INFOTOX (Pty) Ltd

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Retrieval and scientific interpretation of ecotoxicological information

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Project conducted on behalf of Nettzero (Pty) Ltd

Criteria Pollutants and Hexavalent Chromium Community Health Risk Assessment for the Glencore Lion Energy Conversion Project

Report No 023-2022 Rev 2.0

Compiled by

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28 March 2022

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28 March 2022

Expertise and Declaration of Independence

This report was prepared by INFOTOX (Pty) Ltd ("INFOTOX"). Established in 1991, INFOTOX is a professional scientific company, highly focused in the discipline of Health Sciences. Both occupational and environmental human health risks, as well as risks to ecological receptors, are addressed.

Dr Willie van Niekerk, Managing Director of INFOTOX, has BSc, Hons BSc and MSc degrees from the University of Potchefstroom and a PhD from the University of South Africa. He is a Qualified Environmental Professional (Environmental Toxicologist QEP), certified by the Institute of Professional Environmental Practice (IPEP) in the USA (No 07960160), and a registered Professional Natural Scientist (Pr Sci Nat, Environmental Science, No 400284/04). Dr Van Niekerk has specialised in chemical toxicology and human health risk assessment, but he has experience in many other areas in the disciplines of analytical and environmental sciences.

Dr Marlene Fourie has BSc and Hons BSc degrees from the University of Stellenbosch and MSc and PhD degrees from the University of Pretoria. Her field of specialisation is reproductive biology/toxicology. Dr Fourie also has an MSc-degree in epidemiology from the University of Pretoria. Following positions as Medical Natural Scientist at the Andrology Unit, Department of Urology, University of Pretoria and the Pretoria Academic Hospital from 1987 to 2001, she joined INFOTOX as a Medical Biological Scientist. Dr Fourie has conducted many health risk assessments and projects relating to the health status of communities. She is registered as a Professional Natural Scientist (Pr Sci Nat, Toxicological Science, No 400190/14).

Dricky Simpson has a higher diploma in Quality Assurance as well as in Medical Technology. Dricky worked in pathology laboratories and she has done research in human toxicology and pharmacology. She also has experience in animal toxicology and pharmacology. During the last fifteen years as Director of INFOTOX she worked in human health risk assessment for a wide range of industries. She is experienced in contaminated site investigations and waste classification.

This specialist report was compiled for Nettzero (Pty) Ltd. We do hereby declare that we are financially and otherwise independent of Nettzero (Pty) Ltd.

Signed on behalf of INFOTOX (Pty) Ltd, duly authorised in the capacity of Managing Director:

Willem Christiaan Abraham van Niekerk

28 March 2022

Internal review
Dricky Simpson

Executive summary

Background

The Lion Smelter ("Lion") of Glencore Operations South Africa (Pty) Ltd, approximately 13 km south-east of Steelpoort in the Limpopo Province, operates dryers, kilns and submerged arc furnaces for ferrochrome production. Several villages (residential areas) are located within 5 km, including Ga-Mampuru, Ga-Phasa, Ga-Malikane, Eerste Geluk, Booysendal Camp, Matlala and Tubatse.

Carbon monoxide (CO) gas from the furnaces is used to supplement fuel requirements at the dryers and kilns where possible. Lion is investigating the feasibility of an Energy Conversion Project (ECP) to install and operate an energy conversion facility which will convert the excess CO gas from the furnaces to electrical energy. The purpose of this human health risk assessment (HHRA) report is to identify and quantify the expected effect of Lion's implementation of the ECP on community health, emanating from atmospheric emissions on the surrounding ambient air quality. Therefore, this project does not refer to an increase in production. The modelled current impact is treated as the baseline and the modelled air concentrations of the pollutants of interest resulting from the ECP are studied in terms of the increase or decrease in the associated health risks experienced by the community, should the CEP be implemented, in comparison to the current operations.

HHRA methods

The criteria pollutants of interest are particulate matter with a nominal mean aerodynamic diameter less than or equal to 2.5 µm (PM2.5), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and CO. Hexavalent chromium ([Cr (VI)] emissions are also of interest. Relative risk (RR) ratios are the health risk ratios most often used in large epidemiological studies of the effects of criteria air pollutants on the health of receptor populations. The Lion ECP HRA is approached by the calculation of attributable fractions (AFs) for specific health effects, based on the incremental change in the air concentration of the relevant pollutant of interest, using the RR associated with exposure to the pollutant and the specific health effect. Health effects statistically associated with exposure over the short and long terms are investigated.

In epidemiological terms, the AF represents the fraction of disease that can be prevented if exposure to the pollutant in question is avoided. Thus, in terms of the Lion ECP study, the AFs of the criteria pollutants represent the fraction of the health effect that is avoided or added if Lion should implement the ECP, in comparison to the current impact of Lion emissions on the particular health effect.

The Cr (VI) HRA is conducted according to the accepted paradigm for regulatory HRA, which includes the elements of hazard assessment, dose-response (toxicological) assessment, exposure assessment, risk characterisation and the discussion of uncertainties and study limitations. The tiered approach is followed for the Cr (VI) HRA. The Tier-1 assessment is generic in nature, designed to be on the conservative side, thus overestimating rather than underestimating health risks. Modelled air concentrations are compared with health risk-based screening levels (RSLs) for resident air, involving exposure parameters incorporating large safety factors to enable decisions on the side of caution. Should the Tier-1 assessment indicate potential health risks, the HRA assessment proceeds to the Tier-2 level. The level or intensity of risk is not influenced by tier of the HRA. The tiered approach is followed to exclude non-issues at an early stage and to focus the assessment on the most important exposures and risks.

HHRA results and interpretation

The criteria pollutant HHRA indicated that the impact of the ECP on health risks is not unidirectional. That is, positive and negative health risk AFs are noted for any one of the criteria pollutants PM2.5, SO_2, NO_2 and CO. Thus, implementation of the ECP does not cause either a consistent increase or decrease in the fraction of the health effect attributable to emissions from Lion. However, whether positive or negative, most of the AFs are in the range less than 1 per cent and only occasionally in the range of 1 to 3 per cent. Such AFs are for all practical purposes not significant, are in the negligible range and cannot be viewed as a reason for concern.

The Tier-1 HRA results conclusively excluded a risk of non-cancer effects of the respiratory system at all of the sensitive receptors included in the modelling domain. The Tier-1 HRA also excluded the risk of cancer at a limited number of sensitive receptors, namely Tubatse Chrome Club, Tubatse ResArea and Residential Area-SE from. Cr (VI) concentrations in air modelled at the remaining sensitive receptors were such that referral to a Tier-2 cancer HRA was indicated. The result of the Tier-2 HRA is a unitless cancer risk at the receptors of interest, associated with exposure by inhalation to the modelled ambient air concentrations of Cr (VI).

All of the calculated cancer risks are in the range of 1 to 4 in a million and lower (1×10^{-6} to 4×10^{-6} and lower). These risks are in the *de minimis* range. The USEPA generally uses 1 in 1 000 000 (1×10^{-6}) as a *de minimis* cancer risk level for policy development purposes. Acceptable cancer risks cannot be prescribed to communities, but unacceptable community risks are generally in the range of 1 in 10 000 and higher. None of the sensitive receptor cancer risks are in this range. Thus, the calculated cancer risks are negligible and cannot be viewed as a reason for concern.

Conclusions

None of the AFs reported in this section for PM2.5, SO_2, NO_2 and CO indicate any reason for concern with regard to human health risks associated with the air quality consequences of the implementation of the ECP.

The Cr (VI) Tier-1 HRA results conclusively exclude a risk of non-cancer effects of the respiratory system at all of the sensitive receptors included in the modelling domain. The Tier-2 cancer HRA indicated risks in the *de minimis* range, which are negligible and cannot be viewed as a reason for concern.

Implementation of the ECP and the subsequent impact on air quality in the surrounding communities is associated with a negligible risk to health, whether cancer or non-cancer effects are considered, at all sensitive receptors included in the modelling domain.

EIA REGULATIONS 2014 GNR 982 Appendix 6 CONTENT OF THE SPECIALIST REPORTS	Status / Cross-reference in this Report
a) details of the specialist who prepared the report; and the expertise of that specialist to compile a specialist report including a curriculum vitae;	Included under Expertise and Declaration of Independence
b) a declaration that the specialist is independent in a form as may be specified by the competent authority;	Included under Expertise and Declaration of Independence
c) an indication of the scope of, and the purpose for which, the report was prepared	Introduction p1
cA) an indication of the quality and age of base data used for the specialist report	Not applicable to INFOTOX report
cB) a description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change	Summarised in Section 9
d) the duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment;	Not applicable to INFOTOX report
e) a description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used;	Study approach Section 2, page 1
f) details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternatives;	Not applicable to INFOTOX report
g) an identification of any areas to be avoided, including buffers;	Not applicable to INFOTOX report
h) a map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers	Not applicable to INFOTOX report
i) a description of any assumptions made and any uncertainties or gaps in knowledge;	Uncertainties presented in Section8
j) a description of the findings and potential implications of such findings on the impact of the proposed activity or activities;	Conclusions presented in Section 9
k) any mitigation measures for inclusion in the EMPr	Not applicable to INFOTOX report
l) any conditions for inclusion in the environmental authorisation;	Interpretations based on EnviroNgaka dispersion modelling
m) any monitoring requirements for inclusion in the EMPr or environmental authorisation;	Not applicable to INFOTOX report

EIA REGULATIONS 2014 GNR 982 Appendix 6 CONTENT OF THE SPECIALIST REPORTS	Status / Cross-reference in this Report
n) a reasoned opinion • whether the proposed activity, activities or portions thereof should be authorised; • regarding the acceptability of the proposed activity or activities; and • if the opinion is that the proposed activity, activities or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan;	• The proposed activity should be authorised • From a community health risk perspective the proposed activity is acceptable
o) a description of any consultation process that was undertaken during the course of preparing the specialist report;	Not applicable to INFOTOX report
p) a summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	Not applicable to INFOTOX report
q) any other information requested by the competent authority	Not applicable to INFOTOX report
2) Where a government notice gazetted by the Minister provides for any protocol or minimum information requirement to be applied to a specialist report, the requirements as indicated in such notice will apply.	Not applicable to INFOTOX report

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1 Introduction

The Lion Smelter ("Lion") of Glencore Operations South Africa (Pty) Ltd, situated approximately 13 km south-east of Steelpoort in the Limpopo Province, operates dryers, kilns and submerged arc furnaces for ferrochrome production. Several villages (residential areas) are located within 5 km in various directions, which includes Ga-Mampuru, Ga-Phasa, Ga-Malikane, Eerste Geluk, Booysendal Camp, Matlala and Tubatse.

Carbon monoxide (CO) gas from the furnaces is used to supplement fuel requirements at the dryers and kilns where possible. Lion is investigating the feasibility of an Energy Conversion Project (ECP) to install and operate an energy conversion facility which will convert the excess CO gas from the furnaces to electrical energy. The purpose of the air quality investigation is to identify and quantify Lion's current effect on ambient air quality, associated with atmospheric emissions, and to compare this with the expected effect should the ECP be implemented. Therefore, this project does not refer to an increase in production. In terms of the community health study, the modelled current impact will be treated as the baseline. The modelled air concentrations of the pollutants of interest resulting from the ECP will be studied in terms of the increase or decrease in the associated health risks experienced by the community after the implementation of the ECP, in comparison to the health risks associated with the current operations.

The scenarios are thus:

- Scenario 1: Baseline Conditions
  Impact assessment is done per the emissions of all primary pollutants at expected/actual concentrations against current full production capacity (AEL emission limits or achievable emissions); includes no modifications or improvements made to the current process / additional abatement of secondary fugitive emissions and includes the new secondary sources as defined with the 2019 authorisation application.

- Scenario 2: Future Conditions
  Scenario 2 is an extension on Scenario 1 with the ECP facility added to assess the expected combined effect.

2 Study approach

This type of study is often referred to as a burden of disease study, because the outcome is the avoided or added fraction of disease in the community, referred to as the attributable fraction (AF). In epidemiological terms, the AF represents the fraction of disease that can be prevented if exposure to the pollutant in question is avoided. Thus, in terms of the Lion ECP study, the AF represents the fraction of the health effect that is avoided or added if Lion should implement the ECP, in comparison to the current impact of Lion emissions on the particular health effect.

The air pollutants of interest in the study are the criteria air pollutants PM2.5, which is particulate matter in the 2.5 µm aerodynamic range, sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO). Since emissions of hexavalent chromium [Cr (VI)] are of interest at the processing plant, the substance is included in the community health risk assessment (HRA).

3 Criteria pollutant health effects and RRs for risk assessment

Relative risk (RR) ratios are the health risk ratios most often used in large epidemiological studies of the effects of criteria air pollutants on the health of receptor populations. In this study, the human health risk assessment (HHRA) is approached by the calculation of AFs based on the incremental change in the air concentration of the pollutant of interest, using the RR associated with exposure to a specific pollutant over the short- or long term.

The RRs and identified health outcomes are summarised in Table 3.1. The primary scientific references that INFOTOX consulted are also presented.

Table 3.1: Summary of RRs for the criteria pollutants of interest.

Identified outcome	*RR	Exposure averaging time	Reference
PM2.5			
All-cause (natural) mortality all ages	1.0123	24-hour	WHO 2013
Cardiovascular admissions	1.0091		
Respiratory admissions	1.0190		
All-cause (natural) mortality age 30+	1.0676	Annual	USEPA 2019 Pope et al. 2015
Asthma incidence, ages 4 to 17	1.0167		USEPA 2019 McConnell et al. 2010
SO_2			
Asthma exacerbation	1.011	24-hour	Zheng et al. 2015 USEPA 2017
NO_2			
Asthma exacerbation	1.014	24-hour	Zheng et al. 2015 USEPA 2016
CO			
Myocardial infarction HAs	1.052**	8-hour	USEPA 2010 Lee et al. 2020

* RR per 10 µg/m^3 incremental pollutant concentration change
** RR per 1 000 µg/m^3 incremental pollutant concentration change

4 Cr (VI) health effects and HHRA methods

4.1 HHRA methodology

The original paradigm for regulatory HHRA in the USA was developed by the USA National Research Council (NRC 1983). This model has been adopted and refined by the US Environmental Protection Agency (USEPA) and other international agencies as published under the International Programme on Chemical Safety (IPCS 1999; IPCS 2010) and is widely used for quantitative human health risk assessments. The elements of the HHRA approach are described below.

Hazard assessment is the identification of chemical contaminants suspected to pose hazards and a description of the types of toxicity that they evoke. The contaminants of interest are described in Section 2 of this report.

Dose-response assessment (toxicological assessment) addresses the relationship between levels of biological exposure to toxic substances and the manifestation of adverse health effects in humans, and/or how humans can be expected to respond to different doses or concentrations of contaminants. The toxicological assessment follows a quantitative procedure that distinguishes between carcinogens and noncarcinogens.

Exposure assessment includes a description of the environmental pathways and distribution of hazardous substances, identification of exposed individuals or communities, the routes of direct and indirect exposure, and an estimate of concentrations and duration of the exposure. In the case of Lion, the identified exposed receptors are communities inhaling air contaminants emitted by the ECP.

Risk characterisation involves the integration of each component described above, with the purpose of determining whether specific exposures to an individual or a community would lead to adverse health effects.

The assessment begins with Tier 1 risk-based screening levels, involving exposure parameters incorporating large safety factors to enable decisions on the side of caution. The Tier-1 assessment is generic in nature, designed to be on the conservative side, thus overestimating rather than underestimating health risks. Should the Tier-1 assessment indicate potential health risks, the HHRA assessment proceeds to the Tier-2 level.

4.2 Cr (VI) inhalation toxicity values

Long-term exposure to Cr (VI) has been associated with lung cancer in workers exposed to levels in air that were 100 to 1 000 times higher than those found in the natural environment (ATSDR 2008). The USEPA classified Cr (VI) as Group A - known human carcinogen by the inhalation route of exposure, on the basis that results of occupational epidemiological studies of Cr (VI)-exposed workers are consistent across investigators and study populations and that dose-response relationships have been established for chromium exposure and lung cancer. Chromium-exposed workers are exposed to both Cr (III) and Cr (VI) compounds, but because only Cr (VI) has been found to be carcinogenic in animal studies, it was concluded that only Cr (VI) should be classified as a human carcinogen (IRIS 1998).

Long-term occupational exposure via inhalation has been associated with effects on the mucous membranes of the upper respiratory tract, such as chronic rhinorrhea, sinusitis and severe nasal and nasal septum effects (ATSDR 2008). Pharyngitis, bronchitis, pneumoconiosis, decreased pulmonary function and pneumonia have also been reported (ATSDR 2008). The relevance of occupational exposures to chromic acid mists and dissolved Cr (VI) aerosols to exposures to Cr (VI) dusts in the environment is uncertain. Lower respiratory tract effects have been reported in laboratory animals following exposures to Cr (VI) dusts. However, these studies did not comment on nasal mucosal effects (IRIS 1998).

The Tier-1 HHRA approach used for the assessment of Cr (VI) compares modelled air concentrations with health risk-based screening levels (Table 4.1). The USEPA (2021) Regional Screening Levels (RSLs) are risk-based concentration (RBC) limits available for a number of generic exposure scenarios. For the purposes of the assessment of possible inhalation of Cr (VI) in air, INFOTOX used the RSLs for residential air.

Should the assessment need to proceed to the Tier-2 level, the toxicity values needed for calculations of health risks are the inhalation reference concentration (RfC) for the assessment of non-cancer risks and the inhalation unit risk (UIR) for the assessment of cancer risks. These are also presented in Table 4.2.1.

Table 4.2.1: Toxicity values for Cr (VI) in air.

Type of value	Target effect	Toxicity value
Tier-1 RSL: residential air	Cancer by inhalation	0.000012 µg/m^3
Tier-1 RSL: residential air	Non-cancer respiratory effects	0.1 µg/m^3
RfC	Non-cancer respiratory effects	0.1 µg/m^3
UIR	Non-cancer respiratory effects	0.012 (µg/m^3)$^{-1}$

5 Exposure assessment

Modelled criteria pollutant concentrations are summarised in Table 5.1, with the calculated delta (Δ) concentrations (as described in Last et al. 2000), which are the concentration differences between scenarios 2 and 1. Negative delta concentrations (less than 0) indicate lower values modelled for scenario 2 and positive concentrations (more than 0) indicate higher concentrations modelled for scenario 2. Air concentrations of Cr (VI) are presented in Table 5.2.

Table 5.1: Criteria pollutant concentrations.

Sensitive Receptor	Scenario 1	Scenario 2	Δ
PM2.5 99th percentile of maximum 24-hr concentrations (µg/m^3)			
Eastern Limb Training Center	21.515	21.224	-0.291
Ga-Matate	6.909	6.850	-0.060
Degoedeverwachten	6.112	6.078	-0.034
Tubatse Chrome Club	0.676	0.694	0.018
Tubatse ResArea	0.556	0.558	0.003
Residential Area-SE	0.337	0.336	-0.001
Farm House-S	5.424	5.358	-0.065
Tshufi Camp	5.212	5.390	0.177
Ga-Nkgetheng	5.597	6.627	1.030
Farm House-SW	8.736	10.159	1.423
Residential Area-SW1	4.426	4.893	0.467
Residential Area-SW2	2.608	3.007	0.398
Ga-Manapane (Imbita School)	7.636	7.890	0.254
Residential Area-WNW	7.846	7.703	-0.143
Residential Area-NW	3.417	3.750	0.333
Residential Area-S (Mmahlagare School)	4.397	4.385	-0.013
PM2.5 annual averaged concentrations (µg/m^3)			
Eastern Limb Training Center	2.659	2.647	-0.012
Ga-Matate	0.666	0.665	-0.001

Sensitive Receptor	Scenario 1	Scenario 2	Δ
Degoedeverwachten	0.550	0.588	0.039
Tubatse Chrome Club	0.083	0.086	0.002
Tubatse ResArea	0.061	0.061	0.000
Residential Area-SE	0.055	0.055	0.000
Farm House-S	0.353	0.351	-0.002
Tshufi Camp	1.122	1.146	0.024
Ga-Nkgetheng	1.196	1.414	0.218
Farm House-SW	2.021	2.303	0.282
Residential Area-SW1	0.856	0.938	0.082
Residential Area-SW2	0.599	0.662	0.063
Ga-Manapane (Imbita School)	1.028	1.096	0.068
Residential Area-WNW	0.894	0.970	0.076
Residential Area-NW	0.460	0.571	0.111
Residential Area-S (Mmahlagare School)	0.437	0.436	-0.001
SO_2 99th percentile of maximum 24-hr concentrations (µg/m^3)			
Eastern Limb Training Center	45.331	40.067	-5.264
Ga-Matate	16.324	16.062	-0.262
Degoedeverwachten	14.652	17.987	3.335
Tubatse Chrome Club	1.925	2.220	0.294
Tubatse ResArea	1.399	1.406	0.007
Residential Area-SE	0.913	0.884	-0.029
Farm House-S	14.859	14.086	-0.773
Tshufi Camp	10.607	12.613	2.007
Ga-Nkgetheng	10.619	23.250	12.631
Farm House-SW	15.418	30.446	15.028
Residential Area-SW1	8.180	14.052	5.872
Residential Area-SW2	5.800	11.050	5.250
Ga-Manapane (Imbita School)	18.242	20.873	2.631
Residential Area-WNW	15.178	18.906	3.729
Residential Area-NW	8.064	17.845	9.781
Residential Area-S (Mmahlagare School)			
NO_2 99th percentile of maximum 24-hr concentrations (µg/m^3)			
Eastern Limb Training Center	111.686	105.755	-5.931
Ga-Matate	23.986	23.347	-0.640
Degoedeverwachten	31.818	37.123	5.304
Tubatse Chrome Club	2.996	3.600	0.603
Tubatse ResArea	1.903	1.841	-0.062
Residential Area-SE	1.322	1.075	-0.246
Farm House-S	16.445	15.216	-1.229

Sensitive Receptor	Scenario 1	Scenario 2	Δ
Tshufi Camp	20.237	23.111	2.874
Ga-Nkgetheng	25.223	44.243	19.020
Farm House-SW	44.234	66.905	22.672
Residential Area-SW1	15.479	25.072	9.593
Residential Area-SW2	11.835	20.139	8.304
Ga-Manapane (Imbita School)	38.196	43.490	5.294
Residential Area-WNW	47.982	48.252	0.270
Residential Area-NW	31.330	36.733	5.403
Residential Area-S (Mmahlagare School)	13.375	12.705	-0.670
CO 99th percentile of maximum 8-hr concentrations (µg/m^3)			
Eastern Limb Training Center	3 767.760	3 657.888	-109.872
Ga-Matate	1 856.511	1 816.491	-40.020
Degoedeverwachten	1 442.374	1 578.675	136.301
Tubatse Chrome Club	80.949	91.683	10.734
Tubatse ResArea	64.319	62.878	-1.441
Residential Area-SE	57.928	55.748	-2.180
Farm House-S	1 423.897	1 396.023	-27.874
Tshufi Camp	1 590.206	1 648.258	58.052
Ga-Nkgetheng	1 830.428	2 491.047	660.619
Farm House-SW	2 729.065	3 546.295	817.230
Residential Area-SW1	1 027.114	1 261.539	234.425
Residential Area-SW2	325.152	676.047	350.896
Ga-Manapane (Imbita School)	2 549.296	2 770.435	221.139
Residential Area-WNW	2 792.475	2 683.410	-109.065
Residential Area-NW	1 789.969	1 924.764	134.795
Residential Area-S (Mmahlagare School)	1 091.676	1077.272	-14.404

Table 5.2: Cr (VI) annual average air concentrations.

Sensitive Receptor	Scenario 1	Scenario 2
	µg/m^3	
Eastern Limb Training Center	0.00034	0.00034
Ga-Matate	0.00012	0.00012
Degoedeverwachten	0.00009	0.00009
Tubatse Chrome Club	0.00001	0.00001
Tubatse ResArea	0.00001	0.00001
Residential Area-SE	0.00001	0.00001
Farm House-S	0.00007	0.00007
Tshufi Camp	0.00016	0.00016

Sensitive Receptor	Scenario 1	Scenario 2
	µg/m³	
Ga-Nkgetheng	0.00014	0.00015
Farm House-SW	0.00019	0.00021
Residential Area-SW1	0.00011	0.00012
Residential Area-SW2	0.00009	0.00009
Ga-Manapane (Imbita School)	0.00015	0.00016
Residential Area-WNW	0.00011	0.00011
Residential Area-NW	0.00005	0.00006
Residential Area-S (Mmahlagare School)	0.00009	0.00009

6 Criteria pollutant HRA results and interpretation

6.1 Results

The avoided or added risk is expressed as the AFs of all-cause natural mortality and hospitalisation for cardiovascular and respiratory causes related to short-term exposure to PM2.5, summarised in Table 6.1.1. The avoided or added AF of all-cause natural mortality in those older than 30 years of age and the avoided fraction of asthma incidence in those aged 4 to 17 years of age, related to long-term exposure to PM2.5, are listed in Table 6.1.2.

Table 6.1.3 lists the avoided or added fraction of asthma exacerbation in exposed asthmatics of all ages, associated with the modelled changes in 24-hour SO_2 concentrations. Avoided risks of asthma-related emergency visits and hospitalisation associated with short-term exposure to NO_2 are presented in Table 6.1.4. Table 6.1.5 lists the avoided or added fraction of hospitalisation for myocardial infarction, associated with short-term exposure to CO.

AFs are presented in scientific notation. Therefore, 7.2E-06 is equal to 7.2×10^{-6} or 0.000007, etc. Negative values indicate avoided fractions of health effects attributable to emissions from Lion and positive values indicate fractions added in the scenario of ECP operation.

Table 6.1.1: AFs of mortality and hospital admissions associated with short-term exposure to PM2.5.

Sensitive Receptor	Mortality	Cardiovascular hospitalization	Respiratory hospitalisation
Eastern Limb Training Center	-2.9E-04	-2.9E-04	-3.2E-04
Ga-Matate	-6.0E-05	-6.0E-05	-6.6E-05
Degoedeverwachten	-3.4E-05	-3.4E-05	-3.8E-05
Tubatse Chrome Club	1.8E-05	1.8E-05	2.0E-05
Tubatse ResArea	2.7E-06	2.7E-06	3.0E-06
Residential Area-SE	-1.4E-06	-1.4E-06	-1.5E-06
Farm House-S	-6.6E-05	-6.5E-05	-7.2E-05
Tshufi Camp	1.8E-04	1.8E-04	2.0E-04

Sensitive Receptor	Mortality	Cardiovascular hospitalization	Respiratory hospitalisation
Ga-Nkgetheng	1.0E-03	1.0E-03	1.1E-03
Farm House-SW	1.4E-03	1.4E-03	1.6E-03
Residential Area-SW1	4.7E-04	4.7E-04	5.2E-04
Residential Area-SW2	4.0E-04	4.0E-04	4.4E-04
Ga-Manapane (Imbita School)	2.6E-04	2.5E-04	2.8E-04
Residential Area-WNW	-1.4E-04	-1.4E-04	-1.6E-04
Residential Area-NW	3.4E-04	3.3E-04	3.7E-04
Residential Area-S (Mmahlagare School)	-1.3E-05	-1.3E-05	-1.4E-05

Table 6.1.2: AFs of mortality and hospital admissions associated with long-term exposure to PM2.5.

Sensitive Receptor	All-cause (natural) mortality age 30+	Asthma incidence, ages 4 to 17
Eastern Limb Training Center	-8.3E-05	-2.0E-05
Ga-Matate	-3.5E-06	-8.7E-07
Degoedeverwachten	2.6E-04	6.4E-05
Tubatse Chrome Club	1.6E-05	4.0E-06
Tubatse ResArea	-5.4E-07	-1.3E-07
Residential Area-SE	-6.1E-07	-1.5E-07
Farm House-S	-1.6E-05	-4.0E-06
Tshufi Camp	1.6E-04	4.0E-05
Ga-Nkgetheng	1.5E-03	3.6E-04
Farm House-SW	1.9E-03	4.7E-04
Residential Area-SW1	5.6E-04	1.4E-04
Residential Area-SW2	4.3E-04	1.1E-04
Ga-Manapane (Imbita School)	4.6E-04	1.1E-04
Residential Area-WNW	5.1E-04	1.3E-04
Residential Area-NW	7.5E-04	1.9E-04
Residential Area-S (Mmahlagare School)	-6.8E-06	-1.7E-06

Table 6.1.3: AFs of asthma exacerbation associated with short-term exposure to SO_2.

Sensitive Receptor	AF (unitless)
Eastern Limb Training Center	-5.9E-03
Ga-Matate	-2.9E-04
Degoedeverwachten	3.7E-03
Tubatse Chrome Club	3.3E-04
Tubatse ResArea	7.8E-06
Residential Area-SE	-3.2E-05

Sensitive Receptor	AF (unitless)
Farm House-S	-8.6E-04
Tshufi Camp	2.2E-03
Ga-Nkgetheng	1.4E-02
Farm House-SW	1.7E-02
Residential Area-SW1	6.5E-03
Residential Area-SW2	5.8E-03
Ga-Manapane (Imbita School)	2.9E-03
Residential Area-WNW	4.1E-03
Residential Area-NW	1.1E-02
Residential Area-S (Mmahlagare School)	-3.4E-04

Table 6.1.4: AFs of asthma-related emergency visits and hospitalisation associated with short-term exposure to NO_2.

Sensitive Receptor	AF (unitless)
Eastern Limb Training Center	-8.3E-03
Ga-Matate	-9.0E-04
Degoedeverwachten	7.4E-03
Tubatse Chrome Club	8.4E-04
Tubatse ResArea	-8.7E-05
Residential Area-SE	-3.4E-04
Farm House-S	-1.7E-03
Tshufi Camp	4.0E-03
Ga-Nkgetheng	2.6E-02
Farm House-SW	3.1E-02
Residential Area-SW1	1.3E-02
Residential Area-SW2	1.2E-02
Ga-Manapane (Imbita School)	7.4E-03
Residential Area-WNW	3.8E-04
Residential Area-NW	7.5E-03
Residential Area-S (Mmahlagare School)	-9.4E-04

Table 6.1.5: AFs of myocardial infarction hospitalisation associated with short-term exposure to CO.

Sensitive Receptor	AF (unitless)
Eastern Limb Training Center	-3.1E-04
Ga-Matate	-3.3E-05
Degoedeverwachten	2.8E-04
Tubatse Chrome Club	3.1E-05

Sensitive Receptor	AF (unitless)
Tubatse ResArea	-3.2E-06
Residential Area-SE	-1.3E-05
Farm House-S	-6.4E-05
Tshufi Camp	1.5E-04
Ga-Nkgetheng	9.9E-04
Farm House-SW	1.2E-03
Residential Area-SW1	5.0E-04
Residential Area-SW2	4.3E-04
Ga-Manapane (Imbita School)	2.8E-04
Residential Area-WNW	1.4E-05
Residential Area-NW	2.8E-04
Residential Area-S (Mmahlagare School)	-3.5E-05

6.2 Interpretation for criteria pollutants

The impact of the ECP on health risks is not unidirectional. That is, positive and negative health risk AFs are noted for any one of the criteria pollutants PM2.5, SO_2, NO_2 and CO. Thus, implementation of the ECP does not cause either a consistent increase or decrease in the fraction of the health effect attributable to emissions from Lion. However, whether positive or negative, most of the AFs are in the range less than 1 per cent and only occasionally in the range of 1 to 3 per cent. Such AFs are for all practical purposes not significant and in the negligible range. In summary, none of the AFs reported in this section indicate any reason for concern with regard to human health risks associated with the air quality consequences of the implementation of the ECP.

7 Cr (VI) HRA results and interpretation

7.1 Results

The Tier-1 comparison of modelled annual average Cr (VI) concentrations (Table 5.2.2) with the USEPA RSLs (Table 4.2.1) is presented in Table 7.1.1. The concentrations exceeding any of the RSLs are shaded and referred to the Tier-2 HRA. None of the modelled concentrations exceeded the non-cancer RSL, but the concentrations modelled for most of the sensitive receptors exceeded the RSL for cancer. Therefore, non-cancer risks are not included in the Tier-2 risk assessment. Receptors not indicated for referral to the Tier-2 HRA are not included in further discussions.

Table 7.1.1: Tier-1 assessment of modelled annual average air concentrations of Cr (VI).

Sensitive Receptor	Scenario 1	Scenario 2
	µg/m^3	
Non-cancer RSL = 0.1 µg/m^3, cancer RSL = 0.000012 µg/m^3 (1.2E-05 µg/m^3)		
Eastern Limb Training Center	3.4E-04	3.4E-04
Ga-Matate	1.2E-04	1.2E-04
Degoedeverwachten	9.0E-05	9.0E-05

Sensitive Receptor	Scenario 1	Scenario 2
	µg/m³	
Tubatse Chrome Club	1.0E-05	1.0E-05
Tubatse ResArea	1.0E-05	1.0E-05
Residential Area-SE	1.0E-05	1.0E-05
Farm House-S	7.0E-05	7.0E-05
Tshufi Camp	1.6E-04	1.6E-04
Ga-Nkgetheng	1.4E-04	1.5E-04
Farm House-SW	1.9E-04	2.1E-04
Residential Area-SW1	1.1E-04	1.2E-04
Residential Area-SW2	9.0E-05	9.0E-05
Ga-Manapane (Imbita School)	1.5E-04	1.6E-04
Residential Area-WNW	1.1E-04	1.1E-04
Residential Area-NW	5.0E-05	6.0E-05
Residential Area-S (Mmahlagare School)	9.0E-05	9.0E-05

The Tier-2 HHRA entailed the calculation of cancer risks based on modelled Cr (VI) air concentrations and the USEPA UIR of 0.012 $(\mu g/m^3)^{-1}$ indicated in Table 4.2.1. Cancer risks in air are calculated by simple multiplication of the modelled concentration with the UIR. The result is a unitless cancer risk presented in Table 7.1.2.

Table 7.1.2: Tier-2 Cr (VI) inhalation cancer-risk assessment.

Sensitive Receptor	Scenario 1	Scenario 2
	Cancer risk (unitless)	
UIR = 0.012 $(\mu g/m^3)^{-1}$		
Eastern Limb Training Center	4.1E-06	4.1E-06
Ga-Matate	1.4E-06	1.4E-06
Degoedeverwachten	1.1E-06	1.1E-06
Tubatse Chrome Club	Cancer risk conclusively excluded by the Tier-1 assessment	
Tubatse ResArea		
Residential Area-SE		
Farm House-S	8.4E-07	8.4E-07
Tshufi Camp	1.9E-06	1.9E-06
Ga-Nkgetheng	1.7E-06	1.8E-06
Farm House-SW	2.3E-06	2.5E-06
Residential Area-SW1	1.3E-06	1.4E-06
Residential Area-SW2	1.1E-06	1.1E-06
Ga-Manapane (Imbita School)	1.8E-06	1.9E-06
Residential Area-WNW	1.3E-06	1.3E-06
Residential Area-NW	6.0E-07	7.2E-07
Residential Area-S (Mmahlagare School)	1.1E-06	1.1E-06

7.2 Interpretation

The Tier-1 HHRA results conclusively exclude a risk of non-cancer effects of the respiratory system at all of the sensitive receptors included in the modelling domain. The Tier-1 HHRA also excluded a risk of cancer at a limited number of sensitive receptors, namely Tubatse Chrome Club, Tubatse ResArea and Residential Area-SE. Cr (VI) concentrations in air modelled at the remaining sensitive receptors were such that referral to a Tier-2 cancer HRA was indicated.

All of the calculated cancer risks (Table 7.1.2) are in the range of 1 to 4 in a million and lower (1×10^{-6} to 4×10^{-6} and lower). These risks are in the *de minimis* range. The USEPA generally uses 1 in 1 000 000 (1×10^{-6}) as a *de minimis* cancer risk level for policy development purposes, although regulatory actions are sometimes limited to instances where risk exceeds 1 in 100 000 (1×10^{-4}) (Casterina and Woodruff 2003). Acceptable cancer risks cannot be prescribed to communities, but unacceptable community risks are generally in the range of 1 in 10 000 and higher. Clearly, none of the sensitive receptor cancer risks are in this range. Thus, the calculated cancer risks are negligible and cannot be viewed as a reason for concern.

In summary, the impact of Lion ferrochrome processing plant Scenario 1 and 2 emissions on health risks associated with exposure to Cr (VI) in air, in communities surrounding the smelter, is not of concern. Implementation of the ECP is not associated with a risk to health, whether cancer or non-cancer effects are considered, at any of the sensitive receptors included in the modelling domain.

8 Uncertainties

The HRA in this report is based on modelled ambient air concentrations of PM2.5, SO_2, NO_2, CO and Cr (VI) provided by Potgieter (2022) for and on behalf of EnviroNgaka (Pty) Ltd. If is expected that uncertainties associated with the modelled concentrations are discussed in the Air Quality Impact Assesment report to be submitted by EnviroNgaka (Pty) Ltd and are not elaborated here.

The HHRA for the criteria pollutants PM2.5, SO_2, NO_2 and CO follows standard international practice, based on methodologies applied in epidemiological studies. The centrepin of the quantification of the health risk assessment is the relative risk (RR) ratio, used to calculate the likely health effect response following on a modelled exposure to the pollutant of interest. The results of the HHRA are presented with a high degree of confidence in the RRs used to quantify health risks assessed in this report. The RRs were derived from large international epidemiological studies reviewed by international regulatory and scientific agencies, namely the USEPA and the WHO, and from strong epidemiological studies using the systematic review and meta-analysis methodology.

Uncertainty in the results of the study is vested in the use of RRs mostly based on studies in developed countries, since RRs applicable to a developing country such as South Africa were not available. However, the estimates presented in this report are the most accurate that are currently achievable. The ideal source of RRs for risk quantification would be South African epidemiological studies, since socio-economic factors unique to South Africa might influence the estimated outcomes. However, a sufficient database of such epidemiological studies is not currently available in South Africa. Nonetheless, the use of RRs determined in systematic review and meta-analysis studies mitigates this limitation, as the systematic reviews are not limited to westernised or developed countries only. Thus, it is not expected that the potential influence of these factors would significantly affect the outcome of the assessments, and the interpretations presented in this report are the most valid that can be achieved in view of the acknowledged limitations.

Risks associated with short-term exposure are presented as AFs, calculated on the basis of the 99th percentile of daily concentrations, which is considered a highly conservative upper estimate of the daily exposure concentrations for HRA purposes. The 99th percentile represents the concentration exceeded by only 1 per cent of the modelled days, which would be at most 3 to 4 days in a 365-day period.

The Cr (VI) risk assessment is presented with confidence, as it is based on the toxicity values applied by major international health risk assessment and regulatory agencies. The tiered approach used for the assessment is internationally accepted and the HRA paradigm applied by INFOTOX is considered best practice for community HRAs in the international scientific risk assessment community.

9 Conclusions

- Modelled changes in daily and annual PM2.5 ambient air concentrations and in daily SO_2, NO_2 and CO concentrations, due to the implementation of the ECP, were used to assess changes in health risks in communities surrounding the Lion ferrochrome smelter. Very small to negligible changes in health risks associated with inhalation of these criteria pollutants originating from the Lion ferrochrome smelter are indicated. Therefore, there is not any reason for concern with regard to human health risks associated with the air quality consequences of the implementation of the ECP.

- The impact of Lion ferrochrome processing plant Scenario 1 and 2 emissions on health risks associated with exposure to Cr (VI) in air, in communities surrounding the smelter, is not of concern. Implementation of the ECP is not associated with a risk to health, whether cancer or non-cancer effects are considered, at any of the sensitive receptors included in the modelling domain.

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