Air quality measurement and logging in taxi ranks and inside of taxis

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Abstract

English

The English abstract.

Afrikaans

Die Afrikaanse uittreksel.

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Nomenclature

Variables and functions

$p(x)$	Probability density function with respect to variable x.
$P(A)$	Probability of event A occurring.
ε	The Bayes error.
ε_u	The Bhattacharyya bound.
B	The Bhattacharyya distance.
s	An HMM state. A subscript is used to refer to a particular state, e.g. s_i refers to the i^{th} state of an HMM.
$\mathbf{S}$	A set of HMM states.
$\mathbf{F}$	A set of frames.
$\mathbf{o}_f$	Observation (feature) vector associated with frame f.
$\gamma_s(\mathbf{o}_f)$	A posteriori probability of the observation vector $\mathbf{o}_f$ being generated by HMM state s.
μ	Statistical mean vector.
Σ	Statistical covariance matrix.
$L(\mathbf{S})$	Log likelihood of the set of HMM states $\mathbf{S}$ generating the training set observation vectors assigned to the states in that set.
$\mathcal{N}(\mathbf{x}\|\mu, \Sigma)$	Multivariate Gaussian PDF with mean μ and covariance matrix Σ.
a_{ij}	The probability of a transition from HMM state s_i to state s_j.
N	Total number of frames or number of tokens, depending on the context.
D	Number of deletion errors.
I	Number of insertion errors.
S	Number of substitution errors.

Acronyms and abbreviations

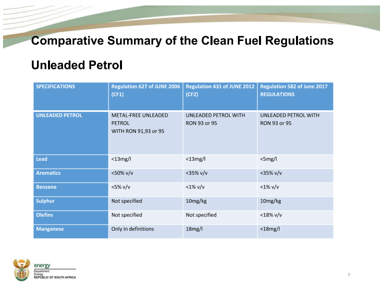
AE	Afrikaans English
PM	Particulate Matter
VOC	Volatile Organic Compounds
UART	Universal Asynchronous Receiver / Transmitter
i2c	Inter-Integrated Circuit
UFP	Ultrafine Particle
LPG	Liquefied Petroleum Gas
CNG	Compressed Natural Gas
PPM	Parts Per Million
PPB	Parts Per Billion

Chapter 1

Introduction

1.1. Background

The majority of South Africa's public sector uses taxis as a means of transport. Millions of commuters use taxis frequently and depend on them for all of their mobility needs [1]. The South African government has recognized the impact of taxi emissions on air quality and has taken steps to address the issue. In 2006, the government gazetted regulations that required taxi operators to convert their vehicles to run on cleaner fuels, such as liquefied petroleum gas (LPG), compressed natural gas (CNG), or diesel with lower sulfur content [2]. However, the implementation of these regulations has been slow and often ineffective as seen in the extract below in figures 1.1, 1.2 and 1.3, resulting in continued poor air quality in many areas. Instead of using expensive and inconvenient formal public transportation like buses and trains, they offer an accessible and affordable substitute. As a result, the effects of air quality in taxis on human health and the impact of taxi exhaust emissions are issues unique to South Africa.

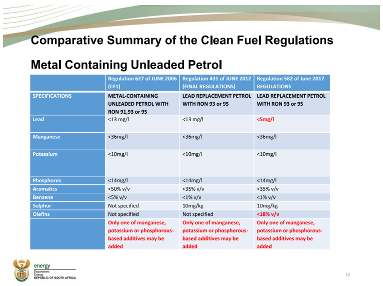


Comparative Summary of the Clean Fuel Regulations

Unleaded Petrol

SPECIFICATIONS	Regulation 627 of JUNE 2006 (CF1)	Regulation 431 of JUNE 2012 (CF2)	Regulation 582 of June 2017 REGULATIONS
UNLEADED PETROL	METAL-FREE UNLEADED PETROL WITH RON 91,93 or 95	UNLEADED PETROL WITH RON 93 or 95	UNLEADED PETROL WITH RON 93 or 95
Lead	<13mg/l	<13mg/l	<5mg/l
Aromatics	<50% v/v	<35% v/v	<35% v/v
Benzene	<5% v/v	<1% v/v	<1% v/v
Sulphur	Not specified	10mg/kg	10mg/kg
Olefins	Not specified	Not specified	<18% v/v
Manganese	Only in definitions	18mg/l	<18mg/l

Figure 1.1: Unleaded

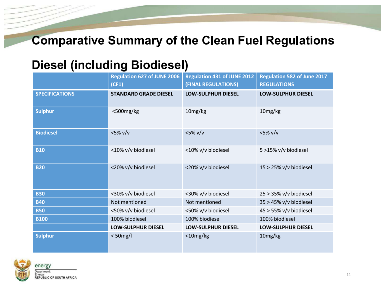


Comparative Summary of the Clean Fuel Regulations

Metal Containing Unleaded Petrol

	Regulation 627 of JUNE 2006 (CF1)	Regulation 431 of JUNE 2012 (FINAL REGULATIONS)	Regulation 582 of June 2017 REGULATIONS
SPECIFICATIONS	METAL-CONTAINING UNLEADED PETROL WITH RON 91,93 or 95	LEAD REPLACEMENT PETROL WITH RON 93 or 95	LEAD REPLACEMENT PETROL WITH RON 93 or 95
Lead	<13 mg/l	<13 mg/l	<5mg/l
Manganese	<36mg/l	<36mg/l	<36mg/l
Potassium	<10mg/l	<10mg/l	<10mg/l
Phosphorus	<14mg/l	<14mg/l	<14mg/l
Aromatics	<50% v/v	<35% v/v	<35% v/v
Benzene	<5% v/v	<1% v/v	<1% v/v
Sulphur	Not specified	10mg/kg	10mg/kg
Olefins	Not specified	Not specified	<18% v/v
	Only one of manganese, potassium or phosphorous-based additives may be added	Only one of manganese, potassium or phosphorous-based additives may be added	Only one of manganese, potassium or phosphorous-based additives may be added

Figure 1.2: Metal+ Unleaded



Comparative Summary of the Clean Fuel Regulations

Diesel (including Biodiesel)

	Regulation 627 of JUNE 2006 (CF1)	Regulation 431 of JUNE 2012 (FINAL REGULATIONS)	Regulation 582 of June 2017 REGULATIONS
SPECIFICATIONS	STANDARD GRADE DIESEL	LOW-SULPHUR DIESEL	LOW-SULPHUR DIESEL
Sulphur	<500mg/kg	10mg/kg	10mg/kg
Biodiesel	<5% v/v	<5% v/v	<5% v/v
B10	<10% v/v biodiesel	<10% v/v biodiesel	5 >15% v/v biodiesel
B20	<20% v/v biodiesel	<20% v/v biodiesel	15 > 25% v/v biodiesel
B30	<30% v/v biodiesel	<30% v/v biodiesel	25 > 35% v/v biodiesel
B40	Not mentioned	Not mentioned	35 > 45% v/v biodiesel
B50	<50% v/v biodiesel	<50% v/v biodiesel	45 > 55% v/v biodiesel
B100	100% biodiesel	100% biodiesel	100% biodiesel
	LOW-SULPHUR DIESEL	LOW-SULPHUR DIESEL	LOW-SULPHUR DIESEL
Sulphur	< 50mg/l	<10mg/kg	10mg/kg

Figure 1.3: Diesel

Charts provided by [2]

1.2. Problem Statement

Despite the popularity and importance of taxis in South Africa, there is a lack of research on the air quality inside and outside of these vehicles. Air quality is a crucial factor for human health and well-being, especially for commuters who spend long hours in taxis exposed to various pollutants. Moreover, taxi emissions contribute to the overall air pollution in crowded spaces(in this case taxi ranks), which affects the environment and the quality of life of the passers by. The closest studies being that of inside single cab taxis [3], road based pollution [4] and general pollution [5]. Therefore, there is a need for a comprehensive study on the air quality in taxis and taxi ranks and its impacts on human health and the environment.

1.3. Objectives

The objective of the study will be as follows:

- To measure and compare the levels of CO2, VOC, particulate matter and NOx both inside taxis and in taxi ranks to that of a known baseline.
- Identify the primary sources of air pollution in taxi ranks and within taxis and evaluate the impact of environmental factors, such as traffic congestion and weather conditions.
- To investigate the potential health risks associated with exposure to air pollution in taxi ranks and within taxis, particularly for passengers, drivers and potential third parties.
- To evaluate the effectiveness of current measures in place to reduce air pollution from taxis, such as emission standards and regulations.
- Propose potential strategies to mitigate the impact of from taxis on public health and the environment such as implementing new technologies.

1.4. Scope

The scope of the project encompasses only the following:

- Building of base station and portable sensor module
- Development of communication network for satellite module and base station as well as data storage and backup
- Deployment of sensor and network
- Analysis of data gathered

1.5. Report Overview

Chapter 2

Literature Study

2.1. Air Quality Monitoring

For this project it is necessary to monitor the air quality and how that pertains to health conditions and what causes the rise in these prarameters.

2.1.1. Choosing Monitoring Parameters

For monitoring it is important to choose parameters relevant to the topic at hand, in this case emissions from taxis, or for the relevance of finding data on the former, minibuses. It is found that vehicles produce the following gases [6] :

- Carbon Dioxide (CO_2)
- Methane (CH_4)
- Nitrous Oxides (NO_x)
- Air Conditioning Refrigerant

With diesel creating 15% more per gallon($3, 78541$L), keeping this information in mind, the relevant gases should also be analysed for harm caused. As well as these parameters, on-road activities contribute to particulate matter, particularly $PM_{2.5}$ [7]

2.1.2. Effects on Human health and safe ranges

$\mathbf{CO_2}$

Exposure to CO_2 in concentrations as low as 1000 ppm can lead to adverse effects [8], this is enhanced by prolonged exposure, as would likely be experienced by the driver or passenger.

Particulate Matter

Short-term exposure to particulate matter in the 2.5 and 10 µg range seems to to aggravate pre-existing conditions, such as respiratory and cardiovascular conditions [9], long term exposure is irrelevant in this context.

Volatile Organic Compounds

Short term exposure to VOCs can lead to eye and respiratory tract irritation, headaches, nausea and cancer [10]. The Environmental XPRT article on acceptable VOC levels in the air (2019) [11] suggests that acceptable ranges for VOC would be between 300 to 500 µg .

$\mathbf{NO_x}$

Symptoms from exposure to NO_2 include inflammation of the airways, increase susceptibility to respiratory infections and to allergens as well as aggravating pre-existing lung or heart conditions. The safe amount that should not me exceeded regularly is 200µg. [12]

2.1.3. Typical Monitoring Instrumentation

Studies doing similar research used pre-existing instrumentation to measure the data collected, some of which will be discussed here.

Aeroqual AQY

This sensor was used in a similar study done to determine the air quality at bus stops [13]. The sensor solution used consists of sensors for the following along with provided ranges [14]:

- Particulate matter ($PM_{2.5}$ & PM_{10}) 0-1000 µg
- Ozone
- Nitrogen Dioxide 0-500 ppb
- Temperature and Relative Humidity
- Dew point

ScioSense APC1 Environmental Sensor

[15]

Most of the other studies used a combination of custom sensors, so the above will be taken as reference.

2.2. Communication

2.3.

Chapter 3

System Overview

Chapter 4

Analysis and Data

Chapter 5

Summary and Conclusion

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Appendix A

Project Planning Schedule

This is an appendix.

Appendix B

Outcomes Compliance

This is another appendix.