INDOOR AIR QUALITY ISSUES IN SOUTH AFRICA

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Abstract

Worldwide, more than three billion people depend on solid fuels including biomass (wood, dung and crop residues) and coal, for cooking and heating. This paper reviews the heath effects of indoor air pollution. International studies that have been carried out regarding indoor air pollution from domestic fuel use, as well as the effectiveness of various interventions used is included. Issues of indoor air pollution in South Africa are discussed as well as projects being carried out to alleviate indoor air pollution in South Africa. Other sources of indoor air pollution are briefly discussed. Indoor air pollution is a major global public health threat requiring greatly increased efforts in the areas of research and policy-making.

Keywords: indoor air pollution, developing countries, fossil fuels, toxicity, lung diseases.

1. Indoor air pollution from domestic fuel burning

1.1. Why is it so important?

Worldwide, more than three billion people depend on solid fuels including biomass (wood, dung and crop residues) and coal, for cooking and heating. Exposure to indoor air pollution (IAP) from solid fuels has been linked to many different diseases, including acute and chronic respiratory diseases, tuberculosis, asthma, cardiovascular diseases and perinatal health outcomes. Acute respiratory infections are the most important cause of death among children under 5 years of age in developing countries. Globally, reliance on solid fuels has emerged as one of the ten most important threats to public health. In 2000, indoor air pollution was responsible for more than 1.5 million deaths and 2.7% of the global burden of disease. In high-mortality developing countries it accounted for 3.7% of the burden of disease, making it the most important risk factor after malnutrition, the HIV/AIDS epidemic and lack of safe waster and adequate sanitation (WHO, 2007).

The WHO National Burden of Disease study for 2002 estimated (for South Africa) that 0.1% of the national burden of disease is attributable to all fuel use. This was based on the assumption that 18% of population uses solid fuels domestically.

The MRC Burden of Disease Research Unit has released a new publication, detailing a selecting group of 17 major risk factors to health (SA CRC, 2008). A risk factor is defined as an exposure which increases a person's chances of developing a disease or disability. In this study, the burden of disease is measured using **disability adjusted life years (DALYs)** as a common metric. Indoor air pollution was ranked at number 15 for 2000, higher than urban air pollution (Table 1). Almost 99% of this burden occurred in the black African population.

Table 1. DALYs attributed to selected risk factors.

Rank	Risk factor	% total DALYs
1	Unsafe sex/STIs	31.5
2	Interpersonal violence	8.4
3	Alcohol harm	7.0
4	Tobacco smoking	4.0
5	High BMI	2.9
6	Childhood and maternal underweight	2.7
7	Unsafe water sanitation and hygiene	2.6
8	High blood pressure	2.4
9	Diabetes	1.6
10	High cholesterol	1.4
11	Low fruit and vegetable intake	1.1
12	Physical inactivity	1.1
13	Iron deficiency anaemia	1.1
14	Vitamin A deficiency	0.7
15	Indoor air pollution	0.4
16	Lead exposure	0.4
17	Urban air pollution	0.3

1.2. Health effects

The incomplete combustion of biomass fuels in simple stoves releases a host of complex chemicals. Pollutants included suspended particulate matter, carbon monoxide, formaldehyde, nitrogen dioxide, ozone and polycyclic aromatic hydrocarbons (see Table 2).

The only health effects used to calculate the burden of disease (Table 1) were acute lower respiratory infections, chronic obstructive pulmonary disease (COPD) and lung cancer. Other health effects (such as asthma and heart disease) weren't considered in the analysis, as evidence for these health effects was considered to be insufficient.

Table 2. Indoor air pollutants and their potential health effects (WHO 2002).

Pollutant	Mechanism	Potential health effects
Particulate matters (PM10/2.5)	Bronchial irritation Reduced mucocilliary clearance	Respiratory infections COPD and exacerbation Wheezing, asthma Excess mortality including cardiovascular disease (CVD)
Carbon monoxide (CO)	Binding with Hb (reduced oxygen delivery)	Low birth weight Increased perinatal deaths
Benzopyrene	Carcinogenic	Lung cancer Cancer of mouth, pharynx, larynx
Formaldehyde	Nasopharyngeal and airway irritation	Increased infections (?) May lead to asthma (?)
Nitrogen oxides (NOx)	Acute: bronchial reactivity Chronic: infections	Wheezing Respiratory infection and reduced lung functions
Sulphur oxides (SOx)	Acute: bronchial reactivity Chronic: particulate effects	Wheezing, asthma COPD, CVD
Smoke	Absorption of toxin into lens, leading to oxidative changes	Cataract

2. International studies on IAP from domestic fuel burning

2.1. Kenya (ITDG, 2002)

In 1998, the ITDG chose 50 households in rural Kenya, to participate in a study to reduce indoor air pollution by implementing interventions. Measurements were taken before and after the interventions were implemented.

Measurements of PM10 (24 hr average) in rural homes were over 5 000 µg/m³, 100 times greater than the US EPA annual standard of 50 µg/m³. Because, cooking takes place every day of the year, the daily average is considered to be representative of the annual average.

The reduction in PM10 and CO are presented in Table 3.

Table 3. Reduction in indoor air pollution in Kenya study.

Intervention	Reduction in PM10 (%)	Reduction in CO (%)
Windows	No observable change	
Smoke hoods	75	78
Eaves spaces	60	28
Stoves	54	42

Positive impacts from the study were reductions in indoor air pollution, improvement of general comfort, more time for other activities therefore increased income, less time spent in hospitals and the women gained confidence.

Negative impacts experienced by the households were cooler houses, lack of privacy and security as well as difficulty with wick lamps.

Problems experienced with the project methodology were constraints in the measurement of pollution (no universal protocol on where to do measurements, e.g. distance from fire and height), equipment issues (power supply, filters full before 24 hr sampling time), occupants of houses moving post intervention and loss of houses in the study post intervention.

2.2. Bangladesh (Dasgupta, 2004)

A survey in Bangladesh analysed exposure to indoor air pollution at two levels: differences within households attributable to family roles, and differences across households attributable to income and education. They found high levels of exposure for children especially for children under 5. Among prime-age adults they found that men have half the exposure of women. They also found that the poorest, least educated households have twice the pollution levels of relatively high-income households with highly-educated adults.

For children in a typical household, they proposed that pollution exposure can be halved by increasing children's time spent outdoors to 5 to 6 hours per day, and concentrating outdoor time during peak cooking times

2.3. Pakistan (WHO, 2005)

Biomass meets about 86% of total domestic energy requirements. 90% of the rural and 50% of the urban population depend on biomass fuels. Biomass is burned in inefficient three-stone stoves leading to incomplete combustion and high levels of indoor air concentration of smoke.

Significant work has been done in the context of fuel-efficient stoves in Pakistan. A fuel-efficient cooking technology project funded by GTZ of Germany was launched successfully and implemented throughout Pakistan.

In a pilot project, implemented by the Aga Khan Planning and Building Services, Pakistan, smoke-free stoves with smoke-hoods were built in northern areas of Pakistan.

There is a potential for using biogas as rural energy throughout the country by a network of community biogas plants. Pakistan produces enough animal waste for the production of biogas.

2.4. Guatemala (WHO, 2006)

A new stove (*plancha*) was installed in 250 homes in the small mountainous community of San Lorenzo, while 250 control homes continued to cook on an open fire. The *plancha* is a wood-burning stove constructed from bricks and concrete blocks, a steel top-plate with 3 pot holes, and has a metal chimney that expels the smoke outside the house. Over a two-year period, all children aged less than 18 months were assessed for pneumonia. This is the only study that has investigated the impact of an improved stove on childhood pneumonia and women's respiratory health.

The primary hypothesis was that inhaled biomass smoke that contains high levels of PM during the critical time window of the first 18 months of life will negatively affect respiratory health later in childhood by causing increased symptoms of cough, phlegm production, and wheeze; decreased rate of growth of lung function; increased risk of sensitization to aeroallergens; and decreased somatic growth.

The secondary hypothesis was that the combustion-generated organic compounds present on fine particles in biomass smoke induce oxidative stress, upregulation of inflammatory cytokine production, and subsequent inflammation in the airways of children who inhale such smoke.

Based on these hypotheses, (i) PM inhalation will generate oxidative stress in the developing airways of infant children exposed to high levels of biomass smoke, (ii) chronic exposure to PM-induced oxidative stress will result in increased respiratory symptoms, decreased somatic growth, and abnormal structural development of the respiratory tract leading to a reduced rate of lung function growth.

3. Indoor air pollution in South Africa

3.1. Issues identified by the Department of Environmental Affairs (DEA) (http://soer.deat.gov.za)

3.1.1. Fuel-burning households

Emissions from household fuel burning are important due to their contribution to both ambient air pollution concentrations, indoor air pollutant concentrations and their associated health impacts.

In areas where households are using fuels such as wood, paraffin or coal for heating or cooking, indoor air pollutant concentrations are of special concern, particularly in poorly ventilated dwellings. Here, people are exposed to very high indoor pollutant concentrations, as well as to elevated ambient pollutant concentrations out of doors.

These fuels continue to be used because:

(i) rapid urbanization and the growth of informal settlements have exacerbated backlogs in the distribution of basic services such as electricity, and

(ii) some electrified households find fossil fuels cheaper for heating purposes and prefer their multi-functional character.

Given the availability of inexpensive coal and the relatively low temperatures of the highveld winter, coal consumption figures are highest for these regions. Wood is burned in place of coal in coastal regions, such as Cape Town and eThekwini, and the continued use of coal and wood by much of South Africa, together with the associated health risks, represents arguably the most persistent and significant local air pollution problem (Figure 1).

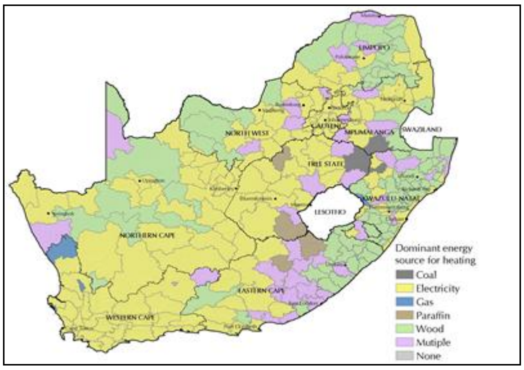

Figure 1. Dominant energy source used for heating.

Population growth, reductions in household income levels and increases in numbers of informal (in-service) households are expected to exacerbate household fuel burning emissions.

It is noticeable that electricity accounted for only 38% of the total energy consumed by the residential sector during 2000, despite the extent of electrification, due to the persistent use of other fuels for heating, cooking and lighting. The remainder of the energy consumed was provided by the combustion of wood (41%), coal (35%), paraffin (13.9%), vegetable wastes (6.9%) and liquefied petroleum gas (LPG) (2.9%) and the use of solar energy (0.3%).

The concentrations of indoor air pollutants in fuel-burning households are much higher than recommended health limits. Suspended particulate concentrations are orders of magnitude higher, while concentrations of fine particulates are even worse in wood-burning homes. Although outdoor SO_2, CO, and NO_2 concentrations within fuel-burning residential areas are generally below ambient air quality guidelines, notable violations of health standards occur because of indoor exposures to these pollutants (Table 4).

Table 4. Ranges of air pollutant concentrations recorded indoors within households during coal burning for cooking and/or space-heating purposes (http://soer.deat.gov.za).

Pollutant	**Indoor air pollutant concentrations (µg/m³)**
Carbon monoxide	25 000-50 000
Nitrogen dioxide	10–5 000
Sulphur dioxide	1 000-3 000
Total particulate matter	100-4 200

The impact of emissions from coal burning is often amplified by the poor ventilation of many low-income households and because many households have no chimneys. It is largely due to the bad thermal efficiencies of many low income households that prompts residents to try and stop cold air from entering their homes. The restriction of air supply often prevents the complete oxidation of dangerous gases such as carbon monoxide resulting in carbon monoxide poisoning of exposed residents.

3.1.2. Non-fuel burning households

The same pollutants can contaminate indoor air as outdoors, namely, nitrogen dioxide (NO_2), particulate matter, carbon monoxide (CO), volatile organic compounds (VOCs) and lead. It can also be affected by pollutants associated with indoor situations such as dust mites, formaldehyde, environmental tobacco smoke (ETS), asbestos and radon. Asbestos and radon are two known human carcinogens and classify as indoor air pollutants. Radon is odourless, colourless and tasteless and is a natural occurring radioactive gas resulting from the decay of radium.

3.1.3. Asbestos

Mining of asbestos started in South Africa around 1893 in areas such as the Northern Cape, Northern Province and Mpumalanga. Three types of commercial asbestos were mined, namely chrysotile (white asbestos), crocidolite (blue asbestos) and amosite (brown asbestos). All of the blue and brown asbestos mines in South Africa have closed and the one remaining white asbestos mine no longer extracts raw fibre and only 20 people are employed in rehabilitating this mine.

All asbestos mining in South African stopped operating in 2000/2001 with subsequent exports being from existing fibre stockpiles. It was expected that these stockpiles would be depleted by June 2003. Up to the 1970s, ~3 000 products were made containing varying quantities of asbestos fibres of all types. Currently, 60 countries still use asbestos, but only the chrysotile variety and primarily in cement building materials such as roofing materials, cladding and piping.

Asbestos exposure causes diseases such as asbestosis, lung cancers and other types of cancers. Inhalation of asbestos fibres is associated with a range of pulmonary diseases, primarily asbestosis (mesothelioma-type lung cancer).

Despite asbestos mining having ceased, exposure to airborne asbestos fibres continues in South Africa. Asbestos materials are still widely used in affordable housing, particularly in KwaZulu-Natal and the Eastern- and Western Cape. Rural communities have used asbestos fibre as a material for building where asbestos tailings (obtained from mine dumps) are mixed with mud to plaster the walls of traditional houses.

According to the data from the Housing Monitor database, 24% of subsidized houses constructed since 1994 were constructed with asbestos-cement roof sheeting. Inappropriate construction techniques in both the construction of new houses as well as the maintenance of existing houses may result in occupational exposure to asbestos. This is also exaggerated in the low income housing sector where the use of unskilled and ill-equipped local labour is extensive and where inadequate or no provision of protective clothing and masks are made due to limited financial resources.

Furthermore high risks to the environment and local communities are currently associated with abandoned, unrehabilitated and/or disturbed asbestos mines and dumps, absence of rehabilitation of asbestos processing plants, randomly discarded asbestos fibre dumps and use of asbestos-containing ores for road construction.

3.1.4. Action needed

Indoor air pollutant exposures are also associated with emissions of various organic pollutants, dust, fibres, moulds, bacteria, and metals released from carpeting, wood products made with synthetics, and combustion sources. Examples include formaldehyde, xylene, ethyl benzene, asbestos, and tobacco smoke. These exposures have been the subject of extensive research in Europe and the United States of America and are increasingly being investigated in South Africa.

The extent of indoor air pollutant concentrations and the associated health implications suggest the need for indoor air quality monitoring.

There is currently no legislation in South Africa prohibiting the use of asbestos-containing building materials, but some Local authorities in the Free State, Mpumalanga, Northern Province and Western Cape have specified that asbestos containing materials by not be used.

3.2. Issues identified by the North West (NW) Province

In the state of the environment report for 2008, it was stated that unemployment and poverty in the NW Province are major factors affecting the state of the environment. Overcrowding in urban and peri-urban areas and rapidly increasing informal settlements, where people live in congested dwellings with inadequate ventilation, have a major impact on air quality in these areas and on human health. The domestic use of fossil fuels by large numbers of people without access to electricity is also a contributing factor to poor air quality in these areas. Some of the highest air pollution levels have been recorded in similar low-income indoor environments. Indoor SO_2 levels become dangerously high when cooking with coal (up to 5 200 µg/m^3) for one hour, with total suspended particulate matter reaching 1 420 µg/m^3 (measured in a rural area in the Free State). The WHO states that the minimum levels of total suspended particulate matter for effects on human health to be detectable are 180 µg/m^3 over a 24-hour period.

Un-rehabilitated asbestos mines present significant impacts to the health of the surrounding communities. This is a continuous environmental problem, and nearby local communities have been exposed to asbestos for many years. Nearby communities are still exposed to blue asbestos fibres or crocidolite (the most toxic form of asbestos) blown from open pits at the mines. Toxic material can be blown 60 to 100 km in strong winds. Many ex-miners and people living in the adjacent communities have died or are suffering from the abovementioned respiratory diseases. It has been proposed that the communities be relocated from the Pomfret area. The Nchweng asbestos mine, which was rehabilitated in 2001, is located very close to the school and village, posing a serious health threat to the people living in the vicinity (www.nwpg.gov.za).

4. Current activities in SA concerning IAP

4.1. Basa njengo Magogo Project

During the winter in 2003, the top-down Basa njengo Magogo fire ignition method was piloted at Orange Farm. In total, 76% of households reported less smoke in the homes, while 67% reported less smoke in the streets after one month of using the method. In addition, 99% of households reported a saving in fuel costs. Particulate emissions from coal in the Basa njengo Magogo fires were on average 87% less than the particulate emission from coal in the conventional bottom-up fires.

The Minister of Mineral and Energy approved a three phase approach to the alleviation of air pollution caused by the use of coal in residential areas. These are:

- Dissemination of the Basa njengo Magogo technology for low-smoke ignition of household fires.
- The production and distribution of low-smoke fuels.
- Improving the thermal efficiency of homes.

4.2. eThekwini municipality creating awareness

In June 2009 an air quality management seminar was held, with indoor air pollution being one of the topics for discussion.

The Health Unit is playing a significant role in creating awareness amongst the people of eThekwini about dangers of poor indoor air quality and the associated health effects, by distributing brochures, giving presentations and workshops (schools, health practitioners and students and lecturers) as well as newspaper articles. The brochure contains information on health effects, possible signs and factors that contribute to poor indoor air quality. An "indoor air quality awareness" article is published every fortnight in local newspapers (www.durban.gov.za).

An important issue raised in the eThekwini region was a high incidence of mould and fungi.

4.3. Behavior changes study in the Mafikeng local municipality

Changing the way people behave has been identified as a possible strategy, particularly where people are unlikely to benefit from improved technologies in the short term. Despite this, no published studies have evaluated how changes in behaviour can relate to the way that children are exposed to indoor air pollution. To address this shortage of information, the effectiveness of promoting outdoor cooking in a poor rural South African community to reduce ill-health caused by kitchen smoke was investigated (Barnes, 2006).

The study was conducted in two poor rural villages in the Mafikeng local municipality, North West province of South Africa.

In this region, every household had a square-shaped outdoor burning area (*segotlo*) in the homestead, which was enclosed by a wall of interwoven dried sticks approximately 1.6 m in height. Outdoor cooking was widespread during summer but less so during winter when open fires are burned indoors where space heating is needed. At the start of the project, only one third of households reported using the *segotlo* for cooking during winter. In terms of child exposure children living in outdoor-burning homes showed significantly lower (88%–90%) levels of exposure to CO compared to indoor-burning homes.

4.4. CHANGE Project (www.changeproject.org)

The CHANGE project provided technical and financial assistance to the Medical Research Council (MRC) of South Africa to identify and test feasible behavioral interventions to reduce children's exposure to Indoor Air Pollution (IAP) in rural South Africa. CHANGE worked with the MRC from 2000 to 2003. Two phases of research were undertaken during the winters (June-August) of 2001 and 2002. The first phase determined the feasibility of potential interventions and during the second phase selected interventions were tried out. Four potential interventions were selected:

- More ventilation sources and/or ventilating for longer periods of time,
- Keeping young children further from heat source,
- Fixing stoves, and
- Burning fuels for a shorter duration.

Each behavior had its own limitations and perceived benefits. Behaviors related to indoor air pollution are influenced by multiple factors including: poverty, weather, and enabling factors such as the availability of someone to watch the child and someone to fix the stoves. Some perceived results from performing the different behaviors included: healthier children, less dust and smoke and savings of money and time.

5. Other sources of pollution

Other sources of pollution besides biomass fuels include environmental tobacco smoke, building construction materials, insulation materials, house dust, mould spores, animal dander, consumer products, furnishings, cleaning agents, and the infiltration of outdoor air pollution.

However, in developing countries the use of biomass fuels (wood, coal, crop residues, etc.) is by far the largest source of indoor air pollution.

6. Way forward

The MRC Burden of Disease Research Unit study recommended the following interventions for indoor air pollution (SA CRC, 2008):

- Technologies which aim at improved cooking/heating devices, improved fuels and reduced need for heating.
- Technologies aimed at improving the living environment.
- Behavioural change to reduce exposure and smoke generation.

WHO state that IAP is a major global public health threat requiring greatly increased efforts in areas of research and policy making. They recommend that the research on health effects should be strengthened. A more systematic approach to the development and evaluation of interventions is desirable, with clearer recognition of the interrelationships between poverty and dependence on polluting fuels (Table 5).

Table 5. Policy instruments for effective household energy programmes (WHO, 2006)

Policy instruments	**Examples**
Information, education and communication	Health professionals
	Community
	Schools
	Media
Taxes and subsidies	Tax on fuels and appliances
	Subsidy on fuels and appliances
Regulation and legislation	Air quality standards
	Design standards for appliances
Direct expenditures	Public programme for provision of appliances
	Funding of finance schemes
Research and development	Surveys
	Development and evaluation of interventions
	Studies of health impacts
	Research capacity development

WHO convened a working group meeting for the development of indoor air quality guidelines representing scientific expertise in epidemiology, toxicology, exposure assessment, developing country issues, indoor combustion, biological agents, building construction, ventilation and indoor air quality management (WHO, 2006).

WHO's programme on household energy and health includes the following:

- Documenting the health burden of indoor air pollution and household energy.
- Evaluating the effectiveness of technical solutions and their implementation.
- Acting as the global advocate for health as a central component of international and national energy policies.
- Monitoring changes in household energy habits over time.

The pollutants and factors to be included in the guidelines are presented in Table 6.

Table 6. Summary of factors to be included in the Guidelines on IAQ.

Group A **Pollutants**	**Group B** **Biological agents**	**Group C** **Indoor combustion**
Formaldehyde Benzene Naphthalene Nitrogen dioxide Carbon monoxide (CO) Radon Particulate matter (PM10 and PM2.5) Halogenated compounds Polycyclic aromatic compounds (PAH), especially benzo[a]pyrene (BaP)	**Dampness and mould** **Ventilation** -natural -forced/mechanical **Allergens** -from house dust mites -from pets	**Stove venting** -flues -hoods **Ventilation** -natural -forced/mechanical **Combustion quality** **Fuels** -solid -processed solid -liquid -gas -electricity

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