28. Fluorosis in China, *Chinese Task Group on prevention and treatment of fluorosis Bulletin* (1989) (in Chinese).
29. Xiao Y.Y., Li P.W., Yan C.Y. and He M.S., Observations on dental fluorosis induced by indoor air pollution from domestic fuel combustion. *Journal of Environment and Health*, 4(1), 36 (1987) (in Chinese).
30. Wang C.L. *et al.*, An endemic fluorosis induced by domestic fuel combustion. *Journal of Environment and Health*, 4(3), 12 (1986) (in Chinese).
31. Yang D.J., Suggestions on the diagnostic and identification of fluorosis induced by food polluted from coal combustion, using x-rays. *Chinese Prevention Medicine Journal*, 21(3), 136, (1987) (in Chinese).
32. Wang Z.M., Tao Y., Zhang Z.Y., Zhang D.C., Zhang Q.H. and Wang Q.L., A survey on the fluorosis induced by coal combustion. *Chinese Preventive Medicine Journal*, 20(4), 217-219 (1986) (in Chinese).
33. Xu R.Q., An epidemiologic study on environmental quality and birth defects. *Archives of National Institute of Family Planning*, Beijing (1990) (in Chinese).

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SICK BUILDINGS AND THE EXPERIMENTAL APPROACH

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ABSTRACT

When dealing with indoor air pollution problems caused by substances known to be toxic, field experimentation has been virtually ruled out by ethical considerations. Even the omission of remedial measures for experimental purposes can be said to be unethical. What remains is the descriptive approach, in which the occurrence of toxic substances and the occurrence of symptoms of ill health are measured and related to each other. This approach is ethically unexceptional, but leaves much to be desired in terms of scientific proof, unless the mechanisms of toxicity are well understood. When applied to the elusive Sick Building Syndrome (SBS), it is fatally flawed: the toxic substances involved, and the mechanisms for their action, are not known, and the sub-clinical symptoms are usually measurable only as subjective complaints. In descriptive surveys, complaints can be manipulated by alarmist reports and by deliberate campaigns; they may even be used by subjects merely as a vote for something to be done. This is not the case in properly conducted field experiments, where subjects know that they may well be part of the reference group. Subjective assessments of symptom intensity may therefore be used as valid dependent variables, and the extent to which they are affected by experimentally established conditions may be examined. Provided that the experimental conditions may or may not be beneficial, the experimental approach is ethically defensible. The recent series of field experiments at Malmö General Hospital (MAS) in Sweden is used to demonstrate the power of the approach.

INTRODUCTION

If a "sick building" is defined as one where many people experience unpleasant symptoms, it is obviously possible to increase the number of such buildings by spreading rumours. SBS is even defined as a set of sub-clinical symptoms with no identified cause, and if the cause of any of them becomes known, the dose-response relationship is given another name. In order to be sure that the unknown cause is some factor in the building it is necessary that the symptoms disappear when the person experiencing them leaves the building, and in conventional questionnaire surveys of SBS the responsibility for determining that this is the case is always delegated to the sufferer. This is why campaigns can and do alter the number of buildings classified as "sick", and why those responsible for making investment decisions to alleviate SBS in a specific building almost invariably find that their caution in committing the often very large sums involved is taken to indicate disbelief of the reality of the symptoms reported by the sufferers. Such a conflict situation can very quickly escalate, resulting in the adoption of untenably extreme positions by both sides, with demands from one side, for example, that the building must be evacuated or pulled down, and claims from the other side that all is for the best in the best of all possible buildings. This can be very expensive to resolve in terms of resources and prestige, and may even be impossible to resolve merely by appealing to existing knowledge, without new information.

In order to justify expensive and energy-consuming technical measures, it should ideally be demonstrated that they will reduce complaints indirectly, that is, by affecting the indoor climate, and not just by their effect on opinion, for in the latter case PR measures might be more cost-effective. They would certainly be quicker and would use less energy. An agreed procedure for proving that the proposed technical measures really do alleviate reported symptoms by means of their effects on the indoor climate is therefore required. This paper addresses that requirement.

LIMITATIONS OF THE EPIDEMIOLOGICAL APPROACH

The most common response to an SBS problem is firstly, to assess the extent and severity of the SBS symptoms experienced by the occupants, using a one–shot, retrospective questionnaire, and secondly, to commit substantial manpower and resources to measuring as many parameters of the physical conditions in the building as possible. There are a number of reasons why this approach will often fail. The questionnaire results may be biased by a number of situational factors, and may thus be useless for comparison with any "normal" questionnaire result. In addition, as occupants are usually asked how often the symptoms had appeared in the last three months or longer, they may bear little relation to the physical conditions available for measurement. These may, for example, vary seasonally, or be affected by activities carried out only intermittently in the building. It is never possible to afford all the physical, chemical and micro–biological measurements that are available, and as selection of those to be made is based only on an educated guess as to what might be the problem, key measures may be omitted. In the absence of any understanding of the mechanisms causing SBS, it is not possible to evaluate the measurements that are made with any certainty: the most common result is that "all measures appear to be within permitted limits". Even if there is sufficient variation within the building for correlations to be found between symptom occurrence and specific physical measures, this does not prove causation. The correlation may be due to their mutual association with some third factor.

ETHICAL CONSIDERATIONS

The concept of field experimentation with human subjects is foreign to toxicologists and epidemiologists alike. The former are used to dealing with substances of proven toxicity, the latter to the transmission of known diseases. It would obviously be unethical to experiment with either in the field. However, in the special case of Sick Building Syndrome, nothing is yet known of the causative substances, which may be assumed to occur in a wide range of buildings in current use, and the symptoms involved are sub–clinical, i.e. they do not indicate the existence of clinical disease. If it can be shown to be useful to experiment with remedial measures, using symptom intensity as the dependent variable to assess their efficacy, an ethical case can easily be made both for making a given change, provided that there is reason to believe that it may help to alleviate SBS–symptoms, and for omitting to do so, because there is no certain knowledge that it will have any effect at all. The preconditions for an empirical experiment are then fulfilled.

ENGINEERING OPTIONS

Building engineers always have a number of options in the operation of a building, and many more in considering ways to modify or rebuild it. It is obviously essential to begin by ensuring that the building is being operated as designed, and many SBS problems are found at this stage to have such trivial causes as closed fresh air dampers, blocked or perforated filters, fan failure, faulty insulation, improper cleaning routines, condensation and subsequent mould growth. Only when such mistakes have been rectified or ruled out should field experimentation be considered as a means of determining the efficacy of the remaining engineering options. In the pilot study described below, this stage had already been reached, and the epidemiological approach had been rejected, for the reasons set out above, before the author was involved.

BACKGROUND TO THE MAS STUDY

A large proportion of the c.1000 people working in the surgical wing of Malmö General Hospital (MAS) in 1987 were dissatisfied with the indoor conditions in this relatively new building, in fact over 250 of them used the formal procedure available in Sweden for registering claims of industrial injury (arbetsskadeanmälning) to document their view that working in the building was causing them to experience symptoms associated with Sick Building Syndrome (SBS). The Technical Division of the hospital (TUT: co–investigators B.Andersson & M. Söderling) examined every part of the air distribution system, and found that it was functioning according to specifications, that filters were changed as prescribed, ducts were clean, and all rooms were equipped and furnished as they were designed. All normal indices of air pollution indicated levels well below their respectively permitted levels. The complaints led to a press campaign, and the surgical wing was classed as a "Sick Building",

one more of the many classed as "sick" during that year, in which it was claimed that "30% of buildings owned by the local authority" were "sick". It was both desirable and necessary to undertake some technical measures to alleviate the symptoms experienced by the staff, but the problem was to know which one of many proposed measures would in fact help.

All of the reported symptoms were of the SBS type, and as the building was new, built and equipped to a very high standard, and apparently in good working order, the probability of being able to identify the causative factor or factors simply by measuring every available physical and chemical parameter of the indoor environment was judged to be very low. Staff representatives expressed their view that humidification of the air and artificial ionisation would alleviate the symptoms. A literature survey showed that the presence of humidification in a building is often associated with SBS, and that although humidification does reduce complaints of dry air, a small temperature reduction may be expected to have an equivalent effect, without causing an increase in complaints of high humidity [1,2]. Humidification is a relatively expensive measure to install and run, consumes a great deal of energy, and improperly installed or maintained humidification equipment has been associated with many serious epidemics of respiratory infection.

Ionisation of indoor air is a well-established technique in southern and eastern Europe, but in the view of the author has never been satisfactorily demonstrated to have any effect at all on man, except, historically, in asthma therapy, and to reduce airborne infection in the treatment of burns, where ionisation contributes to air hygiene by ensuring that airborne particles are charged and are therefore more rapidly deposited on surfaces bearing an opposite charge. This physical effect of ionisation would be a sufficient explanation for every reported case of an apparent effect of ionisation on man. More speculative explanations are unnecessary and unjustified unless the presence of respirable dust and the nature of the electrostatic fields in the vicinity of the subjects are sufficiently well documented for the simpler explanation to be ruled out. No published studies of the possible effects of ionisation on SBS could be found. The decision was taken to set up well-controlled field trials of the effects on SBS, if any, of the three above-mentioned measures, and of the effects of six other technical measures which might, according to other hypotheses of cause and effect, be expected to alleviate SBS. The effects of all nine technical measures were to be studied empirically in the wards of the surgical wing at MAS, with SBS symptom intensity and frequency of occurrence as the dependent measures.

PROJECT GOALS

1. To determine which of nine selected technical measures, if any, have a measurable effect on SBS at MAS.
2. To determine whether available objective measures of SBS symptom intensity co–vary with subjective symptoms, between persons under reference conditions, and/or in response to the technical measures.
3. To separate any effects of the technical measures mediated by expectation or imagination from any effects mediated by their effect on indoor climate.
4. To exclude the effects of external influences, such as season, weather, epidemics, public debate or press campaigns, on the results.
5. To develop a simplified procedure for identifying effective technical measures in buildings subject to similar complaints.

The above goals were explicitly stated at the outset to be more important than the scientific goal of investigating the underlying mechanisms for any effects discovered, or of identifying the air pollutants presumed to be causing the problems. As 20 years of world-wide SBS research directed towards these scientific goals has not yet succeeded, the chances of deriving the necessary basis for investment decisions by adopting them once more were assumed to be small.

DESIGN OF THE STUDY

Table 1 lists the nine different technical measures whose effects on SBS were to be studied, the reference groups for each condition, and those three cases in which it was possible to establish a placebo condition. The study was carried out in consecutive stages in a number of different wards on floors 4-6 of the surgical wing, as shown in the Table, as a comparison between one ward where specified technical measures had been taken to alter the indoor climate, and another where nothing had been done. SBS symptom occurrence and intensity

among the staff in both wards were quantified in the same way on alternate days during the last week of the three-week period in which each measure was applied. Where this was possible and desirable, the staff in a third (placebo) ward were given reason to believe that the same technical measures as had genuinely been undertaken in the experimental ward, had also been taken in their ward, and their SBS symptoms were evaluated concurrently with those of their colleagues in the reference and experimental wards. No placebo ward was necessary in the case of altered airflow rates, or in the case of cleaning routines using fewer chemicals, for example, as the staff could not determine whether they were working under reference or experimental conditions, and no placebo condition was possible in the case of air temperature reduction, as the staff could easily determine the temperatures to which they were exposed, but placebo aircleaners were installed, which resembled real aircleaners and sounded like them, but were not fitted with filters, placebo antistatic measures were taken (the staff were provided with untreated clothing as if it had been specially treated, and surfaces were not in fact treated although they were stated to have been treated to reduce static charge), and placebo ionisers were installed, which looked identical and even had light emitting diodes to indicate operation, but which did not in fact produce any ions.

By evaluating SBS symptoms concurrently in the experimental, reference and placebo conditions, external influences such as season, weather, epidemics, press reports, etc. affect all conditions equally and cannot affect the differences between them. Conventional before-and-after studies can easily be sabotaged by such influences, which are not always detected. By including placebo conditions, any effects of expectation or imagination can be separated from genuine effects.

SBS-SYMPTOM EVALUATION

All staff members were examined individually by a trained nurse (A. Nilsson) from the Industrial Health Service in a room in the ward where they worked, except in a few cases where the examination was carried out by one of the named co-investigators. Each examination took 15-20 minutes per person. The subject first sat at a PC computer and answered 28 questions

Table 1. Experimental conditions in comparable wards.

	Condition	Period	Description
1.	Low airflow	881121–881211	70% of normal airflow
	Reference	(same weeks)	Normal airflow
2.	High airflow	890130–890219	140% of normal airflow
	Reference	(same weeks)	Normal airflow
3.	Aircleaners	890220–890312	Freestanding aircleaners
	Reference	(same weeks)	No aircleaners
	Placebo	(same weeks)	Simulated aircleaners
4.	New cleaning routines	890109–890129	Reduced use of chemicals
	Reference	(same weeks)	Normal cleaning
5.	Low temperatures	(same weeks)	1.5°C lower room T
6.	Antistatic measures	890227–890319	Clothing & surfaces treated
	Reference	(same weeks)	Normal clothing etc.
	Placebo	(same weeks)	Simulated measures
7.	Reduced glare	900115–900204	Modified lightfittings
	Reference	(same weeks)	Normal lighting
8.	Air ionisation	900122–900211	Ionisers in operation
	Reference	(same weeks)	No ionisers installed
	Placebo	(same weeks)	Ionisers disabled
9.	Humidification	900212–900304	Steam humidification +15%RH
	Reference	(same weeks)	No humidification

by marking a scale on the screen corresponding to the experienced intensity of various SBS symptoms: the subject could move a cursor by operating a "mouse" control, and marked the scale by pressing the button on the control. A new scale was then indicated. Eighteen of the scales represented conventional SBS symptoms, similar but not identical to those used in a questionnaire that has been widely used for retrospective studies of the frequency of occurrence of SBS in Sweden (YMK, Örebro). The scales were of the visual analogue, polar adjective type, and had no markings between the endpoints, which were about 100 mm apart. The questions were formulated to elicit an estimate of the subject's symptom intensity at the time of the interview, whereas the YMK questionnaire asks about the subject's experience over several months, i.e. how he usually feels in the environment under investigation, and assumes that the subject can allow for the variable effects of season, weather, health, fatigue, etc., and can remember which symptoms usually, often or sometimes disappear when he leaves the building. There would appear to be a certain risk that the questionnaire tends to elicit only preconceived, subjective opinions, rather than the empirical observations on which objective opinions can later be based.

While working at the PC, each subject's face was video-filmed in closeup, with their consent, so that blinkrates could later be quantified by observation of the taped record. An observer pressed the space bar on the computer each time the subject blinked, and each inter-blink interval was stored in milliseconds. Descriptive statistics such as the mean and standard deviation of the inter-blink interval were added to the subject's record in the computer. Ten other observations of behaviour and appearance were made from the tape by using a checklist procedure, such as whether the subject coughed, yawned, wetted his lips or breathed through his mouth. The tape was then immediately erased, as staff representatives made this an express condition for agreeing to be filmed. Personal data on smoking habits, wearing glasses or contact lenses, age, sex, employment category, etc. were obtained, by question and answer where necessary, and noted. The observer then examined eyes, lips and facial skin, and made notes of any visible symptoms or signs. Nasal congestion was examined by observing the condensation pattern on a mirror placed below the subject's nose, and noted. The subject was asked without forewarning to empty his mouth of saliva into a weighed container, which was later reweighed, and then to swallow a vitamin pill as quickly as possible while the observer measured the time taken to achieve this with a stopwatch. Thirst was investigated empirically by offering the subject a weighed glass of water at this point, and allowing it to remain within easy reach until the end of the examination, when it was reweighed.

Tear-film stability was estimated by using a variant of the so-called BUT-test (Break-Up-Time) that was developed for group studies, in which the subject is taught to report the discomfort experienced when the tear-film ruptures during a period in which blinking is voluntarily suppressed [3]. The subject's nails were inspected and the number of perfect nails (0–10) was noted. Dry skin on the fingers was similarly observed and noted, and an objective test was performed to detect skin imperfection: the subject was asked to draw each hand across a small cushion of nylon material held close to the observer's ear, to determine whether either hand "caught" audibly in the material. The subject was asked to state whether lip-salve, hand-cream, throat tablets or aspirin (for headache), had been used that day. The sense of smell was investigated using five small containers presented in random order, in four of which were concealed household substances such as coffee, tea, fresh onion and cinnamon. The fifth was empty. Correct identification was noted in each case. This concluded the examination and interview. All the above measurements, observations and answers were subsequently added to the subject's file on the computer that had been used to obtain subjective estimates, and later transferred to a larger computer for statistical analysis.

INDEPENDENT MEASURES

The nine experimental conditions were established for three-week periods as shown in Table 1, during the course of the 88/89 and 89/90 heating seasons.

1. Reduced airflow: supply and exhaust airflows were reduced by 30%.
2. Increased airflow: supply and exhaust airflows were increased to their design maximum, an increase of 40% from normal practice.
3. Air filters: 40 free-standing aircleaners were installed in the various rooms of the experimental ward. Each unit was equipped with a

fan which passed room air through a pre-filter and a fine filter. In the placebo condition, 34 apparently identical units were similarly installed, but the filters had in fact been removed. However, the noise level from the fans was too high in both wards (54dBA), especially at night when the ambient noise level was low (25dBA), and the nursing staff was obliged to reduce the fanspeeds for the sake of the patients. The noise level at 40% fanspeed was still 50dBA, and it has been estimated that 95% of the units were set at minimum fanspeed for 95% of the experimental period, and therefore had a negligible effect on air quality. No reduction in particle density could be detected in the airsamples that were taken during the experiment. This phase of the experiment has therefore been treated in the analysis as an unintended opportunity to study differences between three parallel reference wards, all subject to the same external influences from weather, season, etc.

4. New cleaning routines: floors, furniture and shelves were cleaned only with water, i.e. without the normal cleaning and disinfectant agents. Sanitary installations were cleaned in the normal way and then wiped with cloths dipped only in clean water.

5. Reduced room temperatures: set values for supply air were reduced by 3°C, and radiator thermostatic valve settings were reduced by 2°C. The measured reduction in room temperature averaged 1.5°C.

6. Antistatic treatment: conventional measures were taken to reduce static electric charging by treating floors, equipment and clothing. The static electrical charge measured on staff members during their work was thereby reduced from 2–4000 V in the reference ward, to <100 V in the experimental ward. The experimental procedures were simulated in the placebo ward, and did not reduce static charging measurably.

7. Reduced lighting glare: the lighting units in the wards were fitted with baffles to reduce glare, but these were of a reflecting material which still appeared very bright. In the experimental ward these baffles were exchanged for baffles painted a brownish yellow, which decreased glare considerably. The measured lux-value was reduced by 13%, luminance by 33%. The staff of the experimental ward have requested that these baffles be retained.

8. Ionisation: 37 small air ionisation units were installed in the various rooms of the experimental ward, each unit supplying negative ions to the room air and having a small positively charged external panel maintained nominally at 8000 V. The units had no moving parts, i.e. they did not draw room air through them or increase air movement in the ward. 37 apparently identical units were installed in the placebo ward. These units were connected to the mains supply and a red light-emitting diode on each unit apparently indicated that they were in operation, but they had been disabled and did not in fact emit negative ions or charge their external panels. The measured concentration of negative ions was 26000 cm^{-3} in the experimental ward, and 60 cm^{-3} in the reference and placebo wards. The corresponding measured levels of positive ionisation were 0 cm^{-3} and 160 cm^{-3}, respectively. Filter paper placed on the positively charged panels was observed to become rapidly discoloured, and was regularly changed. At the end of the experimental period, when the ionisers were removed, the staff of both experimental and placebo wards protested, which was taken to indicate that they had not detected that the placebo units were dummies.

9. Humidification: steam humidification was provisionally installed in the pressure chamber of one of the two ventilation systems of the building, serving half of the wards. The staff immediately objected strongly when the relative humidity in the wards was raised to 50%, and would not accept 45% as an alternative. 40% RH was reluctantly accepted for the three-week experimental period only, i.e. a 15% increase from the 25% RH in the other half of the building where outside air without humidification was supplied as usual during the same period.

RESULTS

A detailed report was prepared for the funding agencies and is available in Swedish from Malmö General Hospital [4]. The following conclusions may be drawn in relation to the five stated goals for the project set out above:

Goal 1:

SBS-symptoms were not significantly affected by increasing or decreasing the ventilation rate, by reducing the amount of chemicals used in cleaning, or by the reduction of personal static charge. A significant positive effect was obtained by reducing the room temperature by 1.5°C ($P<0.02$) and by reducing lighting glare ($P<0.02$). Humidification of the air (+15%RH) significantly reduced the measured severity of SBS-symptoms ($P<0.001$), as shown in Figure 1, but the observed effects were not only positive: the staff reported significantly more subjectively experienced "stress". Ionisation with negative ions (26000 cm^{-3}) together with the presence of 8kV anodes had a highly significant and beneficial effect on SBS-symptoms ($P<0.002$), in comparison with the placebo condition, as shown in Figure 2. The effects were numerous, large and statistically significant, and no negative effects of ionisation were observed. SBS-symptoms measured concurrently in the same way in the reference ward did not differ significantly from those measured at other times in other reference wards.

Goal 2

A total of 222 subjects were examined in the 8 reference wards, and in these data, subjects who experienced subjective symptoms were more often found to have objectively observable symptoms: this association was significant for 8 different measures, relating to 6 different SBS-symptoms. Thus a subjectively dry mouth was associated both with a reduction of objectively measured saliva quantity ($P<0.05$) and with an increase in the time taken to swallow a vitamin tablet presented unexpectedly ($P<0.001$); subjectively dry lips were associated both with objective observation of dry lips ($P<0.001$) and with reported use of lipsalve ($P<0.01$); objective observation of dry lips was associated with reported use of lipsalve that day ($P<0.001$); subjective eye discomfort was associated with reduced BUT ($P<0.05$); subjective headache was associated with reported use of aspirin that day ($P<0.001$); and a subjective feeling of being "heavy in the head" (a common Swedish expression distinguishable from a true headache) was also associated with reported use of aspirin that day ($P<0.05$).

A total of 339 subjects were examined in the 12 experimental and placebo wards. In six different cases, where the experimental conditions were found to significantly affect subjective symptoms, it was possible to show that corresponding changes in objectively observable symptoms had also taken place. Thus a subjectively dry throat was significantly alleviated by ionisation ($P<0.05$), and reported use of throat pastilles that day was also significantly reduced in the same population ($P<0.05$); subjectively dry lips were significantly alleviated by ionisation ($P<0.001$), and the number of objective observations of dry lips in the same population tended also to be

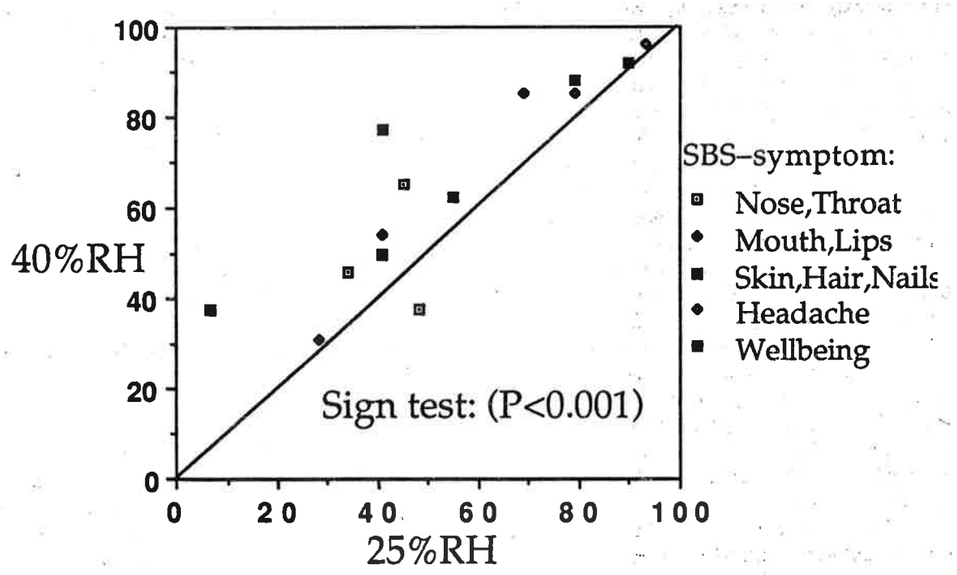

Figure 1. Humidification: % responding positively.

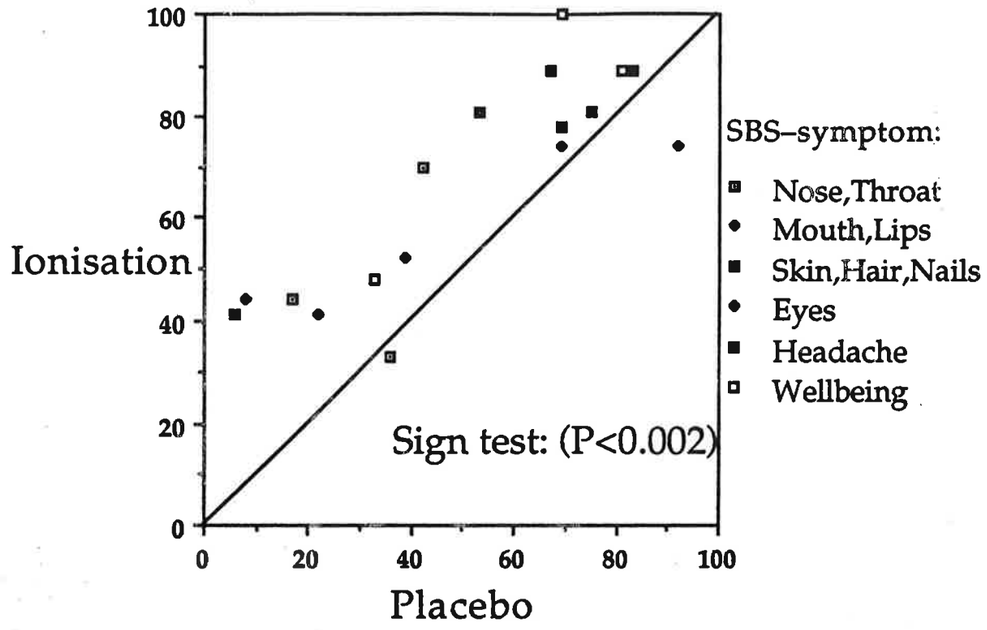

Figure 2. Ionisation: % responding positively.

reduced (P<0.10); subjectively dry skin was significantly alleviated by raised humidity (P<0.01), and dry skin on the fingers was observed significantly less often in the same population during raised humidity (P<0.02); subjectively dry skin was significantly alleviated by ionisation (P<0.001), and dry skin on the fingers tended to be observed less often in the same population during ionisation (P<0.10), in comparison with the placebo condition; subjectively brittle nails were affected positively by ionisation (P<0.02), and cracked or broken nails were objectively observed less often in the same population during ionisation (P<0.05); subjectively dry eyes were significantly alleviated by ionisation (P<0.02), and the objectively measured inter–blink interval of subjects exposed to ionisation of the air was significantly increased (P<0.001), in comparison with measurements made in the placebo condition.

Objective measures have thus been shown to confirm subjective SBS–symptoms, both between people under reference conditions, and in response to environmental changes.

Goal 3:

In the ionisation experiment, 4 significant and positive effects of expectation or imagination were found, three of which were of reported mood or attitude to work. The 15 significant effects of air ionisation, in comparison with the placebo condition, were all on specific SBS–symptoms.

Goal 4:

There were no significant differences in any of the subjective or objective measures between the three wards where the non–existent physical effects of disabled aircleaners were unintentionally studied during the same period. However, there were significant differences between different reference wards when they were studied consecutively, but only in terms of symptoms relating to the lips, facial skin, and the use of lip–salve, all three of which are typically influenced by weather and time of year. The experimental design, in which symptoms experienced under experimental conditions were always compared with symptoms experienced under reference conditions during the same

period, eliminated any such influence on the reported results.

Goal 5:

As the available objective measures tended always to confirm the reality of the subjectively experienced symptoms, as obtained by asking subjects to mark visual analogue, polar adjective scales, it should be possible to use the 18 SBS–symptom scales in practical trials of proposed technical measures to alleviate SBS–symptoms. It is not recommended that subjects should be asked to mark the scales on the screen of a PC, as they did in the present experiment: too many of them were unfamiliar with the use of a mouse control, and tended to place the marker in the middle or at one end of the scale. The resulting response distributions are more difficult to use in statistical analysis than the Normal or J–form distributions that are routinely obtained when subjects mark polar adjective scales of this type using pencil on paper.

DISCUSSION

The approach followed in this study may be said to have succeeded, as all five project goals were attained. For the first time, subjective symptoms of SBS were found not only to be correlated with objective signs in a given population, as demonstrated for "office eye syndrome" [5], but also to co–vary with them in response to changes in the physical conditions under which the subjects worked. Subjective estimates of current symptom intensity, obtained by the use of visual analogue scales, may therefore be used with confidence in experimental field studies, provided that proper placebo techniques are used to separate real from expected and imagined effects. Technical measures which may or may not improve the indoor environment may be tested empirically on a limited scale to see whether they do, regardless of whether the mechanisms by which the measures are supposed to have their effect are properly understood. Scientific study of cause and effect can then proceed after the necessary measures to alleviate SBS have been taken, in an atmosphere of inquiry rather than of mutual recrimination, and without the time pressure associated with providing a rational basis for urgently needed and often very large investments in improving the building stock.

That humidification and ionisation should have been found to be the most effective of the 8 measures that were evaluated in terms of their measurable effect on SBS, was unexpected, to say the least, and must be carefully confirmed in follow–up studies over longer periods. The underlying mechanisms for the observed positive effects on SBS–symptoms are believed to be, for ionisation, a reduction in the density of airborne respirable particles, caused by the deposition of charged particles on charged surfaces of opposite sign, mainly walls, floor and ceiling, but including the ionisers' own positive plates; for humidification and for reduced room temperature, a direct and positive effect on the moisture balance of the mucus membranes, and therefore on mucus flow rates and their ability to deal with airborne particles; and a reduction of glare effects (the staff were significantly less often observed to have red eyes in the experimental lighting condition). It should be emphasised that these are only hypotheses to explain the observed empirical effects of the technical measures on SBS.

CONCLUSIONS

Field experiments, in which the effects of various technical measures on SBS are studied empirically, can provide a cost–effective basis for investment decisions, whether or not the underlying cause of the problem is understood.

REFERENCES

1. Andersson L–O, Frisk P., Löfstedt B. and Wyon D.P., *Human response to dry, humidified and intermittently humidified air in large office buildings*. Document D1, 69p. Stockholm: Byggforskningen (1975).
2. Jaakola J.J.K., Heinonen O.P. and Seppänen O., Sick building syndrome, sensation of dryness and thermal comfort in relation to room temperature in an office building: need for individual control of temperature. *Environment International*, **15**, 163–168 (1989).
3. Wyon N.M. and Wyon D.P., Measurement of acute response to draught in the eye. *Acta Ophthalmologica*, **65**, 385–392 (1987).

4. Wyon D.P., Andersson B. and Söderling M. *Fältprovning av ett nytt åtgärdspaket mot SBS (Sjuka Hus Syndromet): stegvis teknisk sanering med kvantitativ mätning av symtomintensitet.* Project report to AMF, 80p, with English Summary. Malmö, Sweden: Sjukvården Malmö, Allmän Service, 214 01 Malmö (Fax 4640 336216) (1991).
5. Franck C., Eye symptoms and signs in buildings with indoor climate problems (office eye syndrome). *Acta Ophthalmologica*, **64**, 306–311 (1986).
6. Wyon D.P., Andersson B. and Söderling M., Fältprovning av åtgärder mot SBS i vårdrum vid MAS. *Bygg and Teknik*, **3**, 29–31 (1991).
7. Wyon D.P., Andersson B. and Söderling M., *Field trials of technical measures to reduce Sick Building Syndrome in a Swedish hospital.* Contribution to the CIB/W77 Working Group Meeting at Yale University, New Haven, Connecticutt, 9–11 September 1991 (Translation of above) (1991).

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DOES ENVIRONMENTAL TOBACCO SMOKE (ETS) CAUSE ADVERSE HEALTH EFFECTS IN SUSCEPTIBLE INDIVIDUALS ? A CRITICAL REVIEW OF THE SCIENTIFIC LITERATURE: I. RESPIRATORY DISORDERS, ATOPIC ALLERGY AND RELATED CONDITIONS

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ABSTRACT

The epidemiological data with respect to long-term effects of ETS exposure on adult asthmatics are inconclusive. Experimental studies of acute effects of ETS exposure in asthmatic adults have produced equally inconclusive results. A small subset of individuals with asthma may react adversely to ETS exposure. The basis of these reactions remains to be determined. The data with respect to potential effects of exposure to ETS on COPD and other chronic respiratory disorders are virtually non-existent. Studies consistently have failed to find any correlation between subjective complaints of sensitivity to tobacco smoke and either skin or serologic tests of immunologic reactivity to tobacco-related antigens. ETS can cause annoyance, most likely related to odor perception, and eye and upper respiratory irritation, most likely on a non-specific, non-immunologic irritant basis. It has not been convincingly demonstrated that certain individuals are particularly hypersensitive or susceptible to such effects on any physiological basis. Exposure to ETS has been included among the various exposures alleged to precipitate symptoms or perpetuate chronic illness in individuals said to suffer from so-called MCS. However, the unscientific nature of these "data", make it very difficult to conclude that individuals said to have MCS are more susceptible to claimed health risks of exposure to ETS than the general population.

INTRODUCTION

The question of whether or not exposure to environmental tobacco smoke (ETS) poses a risk of acute or chronic disease or physiological impairment in non-smokers has engendered considerable discussion in the scientific literature, resulting in the convening of a number of meetings and considerable publication, including a number of comprehensive symposia and reviews addressing various aspects of the issue [1-4]. Major areas of recent focus and controversy have included: risk of lung cancer associated with spousal smoking; prevalence of respiratory symptoms/illness in children whose parents smoke; and risk of cardiovascular disease [5-12].

Of some concern has been the question of whether or not there are individuals who are particularly sensitive or susceptible to possible adverse health effects of ETS exposure [13]. In the United States, the enactment into law of the Americans with Disability Act of 1990, which mandates accommodation of disabled persons, has raised questions regarding definitions of disability and susceptibility, as well as issues relative to the exposures and conditions under which susceptible individuals may be at risk [14].

This paper and a subsequent paper to follow [15] are intended to provide a comprehensive, critical review and analysis of the scientific literature relative to the issue of whether certain groups of individuals are more susceptible than the general population to possible adverse health effects as a result of short- or long-term