		
Outdoor air	400	32						
Carbon monoxide [ppm]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	<1		<1		<1			
Location 2	<1		<1		<1			
Location 3	<1		<1		<1			
Location 4	<1		<1		<1			
Location 5	<1		<1		<1			
(Location 6)								
Average								
Outdoor air	<1							
Particulate matter [mg/m3]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	0.19	0.02			0.3	0.02		
Location 2	0.34	0.02						
Location 3	0.12	0.02						
Location 4	0.44	0.02						
Location 5	0.23	0.02						
(Location 6)								
Average	0.264	0.02			0.3	0.02		
Outdoor air								
TVOC[mg/m3] Toluene equiv	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	0.15	0.01	0.07	0.01				
Location 2	0.13	0.01	0.07	0.01				
Location 3	0.08	0.01	0.07	0.01				
Location 4	0.12	0.01	0.07	0.01				
Location 5	0.11	0.01	0.07	0.01				
(Location 6)					0.11	0.01		
Average	0.12	0.01	0.07	0.01	0.11	0.01		
Outdoor air	0.03	0.01						

Building CH-G CO2 continuous measurements	Average ppm	SD ppm	Geomean ppm	GSD	Median ppm	Max. ppm
All data points, location 2	703	54	701	1.08	717	817
Reject 12:06-13:30 (presumable lunch break)						
Selected data	725	39	724	1.05	724	817

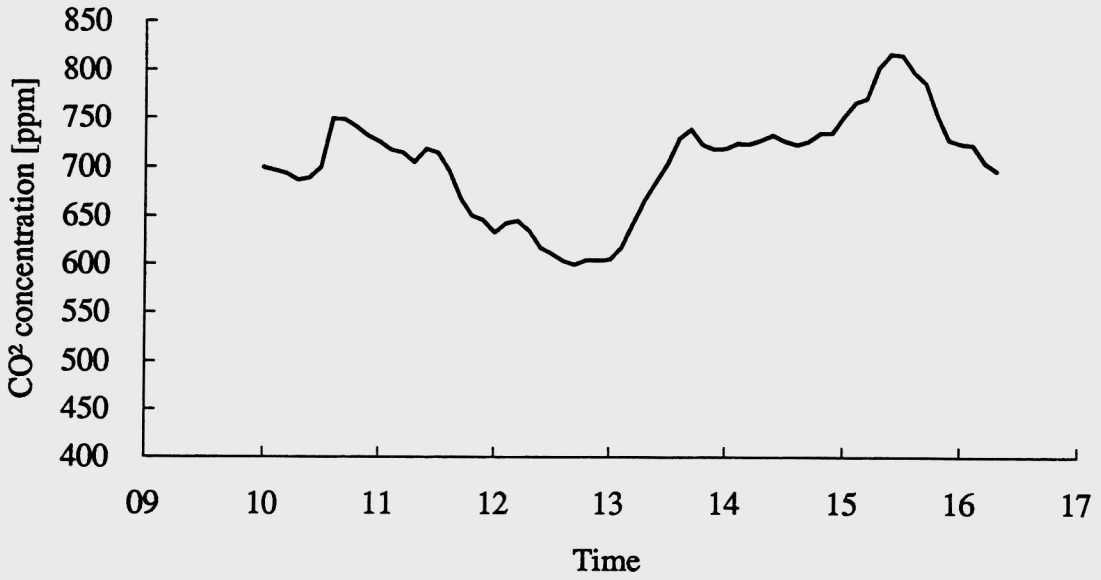


Figure G.1: CO2 concentration versus time. Lunch break can be clearly seen.

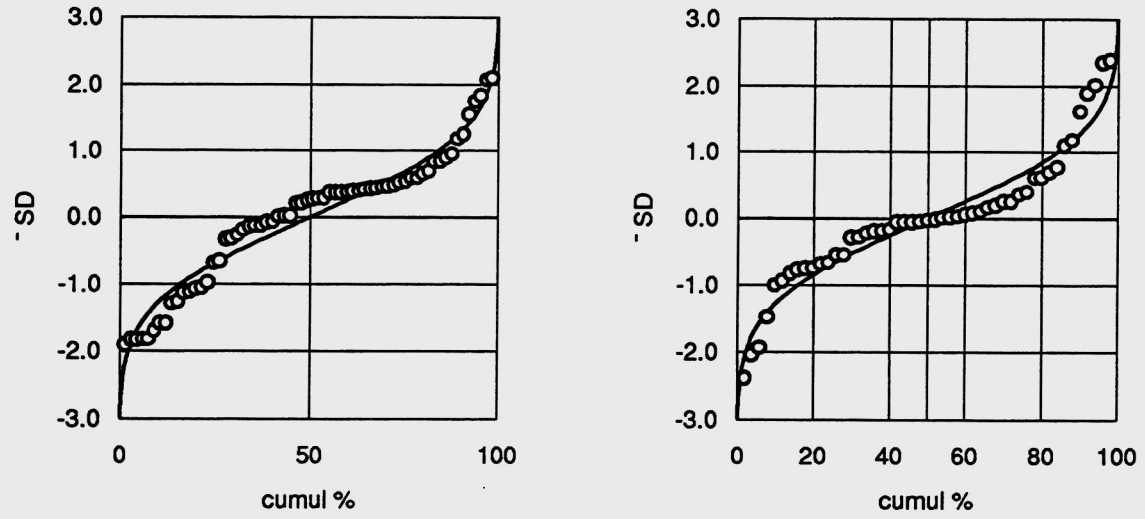


Figure G2: Cumulated frequencies of CO_2 concentrations. Left: all values. Right: selected values.

The data are made up of two unequal populations, as shown by the distribution curves. A low group coincides with noon time (lunch break?) at 600 ppm, while for the main part of the day the concentration is about 150 pm higher. Removing the lunch period still results in a skewed distribution with both the lower and upper ends overrepresented compared to a gaussian.

VOC: compound	Concentration [µg/m3]
toluene	18
C5H2O8 ester	16
aliphatic C7H16	14
Si-compound	12
m-xylene	11
acetone	8
n-heptane	6
aliphatic C7H16	5
dichloro methane	5
2-methyl-pentane	5
o-xylene	4
trimethyl-benzene	4
p-xylene	3
methyl-cyclohexane	3
benzaldehyde	3

The first five VOCs found in this building are also common in other Swiss buildings, except the Si compound, found only in building G.

General Indooor Climate measurements

Continuous measurements	Location Nr.	4				
	Start time	Stop time	µ	σ	Min	Max.
Air temperature 0,1 m [°C]	10:00	16:36	22.9	0.4	22.4	23.9
Air temperature 0,6 m [°C]	10:00	16:36	24.0	0.2	23.7	24.3
Air temperature 1,1 m [°C]	10:00	16:36	24.4	0.2	24.0	24.8
Operative temperature [°C]	10:00	16:36	23.5	0.2	23.1	23.8
Relative humidity [%]	10:00	16:36	29	0	28	30
Carbon dioxide [ppm]	10:00	16:36	703	54	600	817

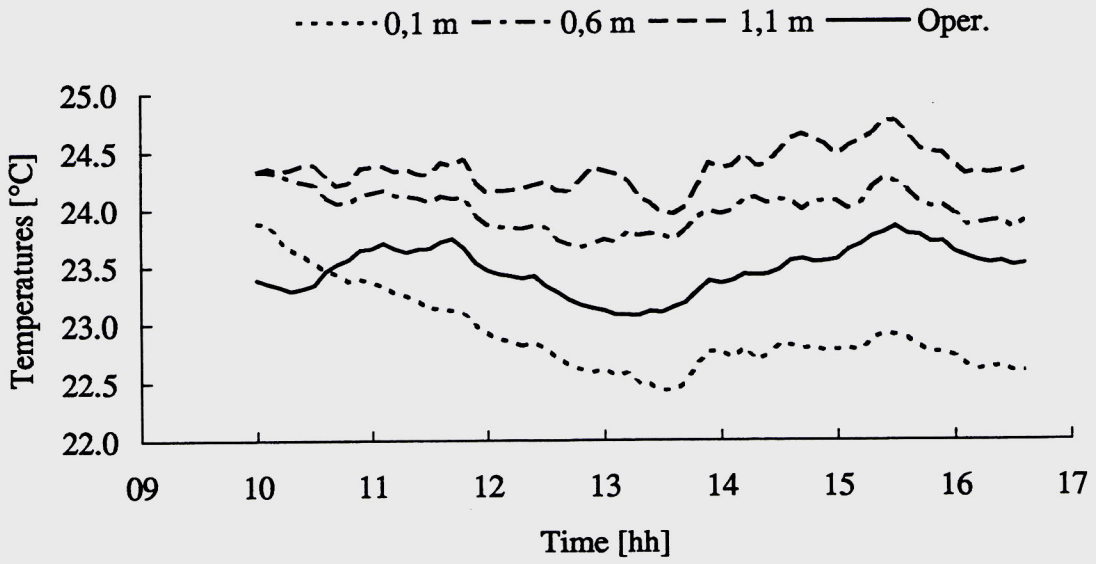


Figure 2: Temperatures in location 4 during the audit day.

Air velocity [m/s] at	0,1 m		0,6m		1,1m	
	μ	σ	μ	σ	μ	σ
Location 1	0.18	0.02	0.15	0.02	0.14	0.02
Location 2	0.08	0.02	0.11	0.02	0.16	0.02
Location 3	0.19	0.02	0.12	0.02	0.21	0.02
Location 4	0.20	0.02	0.11	0.02	0.14	0.02
Location 5	0.12	0.02	0.11	0.02	0.11	0.02
(Location 6)	0.15	0.02	0.20	0.02	0.14	0.02
Average	0.15	0.02	0.13	0.02	0.15	0.02

Note the relatively high velocity at 1.1 m, expecially in location 3.

Air temperatures at	0,1 m	0,6m	1,1m	Supply air
Location 1			23.0	
Location 2			22.3	
Location 3			22.0	
Location 4			22.9	
Location 5			21.5	
(Location 6)				
Average			22.3	
Outside air	11.5			

Mean radiant temperature	At 1,1 m	Calculated	Operative temperature Measured	Calculated
Location 1		19.6	21.4	
Location 2		20.7	22.7	
Location 3		20.3	22.5	
Location 4		21.9	21.1	
Location 5		20.7	21.8	
(Location 6)				
Average		20.6	21.9	

In our cases, mean radiant temperature was always calculated from air and operative temperatures.

Relative Humidity	1,1 m	Supply air	Adj. room
Location 1	33		31
Location 2	30		
Location 3	31		
Location 4	37		
Location 5	33		
(Location 6)			
Average	33		31
Outdoor air	62		

The temperature is low, at the acceptability limit.

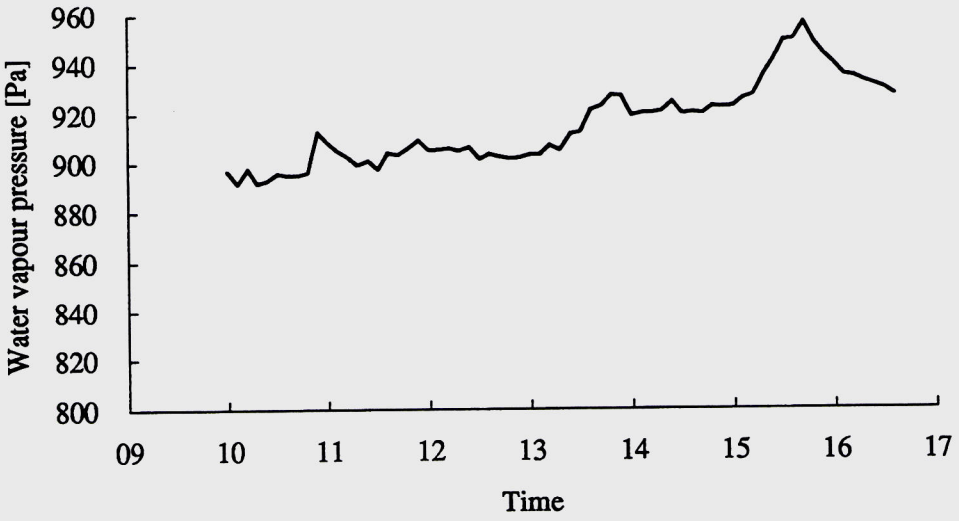


Figure 3: Water vapour pressure versus time during the audit day.

	Noise level	Daylighting		
	[dB (A)]	Lux ext	Lux int	DLF
Location 1	48	1100	60	0.05
Location 2	43	900	225	0.25
Location 3	40	1200	800	0.67
Location 4	40	1100	700	0.64
Location 5	42	1200	900	0.75
(Location 6)	42			
Average	43	1100	537	0.49
Outdoor	55			

DLF= Day Light Factor

Ventilation measurements

Air flow rates in ventilation system [m³/h]	Planned	Measured	±
Total air flow rate into building	35'100	22'300	1'500
Fresh air flow rate into building	35'100	22'300	2'000
Exhaust from building	30'000	18'600	2'300
Extracted to outdoor	30'000	18'600	2'300
Recirculated air flow rate	0		
Recirculation rate	0	0	
Estimated air change rate [/h]	0		
Estimated fresh air per person [l/(s·pers.)]	12	8	

Mesure at location Nr	1	2	3	4	5	Total
Air flow rate from ventilation	300	170	300	250	260	1'300
uncertainty	20	20	10	80	20	200
Air flow rate from hall	90	80	60	200	160	600
uncertainty	20	20	20	200	40	300
Air flow rate from other space	1	50	1	60	0	110
uncertainty	1	10	1	50	0	70
Infiltration	0	0	0	0	0	0
uncertainty	1	1	1	1	1	5

Air flow rates in m^3/h. Total is total air flow rate into monitored area.

Pollution load

Source intensity	1	2	3	4	5	Total	
Total olfactive load	32	36	27	40	40	180	Olf
uncertainty	9	9	7	20	10	50	Olf
Olfactive load	20	30	10	30	30	130	Olf
uncertainty	10	10	10	20	20	80	Olf
Load from ventilation	12	7	12	10	10	50	Olf
uncertainty	9	5	8	8	8	40	Olf
Load from smokers	3	3	3	3	4	14	Olf
uncertainty	1	1	1	1	1	4	Olf
Load from occupants	2	2	2	2	3	11	Olf
uncertainty	1	1	1	1	1	3	Olf
Load from other sources	10	30	10	30	30	100	Olf
uncertainty	10	10	10	20	20	80	Olf

Total is total pollution load in monitored zone

Weather conditions on audit day

Weather station	Pully		
Date	16-02-94		
Description	Overcast		
Weather data	Average	Maximum	Minimum
Temperature 0600-1200	0.6	2.0	-0.6
Temperature 1200-1800	2.9	3.0	2.6
Relative humidity 0600-1200	77	78	76
Relative humidity 1200-1800	72	74	70
Wind speed 0600-1200	1.6	2.4	0.9

Energy consumption

Annual energy use [MJ]	in 1992	1'991	1'990	1'989	Uncertainty
Natural gas	32'717'763	36'204'566	33'709'765	33'632'696	1'703'310
Electricity	18'345'096	15'979'104	16'717'212	16'267'104	841'356
Total	51'062'859	52'183'670	50'426'977	49'899'800	2'544'666
Energy index [MJ/m²]	1'200	1'200	1'200	1'200	100
Heating index	763	820	802	813	100
Electric index	437	380	398	387	0

Note that most digits, resulting from transformation of liters, kg, kWh, etc into MJ, are not significant.

Additional measurements

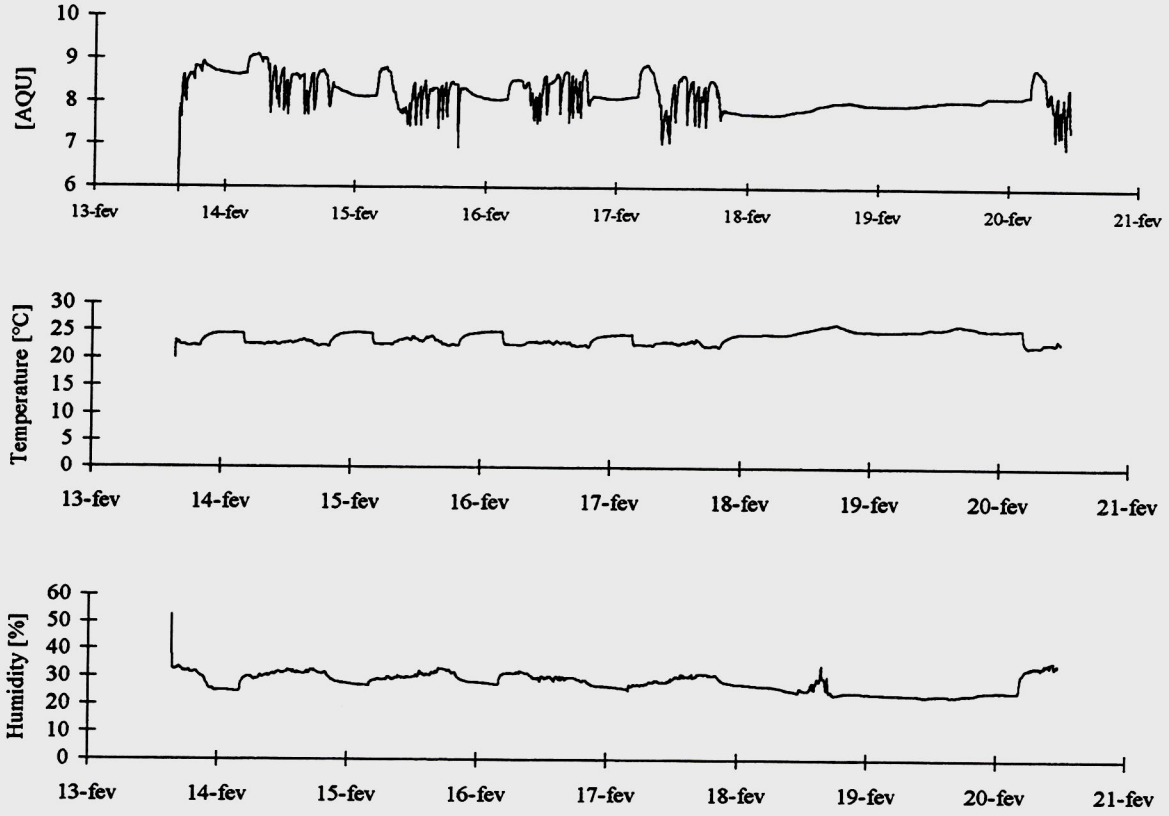
Ions	time		+ ions			- ions		
office	begin	end	Mean	Max.	Min	Mean	Max.	Min
Location 1	09:28	10:31	174	243	3	49	226	0
Location 2	10:33	11:47	145	803	15	41	83	0
Location 3	11:54	13:35	431	563	50	121	260	36
Location 4	13:38	14:46	52	430	0	25	115	0
Location 5	15:47	16:36	46	166	1	25	151	0
(Location 6)								
Average			170	441	14	52	167	7

This building presents on average more positive ions than negative ones. Ion concentrations vary very much with time.

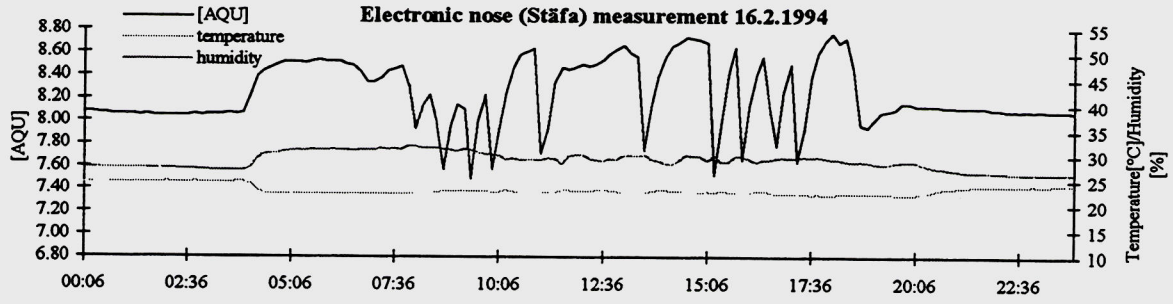
Radon	Bq/m3
Location 1	20
Location 5	25
Location 6	20
inlet	40
outlet	15

Radon concentration is very low everywhere, even at air inlet, which is at ground level.

IAQ Stäfa	Day 8:00-18:00				Night 20:00-06:00			
	Mean	Stdev.	Min.	Max.	Mean	Stdev.	Min.	Max.
Location d	8.27	0.36	7.49	8.73	8.24	0.28	8.07	8.88
Location e	8.47	0.13	8.16	8.77	8.45	0.30	7.55	8.79
Location f	8.47	0.13	8.16	8.77	8.45	0.30	7.55	8.79
Average	8.41	0.21	7.94	8.76	8.38	0.30	7.72	8.82



The audit day, on February 16, looks like other weekdays. February 19 and 20 are week-end days.



Obviously ventilation is swithched on at 4 AM and off at about 7 PM

BUILDING H

General information

1. Building identification.	H		
3. Situation	Downtown.	7. Number of floors	8
4. Traffic within 200 m.	Busy through road.	area of each floor (m2)	1'414
		number of offices	
5. Near sources of pollution	Parking garage.	number of employees	240
	0	8. Year of building completion	1'973
6. Activities besides office work	Only office work.	Year of total renovation	1'973
		Year when present user entered	1'973
9. No. of floors beneath ground	2	10. Position of solar shadings	Inside.
Roof tilt angle	20	Solar shadings: movement	Individual.
11. Number of glazing	Double pane.	12. Modification of?	
Glazing type	Light reflecting.	Flooring	1989
13. Furniture made of	Veneered chip board.	Insulation	None
Age of furniture	More than three years.	Wall or ceiling lining	None
		Windows	None
14. Large green plants	Green leafed plants.	Heating system	None
Plants treatment	0	Ventilation system	None
15. Smoking	Allowed in separate rooms.	16. Office activities	
17. Cleaning frequency		solvents	No solvents
Tables	2-4 times a week.	other chemicals	None
Walls	Less than once a month.	copying machines	No.
Washing floors	Less than once a month.	laser printers	No.
Vacuum cleaning	Once a week.	person per VDU	1-2
Mopping	Less than once a month.	carbonless paper use	Yes.
Sweeping	Less than once a month.		
Waxing	Less than once a month.		
Spring cleaning	Less than once a year.		
Look of the floors			
18. Detergent for cleaning	type/name	content pH	
cleaning agent linoleum	0	0	
cleaning agent carpet	0	0	
cleaning agent tables	0	0	
cleaning agent sanitary	0	0	

Installation

1. Installation identification			
2. Room heating Location of heating	Hot water heating. Fan coil units.	3. Room cooling	Local fan coil units.
4. Temperature control Night set back	Adjustable thermostat on radiator or unit. Yes.	5.Ventilation of rooms Windows	Inductin units balanced system. Windows cannot be opened.
6. Design outdoor air change Lowest outdoor air supply	1 to 3 per hour. l/s·pers	7. Position air intake height above ground distance from exhaust	Close to the ground. 0 vert. 10 hor. 50
8. Equipment vent. system Recirculation [%] Humidification system Water purification	0 Spray. None.	distance from cooling towers	vert. hor.
Cooling type Heat recovery	0 None.		
9. Ventilation system on/off Sensors for demand control Operating at: full performance	Automatically by a clock. No such control. From 06:00	to 18:00	days per week 5
reduced performance stopped	18:00	06:00	5
100% recirculation Partial recirculation	06:00	18:00	0.15 %return air
10. Duct material Duct insulation 11. Service Air intake filter Recirculation duct filter Central unit filter	Galvanised steel. External insulation. Class Eu1 Eu7	Last replacement 15-07-93 14-06-92	Needing service No. 0 No.
Supply filter Induction / fan coil filter Heating batteries Cooling batteries Heat exchanger Humidifier Ducts Air outlets in rooms Air inlet in rooms	 Last cleaning 1-01-94 1-01-94 1-01-94 1-01-94 1-01-94 30-06-92 30-06-92	 Needing service No. No. No. No. No. No. No.	No.
12. Location air supply inlets Location air outlets Designed ventilation principle	At windowsill. High. Mixing ventilation.		

Recirculation occur only in the central part of the buildings, containing staircases, utility rooms. Office rooms receive in principle only fresh air. However, a few grids of central part are located in toe audited rooms, inducing 15 % recirculation.

Investigated rooms

Location Nr	1	2	3	4	5	6
Room name	**Offices**					
Wall materials inside insulation	Metal.					
Insulation material	Polyurethane.					
Thickness of insulation [cm]	8					
Felt carpet (needle) [%area]	100					
Wall covering / treatments	Enamel paint.					
Ceiling material	Acoustic panes.					
Space above acoustic tiles [cm]	50					
Dust above acoustic panes?	Yes.					
Acoustic baffles below ceiling?	No.					
Any other ceiling type?	No					
Room lighting	Artificial and Daylight.					
Lighting location	Ceiling.					
Type of artificial lighting	Fluorescent.					
Control of lighting	Manual.					
Visible mould growth in rooms	No.					
Damp spots	No damp spots.					
Mould odor in room	No					
Area [m²]	103	25	65	42	25	25
Height [m]	2.7	2.7	2.7	2.7	2.7	2.7
Nb of work places	4	1	4	3	2	1
Fleecy material [m²]	1	0.5	1	1	0.5	0.1
Shelf length [m]	16	3	20	15	2	10
Window area [m²]	11.4	11.4	13.8	6.9	4.6	11.4
Office depth [m]	6	2	4	5	5	2
Nb. of laser printers	0	0	0	0	1	0
Nb. of photocopiers	0	0	0	0	0	0
Nb. of VDUs	4	1	3	3	2	1
Acceptable access for cleaning?	Yes	Yes	Yes	Yes	Yes	Yes
Door to corridor open?	Open	Open	Open	Open	Open	Open
Nb. of VDU with reflection	1	0	0	0	0	0
Nb of VDU with glare	0	1	1	1	0	1

The 6 locations are separated by walls, but there are permanent large openings between these locations. Tracer gas measurement have shown a very strong interconnection between these rooms.

Questionnaire

General	Total/Nr	Mean	Stdev	Percentage
Questionnaires distributed	130			
Questionnaires returned	126			97%
Age	126	38.74	11.70	
Number of female occupants	64			51%
Number of male occupants	62			49%
Time at desk before filling questionnaire	116	2.67	1.18	
Managerial work	22			18%
Specialist skill	4			3%
Clerical	89			72%
Other	9			7%
Time spent in the building [years]	125	7.83	7.01	
Time spent in the room [years]	123	5.49	5.80	
Hours per day at the desk	123	8.20	4.65	
Paid hours per week	126	38.69	6.29	
Hours at VDU per week	126	16.41	11.82	
Days per month in the building	126	20.76	3.90	
Number of people in the room	122	3.57	7.07	
Rooms without windows	7			6%
Rooms with windows	116			94%
Distance from the window	109	2.06	1.17	
People opening the window	3			3%
People not opening the window	111			97%

All the windows in this building are sealed. Therefore, there is a doubt concerning the 3 persons pretending to open the windows.

Health

Health during past month		Symptom present for			Better away	
	Answers	1-5 Days	6-10 Days	>10 days	yes	no
Dry eyes	126	27	19	11	42	17
Watering eyes	125	21	6	1	19	15
Stuffy nose	125	35	25	16	54	15
Runny nose	124	26	13	8	36	17
Dry throat	125	36	25	15	61	12
Chest tightness	123	20	10	5	32	7
Flu-like symptoms	123	40	9	9	38	19
Dry skin	125	18	15	15	31	22
Rash or irritated skin	124	15	4	9	13	27
Headaches	123	55	15	7	59	18
Lethargy	121	54	24	13	66	14
Other symptoms	105	11	6	4	13	8
Season when worst		Spring	Summer	Autumn	Winter	Any
(numbers of answers)	83	5	3	1	21	53
Part of the day when worst		Morning	Afternoon	Evening	Any	
(numbers of answers)	85	15	21	12	37	

Health now	Symptom present		In building			Severity	
	Total/Nr	Nb of yes	Better	Same	Worst	Mean	Stdev
Dry eyes	122	43	0	14	32	3.70	1.53
Watering eyes	121	10	0	5	7	3.60	0.30
Stuffy nose	121	47	0	19	31	4.49	0.48
Runny nose	121	18	1	7	12	4.61	1.86
Dry throat	124	55	1	19	34	3.98	0.49
Chest tightness	123	20	0	6	15	4.38	0.49
Flu-like symptoms	122	24	0	14	11	4.05	1.71
Dry skin	122	41	0	22	13	3.74	0.37
Rash or irritated skin	123	21	0	11	10	4.11	0.63
Headaches	124	36	1	7	27	4.26	1.91
Lethargy	123	42	0	16	24	4.05	0.50
Other symptoms	101	17	0	3	11	4.92	0.55

Frequency of building related symptoms

Only symptoms which disappear out of building are taken into account in this table. For each symptom, the frequency is the ratio of the number of person presenting the symptom to the total number of answers..

Symptom	Last month	Now
Dry eyes	34%	36%
Watering eyes	15%	10%
Stuffy nose	45%	39%
Runny nose	28%	16%
Dry throat	52%	41%
Chest tightness	24%	17%
Flu-like symptoms	31%	22%
Dry skin	25%	29%
Rash or irritated skin	9%	16%
Headaches	48%	27%
Lethargy	59%	36%
Other symptoms	12%	16%

Average air humidity on the audit day was 42%. This may explain the symptoms related to dryness.

Environmental conditions

Environmental conditions past month	Total/Nr	Mean	Stdev
Level of thermal comfort	101	0.32	2.03
Indoor air acceptability	122	1.30	2.75
Comfort temperature	120	4.21	1.78
Temperature variation	116	5.30	1.49
Air movement	115	3.88	1.66
Air humidity	117	2.56	1.40
Air stuffiness	118	3.86	1.81
Air odor	121	2.88	1.77
Lighting	120	3.22	2.18
Noise	120	2.71	2.15

Level of thermal comfort are on a -3 to+3 scale, Indoor air acceptability is on a -5 to+5 scale, while other votes are on a 1 to 7 scale.

Environmental conditions now	Total/Nr	Mean	Stdev
Level of thermal comfort	122	-0.09	1.52
Indoor air acceptability	122	1.72	2.64
Comfort temperature	123	3.22	1.83
Air movement	119	3.61	1.47
Air humidity	121	2.64	1.32
Air stuffiness	122	3.28	1.72
Air odor	122	2.47	1.74
Light brightness	118	4.14	1.28
Light flickering	121	2.01	1.54
Glare	120	3.04	2.14
Light uneven	121	4.04	1.51
Lighting satisfactory	119	3.04	2.15
Noise from ventilation	120	2.64	1.54
Other noise	122	2.92	1.91
Noise satisfactory	121	2.85	1.92

As sown on next table, most conditions are found acceptable or good, except indoor air, temperature variations, air moisture, odours and glare.

Environmental conditions: evaluation

Criterion	Past month μ	Past month σ	Now μ	Now σ	Conclusions
Thermal Comfort	0.3	2.0	-0.1	1.5	Comfortable
Termperature	4.2	1.8	3.2	1.8	Acceptable
Termperature variations	5.3	1.5			Variable
IAQ accaptability	1.3	2.8	1.7	2.6	Unacceptable
Air movement	5.3	1.5	3.6	1.5	Nice
Air humidity	3.9	1.7	2.6	1.3	Dry
Air stuffiness	2.6	1.4	3.3	1.7	Acceptable
Air odor	3.9	1.8	2.5	1.7	Faint smell
Light brightness			4.1	1.3	Fine
Light flickering			2.0	1.5	Very stable
Glare			3.0	2.1	Faint glare
Light uneven			4.0	1.5	Nice
Lighting satisfactory	3.2	2.2	3.0	2.1	Good
Noise from ventilation			2.6	1.5	No noise
Other noise			2.9	1.9	No noise
Noise satisfactory	2.7	2.1	2.9	1.9	Good

Health and direct environment

	Total/Nr	Nb yes	Percent
I have smoking neighbors	124	65	52%
I bring comments on my environment	117	31	26%
I had asthmatic problems	120	14	12%
I have suffered from eczema	123	23	19%
I have suffered with hay fever	121	31	26%
Do you smoke?	123	44	36%
Do you smoke in this room?	92	33	36%
Did you ever smoke?	102	45	44%

Estimation of occupant's influence on indoor conditions

μ is the average vote on a 1 (no influence, unsatisfactory) to 7 (total influence, satisfactory) scale. σ is the standard deviation of the votes within the population.

Influence on	μ	σ	Conclusions
-temperature	1.7	1.2	No influence
-ventilation	1.4	1.1	No influence
-lighting	2.9	2.0	Weak influence
Cleanliness	4.4	1.9	Just acceptable

With reason, occupants estimate that they have no influence on their environment.

Building symptom indices

Uncorrected BSI's			Past month		Today	
		Number	Short list	Full list	Short list	Full list
Women	All women	63	2.7	3.8	1.8	2.5
	Managers	3	2.7	3.3	1.7	2.3
	Specialists	0	0.0	0.0	0.0	0.0
	Clerical	53	2.6	3.8	1.7	2.5
	Others	7	3.0	4.0	2.0	2.7
Men	All men	60	2.2	3.2	1.4	1.8
	Managers	19	2.3	3.4	1.1	1.4
	Specialists	4	1.3	1.8	0.5	0.8
	Clerical	35	2.1	2.9	1.6	2.0
	Others	2	4.0	7.0	2.5	4.0

Global building symptom indices		**Number**	**Value**
Last month, short list	BSI fs	123	2.43
Last month, full list	BSI ff	123	3.44
Last month, short list, corrected	BSI fsc	123	3.79
Last month, full list, corrected	BSI ffc	123	6.04
Today, short list	BSI ss	123	1.57
Today, full list	BSI sf	123	2.16
Today, short list, corrected	BSI ssc	123	2.39
Today, full list, corrected	BSI sfc	123	3.32

Correction factors are based on female clerical.

Sensory measurements

Sensory evaluation	**Offices**		**Supply air**		**Adjacent 1**		**Adjacent 2**	
Perceived air quality	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	3.7	1.3	3.0	2.0				
Location 2	3.6	1.3	3.0	2.0				
Location 3	4.8	1.6	3.0	2.0				
Location 4	5.6	2.6	3.0	2.0				
Location 5	3.6	1.4	3.0	2.0				
(Location 6)					3.7	1.9	2.2	1.4
Average	4.3	1.6	3.0	2.0	3.7	1.9	2.2	1.4
Outdoor air	1.1	0.8						

Location 4 contains smokers. Adjacent room 1 is central part of building, with recirculation.

General Indoor Air Quality Measurements

Chemical analysis of air	Offices		Supply	air	Adjacent	1	Adjacent	2
Carbon dioxide [ppm]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	680	54.4	380	30.4				
Location 2	680	54.4	380	30.4				
Location 3	730	58.4	380	30.4				
Location 4	710	56.8	380	30.4				
Location 5	700	56	380	30.4				
(Location 6)	770	61.6						
Average	712	56.9	380	30.4	700	56		
Outdoor air	392	31.36						
Carbon monoxide [ppm]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	<1							
Location 2	<1							
Location 3	<1							
Location 4	<1							
Location 5	<1							
(Location 6)	<1							
Average	<1							
Outdoor air								
Particulate matter [mg/m3]	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	0.1	0.02			0.04	0.02		
Location 2	0.01	0.02						
Location 3	0.08	0.02						
Location 4	0.06	0.02						
Location 5	0.13	0.02						
(Location 6)								
Average	0.076	0.02			0.04	0.02		
Outdoor air								
TVOC[mg/m3] Toluene equiv	μ	σ	μ	σ	μ	σ	μ	σ
Location 1	1.09	0.05	0.82	0.05				
Location 2	1.80	0.05						
Location 3	0.72	0.05						
Location 4	0.52	0.05						
Location 5	0.48	0.05						
(Location 6)					0.39	0.05		
Average	0.92	0.05	0.82	0.05	0.39	0.05		
Outdoor air	0.34	0.05						

Building CH-H Carbon dioxide cont. meas.	Average ppm	SD ppm	Geomean ppm	GSD	Median ppm	Max. ppm
All data points, location 3	665	55	662	1.09	680	746.0
Reject 12:06-14:00 (lunch break, subsequent return to normal)						
Selected data	693	24	692	1.03	688	746.0

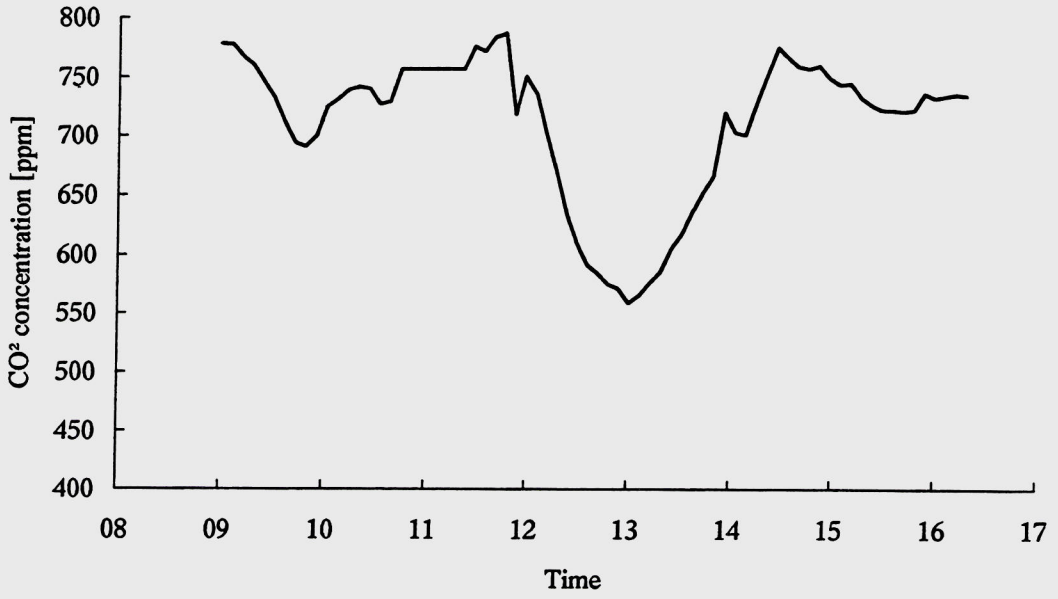


Figure H1: CO_2 concentration versus time. Morning coffee break and lunch time result in clear decreases of concentration.

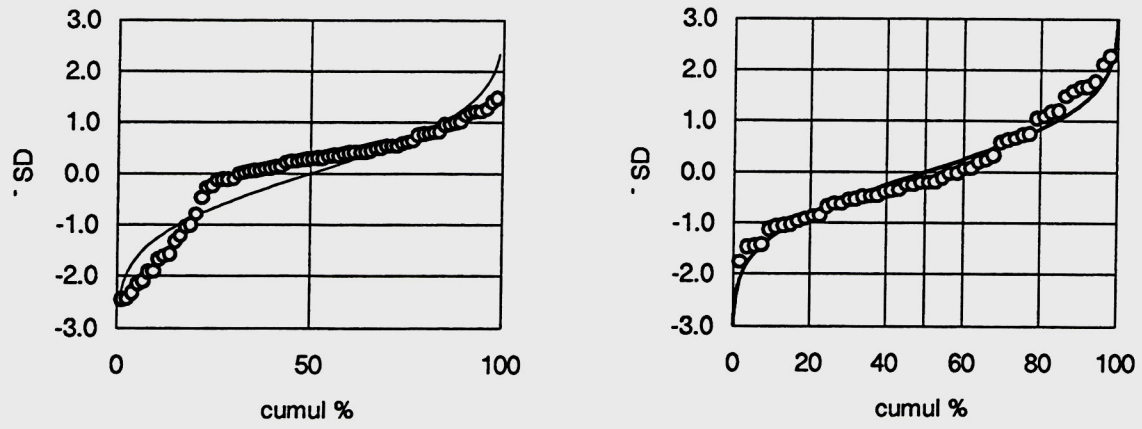


Figure H2: Cumulated frequencies of CO^2 concentrations. Left: all values. Right: selected values.

A very slight decreasing trend can be noticed, from 750 ppm in the morning to about 700 ppm in the late afternoon. A considerable decrease occurs at noon time, with the concentration dropping by about 300 ppm in 1 hour, to to rise again to the usual value in 1.5 hour afterwards. Rejecting this episode causes the mean to rise by about 5%, with the remaining data adequately represented by a normal distribution.

VOC: compounds in location 3	Concentration [µg/m³]
n-hexane	201
toluene	49
aliphatic C7H16	39
methyl-cyclopentane	32
m-xylene	31
n-heptane	28
aliphatic C7H16	27
2-methyl-pentane	26
3-methyl-pentane	25
aliphat. C9H20 ?	21
acetone	15
?	12
trimethyl-benzene	12
dichloro methane	11
o-xylene	11

The presence of n-hexane in large quantities is not explained. It is a general purpose solvent.

General Indooor Climate measurements

Continuous measurements	Location Nr.	3				
	Start time	Stop time	µ	σ	Min	Max.
Air temperature 0,1 m [°C]	09:00	16:18	21.4	0.3	20.8	21.7
Air temperature 0,6 m [°C]	09:00	16:18	22.7	0.3	21.9	23.1
Air temperature 1,1 m [°C]	09:00	16:18	23.9	0.3	23.2	24.4
Operative temperature [°C]	09:00	16:18	22.7	0.3	22.2	23.2
Relative humidity [%]	09:00	16:18	46	3	41	52
Carbon dioxide [ppm]	09:00	16:18	711	63	558	787

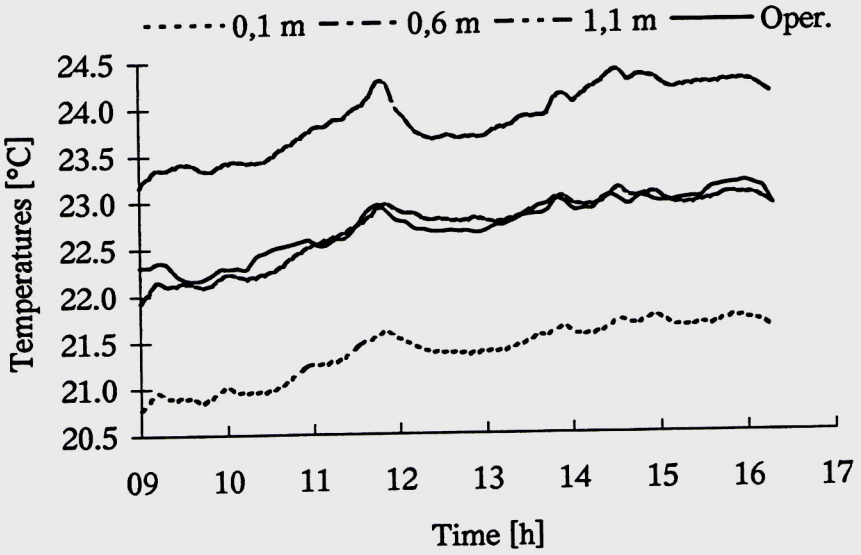


Figure H3: Temperatures during the audit day.

Air velocity [m/s] at	0,1 m		0,6m		1,1m	
	μ	σ	μ	σ	μ	σ
Location 1	0.12	0.02	0.13	0.02	0.14	0.02
Location 2	0.12	0.02	0.12	0.02	0.13	0.02
Location 3	0.14	0.02	0.13	0.02	0.14	0.02
Location 4	0.05	0.02	0.08	0.02	0.07	0.02
Location 5	0.09	0.02	0.06	0.02	0.07	0.02
(Location 6)	0.06	0.02	0.07	0.02	0.11	0.02
Average	0.09	0.02	0.10	0.02	0.11	0.02

Air temperatures at	0,1 m	0,6m	1,1m	Supply air
Location 1			22.9	
Location 2			23.1	
Location 3			23.2	
Location 4			23.1	
Location 5			22.9	
(Location 6)			22.4	
Average			22.9	
Outside air				

Mean radiant temperature	At 1,1 m	Calculated	Operative temperature Measured	Calculated
Location 1		19.9	21.5	
Location 2		20.7	22.0	
Location 3		21.3	22.3	
Location 4		20.2	21.7	
Location 5		20.2	21.6	
(Location 6)		17.3	20.0	
Average		19.9	21.5	

In our cases, mean radiant temperature was always calculated from air and operative temperatures.

Relative Humidity	1,1 m	Supply air	Adj. room
Location 1	46		
Location 2	43		
Location 3	43		
Location 4	41		
Location 5	42		
(Location 6)	39		
Average	42		
Outdoor air	75		

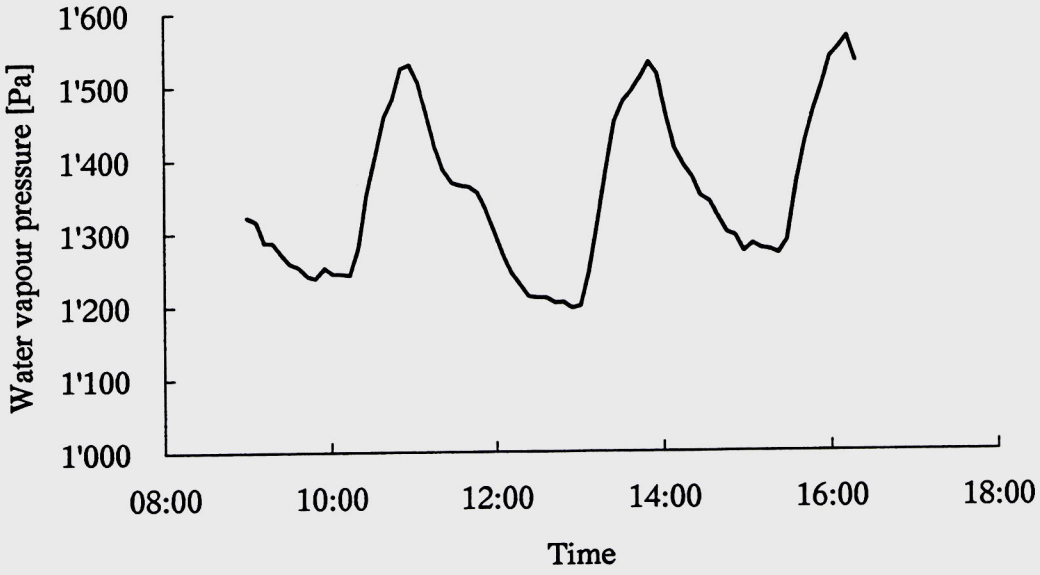


Figure H4: Water vapour pressure versus time during the audit day. Cycles may be caused by air moisture control.

Noise [dB (A)]	Office	Adjacent	Lux
Location 1	45		230
Location 2	42		480
Location 3	45		220
Location 4	40		350
Location 5	35		80
(Location 6)		40	600
Average	41	40	326
Outdoor noise	63		

Ventilation measurements

Air flow rates in ventilation system [m³/h]	Planned	Measured	±	
Total air flow rate into building	67'400	40'000	2'000	m³/h
Fresh air flow rate into building	58'100	38'500	2'000	
Exhaust from building	0	12'000	1'000	
Extracted to outdoor	0	11'000	1'000	
Recirculated air flow rate	9'300	1'500	1'000	m³/h
Recirculation rate	14%	4%	3%	
Estimated air change rate	1.9	1.3		/h
Estimated fresh air per person	67	45		l/s·person

Air flow rates in measured room	Total	± [m³/h]
Air flow rate from ventilation	2'400	200
Air flow rate from hall	30	3
Air flow rate from other space	0	0
Infiltration	0	5

Pollution load

Source intensity		±	
Total olfactive load	170	70	olf
Olfactive load	100	100	olf
Load from ventilation	120	90	olf
Load from smokers	9	9	olf
Load from occupants	4	4	olf
Load from other sources	0	100	olf
Carbon dioxide	720	80	l/h
corresponding to	40		person

Weather conditions on audit day

Weather station	LESO		
Date	1-03-94		
Description	Rainy		
Weather data	Average	Maximum	Minimum
Temperature 0600-1200	7.6	8.2	7.1
Temperature 1200-1800	8.9	9.8	8.2
Relative humidity 0600-1200	94	94	93
Relative humidity 1200-1800	86	92	82
Wind speed 0600-1200	0.1	0.3	-0.1

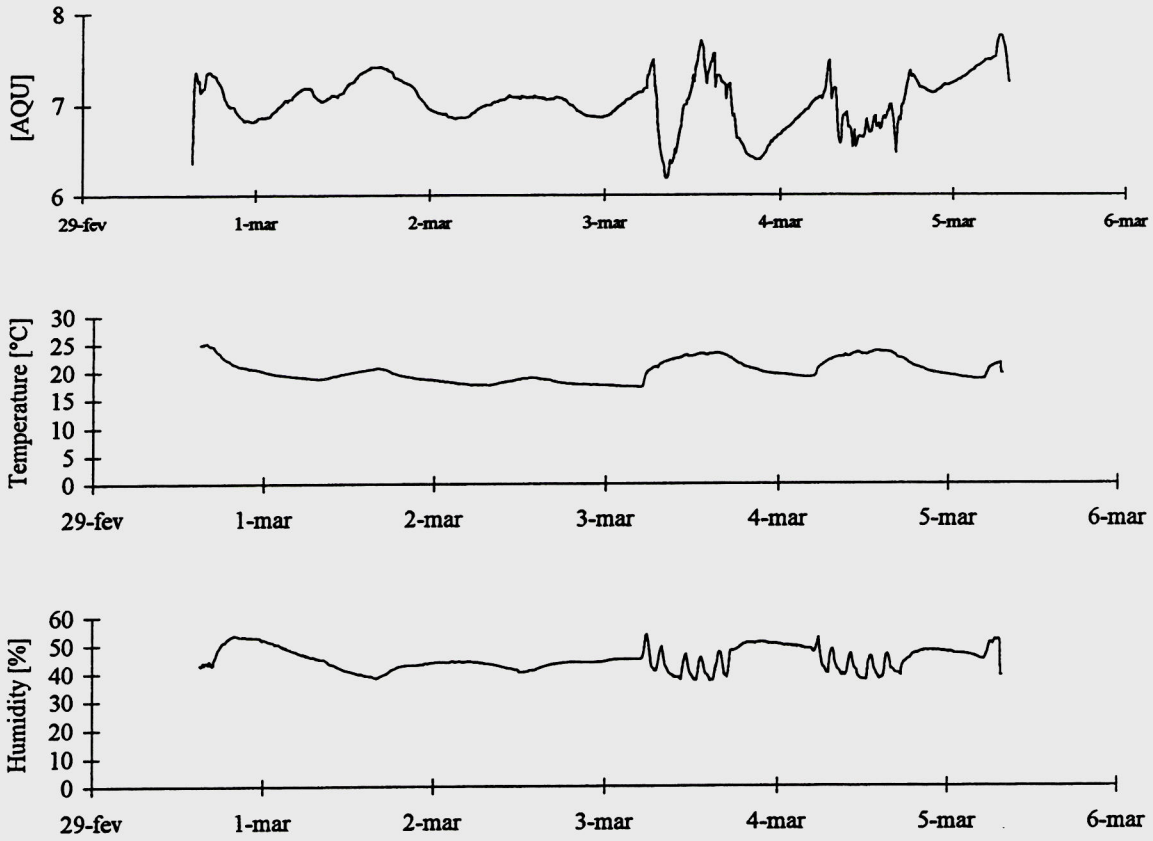
Energy consumption

Annual energy use [MJ]	in 1993	1'992	1'991	1'990	Uncertainty
Electricity	1'362'738				70'000
District heat	10'036'400				500'000
Total	11'399'138				570'000
Energy index [MJ/m²]	1'010				100
Heating degree days	3'100				300
Power index [W/m²K]	3.9				0.5
Heating index	879				90
Electric index	121				10

Note that most digits, resulting from transformation of liters, kg, kWh, etc into MJ, are not significant.

Additional measurements

IAQ Stäfa	Day 8:00-18:00				Night 20:00-06:00			
	Mean	Stdev.	Min.	Max.	Mean	Stdev.	Min.	Max.
Location e	7.35	0.13	7.12	7.52	7.07	0.18	6.91	7.43
Location f	7.22	0.14	7.03	7.41	6.98	0.14	6.84	7.26
Location d	7.68	0.13	7.48	7.88	7.29	0.19	7.11	7.70
Average	7.42	0.14	7.21	7.60	7.11	0.17	6.95	7.46



The audit day, March 1st, is a normal heatingday.