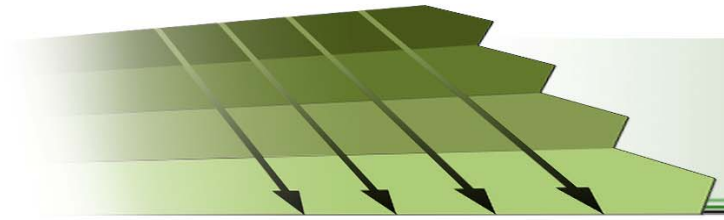

CORE
Public Health Functions for BC

Evidence Review:
Air Quality - Indoor

Population Health and Wellness
BC Ministry of Health

April 2006

This is a review of evidence and best practice that should be seen as a guide to understanding the scientific and community-based research, rather than as a formula for achieving success. This review does not necessarily represent ministry policy, and may include practices that are not currently implemented throughout the public health system in BC. This is to be expected as the purpose of the Core Public Health Functions process—consistent with the quality improvement approach widely adopted in private and public sector organizations across Canada—is to put in place a performance improvement process to move the public health system in BC towards evidence-based best practice. Health authorities will develop public performance improvement plans with feasible performance targets and will develop and implement performance improvement strategies that move them towards best practice in the program component areas identified in the Model Program Paper. These strategices, while informed by the evidence in this review, will be tailored to local context.

This Evidence Review should be read in conjunction with the accompanying Model Core Program Paper.

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Population Health and Wellness, Ministry of Health (June 2004)
Core Functions Steering Committee (April 2006)

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EXECUTIVE SUMMARY

Most Canadians spend over 85-90 per cent of their time indoors. Although some outdoor air pollutants can move into buildings, indoor sources of pollutants can have a major impact. For many pollutants, concentrations are higher indoors than outdoors. This review was conducted to assess the evidence behind public health indoor air interventions.

A literature search on indoor air pollution was conducted using several online databases. The items retrieved included systematic reviews, evidence-based medicine databases and interventions studies. To be included in the review, the studies had to focus on interventions and their effects on health. Several exclusion criteria were identified. The exclusion criteria included: 1) intervention studies on topics addressed by systematic reviews unless they were published after the systematic review and led to conclusions different than the systematic review; 2) studies with specific focus on occupational indoor pollution exposure; 3) smoking cessation intervention if not related to environmental tobacco smoke; and 4) studies or reviews about the association between exposure to air pollution and health effects that did not refer to any interventions. Any papers that did not meet the inclusion or exclusion criteria with certainty were assessed by a second reviewer. All systematic reviews related to indoor air interventions were compiled into tables.

A total of 257 studies were retrieved, of which 19 were reviewed for this report. The studies were grouped by intervention type. The interventions types identified involved humidity control, ventilation, particulate matter/dust, indoor allergens and environmental tobacco smoke.

Only two studies were included that examined the health benefits following interventions on humidity. There was very little evidence that showed the efficacy of humidity control on the reduction of health effects.

Four papers were included that looked at the impacts of ventilation and health. There was sufficient evidence that improving inadequate ventilation can decrease the prevalence of sick building syndrome as well as self-reported symptoms. It is recognized that many building ventilation systems are not functioning up to design specifications. Debate continues on appropriate ventilation standards.

Four studies were reviewed that investigated the health impacts of interventions on particulate matter or dust. The small number and poor quality of the reviewed studies made it difficult to determine the beneficial effects of particle filtration on health.

Five review articles investigated the impacts of controlling indoor allergens on health. Limited evidence was found that avoidance of dust mite in allergic people might provide them with benefit. However, the current available evidence is not strong enough to recommend those interventions to asthmatics.

The intervention studies on environmental tobacco smoke (ETS) only looked at the reduction of exposure to ETS and did not evaluate health impacts. These studies did indicate that programs aimed at decreasing children's exposure to ETS could be effective. There was sufficient evidence to recommend bans and regulations of smoking in public and work places.

Based on the available evidence, banning or restricting smoking in indoor environments and provision of adequate ventilation are measures that are effective in reducing the burden of illness from pollutants in indoor air. Other interventions may also be effective but do not have a large body of evidence to support them.

1.0 OVERVIEW/ SETTING THE CONTEXT

In 2005, the British Columbia Ministry of Health released a policy framework to support the delivery of effective public health services. The *Framework for Core Functions in Public Health* identifies air quality as one of the 21 core programs that a health authority provides in a renewed and comprehensive public health system.

The process for developing performance improvement plans for each core program involves completion of an evidence review used to inform the development of a model core program paper. These resources are then utilized by the health authority in their performance improvement planning processes.

This evidence review was developed to identify the current state of the evidence based on the research literature and accepted standards that have proven to be effective, especially at the health authority level. In addition, the evidence review identifies best practices and benchmarks where this information is available.

1.1 An Introduction to This Paper

The indoor environment plays an increasingly important role on human health. On average, North American people spend approximately 85 per cent of their time indoors, and may be exposed to known health hazards. These exposures can be from biological (e.g., dust mites), chemical (e.g., benzene) and physical (e.g., fine particles) contaminants emitted indoors or coming from polluted outdoor air.

This review of published studies and systematic reviews has been conducted to assess the evidence behind public health indoor air interventions. The purpose of this report is to present a review of the scientific literature that examines the evidence for positive health gains from indoor air interventions, and, in light of this review, present directions/recommendations to the BC Ministry of Health in the development of indoor air public health core programs in BC.

2.0 METHODOLOGY

A literature search on indoor air pollution was conducted in Medline, the Cochrane Database of Systematic Reviews, the US Preventive Services taskforce, the US CDC Task Force on Community preventative services, the Canadian Task Force on preventative services and the Ovid EBM Reviews. The items retrieved included (1) systematic reviews, (2) evidence based medicine databases and (3) intervention studies.

In the Cochrane Database of Systematic Reviews, reviews related to indoor air pollution (searched using "dust mites, molds, combustion by-products, particulates carbon monoxide, carbon dioxide, sulphur dioxide, formaldehyde, hydrocarbons, nitrogen oxides, air quality, air pollutant or indoor air.mp") were identified. Due to the small number of reviews identified, the complete list of reviews in relevant working groups were also searched, to identify systematic reviews that could have been missed by the Medline search.

The US Preventive Services Taskforce, the US CDC Task Force on Community Preventive Services and the Canadian Task Force on Preventive Medical Services were searched for indoor air reviews.

Medline (1966 to March, week 5 2004), was searched using two methods: 1) with the subject heading "air pollution, Indoor" or "indoor air pollution.mp", and limited to systematic reviews, and 2) using the subject heading "air pollution, indoor" or "indoor air pollution.mp" and limited to intervention studies subject heading or intervention studies.mp

The Ovid EBM reviews database was searched with "air pollution, indoor" subject heading or "indoor air pollution.mp". This database includes Cochrane Database of Systematic Reviews (CDSR) 1st Quarter 2004, ACP Journal Club 1991 to January/February 2004, Database of Abstracts of Reviews of Effectiveness (DARE) 1st Quarter 2004, Cochrane Central Register of Controlled Trials (CCTR) 1st Quarter 2004. These were limited by the restricted time frame covered by the search capability of the UBC catalogue of EBM databases.

Exclusion criteria included:

- Intervention studies on topics addressed by systematic reviews were excluded unless they were published after the systematic review and leading to conclusions different then the systematic review,
- Studies with specific focus on particular occupational indoor air pollution exposure (like control of indoor air pollutants in dry cleaners),
- Smoking cessation intervention if not related to environmental tobacco smoke (e.g. reviews on effectiveness of smoking patch for smoking cessation), and
- Studies or reviews about the association between exposure to air pollutants and health effects were excluded if they did not refer to any interventions.

To be included in the review, the studies or reviews had to focus on interventions and their effects on health. All the titles and abstracts with uncertainty regarding inclusion and exclusion

criteria were assessed by a second reviewer. Occasionally reviews and studies were identified more then once; they are reported only in the search result were they were identified originally.

All systematic reviews related to indoor air interventions were compiled in tables outlining (1) the selection criteria and brief summary of methodology of included studies, (2) the main results of those studies, (3) a summary of the discussion and conclusion of those reviews and (4) the implications of those reviews.

3.0 RESULTS

3.1 Studies and Reviews Included

A total of 257 studies were retrieved (Table 1 presents the results of the literature review) in which 19 were reviewed for this report. A summary of all the studies and reviews, according to indoor intervention type, is presented in Table 2.

Table 1: Results of Literature Review on Indoor Air

Database	#Retrieved	#Included
Cochrane Database of Systematic Reviews	120	6
US Preventive Services Taskforce	0	0
US Task Force on Community Preventive Services	1	1
Canadian Task Force on Preventive Services	0	0
Medline (#1 – systematic reviews)	60	4
Medline (#2 – intervention studies)	19	3
OVID EBM Reviews	57	5
Total Studies	***257***	***19***

Table 2: Summary of Included Studies by Intervention Type

Study	Database	Intervention	Health Effects	Bias
Humidity				
Singh et al. (2003)	COCHRANE Review (172 articles reviewed, 1 included)	Portable and fixed mechanical ventilation in 30 residential homes: • with heat recovery (MVHR) • high efficiency vacuum cleaners (HEVC) • MVHR+HEVC • No intervention	Decline in house dust mite and antigen level in the carpets (not in mattress or sofas) for the groups MVHR and MVHR + HEVC. No difference in clinical self-reported symptoms and peak flows. No report of benefit on patient outcomes from dehumidification by MVHR and/or HEVC	Publication bias, small sample, inadequate randomization
Reinikainen et al. (2001)	OVID EBM	Humidification and temperature in office building	Self-reported increase in dryness symptoms and sensation when temperature rises above 22^{o}C regardless of humidity. Increase in SBS symptoms with increase temperature only when air was not humidified.	Reporting bias
Ventilation				
Wargocki, et al. (2002),	MEDLINE Review (105 papers reviewed, 30 included)	Ventilation rate (0→50 l/s) Ventilation system (natural, vs. mechanical, air conditioning) and health effects in office workers	1) Strong association between ventilation, comfort, productivity and health. 2) An outdoor airflow rate of 25 l/s per person is recommended, (higher then many guidelines and regulation) 3) Air change rate > 0.5 h^{-1} decrease house dust mites in Nordic Countries. 4) Air-conditioned buildings should be assessed further.	Publication bias

Study	Database	Intervention	Health Effects	Bias
Ahman et al., (2000,)	OVID EBM	Floor ventilation in a school with known moisture problems and health in school personnel and pupils	General, airway, and eye symptoms determined by interview In personnel - excess of symptoms disappeared In pupils – only stuffy nose remained elevated (POR=3.1, 95% CI=1.3-7.3)	No blinding, reporting bias
Menzies et al., (1997)	MEDLINE Intervention study	Individualized ventilation control in office building	Non-work related and work-related symptoms (headache, concentration, skin, eye, airway, musculoskeletal) 4months post- fewer work-related symptoms reported and fewer frequent symptoms 16months post-fewer work-related symptoms than baseline, improved productivity in intervention group (11% increase in intervention group vs. 4% decrease in control group)	Reporting bias, no blinding
Jaakkola et al., (1994)	MEDLINE Intervention study	Recirculation of air in office building (0% and 70% recirculation)	No difference was found for self-reported diaries of mucosal irritation, skin/allergic reaction and general symptoms, perceptions of air quality between two groups (At 70% re-circulated air, when accompanied by adequate intake of outdoor air can be used without causing adverse effects)	Reporting bias
Particulate Matter				
Skulberg et al. (2004)	MEDLINE Intervention study	Cleaning in office building (mean dust concentrations $67\mu g/m^3 \rightarrow 50\mu g/m^3$)	Reduction in mucosal irritation complaints (OR for 2.0 point reduction in symptom index=3.5, 95% CI=1.2-91) Reduction in nasal congestion by acoustic rhinometry (OR for reduction at 70^{th} percentile=4.2, 95% CI=1.3-11)	Reporting bias
Mendell et al. (2002)	OVID EBM	Replacement of standard filters with high efficiency filters (reduced concentrations by 94%)	No reduction in symptoms Improvement of performance related mental states (-3.7%, 95% CI=-6.5 to -0.9%), Improvement in environmental dissatisfaction (stuffy air=-5.3%, 95% CI=-38.1 to -8.7%) for every 1^oC decrease	Reporting bias
Richardson et al.	MEDLINE Intervention study	2 stage intervention electrostatic air cleaner and PM3 reduction (40% decrease in PM3) in office building	Sample size too small to make any conclusions	Reporting bias, no control group for health outcomes (absenteeism)
Rosen et al.	OVID EBM	Use of electrostatic air cleaner in two daycares (one old, one new) (428 to 232 particles/litre)	Absenteeism monitored for 3 years, year 2=intervention Absenteeism significantly decreased in the older building during the intervention year (from 8.31% to 3.75%), and then rose again in the following control year (7.94%)	No control, blinding

Study	Database	Intervention	Health Effects	Bias
Indoor Allergen				
Gotzsche et al. (2003)	COCHRANE Review 29+2 trials	1) Chemical (Acaricides) 2) Physical (vacuuming, heating, ventilation, freezing, washing, barrier methods, air filtration, ionizers) 3) Combination	House dust mite antigen (No evidence of reduction of asthma symptoms in house dust mite sensitive people)	Publication bias
Sheikh et al. (2003),	COCHRANE Review 4 Trials	1) Acaricides (2 papers) 2) High efficiency particulate air filter (HEPA) (1 paper) 3) Bedroom environment control program (1 paper)	House dust mite allergen (Weak evidence for the reduction of allergic rhinitis symptoms)	Publication bias
Custovic et al. (2002)	MEDLINE Review 31 papers	1) Air cleaners/ionizers/precipitators (7) 2) Avoidance measures (7) 3) Acaricides (1)	Interventions that were beneficial were not discussed (no mention of intervention, except significant reduction in mites/allergen levels) Many trials failed to reduce mite allergen loads	Publication bias
Kilburn et al., (2003)	COCHRANE Review 2 RCT	Pet allergen reduction (high efficiency filters, air cleaner, pillow and mattress covers, prevent cats from entering bedroom)	No significant effects of these interventions on lung function, bronchial hyperresponsivness, symptoms scores, medication usage, allergen concentration, or biochemical markers	Publication bias
Reisman, (2001)	MEDLINE Review (4 articles)	Air filter (mechanical filters, electronic air cleaners, gas phase filters, high efficiency filters)	No evidence for utility of these devices in the prevention or treatment of allergic disease	Publication bias
Environmental Tobacco Smoke (reduction in exposure only!)				
Serra et al. (2003)	COCHRANE Review (22 studies reviewed, 11 included)	Reduction in public exposure to ETS - Population strategies such as education campaigns, written material, non-smoking and warning signs, and comprehensive strategies on ETS exposure	Effective interventions - carefully planned and resourced multi-component strategies Less comprehensive strategies (posted warnings, education material) were less effective.	Publication bias
Roseby et al. (2003)	COCHRANE Review (19 reviewed, 18 included)	Reduction in ETS exposure in children - smoke free policies and legislation, health promotion, social-behavioural therapies, technology, education, and clinical interventions	No detected effect in brief interventions (parents who attended clinical pediatric or child health services). Limited evidence for more intensive counseling interventions. Interventions that concentrate primarily on changing participants' attitude and behaviors, rather than on change in knowledge more effective	Publication bias
Gehrmann et al. (2002)	MEDLINE Review (19 studies reviewed)	Reduction in ETS exposure in children - smoking cessation, modification of smoking patterns (smoking outside, improving ventilation, smoking in different room then the child)	Home-based interventions appeared to be more effective and had longer contact time than interventions based on a known framework. Interventions should target other behaviour modification and not only cessation	Publication bias

3.2 Summary of Findings

The subject of indoor air quality is very broad, and thus, this review of the current literature does not encompass every aspect of indoor air and health. The studies examined in this report have been grouped by interventions concerning humidity, ventilation, particulate matter/dust, indoor allergens and environmental tobacco smoke.

3.2.1 Humidity

There is very little evidence that shows the efficacy of humidity control on the reduction of health effects. Only two studies were included to investigate the health benefits following interventions on humidity.

Singh, Bara, and Gibson (2003) investigated the efficacy of humidity control in the treatment of chronic asthmatics in randomized control trials. Humidity control included use of portable and stationary mechanical ventilation. From 172 retrieved articles, only one study was included. Singh et al. (2003) concluded that there was no evidence to suggest that humidity control is of clinical benefit for asthmatics, and recommended more randomized control trials due to the small sample and inadequate randomization, as well as the report of no benefit on patients' outcomes from the dehumidification interventions included.

Reinikainen and Jaakola (2001), a crossover study, examined the effects of temperature and humidity on Sick Building Syndrome (SBS) symptoms and perceptions of air dryness in office workers. A crossover trial was conducted in two different wings (one humidified, one non-humidified) of a building in Helsinki, Finland, with questionnaires to evaluate health outcomes. Average intensity of dryness symptoms and sensations of dryness increased with each unit increase in temperatures above 22^{o}C, independent of humidification level, while SBS symptoms increased only when indoor air was not humidified relative to temperature (humidification could mitigate the increase in self-reported symptoms of sick building syndrome with increase temperatures).

3.2.2 Ventilation

There is some evidence that ventilation can improve health with respect to indoor air. Four papers were included to investigate the impacts of ventilation and health.

Wargocki et al. (2002) examined the impact of ventilation on health in a non-industrial (offices, schools, homes, etc.) indoor environment. The term "ventilation" included both the rate (amount of outdoor air supplied to indoor air) and system (natural or mechanical). After reviewing 105 papers, 30 papers were considered conclusive. With respects to ventilation rate, data from 22 papers, with ventilation rates ranging from 0 to 50 l/s, showed that increased ventilation rate improves perceived air quality, decreases prevalence of SBS symptoms and intensity of clinical symptoms, reduces absenteeism and improves performance of office work (2 studies found no effect). The authors recommended an outdoor airflow of at least 25 l/s/person. With respect to ventilation system, the article presented the following: the risk of SBS symptoms is higher in air-conditioned than naturally/mechanically ventilated buildings (6/7 papers); the risk of infections

increased with presence of recirculation (1 paper); and dirty HVAC systems can increase risk of SBS symptoms (1 paper).

Åhman et al. (2000) investigated the impact of increased floor ventilation in a school with floor moisture problems on self-reported health indicators (floor slab relative humidity ranged from 70-90 per cent). Pre- and post-intervention interviews were conducted on the occupants of the building (all staff and pupils) in the problem school plus a control school (no known indoor air problems). Pre-intervention, there were more complaints for general, eye, airway, and skin symptoms in the problem school than the control school. Post-intervention, there was some reduction of symptoms; however, 'stuffy nose' symptoms remained elevated. This study has some limitations, but the intervention resulted in improvement of staff self-reported symptoms. The results for the pupils were not as clear.

Menzies et al. (1997) examined the health benefits of individualized control of ventilation. Two groups (one with only mechanical ventilation control, versus one with mechanical ventilation plus individual control) were compared for self-reported symptoms, pre-intervention, 4 months, and 16 months post-intervention. At 4 months and 16 months post-intervention, workers with the new ventilation reported fewer symptoms, and showed that individual control of ventilation improved self-reported symptoms. At 16 months, an 11 per cent increase in productivity was shown in the intervention group compared to a 4 per cent reduction of productivity in the control group.

Jaakola, Tuomaala, and Seppänen (1994) investigated the health impact of recirculated air in mechanically ventilated buildings. A blinded crossover study was conducted in two identical buildings, with parallel control, on 75 workers that reported symptoms or perceptions of poor indoor air quality. Symptoms (mucosal irritation, skin reaction, allergic reaction and general) and perceptions of unpleasant odour, stuffiness or dustiness, were determined by questionnaire. These results suggest that no significant difference in symptoms were found between 70 per cent recirculation of air compared to no recirculation, and thus 70 per cent recirculated air may be adequate.

3.2.3 Particulate Matter/Dust

Four studies were reviewed to investigate the health impacts of interventions on particulate matter or dust. The beneficial effect of particle filtration on health is uncertain mainly because of the small number, and poor quality.

Skulberg et al. (2004) studied the impact of cleaning on dust and health of office workers that complained of mucosal irritation. A double-blind intervention study conducted in Oslo, Norway, consisted of an intervention building where comprehensive cleaning (all surfaces and vacuuming) was done, while the control building got superficial cleaning (placebo – general wipe down, no vacuuming). Mean dust concentrations in the intervention building were 67μg/m^3 (pre-intervention) and 50 μg/m^3 (post-intervention), which was significantly different from the control building, 49μg/m^3 (pre-intervention) and 70μg/m^3 (post-intervention). Health impacts were evaluated by questionnaire and acoustic rhinometry. The odds ratio was significant for achieving a reduction in mucosal irritation symptoms was 3.5 (95% CI=1.3-10) in the

intervention group compared to the control group. Nasal congestion was also reduced after cleaning for those above 70th percentile, odds ratio of 4.2 (95% CI=1.3-11).

Mendell et al. (2002) conducted a double-blind crossover study in an office building with enhanced particle filtration, to investigate the impacts of small airborne particles on health. Standard particle filters (3, 15, 40, and 80 per cent efficiency for 0.3, 0.85, 1.5, and 3µm particles respectively) were replaced on two floors with highly efficient filters (95 per cent efficiency for 0.3µm particles, higher efficiencies for other diameters) for 4 weeks in a US building, and resulted in a reduction of the smallest airborne particles by 94 per cent. Health effects were determined by questionnaire. Enhanced filtration did not show a reduction in symptoms, but performance related mental states, confusion scale, decreased 3.7 per cent.[1]. Environmental satisfaction variables also improved, stuffy air decreased -5.3 per cent.[2]

Richardson et al. (2001) studied a reduction of PM3 (0.3-3.0µm) in an office by altering electrostatic forces. The intervention was done in an administrative building in Plymouth, England, in two stages:

- Stage 1: optimization of existing air processing equipment to original specification (6 weeks).
- Stage 2: 6 weeks with one electrostatic air-cleaning (EAC) unit followed by 12 weeks with a further 3 EAC units with different negatively charged small ions delivery (total of 4).

The control site was a nearby office of similar size with an identical air processor. The small sample size did not allow for any statistical analysis on health outcomes (only 7 employees in both sites), but questionnaire results suggest that some workers perceived better indoor air quality as a result of the intervention (no statistics). A significant reduction in particles from outdoors to indoors did result after the intervention (40 per cent for PM3).

Rosen and Richardson (1999) did a crossover study investigating the impact of electrostatic air cleaning devices on absenteeism in two daycares in Uddevalla, Sweden. One building was larger and older, while the other was more modern, with half as many children. This study was conducted over three years: year 2 was the intervention year, and years 1 and 3 were control years. A 78 per cent significant reduction was found during the intervention; the daily average count of fine particles decreased significantly from 428 (range 340-649) particles/litre, to 232 (range 16-287) particles/litre. The results were different in the two building that received the intervention; results indicated that absenteeism significantly decreased in the older building during the intervention year (from 8.31 per cent to 3.75 per cent), and then rose again in the following control year (7.94 per cent). No significant changes were found in the newer building.

[1] 95 per cent CI=-6.5 to -0.9 per cent.
[2] 95 per cent CI=-10.4 to -0.4 per cent.

3.2.4 Indoor Allergens

Five review articles investigated the impacts of controlling indoor allergens on health. Three reviews examined control measures for house dust mite control, one Cochrane review looked at pet allergen control, and one MEDLINE review examined the efficacy of allergen reduction.

Gotzsche et al. (2003) conducted a meta-analysis on house dust-mite control measures for asthma. Three types of interventions were examined:

- Use of acaricides (chemical).
- Physical (vacuuming, heating, ventilation, freezing, washing, barrier methods, air filtration, ionizers).
- A combination of the two.

A review of 29 plus 2 trials was conducted. For asthma symptoms scores with chemical methods alone, there was a significantly adverse effect. With physical methods alone in crossover trials, there were no significant effects and in a parallel group trial there was a significant beneficial effect (-.44, 95 per cent CI -0.83 to -0.06). No significant differences were noted for the number of patients improved, medication usage, FEV1, for PC20 or PEFR. This paper concluded that there was no secure basis to recommend those interventions. Due to the large number of statistical tests performed, the authors explained that it was expected to obtain two significant results only by chance. The two results reaching statistical significance were: beneficial effect of the use of physical methods alone in one of the outcome of the subcategory of parallel group trial and detrimental effects on one outcome of the chemical control methods.

Sheikh and Hurwitz (2003) reviewed four trials of different house dust mite avoidance measures and the effects on perennial allergic rhinitis. The studies measures included the use of acaricides (two papers), use of high efficiency filters (one paper) and other bedroom control measures (one paper). These studies were considered small and of poor methodological quality but their results suggest that they might be effective in reducing symptoms. All trials showed a significant reduction in house dust mite load; the results suggest that the interventions may be effective in reducing rhinitis symptoms, but no magnitudes were presented in the review.

Custovic et al. (2002) reviewed intervention studies on dust mite allergen and asthma. A total of 31 clinical trials were reviewed (methodology not mentioned) and reported conflicting evidence. Interventions that did not reduce mite allergen exposure included air cleaners/ionizers/ precipitators (7), avoidance measures (7) and the use of acaricides (1). Interventions that were beneficial were not discussed thoroughly (no mention of intervention, except significant reduction in mites/allergen levels). They concluded that many trials had failed to reduce mite allergen loads and that among the trials that had shown reduction some beneficial effects were obtained.

Reisman (2001) examined whether air cleaners have health benefits in allergic disease. Four papers were included in the review. Inclusion criteria were: patient with diagnosed use of an effective air filter, clinical and laboratory evaluation of results and measurement of the results of air filtration on environmental allergen and airborne particles levels and double blind design.

Based on the review, the author concluded that the data presently available were inadequate to establish the utility of these devices in the prevention or treatment of allergic disease.

Kilburn, Lasserson, and McKean (2003) examined the evidence for the efficacy of pet allergen control measures in homes of people with pet-allergic asthma. This review was limited to randomized controlled trials, resulting in only two small trials being reviewed. Interventions that were studied included high efficiency filters, air cleaners, removal of the cat from the bedroom and the use of pillow and mattress covers. This review concluded that there were no significant effects of these interventions on lung function, bronchial hyper-responsivness, symptoms scores, medication usage, allergen concentration or biochemical markers. A sub-analysis of a trial showed difference in FEV1 with active filter compare to baseline, but this was not compared to a change in the control group.

3.2.5 Environmental Tobacco Smoke

The intervention studies on environmental tobacco smoke (ETS) only looked at the reduction of exposure to ETS and did not evaluate health impacts.

On the topic of ETS exposure in public places, two papers were found. They both concluded that the current level of evidence supports the effectiveness of bans or limitations on tobacco smoking in public places and workplaces on the reduction of exposure to ETS.

Serra et al. (2003) investigated the effectiveness of interventions (population strategies such as education campaigns, written material, non-smoking and warning signs and comprehensive strategies) to reduce tobacco consumption in public places. The search was limited to randomized controlled trials only. Twenty-two papers were reviewed, of which 11 were included (all of which were uncontrolled before-after studies). Carefully planned and resourced multi-component strategies effectively reduced smoking within public places. Less comprehensive strategies (posted warnings, education material) were less effective.

The US Task Force on Community Preventive Services (2000) reviewed the published literature to determine which intervention strategies were most effective at reducing exposures to ETS. They found that smoking bans in workplaces resulted in a 72 per cent average reduction in exposure to nicotine vapour. Smoking bans were more effective in reducing ETS exposures than smoking restrictions, and these bans were effective in a wide variety of public and private work places (see Table 3 for recommendations).

Table 3 Recommendations based on systematic reviews from the US Task Force on Community Preventive Services (2000)

Intervention (no, of qualifying studies)	Task Force recommendation regarding use	Intervention Description	Key Findings
Smoking bans and restrictions (n=10)	Strongly recommended	Bans or limits to tobacco smoking in workplaces and public areas (policies, regulations, and laws)	Effective in reducing workplace exposure to ETS in several different settings and populations Eight studies documented decrease in daily tobacco consumption among continuing users Three studies documented increased rates of tobacco-use cessation following implementation of smoking bans
Community educations to reduce home ETS exposure (n=1)	Insufficient evidence	Provides information to persons about reducing ETS exposure in home	Insufficient number of studies evaluating the impact of education efforts on reducing ETS exposure in the home environment

Two studies examined the effectiveness of interventions on reducing exposure of children to ETS.

Roseby et al. (2003) investigated interventions (targeted towards children: smoke-free policies and legislation, health promotion, social-behavioural therapies, technology, education and clinical interventions) directed at people caring for their children. Studies were restricted to randomized controlled trials. Nineteen studies were reviewed, and 18 were included. All studies demonstrated a decline in self-reported exposure in both intervention and control group; however this could be attributed to other interventions in society regarding smoking and ETS or desirability bias. Therefore the authors concluded that there was insufficient evidence to recommend the type of intervention in the study. Brief interventions for parents that attended clinical pediatric or child health services had no detected effect. There was limited evidence for more intensive counseling interventions. There is greater support for interventions that concentrate primarily on changing participants' attitude and behaviours, rather than on change in knowledge.

Gehrman and Hovell (2003) investigated the impact of various ETS preventions (smoking cessation, modification of smoking patterns (smoking outside, improving ventilation, smoking in different room then the child) in smoking mothers on self-reported smoking behaviour. Nineteen studies were reviewed. Their interpretation suggested that small to moderate effects can be expected from interventions. Home-based ones appeared to be more effective and had longer contact time than interventions based on a known framework. Interventions should target other behaviour modification and not only cessation. Most studies found differences in self-reported behaviours; only one study found a difference in cotinine level.

4.0 DISCUSSION

The reviews and studies included present evidence for only a few aspect of interventions related to indoor air. Based on this report, only two interventions have adequate evidence for recommendation:

- The bans and regulations of smoking in public places and office buildings.
- Adequate ventilation.

There is some evidence that programs aiming at decreasing children exposure to ETS could be effective. The absence of strong evidence for these programs does not absolve the clinical evidence behind the harm of ETS, and does not mean that the clinician and the health system should not identify and discuss that issue with parents or caregivers.

There is limited evidence that avoidance of dust mite in allergic people might provide them with benefit. However, the current available evidence is not strong enough to recommend those interventions to asthmatics, despite the well-established acute and long-term effects of dust mite exposure. This might bring into question the current programs promoting systematic environmental control measures of dust mite in sensitized asthmatic patients. Many reasons could be brought forward to try to explain why interventions are not affecting clinical outcomes as discussed in Table 2. It brings back the fact that interventions successful in reducing exposure are not necessarily successful in reducing health effects, as laid out in the analytic model.

None of the intervention studies provided enough evidence to include them into the core program. There is a need for good quality studies and results repeated in more then one study in order to have strong evidence.

The methodology chosen in this report was in line with methodology used in systematic reviews. However it has identified evidence behind only a few topics related to all the possible indoor air pollutants. For many indoor air-specific pollutants there were no studies or reviews identified (e.g., ammonia, benzene, formaldehyde…). Perhaps a different search strategy could provide more information on those specific substances. Some exploratory search could have been done using more specific MESH terms that did not lead to intervention studies. Those exploratory searches have not been applied to all specific air pollutants. Perhaps another explanation is simply the lack of good studies done in this area and published in medical databases. Alternatively, it may reflect the challenges behind conducting interventions targeted at specific pollutants. It is easier to conduct specific experimental exposure studies. This methodology did not attempt to identify exposure studies or link between air pollutants and health; it was purposefully limited to looking at interventions, recognizing that it is not because there is a link between exposure and health that a proposed intervention to decrease exposure will result first in decreased exposure and second in improved health outcomes.

One important finding in this report is the fact that many areas, even with systematic reviews, lack good quality large studies. Perhaps it should be included in considerations related to core programs that research on indoor air interventions should be prioritized. It would be worth exploring further exposure to outdoor air pollutants occurring indoor.

Also, systematic reviews using the RCT (randomized control trial) as the gold standard, and thus rejecting a lot of studies of lower quality, might not reflect all the knowledge that can be gained from the broader literature. There are challenges in applying to public health, evidence-based models that were developed for clinical interventions. It is not always feasible or practical to apply that methodology to community or population based interventions.

The absence of good quality research should not prevent decision makers from exploring promising interventions, as it takes time to produce good quality evidence. However those promising interventions should be evaluated.

5.0 CONTENTS OF A CORE PROGRAM IN INDOOR AIR

Based on the available evidence, the following measures are effective in reducing the burden of illness from pollutants in indoor air:

- Banning or restricting smoking in indoor environments.
- Provision of adequate ventilation.

Other interventions may also be effective, but do not have a good body of evidence to support them. It should be noted that this review excluded interventions that addressed specific contaminants present in unusually high concentrations from a well-defined source (e.g., CO or NO_2 in arenas, mercury spills, or perchloroethylene in dry cleaning establishments). In these cases it is likely that interventions directed at the source will be effective.

A core program in indoor air should include the following:

- Identification of, and intervention to reduce, ETS exposures.
- A proactive program to ensure adequate ventilation in public buildings.
- A response capability to deal with situations where indoor air contaminants may present a health hazard to members of the public.

6.0 CONCLUSION

In conclusion, there is sufficient evidence to recommend bans and regulations of smoking in public places and workplaces. There is evidence to recommend appropriate ventilation. It is recognized that many building ventilation systems are not functioning up to design specifications. There is a debate on what should be recommended regarding ventilation standards and this varies depending on specific situations. Many areas related to indoor air quality impact on health and the impact of interventions do not have high quality evidence published in the health peer-reviewed literature. An effort should be made to strengthen the evidence by prioritizing some of those areas for more research and to look at alternate sources of information to be considered in core programs.

REFERENCES

Åhman, M., Lundin, A., Musabašić, and Soderman, E. 2000. Improved health after intervention in a school with moisture problems. *Indoor Air* 10:57-62.

Custovic, A., Murray, C.S., Gore, R.B., and Woodcock, A. 2002. Controlling indoor allergens. *Annals of Allergy, Asthma, and Immunology* 88:432-441.

Gehrman, C.A., and Hovell, M.F. 2003. Protecting children from environmental tobacco smoke (ETS) exposure: A critical review. *Nicotine and Tobacco Research* 5:289-301.

Gotzsche, P.C., Johansen, H.K., Burr, M.L., and Hammarquist, C. 2003. House dust mite control measures for asthma. *Cochrane Database of Systematic Reviews* 1.

Kilburn, S., Lasserson, T.J., and McKean, M. 2003. Pet allergen control measures for allergic asthma in children and adults. *Cochrane Database of Systematic Reviews* 1.

Jaakola, J.K., Tuomaala, P., and Seppänen, O. 1994. Air recirculation and sick building syndrome: A blinded crossover trial. *American Journal of Public Health* 84 (3):422-428.

Mendell, M.J., Fisk, W.J., Dong, M.X., Petersen, M., Hines, C.J., Faulkner, D., Deddens, J.A., Ruder, A.M., Sullivan, D., and Boeniger, M.F. 1999. Enhanced particle filtration in a non-problem office environment: preliminary results from a double-blind crossover intervention study. *American Journal of Industrial Medicine Supplement* 1:55-57.

Mendell, M.J., Fisk, W.J., Petersen M.R., Hines, C.J., Dong, M.X., Faulkner, D., Deddens, J.A., Ruder, A.M., Sullivan, D., and Boeniger, M.F. 2002. Indoor particles and symptoms among office workers: Results from a double-blind cross-over study. *Epidemiology* 13 (3):296-304.

Menzies, D., Pasztor, J., Nunes, F., Leduc, J., and Chan, C.H. 1997. Effect of a new ventilation system on health and well-being of office workers. *Archives of Environmental Health* 52 (5):360-367.

Reinikainen, L.M., and Jaakola, J.J. 2001. Effect of temperature and humidification in the office environment. *Archives of Environmental Health* 56 (4):365-368.

Reisman, R.E. 2001. Do air cleaners make a difference in treating allergic disease in homes? *Annals of Allergy, Asthma, and Immunology* 87 (Suppl):41-43.

Richardson, G., Harwood, D.J., Eick, S.A., Dobbs, F., and Rosén, K.G. 2001. Reduction of fine airborne particulates (PM_3) in a small city centre office, by altering electrostatic forces. *The Science of the Total Environment* 269:145-155.

Roseby, R., Waters, E., Polnay, A., Campbell, R., Webster, P., and Spencer, N. 2003. Family and carer smoking control programmes for reducing children's exposure to environmental tobacco smoke. *Cochrane Database of Systematic Reviews* 1.

Rosen, K.G., and Richardson, G. 1999. Would removing indoor air particulates in children's environments reduce rate of absenteeism – a hypothesis. *The Science of the Total Environment* 234:87-93.

Serra, C., Cabezas, C., Bonfill, X., and Pladevall-Vila, M. 2003. Interventions for preventing tobacco smoking in public places. *Cochrane Database of Systematic Reviews* 1.

Sheikh, A., and Hurwitz, B. 2003. House dust mite avoidance measures for perennial allergic rhinitis. *Cochrane Database of Systematic Reviews* 1.

Singh, M., Bara, A., and Gibson, P. 2003. Humidity control for chronic asthma. *Cochrane Database of Systematic Reviews* 1.

Skulberg, K.R., Skyberg, K., Kruse, K., Eduard, W., Djupesland, P., Levy, F., and Kjuus, H. 2004. The effect of cleaning on dust and the health of office workers. *Epidemiology* 15 (1):71-78.

US Task Force on Community Preventive Services. 2000. Strategies for reducing exposure to environmental tobacco smoke, increasing tobacco-use cessation, and reducing initiation in communities and health care systems. *CDC MMWR Recommendations and reports* 49 (RR12):1-11.

Wargocki, P., Sundell, J., Bischof, W., Brundrett, G., Fanger, P.O., Gyntelberg, F., Hanssen, S.O., Harrison, P., Pickering, A., Seppanen, O., and Wouters, P. 2002. Ventilation and health in non-industrial indoor environments: Report from a European multidisciplinary scientific consensus meeting (EUROVEN). *Indoor Air* 12:113-128.