AIR POLLUTION IN DENSE, LOW-INCOME SETTLEMENTS IN SOUTH AFRICA

A Friedl[1], D Holm[2], J John[3], G Kornelius[4],
C J Pauw[5], R Oosthuizen[6] and A S van Niekerk[7]

○ **Abstract**

This research is carried out on behalf of the Royal Danish Embassy as part of the Urban Environmental Management Programme in cooperation with the South African Department of Environmental Affairs and Tourism. In the call for proposals the rationale for this project is expressed as follows: "Although air pollution in dense, low-income communities is acknowledged as a major threat to the health and well-being of the people living and working in these communities, research into the problem, cause and effect relationships, possible solutions, impact of interventions, etc. has been, in the main, sporadic, uncoordinated, piece-meal, narrowly focused, etc. As such, and with a view to developing an Integrated Strategy and Action Plan to address this problem, there is a need to synthesise the findings of the various research and pilot projects done over the years and to draw out useful conclusions and recommendations."

This paper synthesises the findings of the major research projects on energy supply for low-income households. Comparisons are made of the measurements of air pollution related to the use of the various fuels and their health impacts. Conclusions are made regarding the context of the energy supply problem in the broader household context, the basis and sustainability of possible future interventions, the impact that carbon trading may have in this regard and the research gaps that still exist.

1. Background

This article summarises the results of research carried out on behalf of the Royal Danish Embassy, as part of the Urban Environmental Management Programme in co-operation with the South African Department of Environmental Affairs and Tourism. The rationale was to synthesise the findings of the hitherto uncoordinated research concerning all aspects related to the problem of air pollution in dense, low-income communities in order to draw useful conclusions and recommendations that will serve as the basis for the development of an integrated strategy and action plan.

2. Scope and method of research

The research carried out for this project took the form of a desktop study that attempted to synthesise the findings of all important published studies on air pollution in dense, low-income communities in South Africa (Friedl et al., 2008). As such, no new empirical research was conducted. The contents was briefly as follows: The introductory Chapter 1 provides some background and defines the most important terms as they are applied in the document. Chapter 2 provides an overview of the nature and extent of the problem. This chapter gives a detailed description of domestic fuel use (wood, coal, biomass, paraffin, as well as the impact of thermal efficiency of houses), key advantages and disadvantages related to the use of various fuels, the potential extent of the problem, key impacts on health and well-being, economic and social cost, the geographic areas that are most affected, fuel conversion technologies, non-fuel burning sources of air pollution, and, finally, those vulnerable people that are most at risk because of air pollution. Chapter 3 analyses past and current interventions (e.g., electrification, housing related interventions, BnM) relating to the health and well-being of households as the most basic social institution. The international case studies presented in Chapter 4 comprise improved cook stoves and various national biogas programmes. Chapter 5 identifies biomass gasification as a promising novel intervention with the potential application to this problem. Chapter 6 discusses indicators that can be used to measure and evaluate various aspects of air pollution in dense, low-income communities. Finally, Chapter 7 summarises the most important conclusions and provides a brief analysis of the changing context to inform recommendations for viable intervention options categorised according to their level of development and potential impact. Finally, a description of the most important role-players and their respective potential contributions is presented.

3. Summary of Results

Of all sources of air pollution that have an impact on health in South Africa, domestic sources have by far the largest impact. One study found that domestic sources were responsible for 69% of total health impacts of ambient air pollution in a selection of urban and industrialised areas (FRIDGE, 2004:iii, 66). It is estimated that ambient air pollution in the six metropolitan areas of SA, as well as Rustenburg and Sasolburg (a population of approx. 5.5 million people), has been responsible for 4 637 deaths for the year 2000 (Norman *et al*.:2007b) and that indoor air pollution has been responsible for 2 489 deaths in all areas of SA for the same year (Norman et al.:2007a). Deaths caused by fires (mainly due to paraffin) and paraffin poisoning have to be added to arrive at a total annual death estimate. A summary for the year 2000 is given in Table:1: According to these estimates, more than 9 000 people die annually as a result of domestic use of “dirty” fuels in the metropolitan areas of South Africa. These estimates exclude about 60% of the population and the total could be much higher. Paraffin burns caused between 2 500 and 3 000 deaths which have to be added to the total (PARASA 2005, Panday and Mafu 2007:60).

Table 1: Estimations of annual deaths related to domestic use of dirty fuels for the year 2000

Cause of death	**Nr. of deaths**	**% related to domes-tic use**	**Area**	**Source**
Ambient PM	4 6371	69%	Metro-politan areas, Rusten-burg, Sasol-burg	Norman et al. (2007b)
Indoor PM	2 4893	100%	SA	Norman et al. (2007a)
Paraffin poison-ing	4 000	100%	SA	Lloyd (2006:1), Bizzo et al (2004:66)

Geographic areas most affected by air pollution can be differentiated into areas with high population densities and areas with high source densities, with the highest impact being in areas where both sources and population are dense. Within the large metropolitan areas, the former black townships generally have the highest levels of ambient air pollution, caused by a combination of density of domestic sources and proximity of industrial sources. Although electrified areas with formal housing have fewer coal users, electrification does not totally replace dirty fuels, because these fuels remain relatively economical for space heating. Higher income is also correlated with less use of dirty fuels (Statistics South Africa: 2008). Areas with low minimum temperatures that are situated closer to the coal mines have higher levels of coal use than areas that have milder weather or are further away from the mines, where coal is more expensive. This study has found that exposure to ambient air pollution beyond the large urban centres is probably a much greater cause for concern than was previouly thought, because of high source densities in such areas and due to the fact that the size of a settlement has only a limited influence on the level of air pollution. This means that there is a strong possibility that the impact of air pollution is underestimated because many settlements where ambient air pollution may have significant negative health effects are not included in the current calculations of deaths caused by air pollution (see the scope of Norman *et al*.:2007b).

In 2006, about 50% of all households used an energy carrier other than electricity and may thus have been exposed to indoor air pollution (Statistics SA 2007). About 14% of these households used paraffin, which is regarded as a clean fuel. Lloyd (2006:6) reports indoor CO levels of 1 600 ppm in paraffin-using households in Kimberley. The other dangers of paraffin include fire and the drinking of paraffin, especially by children. The death toll caused by these dangers is very close to that from ambient air pollution exposure in urban areas. The drinking of paraffin is facilitated by the way it is handled and sold; it can be bought anywhere and in any container and thus may be easily drunk by children. Fire caused by paraffin is a very serious matter: annually 83 000 households, 2% of total paraffin using households, suffer as a result of paraffin related fires (Truran and Singh 2006:2). None of the wick stoves on the market in 2007 met the safety specifications set by the SABS (Panday and Mafu 2007:61, Standards South Africa 2006, 2007).

Energy use in low-income households shows a trend towards the use of a mix of energy carriers, especially among the lower 50% of income earners. This pattern implies that low-income households switch between energy carriers as it suits their needs. More households use a dirty fuel for heating than for cooking and least for lighting. It is likely that the electrification of houses has peaked and will remain stable at 80% of all households. The percentage of households that use dirty fuels has also stabilised with a constant 21% of electrified households still relying on a dirty fuel source for heating or cooking; the use of dirty fuels has however increased in absolute terms between 2001 and 2007. The proportion of households that used a dirty fuel for heating only has also remained constant between 2001 and 2007, at about 50%.

The largest contribution to air pollution in dense, low-income communities is caused by the domestic use of wood in rural areas and wood and coal in urban areas around the coal mines for space heating. Electricity and paraffin are preferred by many of the same households for cooking. Colder areas and colder periods are associated with higher levels of solid fuel use and an increase in air pollution. Wood use is the most significant contributor to health impacts from air pollution in the urban areas. However, the majority of wood users (about 95% of wood users or 2.47 million households) live ***outside*** these areas in rural areas. This is a highly neglected problem in the available research findings: there is no data available on the types of devices and volumes of wood used, as well as what proportion of cooking is done indoors. This lack of information makes it difficult to estimate health impacts related to wood use, but it must be serious, considering that about 30% of all households in SA still use a dirty fuel for cooking. The choice of energy carrier is not only determined by availability (about 80% of households have access to electricity) but also by the absolute cost and cost-efficiency of appliance systems. Paraffin is generally preferred to coal for cooking (when space heating is not required simultaneously), because it is more convenient, faster and cheaper (cf. Graham and Dutkiewicz, 1999; Graham, 1998).

4. Future scenarios

Four factors have emerged that will play a decisive role in future trends in the use of dirty fuels. In combination, these factors clearly indicate that ‘business as usual’ is not a viable option:

4.1. Oil price

The oil price has a direct influence on the price of paraffin and indirectly on coal and wood. The effects of a high and rising oil price on energy use patterns cannot be predicted with certainty.

4.2. Housing

SA needs to build 500 000 subsidy houses per year between 2008 and 2015 to eradicate the housing backlog of about 2.2 million houses (Leshabane 2008). Rapid household formation and urbanisation contribute to a high demand for houses, especially in urban areas. If the rate of housing delivery falls behind the rate of household growth, more people will live in informal houses which are thermally extremely inefficient. Presently, thermal properties are not integrated in the design of subsidy houses, the need for large quantities of artificial space heating to achieve thermal comfort is thus being structurally entrenched. Dirty fuels are the most common way of delivering bulk heat. If the housing backlog is not reduced, a stabilisation or even an increase in dirty fuel use may occur. Much research has been done into improvement of this situation (see for example the work by Holm *et al*., 2004; Klunne, 2003; Irurah, 2000) but there is incongruence between the state of knowledge and the state of implementation.

4.3. Electricity supply

Whether SA can avoid an electricity supply crisis and the cost to the consumer of such avoidance, are two concerns likely to have a decisive impact on the future use of dirty fuels.

In the event of a supply shortage dirty fuels will function as a backup strategy for many households. Episodes of increased air pollution in this scenario will correspond to episodes of power failure.

In the event of a complete supply crisis, dirty fuels will become or remain the fuels of choice for many households.

If the power generation capacity shortage is overcome in such a way as to drastically increase the price of electricity and this increase is not softened for the poor, an increase in dirty fuel use will also result.

The result of tariff structures which charge an increased price for increased use may have the unintended consequence that low-income households will try to minimise their cost by avoiding the use of electricity for space heating and cooking. On the other hand, an increase in free basic electricity to such an extent that a household can use lights, watch TV and cook with free electricity, will place an additional burden on the generational capacity.

A drastic increase in energy efficiency on the level of all housholds, including the low-income households, is the only way out of this dilemma.

4.4. Income

Whether households in the low-income communities are becoming poorer or richer in terms of their real purchasing power, will have a dramatic influence on the future of dirty fuel use, because an increase in income is negatively correlated with the use of dirty fuels if cleaner fuels, especially electricity, are available. There are analysts who are convinced that a large proportion of the population has become poorer over the last two decades.

There has been a major shift in the macro-context of energy service delivery since 1994, when the National Energy Programme (NEP) was initiated. More than 3 million electricity connections have been made already. The NEP was based on the assumption that electricity would eventually replace all other energy carriers. This assumption is being replaced by the expectation that there will always be an energy mix, where availability, cost and social preferences will determine the most cost-effective and socially desirable mix. Despite its desirability, having electricity makes a household a new type of consumer and leads to increased expenditure patterns, followed by financial constraints and an inability to pay for the electricity. This often results in electricity cuts, which is a source of alienation: being cut off creates a feeling of not belonging and therefore of not having to obey the rules of the unjust or unkind 'system'. Electricity is found to save time from labour-intensive work but eventually some people have less time for constructive activities because the TV – seemingly a usual commodity investment upon introduction of electricity across income groups – consumes so much of their time. Elderly people are sometimes found to want to continue using fire for a number of reasons (e.g., smoke is a sign of life to visitors and to the ancestors).

4.5. Carbon trading

The market for the trading of carbon credits, both under the Clean Development Mechanism (CDM) or in the informal market, has led to a completely new dimension in clean household energy, that should be utilised to the full benefit of all. Carbon finance is directly applicable to projects that have a bearing on the problem of air pollution in dense, low-income communities. The implementation of Basa njengo Magogo, (BnM), a clean burning method for domestic coal use which achieves a drastic decrease in air pollution as well as significant savings in coal use, is a good example of how carbon finance can fast-track a project that has a drastic impact on air quality. The fact that it burns cleaner leads to a significant reduction in the negative health impacts of air pollution on residents. Since the Nova Institute has succeeded to verify the reduction in the emissions of GHGs, caused by a reduction in the quantity of coal use, the trading of these emissions has provided funding for large scale implementation (24 000 households were converted in 2007). If it is assumed that government should only provide those services that cannot be supplied by the private sector, it seems that the trading of carbon credits has made it possible that civil society and the private sector will be able to implement BnM in a number of areas, leaving government free to attend to other, as yet unsolved problems. Therefore, government should come to an agreement with civil society and private sector role players on the allocation of their roles. For other technologies (e.g., energy efficient designs, renewables) strategies still have to be worked out based on reliable information and research on the funding available, the technology available, the relevant policies and, importantly, the needs of the households.

The fact that many household switch between suitable energy carriers implies that new possibilities that really meet user requirements, have a significant potential to reach large proportions of low-income households.

5. State of readyness of various interventions

This report has evaluated a number of intervention options to reduce air pollution in dense, low-income communities. Implementation options that were found to be viable will now be briefly presented in order of their state of development, i.e., their readiness for mass implementation. Readiness for mass implementation means that the project has undergone a thorough process of evaluation in real operating conditions, improvements to better meet the needs of the end-users, and validation of the impact and results. Only after such a process can a project be ready to be implemented, first as a pilot project and then en masse.

The development of a project has to proceed through a number of phases in order to guarantee that all requirements are met [sub:Working-definitions]. This phased approach has been used in the past by the Nova Institute to develop the improved top-down ignition technique for coal fires that has already reached more than 100 000 households (Van Niekerk and Swanepoel: 1999). The project phases are as follows:

Plan/establish In this phase, the following is important: Role players are identified, brought together, and consensus is reached on the way forward. These role players may include people from the community, social workers, care givers, field workers, researchers, team leaders, government officials, industry representatives, etc.

Research and Development The impact of all of the relevant legal provisions on a vulnerable family would need to be identified and considered to determine the problems that are experienced. Then it should be considered which of those problematic provisions of law could be replaced with a sensible alternative, or what other solution would be possible to eliminate the problems experienced. This phase is completed when there is consensus amongst the role players on the most suitable strategy or strategies to be followed.

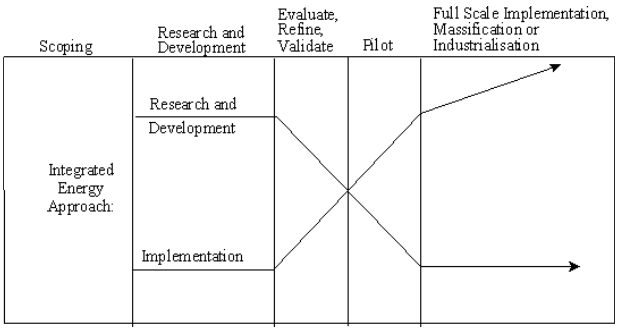
Evaluate, Refine and Validate The most promising solution is implemented on a small scale in individual households. The results are evaluated, the solution is improved and then implemented again. This process is repeated until the results are satisfactory.

Pilot implementation The solutions will be implemented in one whole community, which consists of mostly vulnerable households, to demonstrate the actual effect and success. Afterwards a final round of minor changes can be made to the solutions, based on the problems experienced in the implementation.

Full-scale implementation After the success of the solutions has been proven in a whole community, it will be ready for full-scale implementation, expanding over time until it has been fully implemented in all target communities.

The relationship between the intensity of R&D and implementation in the phased approach to the development of interventions is shown in fig 1 below.

Figure 1: The relationship between research and implementation intensity in the development of interventions (Van Niekerk and Swanepoel, 2002)



Intervention options will be summarised in the order of readiness for mass implementation in the section that follows.

6. Recommendations for action

In the next paragraphs, a number of intervention options to reduce air pollution in dense, low-income communities are discussed very shortly, beginning with the interventions which are viable and ready for mass implementation, followed by those that are less ready for implementation but show potential and could be made ready with some more R&D.

Improved top-down ignition is one of those intervention options that are already being implemented on a large scale (Swanepoel and Wentzel, 2004b; Le Roux, 2005). It has been demonstrated to more than 100 000 households and studies show that retention is very high and users who have mastered the technique rarely backswitch to bottom-up ignition (Coetzee and Pauw 2001). Well managed demonstration campaigns have reached between 50% and 70% of coal users in the implementation area which means that a total of 420 000 of the estimated 600 000 primary coal users may be reached using the existing best practise (Lokkers and Swanepoel, 2005). The remaining 180 000 can most probably be reached by adapting the existing practice. Its positive impacts affect health (reduction of ambient and indoor exposure to PM, SO, NO and VOCs), economy (25-33% coal savings), environment (25-33% ash reduction), and labour market.

6.1. Thermally comfortable subsidy houses

Another viable intervention option is the provision of thermally comfortable houses. Government builds between 200 000 and 300 000 subsidy houses per year and needs to build about 500 000 per year in order to reduce the housing backlog. Some technologies, techniques and design features are ready to be implemented (off-the-shelf technologies), and are already standard practice in the building industry (e.g., use of ceilings, ceiling insulation, and correct orientation). Building semi-detached or duplex houses has a great advantage concerning thermal comfort and does not have to increase the cost of a subsidy housing development. Correct orientation will also not increase the cost and will lead to improved thermal comfort. All new houses should be the target of the first option: build houses first time right with energy conscious design, including ceiling and roof overhang. The second option is applicable to existing houses: retrofit insulation, mainly ceilings and ceiling insulation. All households that use dirty fuels for heating, i.e., those in areas with high numbers of coal and wood users, would benefit from an increase in thermal comfort. This intervention affects positively health and environment (reduction of 40% in fuel use and thus in indoor exposure and ambient pollution), economy and labour market. Retrofit of insulation as well as passive solar heat absorbers are needed in all subsidy houses in cold areas. Despite higher expenditure in comparison with fitting the technology to new structures, the cost-benefit ratio will still be positive.

6.2. Solar cookers

Solar cookers have been evaluated (average fuel saving of 38%), improved and validated but still have not been implemented on a large scale.

6.3. Free basic electricity

An increase in free basic electricity and safety standards for paraffin appliances are two potential interventions that are still in need of validation.

6.4. New generation energy efficient housing

A new generation energy efficient houses, biomass gasification stoves, gel fuels, and the domestic use of biogas are interventions that show potential to reduce air pollution in dense, low-income communities but have to go through the process of evaluation first. What is needed, is understanding on how they will function within the communities for which they are intended and in which way the current designs will have to be adapted based on a better understanding of end-user requirements.

6.5. Basic research

There are four areas where basic research has to be conducted in order to understand air pollution in dense, low-income communities better and formulate possible intervention options:

a) Very little air quality data is available for rural areas and small towns so that ambient air monitoring may provide very valuable information on current levels of pollution in these areas.
b) At the moment it is impossible to give an overview of the national situation of indoor air quality in SA. More reliable information on actual levels of indoor air pollution across different areas, structure types and fuel types would enable a better estimation of the extent of indoor air pollution in the country.
c)There is very little information about wood use although wood is the country's second most prevalent source of domestic heating. The number of households that primarily use another energy carrier for heating or cooking but that use wood occasionally, the numbers and types of devices as well as their influence on emission are unknown. When one takes into consideration that wood is the most important contributor to health effects even in those areas where there are very few wood users, it becomes apparent that this information is needed in order to successfully address the problem of air pollution in SA.
d) In general, research tends to underestimate the functioning of the household and multi-factorial causation of air pollution. Pollution is often seen as a technical problem only that has to be solved by technical means. In the case of air pollution caused by domestic coal use, for example, various efforts that were made to solve the problem failed because they were not based on a thorough understanding of the social dynamics involved. Similar procedures were followed regarding the provision of other energy technologies. Low-cost housing, for example, is not designed to be both energy efficient and socially desirable or beneficial. Available technology that could have achieved these aims is not implemented. It seems as if decision makers forget that technology usage is driven by social needs and facilitated by technical designs and financial means. The quality of life of low-income households will only be enhanced if residents are engaged in the process of designing technology that is functionally integrated within the social dynamics of their people.

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