HELPING AIR QUALITY MANAGERS IDENTIFY VULNERABLE COMMUNITIES

Caradee Y. Wright[1,2*], Roseanne D. Diab[2] and Michelle L. Binedell[3]
[1]CSIR Natural Resources and the Environment, Pretoria, South Africa. cwright@csir.co.za
[2]University of KwaZulu-Natal, Durban, South Africa
[3]South African Sugar Research Institute, Durban, South Africa

Abstract

Air quality management plans identify prioritised strategies and actions independent of any consideration of population exposure and vulnerability. This is seen as a major shortcoming, particularly in a country such as South Africa where funding and capacity are scarce, and many vulnerable communities are living on marginalised land. While ambient air pollution levels in excess of prescribed health standards are generally unacceptable, the exceedance is even more serious in areas where people reside. A population exposure and vulnerability risk prioritisation model is proposed for potential use by air quality managers in conjunction with their air quality management plans. The model includes factors such as vulnerability caused by poverty, respiratory and other diseases, lack of education and poor living conditions, all of which are important in areas occupied by previously disadvantaged communities. In this way, high-risk areas in terms of air pollution health impacts were identified using a specifically-tailored set of indicators that assessed air pollution sources (industrial, vehicular, agricultural, domestic); ambient air pollution levels; air pollution potential (wind speed, mixing depth, solar radiation, humidity, topography); community awareness, observations, perceptions and actions; and several vulnerability factors, including population demographics, health status, personal exposure risk and socioeconomic factors. The model was applied to the eThekwini Municipality, KwaZulu-Natal. Data were extracted from multiple sources for a selection of municipal wards and scored to illustrate categorisation of vulnerable communities at risk of excess exposure to ambient air pollution. Results were used to identify high risk areas and specific local communities, as well as to develop focussed management strategies for the municipality and design customised interventions to reduce vulnerability and more importantly the incidence of adverse respiratory health impacts. Finally, obstacles and challenges encountered during model development and data collection are described.

Keywords: air pollution, population exposure, vulnerability, risk

1. Introduction

Air pollution is a major environmental health threat to humans, especially children in whom respiratory function is still developing. Certain outdoor pollutants are known risk factors for acute and chronic respiratory infections. Recently, South Africa passed the National Environmental Management: Air Quality Act No. 39 of 2004 (NEM AQA) (DEAT, 2004) to manage ambient air quality and thereby protect the health of the South African population. This legislation marks a paradigm shift in the manner in which air quality is managed in South Africa and for the first time presents an opportunity to include human health considerations. Each South African local municipality is required to draft and implement an air quality management plan (AQMP) with the aim of maintaining ambient air quality levels below specified standards and thus minimising adverse human health impacts.

The AQMPs identify a number of prioritised strategies and actions that must be implemented, but as they are currently conceived these actions are prioritised independently of any consideration of population exposure and vulnerability. This is seen as a major shortcoming, particularly in a country such as South Africa where funding and capacity are scarce. While ambient air pollution levels in excess of prescribed health standards are generally unacceptable, the exceedance is even more serious in areas where people reside. Such areas should be prioritised for action in any AQMP given the consequent detrimental acute and chronic health risks.

A National Framework to guide implementation of the Act was prepared following the promulgation of the NEM AQA (DEAT, 2007). This presents an opportune time to make meaningful recommendations for the inclusion of population exposure and health risk assessment into air quality management planning policy.

Indicators are one possible set of tools to adapt for use in population exposure risk assessment. To date, most air quality research has focused on measurement of ambient air pollution concentrations compared to prescribed health standards (for example, Kyrkilis et al., 2007; Shiva Nagendra et al., 2007). However, at least for South African conditions, there is a need to include population factors relevant to those individuals exposed, such as vulnerability caused by poverty and poor living conditions. Thus, the proposed research will provide for the development of a set of indicators in a model that assesses population health effects, and appraises and quantifies inequalities in exposures and health effects to prioritise at-risk communities. Model results may be interpreted for the design and evaluation of affordable and efficient interventions for municipalities to use, thereby reducing their workload while meeting the goal of alleviating adverse health impacts associated with air pollution exposure (i.e. the ultimate goal of their AQMP).

2. Methods

The proposed model was derived through the review of several sources and informed by three main theories, i.e. Risk Assessment, Human Health Risk Assessment and DPSEEA (Driving force, Pressure, State, Exposure, Effects, Action) (Corvalan et al, 1996). This is a framework developed by the World Health Organization that brings together the environment and health with action-based outcomes at appropriate intervention levels. A systematic approach was adopted and five themes identified, namely, air pollution sources; ambient air pollutant levels; air pollution potential; population vulnerability factors including population exposure; and community awareness, perceptions, observations and actions.

The main goals and specific indicators for each theme are provided in Table 1. It is reiterated that the purpose of this model is to assist air quality managers of district or local municipalities to identify at-risk communities in terms of air pollution exposure and vulnerability to thereby allocate resources and prioritise service delivery to alleviate risk conditions and assist communities to better cope with their situations. Therefore, an important consideration for all indicators is that there are local data available for application in the model and that the model is simple yet efficient at identifying vulnerable communities exposed to high levels of air pollution.

The proposed model was developed through several iterations taking into account specific needs of the South African environment and applied to the eThekwini Municipality (Kwa-Zulu Natal). This municipality was selected as an ideal case study candidate since several data sources exist, an AQMP is almost in place, small research studies have been undertaken and there is public willingness to ensure air quality managers prioritise resource allocation to improve community vulnerability to excess air pollution.

Seven of the 100 wards in the eThekwini municipality (see Figure 1) were selected for inclusion in the case study based on their location. Four were peri-urban wards located in the far north of the municipality and three were urban wards in the South Durban Basin. The peri-urban wards included Cato Ridge, Ximba, Nkandla, Sthumba and Nonoti (ward 1); Mgezanyoni, Mgangeni, Inanda and Mshazi (ward 2); Hammarsdale, Drummond and Inchanga (ward 4); and Mophela/Georgedale and Sankontshe (ward 5). The urban wards included Wentworth and Brighton Beach (ward 67); Mobeni, Jacobs, Austerville and Merewent (ward 68); and Durban Airport Area, Isipingo Beach and Orient (ward 90).

Data were collected from multiple sources and collated in Microsoft Excel spreadsheets. The data collection process was fraught with challenges and difficulties. Since this was the initial application of the model, all data including air pollution sources (i.e. the emission inventory) needed to be obtained. For future model runs, these data will only need to be updated and therefore the process will prove less time consuming.

An attempt to ground-truth the collected data was also made by contacting a sample of local residents in each of the seven wards. Data verified in this way included recent disasters; media through which complaints are made; presence of action groups; and schools provided with food by the Kwa-Zulu Natal Department of Education.

Table 1. Five themes, their main goals and specific indicators

Theme and Main Goal	Indicators
Air pollution sources To identify at-risk communities based on proximity to air pollution sources	Presence of industrial point sources Presence of vehicular emissions Presence of agricultural burning
Ambient air pollutant levels To determine the extent of the air pollution problem	Number of exceedances* for sulphur dioxide, nitrogen dioxide, carbon monoxide, particulate matter, ozone, lead, benzene
Air pollution potential To consider environmental factors which may exacerbate the problem	Predominant wind speed (i.e. community downwind of source) Mixing depth Solar radiation Humidity Topography
Population vulnerability factors To consider demographic factors which may affect a community's ability to cope with exposure to air pollution, and to identify especially vulnerable communities and factors influencing their vulnerability	Age Sex Population group Health status Access to health care Immunisation Personal exposure to air pollution Enumeration area type Population density Highest education level Employment status Annual household income Waste collection Energy use (also as a proxy for domestic air pollution sources) Water supply Sanitation Evidence of disaster impacts Crime and insecurity Nourishment/nutrition Psychosocial factors
Community awareness, perceptions, observations and actions To include community complaints, media coverage, NGO activity etc	Complaints; media articles; Other e.g. NGOs; public information campaigns to promote environmental health

Note. * Measured or modelled data where available.

Data were not always available at sufficiently low resolutions, especially meteorological data (i.e. no monitoring station, or one station representing the entire municipality) and health data.

Many of the original indicators were removed from the model since the data were not available or the means for collecting the data were too difficult or time consuming. For example the indicators: 'proximity of the community to the nearest road' and 'type of road', were removed. At ward level, there are multiple communities in each ward; however, these are not delineated on any map. In this instance, a site visit would probably be best to collect and verify these data. This might not be possible for the air quality manager.

Data were extracted for each of the seven wards and entered into Microsoft Excel spreadsheets programmed to score each indicator, determined by a given threshold value and associated score. The threshold values were determined by extensive literature review, expert consultation and available data verification. 'Presence of' for an indicator was coded yes: 3 and no: 0. Where threshold ranges were possible, greatest risk was assigned a value of '3', moderate risk '2' and minimal risk '1'. In most cases, 'no known risk' or 'no available data' was assigned '0', therefore, indicator results scored 0 must be interpreted with caution. Thus, the higher the total score, the greater the risk or vulnerability for that indicator.

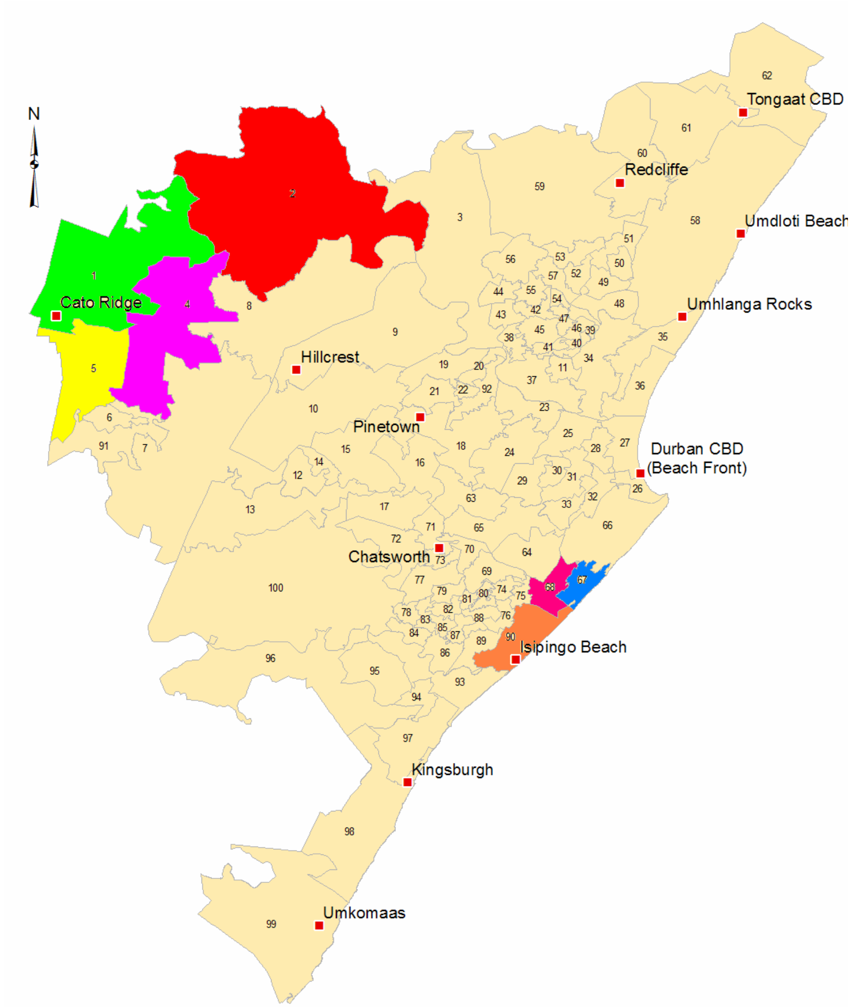

Figure 1. Wards in the eThekwini municipality

3. Results and Discussion

The results of the scored indicators for each of the five themes and an overall total are provided in Table 2. The ward with the maximum scores for four of the five themes (population vulnerability factors theme excluded) was Ward 68: 'Mobeni, Jacobs, Austerville and Merewent'.

In terms of community awareness, perceptions, observations and actions, a high score in this category indicates that air pollution is likely to be a problem because of the presence of these groups/complaints etc. However, the actions of community groups may offset impacts by providing forums for lowering people's resilience and increasing their coping mechanisms. The three urban wards scored equally for the community factors, probably since they are located within close proximity to each other and share the efforts of a combined community action group, i.e. South Durban Community Environmental Alliance (SDCEA).

The peri-urban ward of 'Mgezanyoni, Mgangeni, Inanda and Mshazi' (Ward 2) was identified at greatest risk using the specified indicators for population vulnerability. There was some evidence of three of the four peri-urban wards being potentially at greater risk in terms of population vulnerability compared to the urban wards, although the range in scores was relatively small, i.e. 44 - 52.

Ambient pollutant levels for the peri-urban wards were determined using a proxy peri-urban monitoring station since no stations are presently located in any of the four wards. Since the emphasis of the model's application is on air pollution, it would be beneficial for the current monitoring network to extend its range and include a new station in the Cato Ridge area where air pollution sources include poultry farms, i.e. emitting sulphides and other odour-related pollutants, and vehicular pollution.

Table 2. Air pollution population exposure and risk prioritisation results for seven wards in the eThekwini municipality (un-weighted results)

		Factors (total score)					
	Ward name (and ward number)	**Air Poll Scs (18)**	**Amb Poll lvls (63)**	**Air Poll Pot (15)**	**Pop Vulner (75)**	**Comm Aware Percep Observ Action (12)**	**Total (183)**
Peri-urban	Cato Ridge, Ximba, Nkandla, Sthumba and Nonoti (1)	11	3	6	51	6	77
	Mgezanyoni, Mgangeni, Inanda and Mshazi (2)	9	3	6	56	0	74
	Hammarsdale, Drummond and Inchanga (4)	11	3	6	47	0	67
	Mophela/Georgedale and Sankontshe (5)	8	3	6	49	0	66
Urban	Wentworth and Brighton Beach (67)	12	7	10	45	12	86
	Mobeni, Jacobs, Austerville and Merewent (68)	14	10	10	52	12	98
	Durban Airport Area, Isipingo Beach and Orient (90)	10	0*	7	44	12	73

Note. Total scores per theme were calculated by multiplying the number of indicators by three, the maximum score for each indicator.

* There is no monitoring station in this ward therefore no data were available for processing in the model.

Table 3. Air pollution population exposure and risk prioritisation results for seven wards in the eThekwini municipality (weighted results)

		Factors (total score)			
	Ward name	**Air combined (75)**	**Pop Vulner (20)**	**Comm Aware Percep Observ Action (5)**	**Total (100)**
Peri-urban	Cato Ridge, Ximba, Nkandla, Sthumba and Nonoti (1)	15.6	13.6	2.5	31.7
	Mgezanyoni, Mgangeni, Inanda and Mshazi (2)	14.0	14.9	0	29.0
	Hammarsdale, Drummond and Inchanga (4)	15.6	12.5	0	28.1
	Mophela/Georgedale and Sankontshe (5)	13.2	13.0	0	26.3
Urban	Wentworth and Brighton Beach (67)	22.6	12.0	5.0	39.6
	Mobeni, Jacobs, Austerville and Merewent (68)	26.5	13.0	5.0	45.3
	Durban Airport Area, Isipingo Beach and Orient (90)	13.2	11.7	5.0	30.0

The three themes: air pollution sources, ambient pollutant levels and air pollution potential, were combined and weighted as 75% of the total score for each ward. The remaining 25% was allocated to population vulnerability factors (20%) and community factors (5%). These results are provided in Table 3.

There was no significant alteration in the ranking of the wards by greatest risk when the results were weighted. The main reason for this is that the number of indicators in the ambient air pollutant theme is large therefore generating a large subtotal score even though many of these data are not available (either not measured or missing). An improvement to the model may be to select some of these indicators for inclusion and exclude those pollutants not regularly monitored, even though included in the national standards, e.g. number of exceedances_24hr_Pb since the effects of lead inhalation are long-term and diurnal concentrations are considerably low.

The most common problem encountered when processing the collected data was not having the data at the ward level and having to use provincial or municipal level data to represent each ward, i.e. the same value for each ward, when differences are highly likely to occur. Some of the problems encountered during the data collection and management phase included lengthy time delays and not knowing what institution to contact for the required data. Then, within the institution, it was difficult to connect with the correct individual. This was particularly the case with Provincial Government Departments and the South African Police Service. When data were supplied, no indication was provided of its uncertainty or specific collection methods. These factors contribute towards the overall uncertainty of the model's results. Since no similar work has been carried out, fixing threshold values was extremely difficult. The nature of the available data led to the subsequent altering of threshold values after searching for possible comparatives in other countries and published research.

4. Conclusions

The proposed air pollution population exposure and risk prioritisation model was applied to the eThekwini municipality to assess indicator feasibility, data availability and ease of application. Several suggested indicators were not viable because the required data were not available. Data collection was lengthy since this was the first time the model was applied but future applications will only require that data are updated where necessary. Proxy data were used in many cases since data were not available at the appropriate resolution, i.e. ward level. Improvements to the model's efficacy will be possible when these data are made accessible. Future work will entail application of the model in a second municipality to test indicator robustness, current threshold values appropriateness and overall usefulness for air quality managers.

5. Acknowledgements

Financial support for this post-doctoral research project was provided by a grant-holder National Research Foundation (NRF) bursary and the Council for Scientific and Industrial Research (CSIR). C. Wright received a University of Kwa-Zulu Natal Post-doctoral Research Fellowship. Archie van der Meer (eThekwini Municipality), Siva Chetty (eThekwini Municipality), Helen North (Statistics SA), Frank Sokolic (EduAction) and Mogesh Naidoo (CSIR) are acknowledged for their generous provision of data and information.

6. References

Corvalan C., Briggs D. and Kjellstrom T. 1996, Development of environmental health indicators. In: Linkage Methods for Environment and Health Analysis: General Guidelines. A Report of the Health and Environment Analysis for Decision-making (HEADLAMP) Project. UNEP, US EPA, WHO (Briggs D, Corvalan C, Nurminen M, eds). Geneva: Office of Global and Integrated Environmental Health, WHO, pp. 19-53.

DEAT 2004, National Environmental Management: Air Quality Act No. 39 of 2004.

DEAT 2007, National Framework for Air Quality Management in the Republic of South Africa. http://nfaq.csir.co.za/cocoon215/nfaqg/docs/downloads.htm

Kyrkilis, G., Chaloulakou, A. and Kassomenos, P.A. 2007, 'Development of an aggregate Air Quality Index for an urban Mediterranean agglomeration: Relation to potential health effects' *Environment International* 33(5):670-676.

Shiva Nagendra, S.M., Venugopal, K. and Jones, S.L. 2007, 'Assessment of air quality near traffic intersections in Bangalore city using air quality indices' *Transportation Res* D 12:167-176.