

Air quality assessment of the industrialized western Bushveld Igneous Complex

A.D. Venter

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Supervisor: Dr. P.G. van Zyl

Co-supervisor: Dr. J.P. Beukes

Assistant supervisor: Prof. J.J. Pienaar

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By this it appears how necessary it is for any man that aspires to true knowledge to examine the definitions of former authors; and either to correct them, where they are negligently set down, or to make them himself. For the errors of definitions multiply themselves, according as the reckoning proceeds, and lead men into absurdities, which at last they see, but cannot avoid, without reckoning anew from the beginning; in which lies the foundation of their errors... For between true science and erroneous doctrines, ignorance is in the middle. (Hobbes, 1651)

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Abstract

South Africa has the largest economy in Africa, with significant mining and metallurgical activities. A large fraction of the mineral assets is concentrated in the Bushveld Igneous Complex (BIC), with the western limb being the most exploited. Although the western BIC is considered to be an air pollution hotspot, inadequate air quality data currently exists for this area.

To partially address this knowledge gap, a comprehensive air quality monitoring station was operated for more than two years at Marikana in the western BIC. Basic meteorological parameters, precipitation, Photosynthetic Photon Flux Density (PPFD), trace gas concentrations (SO_2 , NO, NO_x , O_3 , and CO), physical aerosol parameters (particle number and air ion size distributions, as well as aerosol light absorption) and total PM_{10} mass concentration were measured.

Compared with South African and European ambient air quality standards, SO_2 , NO_2 and CO concentrations were generally below the air quality standards, with average concentrations for the sampling period of 3.8ppb ($9.9\mu\text{g}/\text{m}^3$), 8.5ppb ($15.9\mu\text{g}/\text{m}^3$) and 230ppb ($270\mu\text{g}/\text{m}^3$), respectively. The major source of SO_2 was identified as high-stack industry emissions, while household combustion was identified as the predominant source of NO_2 and CO. In contrast, O_3 exceeded the eight-hour moving average standard (61ppb / $120\mu\text{g}/\text{m}^3$) 322 times per year. The main contributing factor was identified to be the influx of regional air masses, with high O_3 precursor concentrations. PM_{10} exceeded the current South African 24-hour standard ($120\mu\text{g}/\text{m}^3$) on average 6.6 times per year, the future 2015 standard ($75\mu\text{g}/\text{m}^3$) 42.3 times per year and the European standard ($50\mu\text{g}/\text{m}^3$) 120.2 times per year. The PM_{10} average concentration for the sampling period was $44\mu\text{g}/\text{m}^3$, which exceeded the current European and future (2015) South African annual average standard ($40\mu\text{g}/\text{m}^3$), emphasising the PM pollution problem in the western BIC. The main source of PM_{10} was identified as household combustion.

Keywords: NO_2 , SO_2 , O_3 , CO, PM_{10} , BC, legislation, seasonal, diurnal

Opsomming

Suid-Afrika het die grootste ekonomie in Afrika, met die mynboubedryf en metallurgiese industrieë wat 'n noemenswaardige bydrae maak. 'n Groot gedeelte van die plaaslike mineraalrykdom is gekonsentreer in die Bosveldstollingskompleks (BSK), waarvan die westelike deel die mees ontginde is. Alhoewel die westelike BSK as 'n atmosferiese besoedelingsbrandpunt beskou word, is daar tans te min lugkwaliteitsdata beskikbaar vir hierdie gebied.

Om hierdie kennisleemte gedeeltelik aan te spreek, is 'n omvattende atmosferiese moniteringstasie vir meer as twee jaar in die westelike BSK, te Marikana, onderhou. Daar is basiese metrologie, gaskonsentrasies (SO_2 , NO, NO_x , O_3 , CO), fisiese aërosol-eienskappe (aantal deeltjie en ionverspreiding, sowel as aërosol-ligabsorpsie) en totale PM_{10} massakonsentrasie gemeet.

Vergeleke met Suid-Afrikaanse en Europese voorgeskrewe standarde het SO_2 -, NO_2 - en CO-konsentrasies oor die algemeen aan die vereiste lugkwaliteitstandaarde voldoen. Vir die moniteringstydperk was die gemiddelde konsentrasie vir SO_2 3.8ppb ($9.9\mu\text{g}/\text{m}^3$), NO_2 8.5ppb ($15.9\mu\text{g}/\text{m}^3$) en CO 230ppb ($270\mu\text{g}/\text{m}^3$). Die hoofbron van SO_2 is geïdentifiseer as hoë skoorsteenuitlate, terwyl NO_2 en CO hoofsaaklik van huishoudelike verbranding afkomstig was. Die bewegende agt-uurlikse gemiddelde standaard van 61ppb ($120\mu\text{g}/\text{m}^3$) vir O_3 is gemiddeld 322 keer per jaar oorskry. Dié hoë O_3 -vlakke word toegeskryf aan die hoë konsentrasie van O_3 -voorgangerspesies wat in 'n streekskonteks voorkom. Jaarlikse gemiddelde PM_{10} -konsentrasies het die voorgeskrewe Suid-Afrikaanse standaard ($120\mu\text{g}/\text{m}^3$), toekomstige 2015-standaard ($25\mu\text{g}/\text{m}^3$) en Europese standaard met ($50\mu\text{g}/\text{m}^3$) onderskeidelik 6.6, 42.3 en 120.2 keer per jaar oorskry. Die totale gemiddelde PM_{10} -konsentrasie vir die moniteringstydperk was $44\mu\text{g}/\text{m}^3$. Dit het die Europese en toekomstige (2015) Suid-Afrikaanse lugkwaliteitstandaard ($40\mu\text{g}/\text{m}^3$) oorskry. Dié hoë waardes van PM_{10} kan grotendeels aan huishoudelike verbranding toegeskryf word.

Sleutelwoorde: NO_2 , SO_2 , O_3 , CO, PM_{10} , BC, wetgewing, seisoenaal, daaglik

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List of abbreviations

AMSL:	Above Mean Sea Level
BC:	Black Carbon
BIC:	Bushveld Igneous Complex
BSK:	Bosveld Stollings Kompleks
CCN:	Cloud Condensation Nuclei
DEAT:	Department of Environmental Affairs and Tourism
EEA:	European Environmental Agency
EPA:	Environmental Protection Agency
EU:	European Union
HEPA:	High Efficiency Particulate Arresting
HPA:	Highveld Priority Area
IN:	Ice Nuclei
IPCC:	Intergovernmental Panel on Climate Change
LOSU:	Level of Scientific Understanding
NAAQS:	National Ambient Air Quality Standards
NEMA:	National Environmental Management Act
NMHC:	Non-Methane Hydrocarbons

NSCR:	Non-Selective Catalytic Reduction
NWU:	North-West University
OC:	Organic Carbon
PGM:	Platinum Group Metals
PM:	Particulate Matter
PMT:	Photomultiplier Tube
PPFD:	Photosynthetic Photon Flux Density
RAQF:	Rustenburg Air Quality Forum
RF:	Radiative Forcing
SCR:	Selective Catalytic Reduction
SHARP:	Synchronized Hybrid Ambient Real-time Particulate Monitor
TEOM:	Tapered Element Oscillating Microbalance
UH:	University of Helsinki
VOC:	Volatile Organic Compounds
VTAPA:	Vaal Triangle Airshed Priority Area
WHO:	World Health Organization

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