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DOMESTIC FUEL BURNING EMISSION REDUCTION: ESKOM'S KWAZAMOKUHLE PILOT STUDY

Kristy Langerman[1], Bianca Wernecke[1], Gabi Mkhatshwa[1], Deidre Herbst[1], Stuart Piketh[2], Roelof Burger[2], Christiaan Pauw[3], Hendrik Snyman[3], Henry Murray[3], Theo Fisher[4] and Michael Weston[4]

[1] Eskom Holdings SOC Ltd, Megawatt Park, Maxwell Drive, Sunninghill, Sandton, rosske@eskom.co.za
[2] North-West University, Potchefstroom
[3] The NOVA Institute, 13 Beuke Place, The Willows Ext 14, Pretoria
[4] E-Science Associates, 9 Victoria Street, Oaklands, Johannesburg

Scientific studies show that in South Africa the main cause of harmful health effects due to poor air quality is the domestic burning of solid fuels, usually in dense, low income settlements. The reduction of emissions from domestic burning therefore needs to be addressed as an equally pressing priority in parallel to industrial point source emission reduction, in order to meaningfully improve the health and quality of life of people living in areas with poor air quality. Eskom, in partnership with the North-West University, the NOVA Institute, E-Science Associates, the CSIR and Prime Africa Consultants, have embarked on a pilot study in order to test the feasibility of several interventions intended to reduce emissions from domestic solid fuel burning. 140 households in KwaZamokuhle (near Hendrina in Mpumalanga) have been randomly selected to participate in the pilot study. Twenty households form the control group, and the interventions have been rolled out at the remainder. Each of the treatment houses has either been fitted with a ceiling or full thermal insulation, and then either supplied with a more efficient coal-burning stove, or an LPG heater and stove, or an electricity subsidy. Amounts of solid fuel used, indoor temperature and indoor air quality will be monitored, in addition to ambient air quality and personal exposure monitoring. Preliminary results show that around 74% of households burn coal as their main energy source. Domestic burning is the main contributor to ambient PM10 concentrations in summer and winter, and the main contributor to ambient SO_2 and NO_2 concentrations in winter. Reducing solid fuel burning emissions thus has the potential to reduce levels of all three criteria pollutants in low income settlements.

Keywords: domestic burning, air quality offsets

1. Introduction

Indoor air pollution arising from the burning of coal and wood for domestic cooking and heating is the seventh greatest disease risk in southern Africa, while ambient air pollution is the 25th highest disease risk (Lim et al, 2012). Large point sources of emissions in South Africa are effectively controlled by the National Environmental Management: Air Quality Act (2004) through Atmospheric Emission Licences and the Minimum Emission Standards. Domestic burning of solid fuels and other emission-generating activities in settlements, like waste burning and unvegetated surfaces, are much more difficult to control, however. Because these activities are undertaken in areas where people live, they impact directly on exposure to pollution and thus human health. Air quality offsets, as envisioned in the draft Air Quality Offsets Guidelines published for public comment on 26 June 2015, present a mechanism for enforcing and financing emission reduction from those sources which are difficult to address through any other legislation.

Eskom has recognised the need to address poor air quality in low income settlements, and has initiated a domestic fuel burning emission reduction programme to complement its own emission reduction programme. Eskom's emission reduction plan is projected to reduce relative particulate emissions from power stations by 67% by 2027, relative NOx emissions by 25% by 2025 and relative SO_2 emissions by 30% by 2027, relative to 2013 emissions. However, these emission reductions will have almost no positive impact on indoor air pollution. Eskom, in partnership with the NOVA Institute, North-West University, E-Science Associates, the CSIR and Prime Africa Consultants, has been developing and testing interventions to reduce emissions from domestic fuel burning, with the view to rolling these out on large scale in low income settlements affected by power station emissions. The interventions are currently being tested in KwaZamokhule, near Hendrina in Mpumalanga. Preliminary results from the pilot study are presented in this paper.

2. Pilot study design

The pilot study is conducted in three phases:

a) *Baseline determination* (July 2014 – February 2015) in which the air quality, quality of life and energy consumption patterns of the people in the study area are determined
b) *Intervention implementation* (March – August 2015)
c) *Analysis of findings* (September – December 2015)

2.1 Interventions

The main aims of the domestic fuel burning emission reduction pilot study are to test whether the interventions are readily accepted and adopted by the households, and whether they do indeed result in a reduction in solid fuel use (or at least a reduction in emissions). The interventions to be tested are informed by a pre-feasibility study conducted in 2013 by NOVA and E-Science Associates for Eskom, in which an exhaustive list of interventions was evaluated according to a number of weighted criteria. The interventions are:

- The exchange of coal/wood-burning stoves for low emission stoves
- An electricity subsidy during the winter months
- Provision of an LPG heater and stove and LPG cylinders
- A ceiling retrofit
- A full thermal insulation retrofit

For the pilot study, 120 formal households in KwaZamokhule were randomly selected to test the interventions, and a further 20 formal households were selected to be the control group. Of the 120 households, all have been fitted with a ceiling (60 households) or full thermal insulation (60 households), and then each of the households has been given either a low emission coal stove or LPG appliances or an electricity subsidy.

The interventions have been installed by 12 teams consisting of 48 previously unemployed local residents, who have been trained to perform their jobs.

Extensive consultation with the community has been conducted through targeted focus groups, through the Local Stakeholder Reference Group, and through continual informal engagements with the project participants. Engagement with other stakeholders, including government departments and NGOs, takes place through a Multi-Stakeholder Reference Group.

The effectiveness of the interventions is evaluated by measuring in selected households:

- Solid fuel use
- Indoor temperature
- Indoor PM, SO_2 and NOx concentrations
- Personal exposure to PM
- Ambient air quality and meteorological conditions

2.2 Study site: KwaZamokhule

Figure 1: Location of KwaZamokuhle in relation to Hendrina town and Komati, Hendrina and Arnot Power Stations

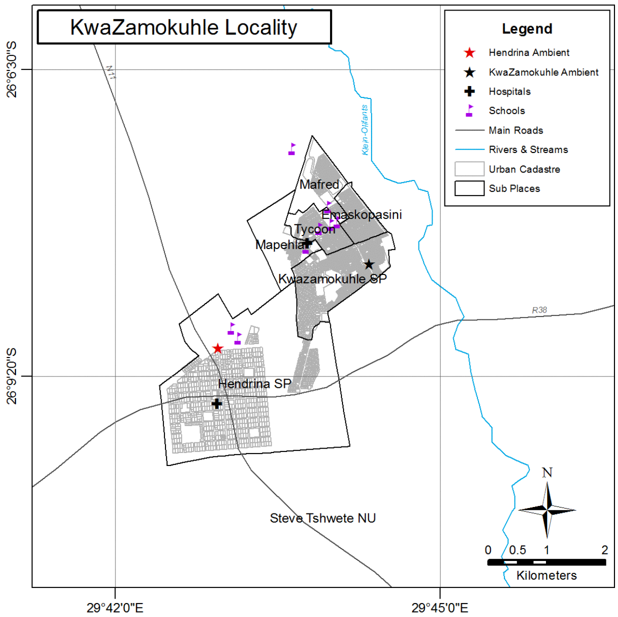


Figure 2: KwaZamokuhle and its sub-places

KwaZamokuhle, situated immediately north-west of Hendrina in Mpumalanga (Figure 1 and Figure 2), was selected as the site for the pilot study since domestic coal burning is prevalent there, and the only other significant influence on ambient air quality is power station emissions.

3. Socio-economic conditions

Socio-economic surveys have been completed by 693 of the approximately 6 000 households in KwaZamokuhle, and have given useful insights into the residents:

- The population is relatively young with a median age of 24.
- The average number of members per household is 4.1.
- Only 21% of the population is in full-time employment, although approximately 66% of the population is of working age.
- The mean monthly household income is R1 965, although income levels are highly variable.
- 30% of the respondents live in informal housing
- Most people perceive themselves as being healthy: over 90% of respondents reported that they had no health complaints in the last 12 months.

3.1 Energy usage patterns

Coal is the most commonly used energy source in KwaZamokuhle, with around 74% of households using coal according to the socio-economic survey. The average amount of coal used by a household ranges between 246 kg per household in a winter month and 141 kg per household in a summer month. Wood is used by less than 1% of households in KwaZamokuhle, according to the Census 2011. The average amount of wood used by these households ranges between 379 kg per household in a summer month and 419 kg per household in a winter month. All formal houses (around 70% of all houses) also have access to electricity. The average household spends around R400 on energy costs in a winter month.

4. Ambient air quality

4.1 Status quo: monitoring results

An ambient air quality monitoring station measuring PM10, PM2.5, SO_2, NO, NO_2, O_3 and meteorological parameters has been operational at a church near the centre of KwaZamokuhle since September 2014. Measurements from 1 January to 31 June 2015 show that PM10 levels are significantly higher in the winter months (May and June) than in the summer months (Figure 3). Fifty exceedances of the daily PM10 ambient air quality limit value were recorded in the first six months of 2015.

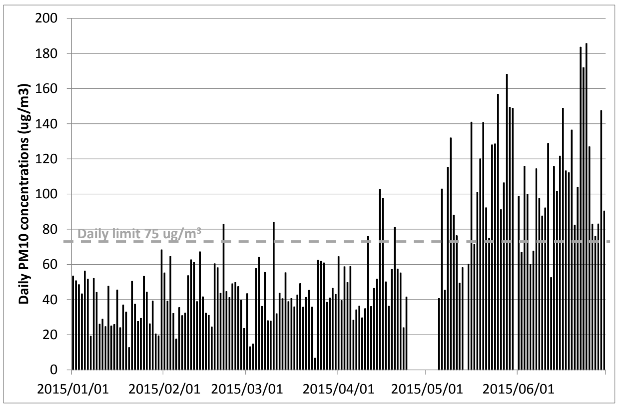


Figure 3: Daily PM10 concentrations in KwaZamokuhle between 1 January and 30 June 2015.

The average diurnal variation of PM10 concentrations shows an influence of domestic burning in winter and summer as indicated by the peaks in PM10 concentrations in the morning and evening (Figure 4). As expected, the peaks in PM10 levels when fires are active are higher and more prolonged in winter than in summer. Similar diurnal PM variations were made by Venter et al. (2012) in the industrialised Bushveld Igneous Complex.

In winter SO_2 concentrations are also strongly influenced by local burning activities, as indicated by the particularly high concentrations in the early evening (Figure 4 middle). This contrasts with observations made by Collett et al. (2010) in the industrialised Highveld and Venter et al. (2012) in the Bushveld Igneous Complex, where SO_2 concentrations dropped significantly in the evening. Tall stack sources are the main source of SO_2 in summer, however, as reflected by the increase in ambient SO_2 concentrations in the morning, reaching a maximum at midday. Local burning is the main source of NO_2 in the winter, as reflected by the morning and evening peaks, but tall stack and local burning sources are roughly evenly important in the summer (Figure 4 lower). Morning and evening peaks in NO_2 concentrations were also observed by Venter et al. (2012) in the industrialised Bushveld Igneous Complex.

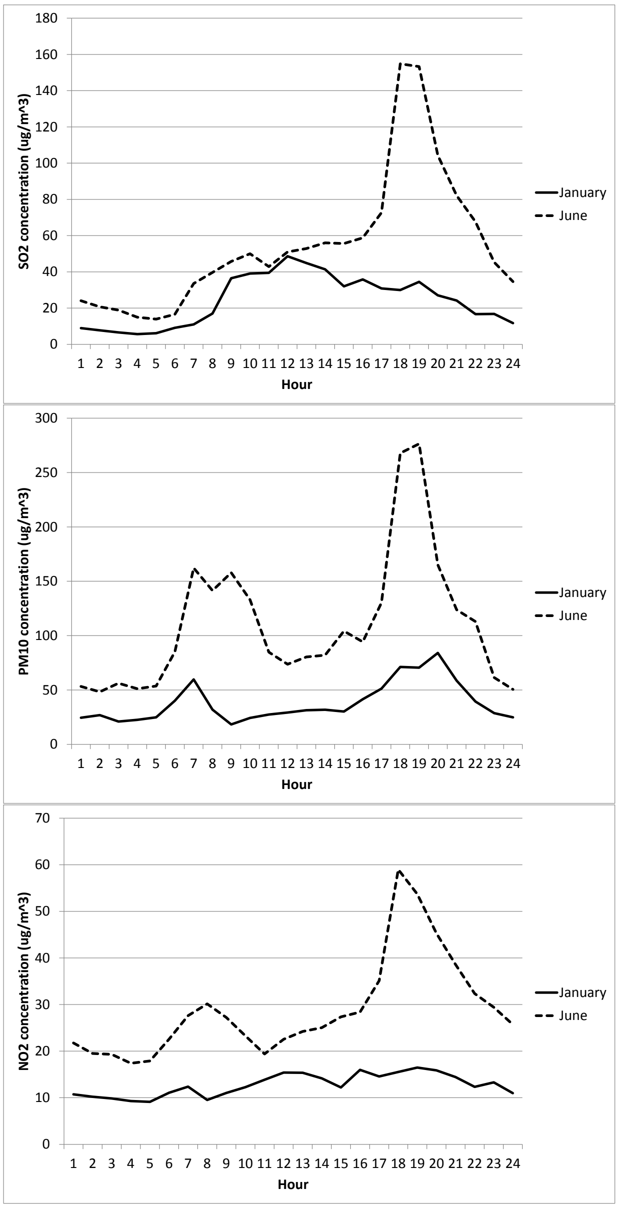


Figure 4: Average diurnal hourly variations of PM10 (top), SO_2 (middle) and NO_2 (lower) concentrations in summer (January) and winter (June) 2015

4.2 Contribution of local domestic burning: dispersion modelling results

Total PM and SO_2 emissions from domestic burning in KwaZamokuhle have been calculated based on the average amount of fuel used per household (see section 3.1 above) and the emission factors from le Roux et al. (2005). (Table 1). Around 125 tons of PM10 and 93 tons of SO_2 are emitted annually from domestic fuel (mainly coal) burning in KwaZamokuhle (Table 2).

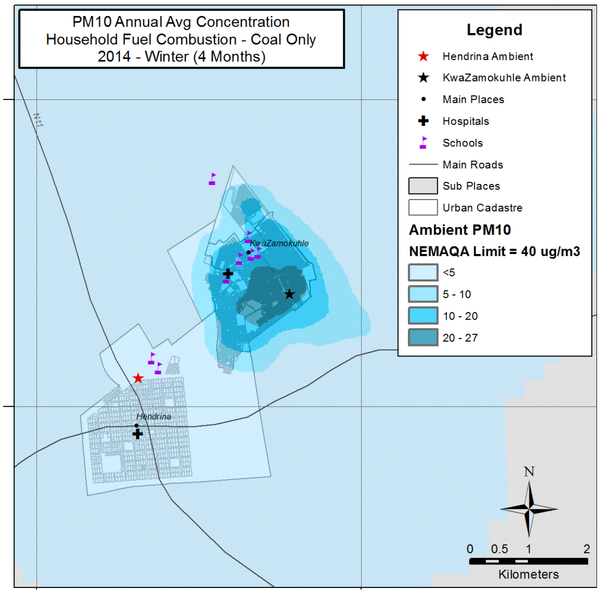
Table 1: Emission factors for household combustion (le Roux et al., 2005)

Fuel	Pollutant	Emission factor
Coal	PM10	12.91 g/kg
	SO_2	9.91 g/kg
Wood	PM10	17.3 g/kg
	SO_2	0.2 g/kg

Table 2: PM10 and SO_2 emissions from domestic burning of solid fuels in KwaZamokuhle (tons/annum)

	Coal	Wood	Total
PM10	121.0	4.2	125.2
SO_2	92.9	0.1	93.0

Household burning makes a significant contribution to ambient PM10 and SO_2 levels. The CALPUFF dispersion model has been run to calculate ambient PM10 and SO_2 concentrations resulting from domestic coal burning in KwaZamokuhle, initially for the four winter months. The diurnal pattern of emissions was derived from the ambient PM10 measurements (Figure 4). In the south-eastern section of KwaZamokuhle, where household density and emissions are the greatest, average PM10 concentrations from household emissions alone for the winter period exceed 20 $\mu g/m^3$ (the annual limit value is 40 $\mu g/m^3$). Ambient SO_2 concentrations (exceeding 15 $\mu g/m^3$ for the winter period) are a bit lower, but nevertheless significant.



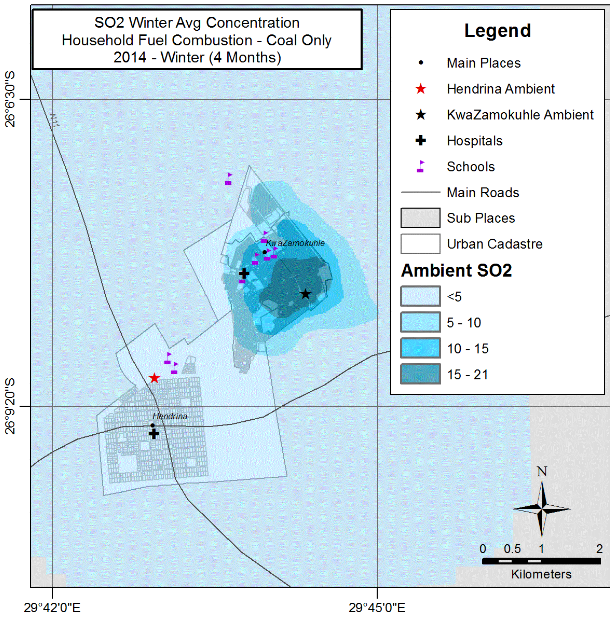


Figure 5: Average PM10 (previous page) and SO_2 (this page) ambient concentrations for the 4 winter months, resulting from the emissions from domestic coal burning in KwaZamokuhle.

5. Preliminary musings on the success of the interventions

In general, the interventions have been very well received by the KwaZamokuhle households. The new coal stoves are preferred over the old stoves, although residents would prefer a larger stove. Verbal feedback indicates that around 50% less coal is now required, although one household reported using as much coal (and presumably heating the house for longer).

Safety is a concern for the LPG appliances, and a trainer from the LPG Safety Association of South Africa trained most of the households with LPG appliances, and the NOVA project coordinator and a technical support field worker who now acts as a local safety officer. To date, no safety incidents have occurred. One household refused to have the LPG appliances installed after they signed the contract, however, probably due to safety concerns.

Brown markings have appeared on ceilings installed in newer RDP houses. The roofs of these houses are generally in poor condition, and it is thought that the markings are from leaks in the roofs and resulting rust. The project team is investigating facing the ceiling boards with a plastic cover in order to prevent moisture seepage.

6. Conclusion

Although the scale of the pilot study will not enable a significant impact on ambient air quality to be realised, the success of the interventions will be determined based on the acceptability of the intervention to the households, the reduction on solid fuel use, the increase in indoor temperature and the improvement in indoor air quality. Ambient air quality monitoring and dispersion modelling conducted in KwaZamokuhle show that domestic burning indeed makes a significant contribution to ambient PM10 and SO_2 concentrations. There is thus significant potential to improve air quality through reducing emissions from solid fuel burning. This is probably most effectively achieved through both providing some sort of insulation for houses, and either reducing solid fuel use, or switching to a cleaner form of energy entirely. A question remains, however, as to how to deal with informal houses, as it is not be possible to install insulation or ceilings in these dwellings.

7. Acknowledgments

The local NOVA project team, headed up by project coordinators Thembi Tsotetsi and Sunday Mashinini, is acknowledged for implementing the interventions.

8. References

Collett, K.S., Piketh, S.J. and Ross, K.E. 2010: ‘An assessment of the atmospheric nitrogen budget on the South African Highveld’, *South African Journal of Science*, **106 (5/6)**: Art. #220, 9 pages.

Le Roux, L.J., Zunckel, M. and McCormick, S.G., 2005: *Laboratory Controlled Quantitative Information About Reduction in Air Pollution using the “Basa Njengo Magogo” Methodology and Applicability to Low-Smoke Fuels (Revised)*, Division of Water, Environment and Forestry Technology, CSIR, Durban, Report No. ENV-D-C 2005-004.

Lim S.S. et al. 2012: ‘A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010’, *The Lancet*, **380**:2224-2260.

Venter, A.D., Vakkari, V., Beukes, J. et al., 2012: ‘An air quality assessment in the industrialised western Bushveld Igneous Complex, South Africa,’ *South African Journal of Science*, **108 (9/10)**, Art. #1059, 10 pages