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Indoor exposure to chemical and biological agents and health efects in primary school children

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Abstract: The aim of this study has been to estimate effects of indoor air pollutants on children's health. An anamnestic retrospective study was done on 1074 children aged between 7 and 11 years old who lived in Nis (Serbia). An original questionnaire was used in an interview between training physicians and children's parents. Interview data were processed by using Microsoft Excel and Epiinfo 6. The investigation determined that children who were more often exposed to combustion by-products had respiratory and nonspecific symptoms. Parental smoking was strongly associated with wheezing, bronchitis, headache and fatigue. There was no association between health and keeping pets, apart from partial nasal congestion. Presence of insects (e.g., cockroaches) and rats in households was a significant risk factor for all symptoms and diseases estimated except for asthma and pneumonia. Homes abundant in textiles were the cause of nasal congestion, wheezing and fatigue in children. Old mattresses were associated with respiratory symptoms, bronchitis, and nonspecific symptoms. It has been concluded that indoor air quality plays a major role in children's health. Sources of indoor air pollution are present in every home. Being aware of the risks associated with indoor air quality problems, consequently, leads to their mitigation.

Keywords: Indoor air pollution, children's health

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1 Introduction

Although many people primarily associate exposure to air pollution with outdoor urban settings, indoor environments can be contaminated as well, both from outer and inner sources. During the last two decades, the impact of air pollution on health has been primarily associated with exposure to air pollutants in indoor environments.

Indoor air pollutants are numerous, and can be grouped according to origin into four primary classes: combustion products; semi-volatile and volatile organic compounds released by building materials, furniture, and chemical products; soil gas pollutants; and pollutants generated by biological processes.

Children are at high risk, when inhaling toxins, because of their pulmonary physiology. They have higher ventilatory rates per minute (400mL/min/kg in newborns compared to 150mL/min/kg in adults). The volume of inhaled air also varies with activity level: active children inhale much more than those who are calm or asleep. Children breathe through the mouth much more than adults. This breathing behavior may increase child's risk of pulmonary exposure to respirable particles and fibers, otherwise filtered in the upper airway. A higher cardiac pulse rate and the extent of tissue perfusion allow more rapid exposure to toxins absorbed into the blood [1].

Defense against pulmonary infection includes anatomical barriers, mucociliary pulmonary clearance, secretory Ig A and opsonizing IgG, surfactant, complement, plasma components, vasoactive substances, and certain cell types (e.g., macrophages, polymorphonuclear leukocytes). When these are compromised by chronic exposure to indoor air pollutants, lower respiratory tract infections are more likely to develop [2].

Many studies have shown that one of the main reasons for increased prevalence of respiratory diseases in children especially asthma, and acute respiratory infection (ARI), is the inhalation of airborne pollutants [3–7].

In a recent American study, significant data about exposure to pollution from wood stoves has been associated with chronic respiratory symptoms, changes in pulmonary function and hospital visits in school children [2].

An investigation in Great Britain has shown that exposure to volatile organic compounds (formaldehyde) can make respiratory symptoms worse [8].

In another study, a survey of respiratory symptoms in children aged between 12 and 14 conducted throughout Great Britain, as a part of the International Study of Asthma and Allergies in childhood, noted that passive smoking is a major cause of respiratory symptoms. The same survey confirmed that pets increase the risk of wheezing and rhinitis [9].

Environmental tobacco smoke (ETS) can also cause injuries of other systems and organs. A group of scientists from Boston have established a connection between exposure to ETS and higher prevalence of tooth caries in children (OR = 3, 38; P=0, 01) [10]. Some studies have also shown a relationship between exposure to environmental tobacco smoke and cognitive abilities among U.S. children and adolescents [11, 12]. Exposure of children to ETS leads to significant alterations in serum ascorbic acid levels [13].

The evidence of epidemiological studies demonstrates that children's exposure to ETS is a risk factor for middle ear diseases [14].

Home exposures to aeroallergens are an important environmental factor in allergic sensitivity and in the development and exacerbation of asthma [15].

The objective of this study was to estimate the effects of indoor air pollutants on the prevalence of respiratory symptoms and diseases, as well as the prevalence of nonspecific symptoms of different organs in children.

2 Statistical methods and Experimental Procedures

2.1 Experimental Procedures

The study sample consisted of 1074 children aged between 7and 11 from three primary schools in Nis (Serbia). These schools are situated in parts of the town with lower emissions of sulfur dioxide and soot. Data about the outdoor air pollutants from January 1994 to December 2003 were obtained from the Public Health Institute in Nis. Laboratory examination of sulfur dioxide and black smoke was done according to the Regulation of Guideline Values of Emmissions (Official Register Republic of Serbia 54/92). Concentrations of sulfur dioxide were analyzed by spectrophotometry, and concentrations of soot were analyzed by reflectometry.

Assessment of exposure to indoor air pollution was done by using the original questionnaire. Training physicians filled out questionnaires during interviews with children's parents. Investigation was carried out from January to June 2004.

The first part of the interview consisted of questions about a child's home. The child's exposure to combustion products was determined by asking: "Do you have a central heating system in the home?" "Do you heat your living room?" "Which kind of heating material do you use?".

Exposure of children to ETS was specified as in the previous case, from the following questions: "Does anyone smoke in the house?" and "How many smokers live in the house?"

Positive answers to questions like: "Have you any pets in the house?" "Have you got problems with insects and rats in the house?" "Do you have too much textile (such as carpets, curtains, covers) at home?" "Have you got an old mattress in your bed?" meant that a child has been in one way or the other exposed to biological agents.

The second part of the questionnaire was about prevalence of respiratory symptoms (nasal congestion, nasal secretion, dyspnea, wheezing, cough), respiratory diseases (sinusitis, bronchitis, asthma, pneumonia) and nonspecific symptoms (watery eyes, dry throat, headache, fatigue) of children in the past 12 months.

2.2 Statistical methods

All collected data were processed with a software system. All children were divided into an exposed group of determined indoor air pollutants (combustion by-products, ETS,

biological agents) and a nonexposed group. In both groups, prevalence of symptoms and disease was scrutinized. Interview data were analyzed using programs Epiinfo 6 and Microsoft Excel. Statistical significance of difference was established by using a Pearson Chi – Squared test. The odds ratio and 95% confidence interval were calculated to evaluate the presence of associations between all symptoms and diseases in children and environmental variables.

3 Results

3.1 Characteristic of examinees

In a sample of this investigation, 554 (51.60%) were boys and 520 (48.40%) were girls. The average (mean) age was 9.067 (SD ± 1.297) for boys and 9.096 (SD ± 1.233) for girls (Table 1).

Table 1 Characteristics of the Population Study.

SEX	Number (%)	Mean age
Male	554 (51.60)	9.067 ±1.297
Female	520 (48.40)	9.096 ±1.233

3.2 Air pollution monitoring

Children, who attend three primary schools, were situated in point areas for air pollution monitoring. In the examination period, noticed values of sulfur dioxide and soot were below values accounted for in the Regulation of Guidelines Values of emissions ($50\mu g/m^3$ in the urban area, $30\mu g/m^3$in the recreation area). Table 2 shows annual average concentrations of sulfur dioxide and soot in primary schools in period between 1994 and 2003.

Taking into consideration low values of these air pollutants, we concluded that the outdoor air pollution did not have an important influence on the prevalence of respiratory symptoms and diseases, as well as prevalence of nonspecific symptoms.

On the other hand, according to answers given by parents, it was defined that children were exposed to different sources of indoor air pollution (Table 3).

It has been estimated that a large number of children (78.21%) live in houses with individual heating, while 60.71% live in houses with wood or coal heating.

ETS was highly associated with respiratory symptoms, and as many as 69.65% of examinees were exposed to this risk factor.

Almost 20% of children keep pets in a household, most of which are birds, while 23.74% of children live in homes which have problems with insects or rats.

Table 2 Annual average concentrations of sulfur dioxide and soot in the period between 1994 and 2003.

Years	School I		School II		School III	
	SO_2 ($\mu g/m^3$)	SOOT ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	SOOT ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	SOOT ($\mu g/m^3$)
1994	35.02	34.11	44.01	5.02	26.02	2.25
1995	35.34	35.03	41.12	5.00	24.45	1.36
1996	33.68	16.05	39.32	3.23	18.26	1.45
1997	52.44	21.34	43.07	4.07	30.04	1.02
1998	19.32	24.79	16.25	5.31	7.01	1.09
1999	12.01	37.76	21.03	10.01	8.34	2.24
2000	10.32	41.11	5.12	5.23	2.22	0.98
2001	15.45	39.09	7.24	6.45	4.05	1.56
2002	23.09	30.88	7.32	6.63	5.07	0.79
2003	29.02	39.12	2.02	5.25	2.01	0.45

Table 3 Children's exposure to different sources of indoor air pollution.

Sources of indoor air pollution	Number of exposed children (%)	Number of nonexposed children (%)
Individual way of heating	840 (78.21)	234 (21.79)
Heating in living room	652 (60.71)	422 (39.29)
Parental smoking	748 (69.65)	325 (30.35)
Keeping pets	200 (18.62)	874 (81.38)
Insects and rats	255 (23.74)	819 (76.26)
Excessive textile presence	523 (48.70)	551 (51.30)
Old mattresses	251 (23.37)	823 (76.63)

Large amounts of textile susceptible mites have caused problems for more than 48.70% of children, while 23.37% have had old mattress (more than seven years old) to sleep on.

3.3 Effects of indoor air pollution on children's health

Indoor air pollutants are divided into two groups: a group of chemical and a group of biological agents. Influence of combustion products (wood and coal heating, passive smoking) on children's health has been taken into consideration from the first group, while the influence of biological agents, in comparison to health problems associated with pets, insects, rats, textile, and old mattresses has been monitored.

What has been confirmed is that children exposed to combustion by-products had respiratory symptoms more frequently (nasal congestion, nasal secretion, dyspnea and cough). Also, exposure to combustion by-products has been noticeably associated with headache and fatigue.

Table 4 shows statistical associations between exposure to wood or coal heating and presence of symptoms and diseases.

Table 4 Exposure to smoke from wood and coal heating and its influence on children's health.

Symptoms and diseases	exposed		nonexposed		$\chi 2$	OR	CI
	Yes	No	Yes	No			
nasal congestion	447	108	380	139	8.21*	1.51	1.13 - 2.04
nasal secretion	307	248	251	268	5.19*	1.32	1.03 - 1.69
dyspnea	89	466	55	464	6.83*	1.61	1.11 - 2.35
wheezing	175	380	145	374	1.66	1.19	0.91 - 1.56
cough	120	435	86	433	4.41*	1.39	1.01 - 1.91
sinusitis	19	536	9	510	3.01	2.01	0.85 - 4.84
bronchitis	197	358	165	354	1.65	1.18	0.91 - 1.53
asthma	21	534	10	509	3.30	2.00	0.89 - 4.60
pneumonia	75	480	62	457	0.59	1.15	0.79 - 1.68
watery eyes	89	466	68	451	1.85	1.27	0.89 - 1.81
dry throat	119	436	88	431	3.47	1.34	0.97 - 1.84
headache	204	351	146	373	9.08*	1.48	1.14 - 1.94
fatigue	206	349	146	373	9.83*	1.51	1.16 - 1.97

* $p<0.05$

Together with wood and coal stoves, tobacco smoking has been the most common indoor pollution source. This investigation has reported that parental smoking is notably associated with wheezing, bronchitis, headache and fatigue in the exposed children (Table 5).

A positive relationship has not been established between keeping pets and health (Table 6), except in cases of nasal congestion.

Presence of insects (e.g. cockroaches) and rats in household have been proven a significant risk factor for all symptoms and diseases estimated, apart from asthma and pneumonia (Table 7).

Large indoor presence of textile acts as a significant source of irritants and allergens and has an impact on the indoor air quality and health of the exposed. Children in contact with a lot of textile at home are at higher risk of nasal congestion, wheezing, asthma and nonspecific symptoms (fatigue and dry throat). Data are shown in Table 8.

Old mattresses are mostly associated with respiratory symptoms (nasal congestion, nasal secretion, dyspnea, wheezing, and cough), bronchitis, and nonspecific symptoms (watery eyes and dry throat). Table 9 shows statistical significance of differences between exposure to biological agents from old mattresses and children's health.

Table 5 Exposure to ETS and its influence on children's health.

Symptoms and diseases	exposed Yes	exposed No	nonexposed Yes	nonexposed No	$\chi 2$	OR	CI
nasal congestion	589	160	238	87	3.74	1.35	0.98 - 1.84
nasal secretion	390	359	168	157	0.01	1.02	0.78 - 1.33
dyspnea	101	648	43	282	0.01	1.02	0.69 - 1.53
wheezing	241	508	79	246	6.71*	1.48	1.09 - 2.01
cough	147	602	59	266	0.32	1.1	0.78 - 1.56
sinusitis	19	730	9	316	0.05	0.91	0.39 - 2.21
bronchitis	277	472	85	240	11.89*	1.66	1.23 - 2.23
asthma	23	726	8	317	0.3	1.26	0.53 - 3.08
pneumonia	100	649	37	288	0.79	1.2	0.79 - 1.83
watery eyes	119	630	38	287	3.2	1.43	0.95 - 2.15
dry throat	150	599	57	268	0.9	1.18	0.83 - 1.67
headache	262	487	88	237	6.44*	1.45	1.08 - 1.95
fatigue	261	488	91	234	4.82*	1.38	1.02 - 1.85

* $p<0.05$

Table 6 Exposure to pets allergens and its influence on children's health.

Symptoms and diseases	exposed Yes	exposed No	nonexposed Yes	nonexposed No	$\chi 2$	OR	CI
nasal congestion	165	35	662	212	4.2*	1.51	1.00 - 2.29
nasal secretion	115	85	443	431	3.03	1.32	0.95 - 1.82
dyspnea	29	171	115	759	0.25	1.12	0.70 - 1.77
wheezing	62	138	258	616	0.17	1.07	0.76 - 1.52
cough	35	165	171	703	0.45	0.87	0.57 - 1.33
sinusitis	3	197	25	849	1.19	0.52	0.12 - 1.82
bronchitis	74	126	288	586	1.19	1.19	0.86 - 1.67
asthma	9	191	22	852	2.28	1.82	0.77 - 4.24
pneumonia	25	175	112	762	0.01	0.97	0.59 - 1.58
watery eyes	31	169	126	748	0.15	1.09	0.69 - 1.7
dry throat	40	160	167	707	0.08	1.06	0.71 - 1.58
headache	71	129	279	595	0.95	1.17	0.84 - 1.64
fatigue	67	133	285	589	0.06	1.04	0.74 - 1.46

* $p<0.05$

4 Discussion

To the present day, this has been the first study about the relation between indoor air pollution and children's health in Serbia. Significant effects of exposure to indoor air

Table 7 Exposure to insects and rats allergens and its influence on children's health.

Symptoms and diseases	exposed Yes	exposed No	nonexposed Yes	nonexposed No	$\chi 2$	OR	CI
nasal congestion	210	45	617	202	5.41*	1.53	1.05 - 2.22
nasal secretion	158	97	400	419	13.41*	1.71	1.27 - 2.3
dyspnea	52	203	92	727	14.05*	2.02	1.37 - 2.99
wheezing	99	156	221	598	13.03*	1.72	1.26 - 2.33
cough	69	186	137	682	13.39*	1.85	1.31 - 2.61
sinusitis	12	243	16	803	5.8*	2.48	1.09 - 5.62
bronchitis	114	141	248	571	18.11*	1.86	1.38 - 2.51
asthma	9	246	22	797	0.49	1.33	0.56 - 3.07
pneumonia	40	215	97	722	2.58	1.38	0.91 - 2.1
watery eyes	57	198	100	719	16.03*	2.07	1.42 - 3.02
dry throat	70	185	137	682	14.37*	1.88	1.33 - 2.66
headache	105	150	245	574	11.23*	1.64	1.21 - 2.22
fatigue	112	143	240	579	18.86*	1.89	1.4 - 2.55

* $p<0.05$

Table 8 Exposure to textile allergens and its influence on children's health.

Symptoms and diseases	exposed Yes	exposed No	nonexposed Yes	nonexposed No	$\chi 2$	OR	CI
nasal congestion	424	99	403	148	9.53*	1.57	1.17 - 2.12
nasal secretion	279	244	279	272	0.79	1.11	0.87 - 1.43
dyspnea	66	457	78	473	0.55	0.88	0.61 - 1.26
wheezing	172	351	148	403	4.66*	1.33	1.02 - 1.75
cough	102	421	104	447	0.07	1.04	0.79 - 1.43
sinusitis	12	511	16	535	0.39	0.79	0.35 - 1.77
bronchitis	183	340	179	372	0.75	1.12	0.86 - 1.45
asthma	9	514	22	529	4.94*	0.42	0.18 - 0.97
pneumonia	63	460	74	477	0.46	0.88	0.61 - 1.28
watery eyes	83	440	74	477	1.28	1.22	0.85 - 1.73
dry throat	115	408	92	459	4.83*	1.41	1.03 - 1.93
headache	182	341	168	383	2.27	1.22	0.93 - 1.58
fatigue	198	325	154	397	11.96*	1.57	1.21 - 2.05

* $p<0.05$

pollutants on children's health have been found,.

The results of this investigation show that wood and coal heating represent increasing factors for the prevalence of respiratory and nonspecific symptoms. Smoke from household solid fuels is a complex mixture which contains many potentially relevant com-

Table 9 Exposure to biological agents from old mattresses (more than 7 years old and its influence on children's health.

Symptoms and diseases	exposed		nonexposed		$\chi 2$	OR	CI
	Yes	No	Yes	No			
nasal congestion	211	40	616	207	9.22*	1.77	1.20 - 2.62
nasal secretion	151	100	407	416	8.83*	1.54	1.15 - 2.08
dyspnea	48	203	96	727	9.22*	1.79	1.20 - 2.66
wheezing	90	161	230	593	5.75*	1.44	1.06 - 1.97
cough	64	187	142	681	8.43*	1.64	1.16 - 2.33
sinusitis	9	242	19	804	1.24	1.57	0.65 - 3.72
bronchitis	99	152	263	560	4.82*	1.39	1.02 - 1.88
asthma	10	241	21	802	1.41	1.58	0.69 - 3.59
pneumonia	37	214	100	723	1.16	1.25	0.82 - 1.91
watery eyes	56	195	101	722	15.53*	2.05	1.41 - 3.00
dry throat	61	190	146	677	5.32*	1.49	1.05 - 2.12
headache	85	166	265	558	0.24	1.08	0.79 - 1.47
fatigue	86	165	266	557	0.33	1.09	0.80 - 1.49

* $p<0.05$

ponents from a toxicological point of view. This mixture is inherently highly variable with characteristics determined by sources, materials burned, time span of application and other factors.

The fuels, which burn in furnaces, heaters, fireplaces, and gas stoves can release pollutants into the air. These fuels include kerosene, natural gas, wood, and oil. Kerosene, natural gas and oil can product nitrogen dioxide, sulfur dioxide, carbon monoxide, and formaldehyde. Carbon monoxide is colorless, odorless gas that interferes with the intake of oxygen. High concentrations can cause a wide range of symptoms from headaches, dizziness, weakness, nausea, confusion, and disorientation, to fatigue in healthy people and episodes of increased chest pain in people with chronic heart disease. Wood burned in fire places produces fine particles. These pollutants are risk factors for health. Particles released when fuels are incompletely burned can settle in the lungs and irritate or damage lung tissue [16].

Recent studies have also shown the same results. Smith et. al. [2] have reported frequent occurrence of cough, bronchitis and asthma in children aged between 7 and 10 exposed to wood smoke. The same author established the connection between changes of pulmonary function, frequent hospitalization and exposure to wood smoke.

A group of scientists in Guatemala [7] have examined the influence of indoor heating on frequency of asthma symptoms in 1058 children aged between 4 and 6. They found the increased prevalence of asthma symptoms in children who lived in homes with burning fuels.

Ostro et. al. have confirmed that combustion products cause frequent occurrence of

dyspnea (OR-1.60; CI – 1.11 to 2.32) and night asthma attacks (OR-1.01; CI – 0.91 to 1.13) [17].

Numerous studies [18, 19] have shown that particles with lower diameter found in combustion products, are the main reason for the increased occurrence of respiratory symptoms. The particles can induce oxidative stress, cause inflammation and damage of the respiratory epithelia.

Environmental tobacco smoke also represents a serious health risk in infants and children, whose respiratory system is still in development. It may affect children directly, by decreasing pulmonary function, or indirectly by increasing their exposure to infectious diseases. ETS worsens asthma and is responsible for high level of lower respiratory irritation, infections, and reduced lung function [19].

Our findings also show strong exposure – response associations between passive smoking and health problems. It has been determined that children exposed to passive smoking have an increased incidence of bronchitis. Consequently wheezing, headache and fatigue are more frequent in the exposed children. Other investigations give similar results, and show a positive relationship with the occurrence of asthma and pneumonia.

For example, Mc Kenzi and Bush [19] have estimated that exposure to passive smoking can worsen symptoms in children with asthma.

Hajnal et. al. have determined the way prevalent exposure to environmental tobacco smoke and its relation affects respiratory and allergic symptoms in school children in Switzerland. Children exposed to environmental tobacco smoke at home are at higher risk of respiratory infections (OR-1.19; CI-1.03 to 1.37). The aforementioned authors have concluded that children exposed to more than 20 cigarettes per day are at higher risk of respiratory problems [20].

Biological agents in indoor air are known to cause three types of human diseases: infections, where pathogens invade human tissues; hypersensitivity diseases, where specific activation of immune system causes diseases; and toxics, where biologically produced chemical toxins cause direct toxic effects. In addition, exposure to conditions conducive to biological contamination (e.g. dampness, water damage) has been related to nonspecific upper and lower respiratory symptoms [21].

The effects of pet-keeping in childhood varied according to pet type, allergic sensitivity of an individual and greater environmental exposure to allergen [22]

Domestic animals such as cats, dogs, birds and rodents may cause allergic asthma and rhino conjunctivitis [23].

Biological agents in pets did not have any impact on children's health in our investigation. Nasal congestion proved to be only a symptom. This symptom can be a part of allergic rhino conjunctivitis which occurs more often in children who keep pets [24]. Results of other studies show that dogs and cats have the strongest impact on health. In our case the largest numbers of children have kept birds. It was probably the reason for the discrepancy in results.

Alongside pets, insects, and rats, mites account for indoor biological air pollution. It has been determined that excretions of insects and rats, as well as their body parts

have significant allergen characteristics. A domestic cockroach is considered an important source of indoor aeroallergens worldwide. Results of this investigation show that presence of insects and rats in homes, where children reside, is a very important risk factor in all examined symptoms and respiratory diseases (sinusitis and bronchitis). Increasing prevalence of asthma has not been established, but symptoms characteristic of asthma (wheezing, dyspnea and cough) have been more frequent in the exposed children. Recent studies have suggested that the increased morbidity and mortality, when asthma and allergies are concerned, may be due to the increase in exposure to allergens in the modern indoor environment. Indoor allergen exposure is recognized as the most important risk factor for asthma in children [24].

Investigation in New England has shown that cockroaches in homes have been the cause of asthma in children three times as much as those who have not been in contact with them [2]. Litonjua et.al. [25] have established that exposure to cockroach allergen early in life may contribute to the development of asthma in susceptible children.

Major allergen in house dust derives from mites. Mites allergens are usually airborne and are found mostly in beds, soft furniture, and carpets. Therefore, studies have confirmed that the environmental control of allergens should be an integral part in the management of sensitive patients [26].

Our investigation has established that respiratory and nonspecific symptoms are more frequent in children, who have been in continuous contact with textiles. Jakkola et.al. [27] have also examined the impact of textiles on respiratory symptoms and established that the risk of bronchial obstruction was 1.58 (CI-0.98 to 2.54).

Mattresses are of great importance because they can contain from several thousands to millions of mites. Duration of using a mattress is very important. Older mattresses can contain more mites. Children, who sleep on an older mattress (more than seven years old), had more prevalence for all respiratory symptoms, bronchitis and nonspecific symptoms (watery eyes and dry throat).

To conclude, these results add more evidence to the knowledge about the impact of indoor air pollution on children's health, in this case in Nis, Serbia.

Understanding the risks associated with indoor air quality problems and actingto correct them can mitigate respiratory symptoms. Families should identify possible sources of indoor air pollutants and seek health care if poor indoor air quality causes problems.

Source elimination, proper ventilation, air filtration, and cleanliness are crucial steps in resolving many indoor air problems.

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