Briefing note, July 2023

Potential health impacts of bypassing SO_2 controls at Kusile

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Introduction

After a technical failure at the Kusile power station, Eskom applied for permission to operate three units at the plant without sulphur dioxide (SO_2) control devices — Flue Gas Desulfurization (FGD) — using "temporary" stacks, in a gross breach of its Atmospheric Emission License (AEL) conditions. This application was granted on 5 June 2023.

The company plans to build "temporary" stacks on different units of the power plant that would allow the bypassing of the FGD. The construction of these stacks could be completed in 9–11 months, and the stacks would be commissioned in November–December 2023. Therefore, we have assumed that the applied operational period would run from December 1, 2023 to March 31, 2025.

In its motivation for the application, Eskom says the plant could provide 2,100 MW of electricity to the grid during the bypass period. Although this would be an exceptionally high rate of utilisation (97%) for an Eskom power station — given the rated capacity of the three units is 2,160 MW and the global average coal plant utilisation rate of 53% (IEA, 2022)[1] — we modelled the impacts assuming that Eskom can deliver on this promise. If the utilisation of the plant turned out to be lower, the health impacts would correspondingly be smaller, but so would any benefits of allowing the plant to operate in breach of its current emission licence limits.

In this briefing note, we quantify the increased emissions due to operating the plant without the control devices (excess emissions), and the corresponding impacts on air

[1] International Energy Agency (IEA). (2022). World Energy Outlook 2022, IEA. Licence: Creative Commons Attribution CC BY-NC-SA 4.0.

pollution, human health and the economy, and compare our health impact results to those of Eskom's.

Calculating excess emissions

Emissions during "normal operation" of the plant with the FGD were taken from Eskom Atmospheric Emission Licence (AEL) reports, except for mercury which is not reported by Eskom and was taken from the CREA (Myllyvirta and Kelly, 2023) report "Health impacts of Eskom's non-compliance with minimum emissions standards".[2]

SO_2 emissions during operation without FGD were calculated as:

[coal consumption] x [coal sulphur content] x 2 $kgSO_2/kgS$.

Mercury emissions were calculated as:

[coal consumption] x [coal mercury content] x [emission capture efficiency]

The increase in mercury emissions was calculated based on the UNEP (2017)[3] default mercury content concentrations and mercury capture efficiencies for a coal power plant burning bituminous coal with fabric filters, with and without FGD. Different emission capture efficiencies were given for different levels of air pollution controls.

For all pollutants, the effect of the high utilisation rate envisioned by Eskom was taken into account by scaling the emissions by the ratio of the envisioned output (2,100 MW) to the average output during the base period.

The base period used for all calculations is August 2021 to July 2022.

[2] Myllyvirta, L. and Kelly, J. (2023). Health impacts of Eskom's non-compliance with minimum emissions standards. Centre for Research on Energy and Clean Air. https://energyandcleanair.org/publication/health-impacts-of-eskoms-non-compliance-with-minimum-emissions-standards/

[3] United Nations Environment Programme (UNEP). (2023). Toolkit for Identification and Quantification of Mercury Releases. Reference Report and Guideline for Inventory Level 2. Version1.7, February 2023. UN Environment Chemicals Branch, Geneva, Switzerland.

https://wedocs.unep.org/bitstream/handle/20.500.11822/30684/HgTlktRef.pdf?sequence=1&isAllowed=y

The bypass would result in an estimated 6-fold increase in SO_2 emissions from the plant, based on the reported emissions at Kusile, and the reported average sulphur content of the coal. It would also increase mercury emissions by approximately 40%, as the FGD captures toxic mercury from the flue gases as a side benefit.

The total excess SO_2 emissions resulting from the exemption, compared with normal operation at the same utilisation, would be a projected 280,000 tonnes, while excess mercury (Hg) emissions would amount to 7,200 kg (Table 1). The excess SO_2 emissions correspond to almost 20 years worth of emissions from the normal operation of the plant.

Table 1. *Emissions in the two scenarios*

Scenario	SO_2 (t)	Hg (kg)	NO_x (t)	PM (t)
high utilisation with FGD	55,679	16,914	56,566	1,333
high utilisation, no FGD	337,615	24,163		

Excess health impacts

Using the excess pollutant emissions for SO_2, NOx, and PM (Table 1), we calculated the corresponding excess health impacts. To achieve this, we used methodology, data, and tools which are widely used by scientists and regulators internationally, and the details of which can be found in our previous publications (Myllyvirta and Kelly, 2023).[4] Operating Kusile with no FGD increases the air pollution-related deaths substantially, from 250 deaths (95% Confidence Interval: 140–440) to 930 deaths (95% CI: 570–1,380) (Table 2). The deaths are attributed to an increased risk of stroke, ischemic heart disease, lung cancer, chronic obstructive pulmonary disease and lower respiratory infections.

[4] Myllyvirta, L. and Kelly, J. (2023). Health impacts of Eskom's non-compliance with minimum emissions standards. Centre for Research on Energy and Clean Air. https://energyandcleanair.org/publication/health-impacts-of-eskoms-non-compliance-with-minimum-emissions-standards/

Table 2. *Deaths and total economic costs of health impacts in the FGD bypass scenario from air pollution (*SO_2, NO_x, and PM*), compared with the normal operation of the plant at the same utilisation*

Scenario	Air pollution-related deaths	Economic costs, R billion
high utilisation with FGD	254 (144 – 436) *	4,426 (2,518 – 7,398)
high utilisation, no FGD	928 (574 – 1,384)	16,766 (10,293 – 24,461)

* *95% Confidence interval in parentheses, low and high estimates*

In other words, the variation of the AEL requested by Eskom would result in a projected 670 excess deaths from air pollution (95% CI: 430–950), compared with the operation of the plant in accordance with the AEL. Other excess health impacts in the FGD bypass scenario would include a projected 3,000 asthma emergency room visits, 1,400 preterm births, 720,000 days of work absence and 900 years lived with disability due to chronic obstructive pulmonary disease, diabetes and stroke (Table 3).

In addition, given Eskom's track record, there is a very likely possibility the repairs to the plants required to operate the FGD are not completed by the end of the period for which Eskom has now requested an exemption from the plant's current AEL. In this case, the operation of the plant without any SO_2 control equipment could continue longer, resulting in even larger impacts. Naturally, this would require a new application for an exemption from the AEL.

Table 3. *Excess non-fatal health impacts in the FGD bypass scenario from air pollution (*SO_2, NO_x, and PM*).*

outcome	pollutant	central estimate	95% CI: low estimate	95% CI: high estimate
asthma emergency room visits	$PM_{2.5}$	3,012	1,767	4,244
low birthweight births	$PM_{2.5}$	1,076	334	1,868

preterm births	$PM_{2.5}$	1,374	665	1,459
work absence (sick leave days)	$PM_{2.5}$	717,419	610,314	823,807
Years lived with disability				
chronic obstructive pulmonary disease	$PM_{2.5}$	453	255	630
diabetes	$PM_{2.5}$	395	88	893
stroke	$PM_{2.5}$	101	39	161

Overall, the air pollution impacts on human health will have a major impact on the economy. Without FGD, the health damages due to air pollution from Kusile would cost R16.8 bln (R10.3–24.4 bln).

Using the excess pollutant emissions for Hg (Table 1), we calculated the corresponding excess health impacts (Schucht et al., 2021)[5]. We found that allowing Kusile Power Station to operate with FGD increases mercury-related deaths from 280 to 400, and increases the loss of IQ points from 1,890 to 2,700 (Table 4).

Table 4. *Excess deaths and non-fatal health impacts (central value) in the FGD bypass scenario from mercury air pollution.*

Scenario	Mercury-related deaths	IQ Points Lost due to Mercury
high utilisation with FGD	280	1,890
high utilisation, no FGD	400	2,700

[5] Schucht, S. et al. (2021). Costs of air pollution from European industrial facilities 2008–2017. European Topic Centre on Air pollution, transport, noise and industrial pollution. https://www.eionet.europa.eu/etcs/etc-atni/products/etc-atni-reports/etc-atni-report-04-2020-costs-of-air-pollution-from-european-industrial-facilities-200820132017

Comparison with Eskom's estimate

Our estimate for the impact of the SO_2 bypass on air pollution and human health is substantially higher than the estimate produced by Eskom (Eskom, 2023). Without FGD technology, we find that Kusile would emit 337,615 tons of SO_2 which would lead to 928 deaths (Table 2), and emit 24,163 kg of mercury. Eskom estimates similar SO_2 emissions (300,000 tonnes), but health impacts which are nearly 100 times lower — only 10 human deaths — and they do not consider the impacts of mercury emissions. Our sensitivity of human health to SO_2 emissions (i.e. 337,615 tons of SO_2 leading to 928 deaths), is in much better agreement with multiple previous peer-reviewed studies (Orellano et al., 2021[6]; Koplitz et al., 2017[7]; Lee et al., 2015[8]; Kan et al. (2010)[9].

Similarly, Eskom's estimates of excess morbidity impacts from Kusile Power Station (Figure 1) are also much lower than our estimates (Table 3). Overall, Eskom concluded that the SO_2 bypass at Kusile Power Station will lead to insignificant impacts on human health. However, the air pollution and health impacts estimated by Eskom are unrealistically low, due to (i) the use of outdated methods which underestimate pollution levels, (ii) only considering the impacts on local communities, and (iii) only considering emissions of SO_2.

[6] Orellano, P. et al. (2021). Short-term exposure to sulphur dioxide (SO_2) and all-cause and respiratory mortality: A systematic review and meta-analysis. *Environmental International*, Vol. 150 (106434). https://www.sciencedirect.com/science/article/pii/S0160412021000593/pdfft?md5=17ab3a26598b747c840cdfbe2725e338&pid=1-s2.0-S0160412021000593-main.pdf

[7] Koplitz, S. N. et al. (2017). Burden of Disease from Rising Coal-Fired Power Plant Emissions in Southeast Asia. *Environ. Sci. Technol.*, Vol. 51(3): 1467–1476. https://pubs.acs.org/doi/full/10.1021/acs.est.6b03731

[8] Lee, C. J. et al. (2015). Response of Global Particulate-Matter-Related Mortality to Changes in Local Precursor Emissions. *Environ. Sci. Technol.*, Vol. 49 (7): 4335–4344. https://doi.org/10.1021/acs.est.5b00873

[9] Kan, H. et al. (2010). Short-term association between sulfur dioxide and daily mortality: The Public Health and Air Pollution in Asia (PAPA) study. *Environmental Research,* Vol. 10 (3): 258-264. https://www.sciencedirect.com/science/article/abs/pii/S0013935110000186

Health statistic	Current number of cases	Future (post-repairs)		Temporary scenarios	
		Licence conditions	Average emissions	@ 3 000 SO2	@ 3 500 SO2
Natural mortality all ages	2 404	7	5	10	10
Cardiovascular hospital admissions, all ages	5 273	15	11	21	23
Asthma exacerbation, all ages, as hospital admissions and emergency department visits	699	10	5	37	43
Acute bronchitis symptoms, number of children aged 8 to 12	1 669	18	13	24 - 25	26
Chronic bronchitis incidence, new cases per annum, persons aged 27+	840	4 to 5	3	6	6 to 7
Lung cancer, new cases per annum, persons aged 30+	11	<1 per year	<1 per year	<1 per year	<1 per year
Respiratory mortality - COPD mortality	77	<1 per year	<1 per year	<1 per year	<1 per year
Number of persons exposed (receptor area) in 2023: 402 621					

Figure 1. *Current and additional health effects of the Kusile project according to Eskom's AIR (Eskom, 2023)*

Eskom uses outdated tools that underestimate the impacts of pollutant emissions on atmospheric concentrations. Sulphur dioxide (SO_2) emitted into the atmosphere undergoes complex chemical reactions in the atmosphere, leading to the formation of $PM_{2.5}$. Eskom uses the CALPUFF air dispersion model to estimate the pollutant concentrations in the atmosphere, but incorrectly applies an old chemical mechanism within the CALPUFF model (RIVAD), which uses outdated SO_2 chemical processes, and therefore estimates extremely low annual mean concentrations of $PM_{2.5}$ (0.3-0.8 µg/m^3). Previous peer-reviewed scientific literature shows that using the outdated chemical mechanism (RIVAD) leads to estimates of $PM_{2.5}$ concentrations which are up to 200 times lower than when using the updated version (Oleniacz et al., 2016).[10] We use the same CALPUFF air dispersion model, but do not apply the outdated chemical mechanism, and therefore our simulations produce much higher annual mean $PM_{2.5}$ concentrations of 2 µg/m^3. Our estimated values are in better agreement with results for coal power plants in

[10] Oleniacz, R. et al. (2016). Impact of Use of Chemical Transformation Modules in Calpuff on the Results of Air Dispersion Modelling. *Ecological Chemistry and Engineering. S = Chemia i Inżynieria Ekologiczna*, S Vol. 23 (4): 605-620. DOI:10.1515/eces-2016-0043

South Africa from a state-of-science model (Marais et al., 2019)[11] developed by Harvard University. [12]

Eskom only considers the air pollution and health impacts on local communities within a 50 km radius — meaning a small geographic domain — whereas the impacts of emissions from coal-fired power plants can extend up to hundreds of kilometres. $PM_{2.5}$ can persist in the atmosphere for up to 1 to 2 weeks, and can therefore travel thousands of kilometres in the atmosphere (U.S. EPA, n.d).[13] Therefore, Eskom's calculations neglect the impacts of the emissions from Kusile further afield. Comparing this reduction of the geographic domain from several hundred kilometres to only 50 x 50 km (as Eskom does) to one of our previous air quality assessments on Kusile Power Station, we can note that our estimated health impacts are reduced by 99 % (Myllyvirta and Kelly, 2023).[14] This is also corroborated by studies from other authors and organisations that record much higher health impacts from South African coal power (OECD, 2016).[15]

Eskom only considers how the lack of FGD will affect emissions of SO_2, whereas this technology will also affect emissions of other dangerous pollutants. Burning coal also leads to the emissions of mercury, which is an extremely potent neurotoxin that persists in the environment for several years. Our results show that running Kusile without FGD will increase mercury emissions dramatically (Table 1), and lead to a substantial loss of life and IQ points (Table 3) Eskom failed to capture this effect, and therefore underestimated the true impacts of the SO_2 bypass on air pollution and human health.

[11] Marais, E. A. et al. (2019). Air Quality and Health Impact of Future Fossil Fuel Use for Electricity Generation and Transport in Africa. *Environ. Sci. Technol.*, Vol. 53: 13524-13534. https://pubs.acs.org/doi/pdf/10.1021/acs.est.9b04958

[12] Harvard University (n.d). GEOS-Chem. Atmospheric Chemistry Modeling Group. https://acmg.seas.harvard.edu/geos_chem

[13] U.S. EPA. (n.d). Particulate Matter Emissions. https://cfpub.epa.gov/roe/indicator_pdf.cfm?i=19

[14] Myllyvirta, L. and Kelly, J. (2023). Health impacts of Eskom's non-compliance with minimum emissions standards. Centre for Research on Energy and Clean Air. https://energyandcleanair.org/publication/health-impacts-of-eskoms-non-compliance-with-minimum-emissions-standards/

[15] OECD. (2016). Policy Highlights. The economic consequences of outdoor air pollution. https://www.oecd.org/environment/indicators-modelling-outlooks/Policy-Highlights-Economic-consequences-of-outdoor-air-pollution-web.pdf

Conclusion

Overall, our results indicate that the excess SO_2 emissions released from Kusile Power Station during the period it is allowed to operate without SO_2 controls will have deadly consequences on human health, both in local and distant communities, that will also lead to substantial health-related costs. While our study is in agreement with Eskom over the excess emissions, Eskom estimates much lower air pollution and human health impacts due to two major methodological limitations: (i) using outdated tools to model air pollution, (ii) only modelling the impacts on local communities, and (iii) neglecting emissions of mercury. Air pollution control measures, such as FGD, have played a vital role in reducing air pollution around the world. During the period Eskom is permitted to operate Kusile power Station without these vital air pollution control measures, excess SO_2 emissions will pollute the air, kill humans, and damage the economy.