

Report

Activity 3: Rapid in-situ assessment at the Ezamokuhle community



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Report

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EXECUTIVE SUMMARY

The effect of air pollution on the environment, economic and health of the people in an affected community cannot be overemphasized (Anderson et al., 2012; Anenberg et al., 2010; Jian et al., 2016; Krall et al., 2013; Schwartz et al., 2017; Tao et al., 2011). It must be noted that some of these pollutants sources occur naturally in the environment whilst other sources are due to man-made activities.

Ezamokuhle is characterised by a myriad of agricultural, commercial, industrial and residential land use activities which are all located in close proximity to one another. Thus there is a broad spectrum of emission sources impacting on this area. This includes *inter alia*: industrial emissions, domestic fuel burning, vehicle tailpipe emissions, biomass burning, agricultural activities and numerous other fugitive sources (paved roads, unpaved roads and open sports fields). Thus for the *Rapid in-situ assessment* of Ezamokuhle, ARM utilised a combination both ground and aerial based in-situ assessments.

A civil dawn to civil dusk drive through the Ezamokuhle road network was conducted on 4th February 2021 wherein all air pollution sources were documented. Questionnaires were employed to identify, evaluate & document these air quality sources & issues. In order to create a robust and reliable data set, the drive-through was repeated for 3 separate occasions on the day (morning, midday and afternoon). Two unmanned aerial vehicle (UAV) were flown to conduct an aerial assessment for Ezamokuhle. The UAVs flew at an altitude of 150m above Ezamokuhle at a pre-determined flight path.

The study has identified three categories of air pollution sources: historical, current and potential future sources of air pollution. Historical emission sources have been identified based on evidence indicating a historical air pollution episode, for example a veld burn scar indicating a historic veld fire burning emissions incident. Current air pollution sources were identified based on active and visible atmospheric emissions captured in the in-situ assessments. Potential future sources of air pollution were identified on the basis that whilst the source was dormant and in-active on the day of the in-situ assessment, the source had the potential to be an active emission source in the future.

The only historical air pollution source category identified in the assessment were three historic waste burning sites. Current air pollution source categories identified in the assessment included: residential fuel burning; brick manufacturing facility; traffic emissions; odours and formal traders. The potential future sources of air pollution identified in the study include: residential fuel burning; waste burning and fugitive dust emissions for paved roads, unpaved roads and open sports fields.

It was interesting to note that every house in Ezamokuhle had a visible chimney. In total approximately 20 household chimneys were emitting smoke at any one time during the day in Ezamokuhle. The residential fuel burning emissions emitted from the household chimneys have a low plume momentum and buoyancy thus result in high ground level concentrations. Often the poorly diluted residential fuel burning looping plume impacts directly on the neighbouring households. In total 1138 RDP houses were calculated from the UAV survey. The majority of RDP houses in Ezamokuhle have one or two informal households located on their property. Each informal dwelling contained a chimney indicating a potential pollution source when fuel is burned. It was interesting to note that there were visible electricity cables attached from the RDP house which extended to these adjacent informal dwelling/s.

The UAV captured visible smoke stack emissions for the local primary school. Additionally the UAV identified sporadic incidents of residential fuel burning occurring in burn barrels (steel drums). During the survey the ambient temperatures ranged between 19°C and 29°C. However, during winter, power-interruptions and lower ambient temperatures it is anticipated that more wood, coal and dung burning will occur for purposes of space heating, bathing and cooking.

Very few industrial activities were detected in Ezamokuhle, with the exception of the clay brick and paving manufacturer located in Roestein. With the substantial low release height of these pollutant emissions, the nearby communities and primary school would be potentially exposed to the adverse environmental and health impacts from this facility. A low traffic density was observed in Ezamokuhle during peak traffic hours. The majority of vehicles on the roads were taxis. A number of coal trucks were observed passing Ezamokuhle and going towards the direction of the Majuba Power Station. These trucks additionally impact the air pollutant loading in Ezamokuhle. The only odours detected, were from household chimney stack emissions. Informal traders along the main routes were not apparent, probably due to the rainy conditions experienced during the survey and preceding days.

Waste and litter appear along all the streets in Ezamokuhle. ARM identified several communal areas where waste dumping was prevalent. The accumulation of this waste during summer is susceptible to burning during the dry season (winter). The prevalence of tall grass along the roads suggest that veld fires will be common in the dry season. Additionally a veld fire can easily reach an area where waste is dumped and ignite all waste sources at the site.

Fugitive dust emissions were identified for paved roads, unpaved roads and open sports fields in Ezamokuhle. As sidewalks are absent along the roads and it will result in the re-entrainment of dust emissions due to pedestrian traffic. Additionally the inner roads of the township are all dust roads which compound the impact of particulate emissions. It's anticipated that at the intersection of paved/tarred roads and unpaved roads there will be abrasion & re-entrainment of dust emissions which will be exacerbated by the dry season. The UAV assessment has shown that the sport fields in Ezamokuhle as having inadequate vegetative cover and thus susceptible to abrasion and entrainment of fugitive dust particles.

In summary study has identified historic; current and potential future air pollution source for Ezamokuhle. The potential future sources of air pollution include: residential fuel burning; waste burning and fugitive dust emissions. Air quality offset intervention targeted for waste burning and fugitive dust from open sport fields are potentially low-hanging fruit opportunities. Both the ground based and aerial assessment identified that households in Ezamokuhle had a visible chimney. This indicates the proliferation on residential fuel burning in Ezamokuhle. This residential fuel burning is further exacerbated during: lower ambient temperatures, power-interruptions and winter which result in elevated ambient air quality pollutant concentrations. Thus there is an opportunity herein to reduce human exposure to harmful levels of air pollution by reducing emissions from residential burning. Thus supporting the roll-out of Eskom's PMV air quality offset intervention project in Ezamokuhle.

1 INTRODUCTION

1.1 BACKGROUND

For Eskom's Planning Monitoring and Verification (PMV) Project, interventions to reduce household emissions from domestic coal/wood burning will be rolled out in KwaZamokuhle and Ezamokuhle in the Mpumalanga Highveld. For formal dwellings the intervention will be a thermal insulation retrofit and an electricity starter pack and installation. The intervention for informal dwellings still needs to be selected and tested. Interventions also need to be identified and implemented to improve air quality in Sharpeville, Gauteng. Since domestic coal burning is less prevalent in Sharpeville, it is expected that a community-scale intervention, like reducing waste burning, will be more suitable there.

1.2 SCOPE OF WORK

Air Resource Management (Pty) Ltd (*herein referred to as ARM*) has been appointed by Eskom to support the PMV services in support of the *Phase 1: Lead implementation* at: KwaZamokuhle; Ezamokuhle and Sharpeville. In order to achieve this, Eskom has included sixteen targeted work package *Activities* (Table 1) for these respective communities. In accordance with the scope of work, *Activity 3* requires ARM to undertake a rapid in-situ assessment at Ezamokuhle community. The in situ assessment will provide a high-level, expert, objective perspective on the area. This entails a dawn to dusk drive-through Ezamokuhle where all potential pollution sources are documented.

1.1.1 VALUE PROPOSITION OF STUDY

The information garnered from the Study shall provide:

- evidence of historical, current and forthcoming (future) air quality problems;
- indication of possible pollution hotspots;
- a qualitative assessment of the ambient pollutant concentrations in the vicinity of the area;
- a qualitative assessment of the spatial variability of ambient pollutant concentrations &

- support the project team in getting an early indication of the target area in order to evaluate and correct oversights in the project plan.

Table 1: Eskom PMV Activity Schedule

Activities	Kwazamokuhle	Ezamokuhle	Sharpeville
Activity 1: Preliminary air quality assessment		✓	
Activity 2: Gather Area intelligence		✓	
Activity 3: Rapid in situ assessment		✓	
Activity 4: Obtain ethical clearance		✓	
Activity 5: Census	✓	✓	✓
Activity 6: Community source survey		✓	
Activity 7: Fuel source survey		✓	
Activity 8: Household surveys		✓	
Activity 9: Annual (household/community) surveys and monitoring of project effectiveness	✓	✓	✓
Activity 10: Ambient air quality monitoring	✓	✓	✓
Activity 11: Conduct indoor air quality monitoring	✓	✓	
Activity 12: Atmospheric Dispersion Model	✓	✓	✓
Activity 13: Design of Intervention		✓	✓
Activity 14: Development of Database Reporting	✓	✓	✓
Activity 15: Strategic Assistance and offsets methodology	✓	✓	✓
Activity 16: Research and Development	✓	✓	✓

2 GENERAL DESCRIPTION OF AREA

2.1 PROJECT LOCATION

Ezamokuhle which means “to make it beautiful”, is situated 1 km to the north-west of Amersfoort in the Mpumalanga Province. In terms of geo-political boundaries, the township is located within Dr Pixley Ka Isaka Seme Local Municipality of the Gert Sibande District Municipality as part of Ward 7 and Ward 8. As illustrated in Figure 1, the township is divided into six sections namely: China 1, China 2, Jabavu, Roestein, Smallville and Phumlani (Mchunu & Nkambule, 2019). China 1 is part of Amersfoort town.



Figure 1: Locality map for Ezamokuhle

2.2 CLIMATE & METEOROLOGY

The Highveld experiences a temperate climate with dry winters according to the Köppen Climate Classification system. The section provides an overview of the prevailing meteorological conditions present at Ezamokuhle when the Rapid in-situ assessment was conducted (4/02/21).

2.2.1 RAINFALL & TEMPERATURE

Due to Cyclone Eloise, the low-pressure trough extending towards the interior and the ridging high pressure from the east that hit South Africa over the previous two weeks, the Ezamokuhle area was very wet after 62.9 mm of rain the past week. The morning of the assessment heavy fog was present at 05:20 that lifted slowly from 07:00 onwards. An ambient temperature of 15 to 17°C was experienced in the morning peaking to around 26°C at midday and to ~17°C in the afternoon. Intermittent rain started at ~ 14:00 and continued for the rest of the day until 20:00 in the evening.

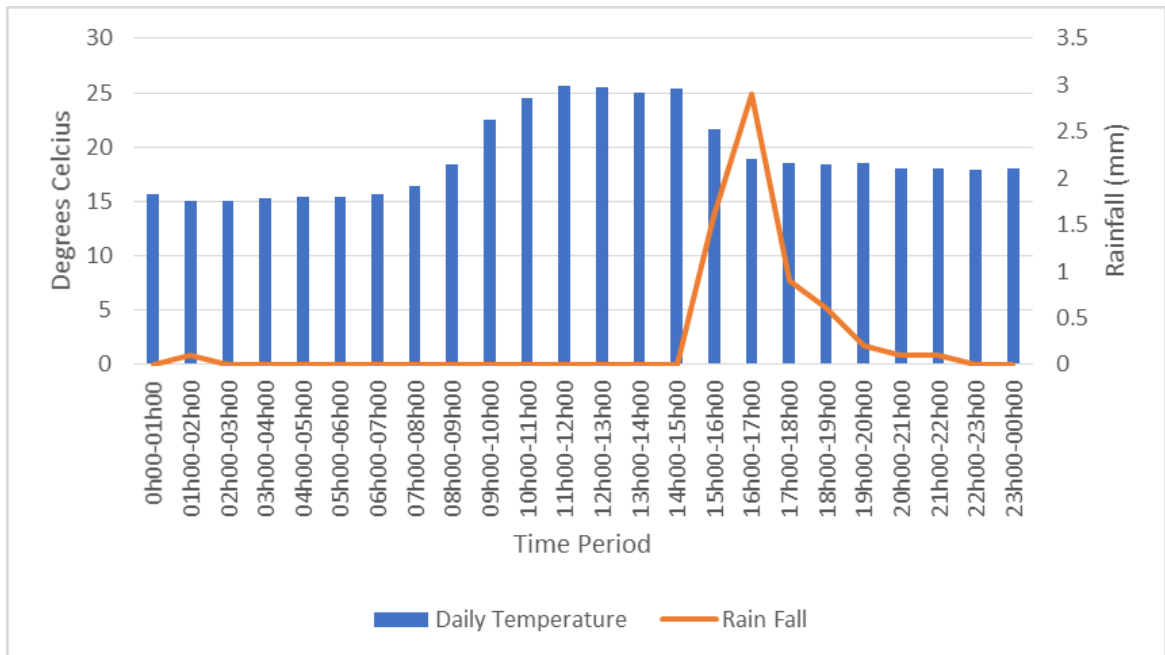


Figure 2: Average temperatures and rainfall for Ezamokuhle for the period (4/02/21)

2.2.2 SURFACE & NEAR-SURFACE WINDS

The analysis of hourly average meteorological data is necessary to facilitate a comprehensive understanding of the dispersion potential of the site. The horizontal dispersion of pollution is largely a function of the wind field. The wind speed determines both the distance of downward transport and the rate of dilution of pollutants. The windrose for the Eskom Ezamokuhle station is presented in Figure 3.

At the Eskom Ezamokuhle air quality station the average wind speed for the period was recorded at 1.7 meters/second with calm condition 0%. Calm condition were defined as wind speeds recorded at zero meter/second (Carlaw, 2015). The predominant wind directions were westerly winds (~ 26% frequency of occurrence) followed by a north westerly winds (~ 18% frequency of occurrence) with maximum wind speed of 4 – 6 meters/second.

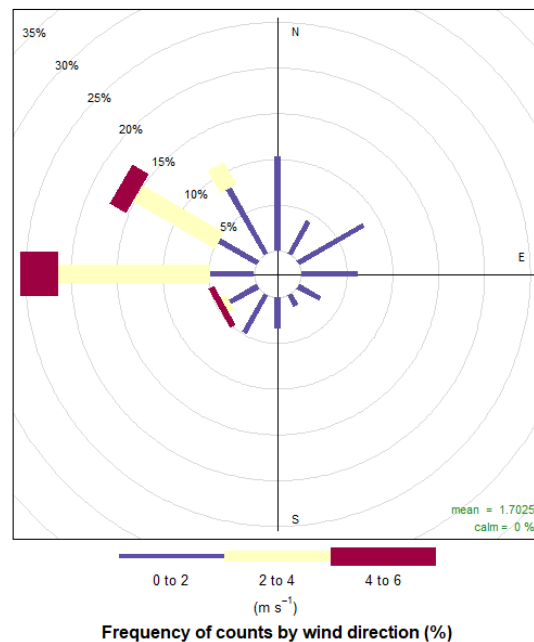


Figure 3: Wind rose for the Eskom Ezamokuhle station for the 4th February 2021

2.3 AMBIENT AIR QUALITY MONITORING ANALYSIS

This section provides an overview of the relationship between measured air pollutant concentrations and prevailing meteorological conditions present at Ezamokuhle when the *Rapid in-situ assessment* was conducted (4/02/21). The Openair air quality model was utilised to statistically analyse these semi-empirical mathematical relationships.

2.4.1 TREND ANALYSIS PLOTS

The trend analysis (mean with 95% confidence interval) of ambient pollutant concentrations measured at the Eskom Ezamokuhle station show the variation of these pollutants over for the period. All pollutants (SO_2 , NO_2 & $\text{PM}_{2.5}$) show a typically industrial signature with increased ambient air quality concentrations at just around midday due to the break-up of an elevated inversion layer, in addition to the development of daytime convective conditions causing the plume to be brought down to ground level relatively close to the point of release from tall stacks (Figures 4 to 6).

The impact of non-buoyant localized sources is also seen for all pollutants measured at the Eskom Ezamokuhle station. For SO_2 there is a second less pronounced peak compared to midday peak that occurs at 18:00 (Figure 4) indicating the impact of residential fuel burning emissions. Figure 5 shows NO_2 concentrations rise with the peak of the morning rush-hour vehicular traffic at around 06:00 and a second less marked rise with the evening rush-hour peaking at around 18:00.

The particulate matter ($\text{PM}_{2.5}$) morning peak occurs at 08:00 whilst the evening peak occurs at 19:00 (Figure 6) which is a typical profile for residential fuel burning. The morning peaks reduces towards midday as the inversion layer rises & improves the mixing height of the planetary boundary layer. It's interesting to note that the a peak $\text{PM}_{2.5}$ occurs at ~16:00 which corresponds to the period of peak rainfall experienced at Ezamokuhle (Figure 2), indicating that it was likely residential fuel burning was conducted for space heating.

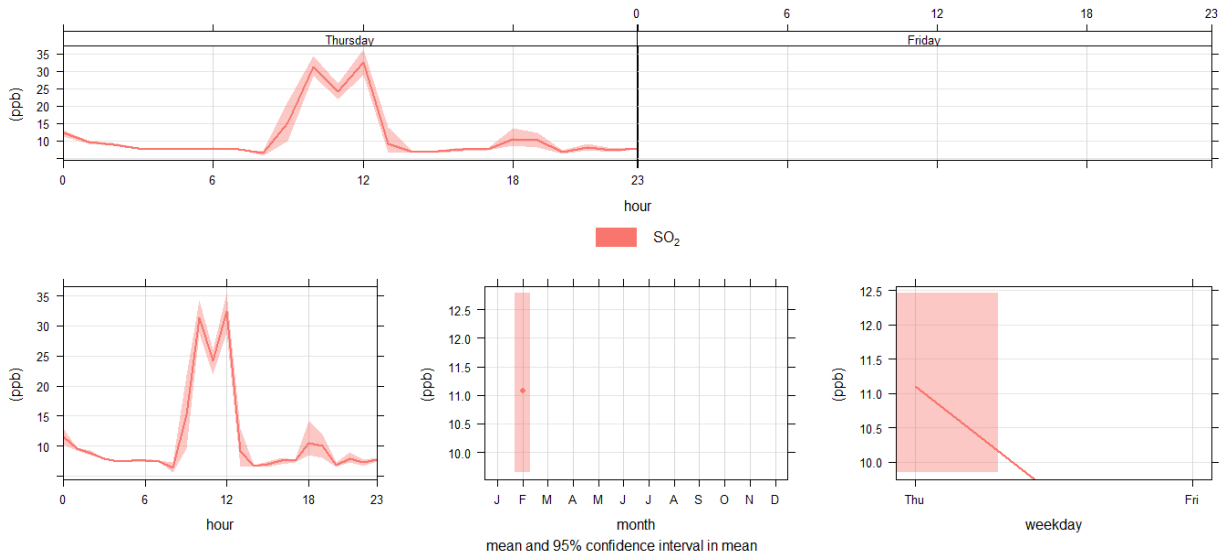


Figure 4: Mean SO₂ concentrations in ppb for the Eskom Ezamokuhle air quality station calculated for 4th February 2021

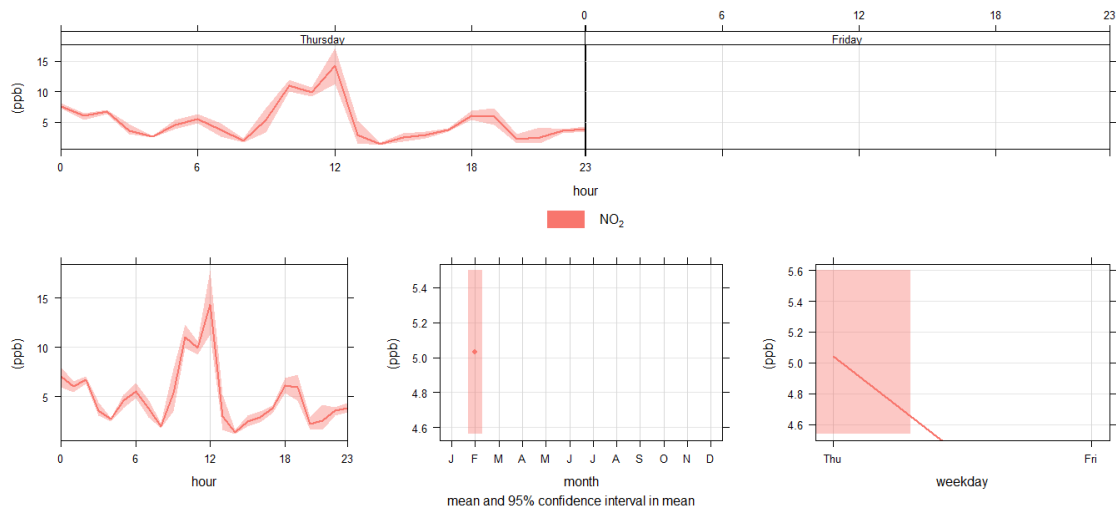


Figure 5: Mean NO₂ concentrations in ppb for the Eskom Ezamokuhle air quality station calculated for 4th February 2021

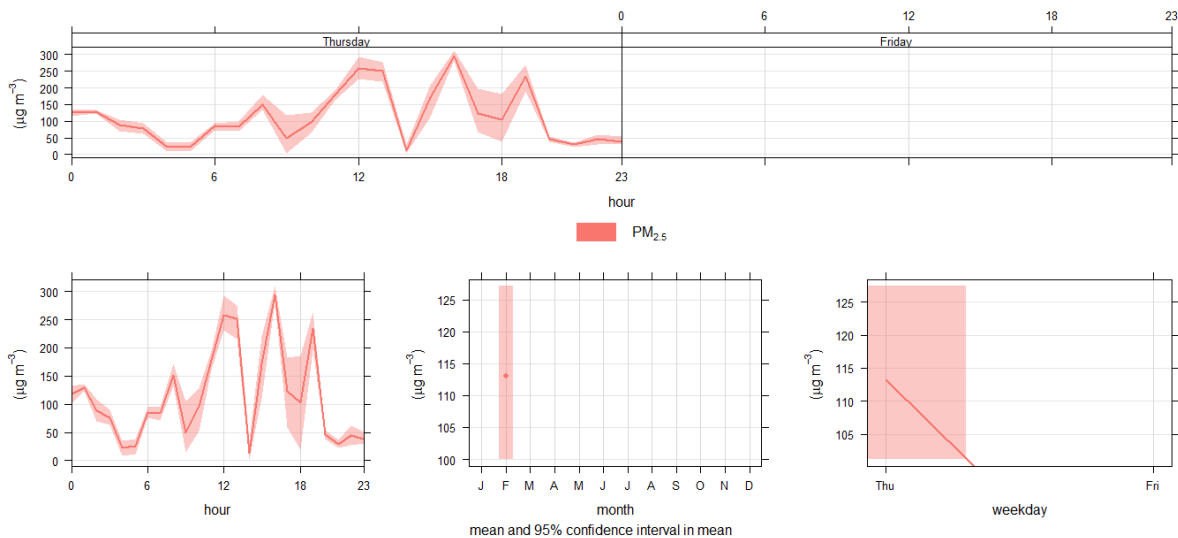


Figure 6: Mean PM_{2.5} concentrations in ppb for the Eskom Ezamokuhle air quality station calculated for 4th February 2021

2.4.2 BIVARIATE POLAR PLOTS

Bivariate polar plots have proved to be extremely valuable for identifying and understanding sources of air pollution (Carslaw et al., 2006; Westmoreland et al., 2007).

2.4.2.1 BIVARIATE POLAR PLOT FOR MEAN CONCENTRATION & WIND

These plots show how the concentration of a pollutant varies by wind direction and wind speed at a receptor. The wind speed dependence of a source can provide important information concerning the source type and characteristics (Carslaw et al., 2006; Jones et al., 2010).

Figures 7 to 9 shows the bivariate plots for the Eskom Ezamokuhle station conditioned for the mean pollutant concentration. The SO₂ concentrations observed at the station (Figure 7) show two distinct wind directions, namely from the west and the north-west. The impact of localised emission sources is observed during weak-wind conditions. The peak SO₂ concentrations present at high

wind speeds are indicative of emissions from stacks rather than non-buoyant ground-level sources. Hence the higher SO_2 concentrations associated with the north-westerly winds are due to a tall stack emission source. Figure 8 shows the highest NO_2 concentrations are more prevalent during stronger wind speeds indicating the impact of tall stack emissions from a north westerly direction. The impact of localised non-buoyant ground-level NO_2 sources (road transport emissions) is evident herein as well. Elevated particulate concentrations at Ezamokuhle show contributions from the west at higher wind speeds (Figure 9). At low wind speeds the symmetrical plot shows a localised contribution, most likely the result of residential fuel burning (Figure 9).

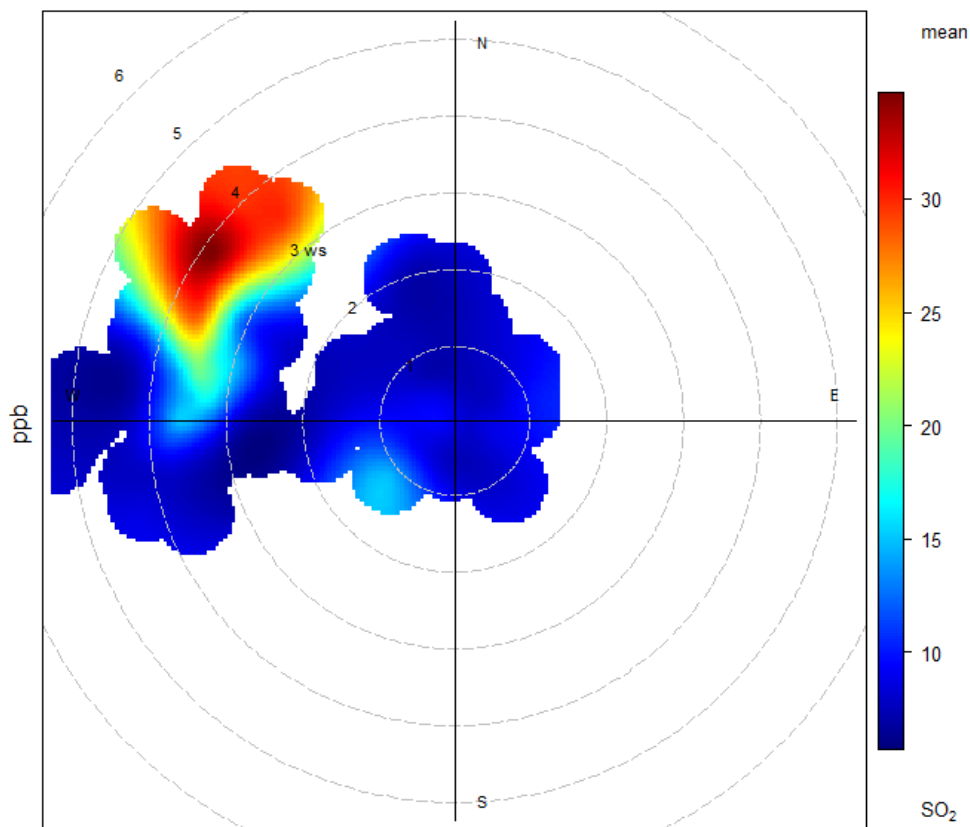


Figure 7: Polar plot of hourly mean SO_2 concentration at the Eskom Ezamokuhle Station for period (4/02/21)

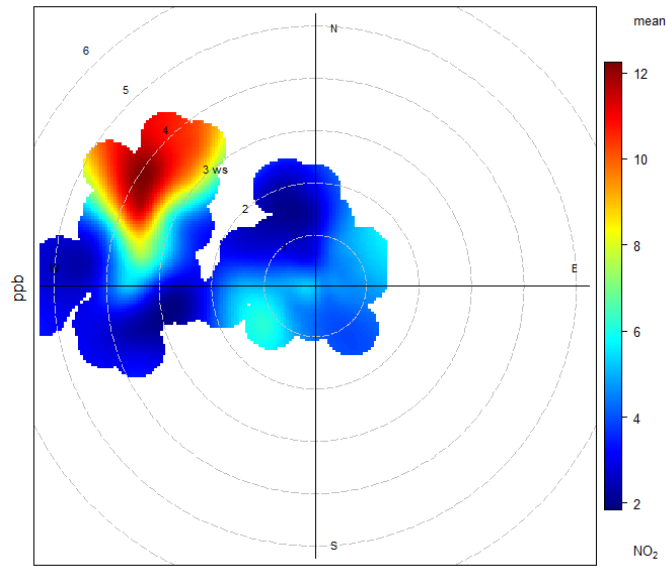


Figure 8: Polar plot of hourly mean NO₂ concentration at the Eskom Ezamokuhle Station for period (4/02/21)

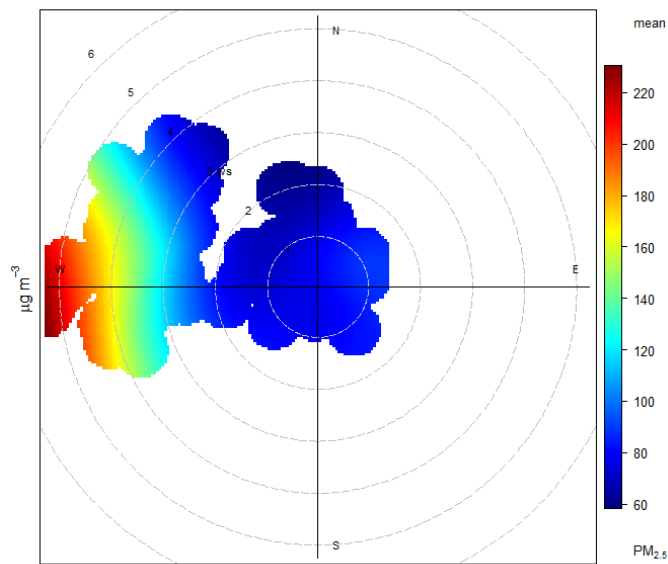


Figure 9: Polar plot of hourly mean PM_{2.5} concentration at the Eskom Ezamokuhle Station for period (4/02/21)

2.4.2.2 BIVARIATE POLAR PLOT FOR MEAN CONCENTRATION & TEMPERATURE

Figures 10 to 12 show the bivariate polar plots for ambient pollutant concentrations (SO_2 , NO_2 & $\text{PM}_{2.5}$) show a as a function of wind direction and surface temperature. It is apparent that there is a clear dependence of both SO_2 and NO_2 peak concentrations (Figure 10 & 11) with increasing ambient temperature. The reason why concentrations increase with increasing temperature is that dispersing plumes from tall stacks are brought down to ground level under unstable atmospheric conditions when thermal turbulence is increased. However lower SO_2 and NO_2 concentrations are observed at lower temperatures as well, which points to the influence of localised non buoyant emission sources. This is the result of vehicular emission sources for NO_2 and residential fuel burning for SO_2 . For particulates (Figure 11) the higher concentrations occur during lower temperatures, which results mostly from residential fuel burning.

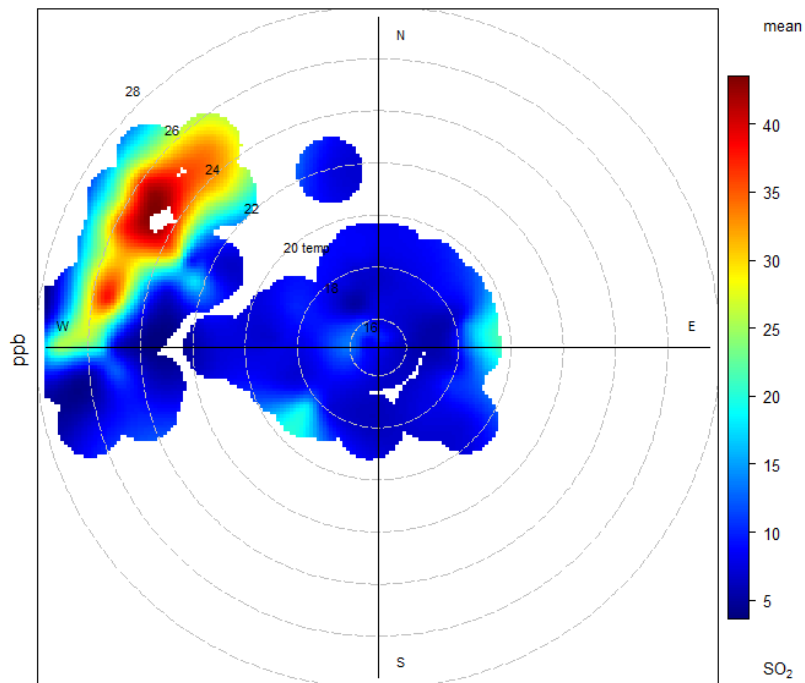


Figure 10: Polar plot function for the mean SO_2 concentration plotted against temperature at the Eskom Ezamokuhle Station for the period (4/02/21)

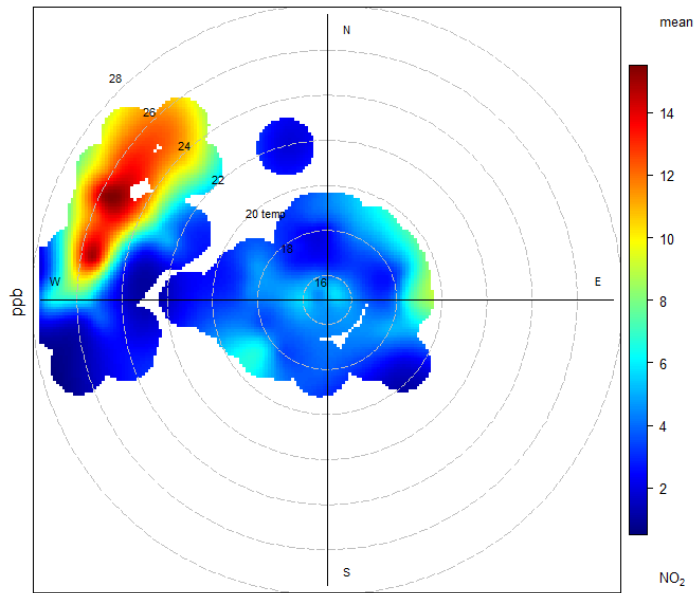


Figure 11: Polar plot function for the mean NO₂ concentration plotted against temperature at the Eskom Ezamokuhle Station for the period (4/02/21)

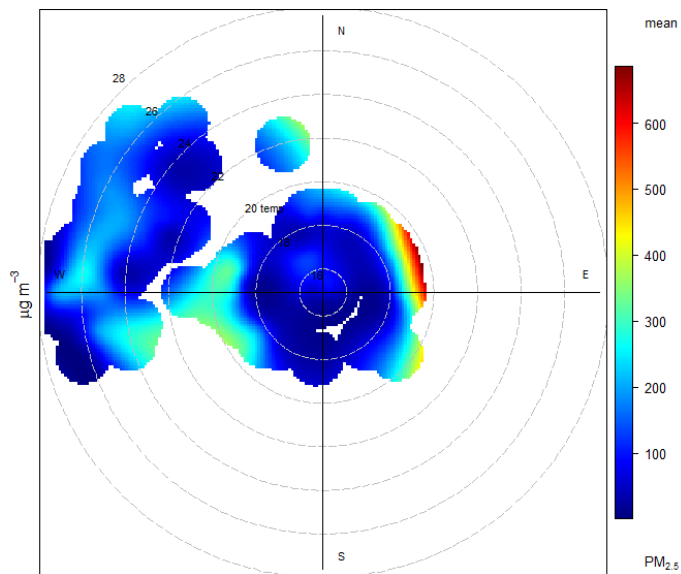


Figure 12: Polar plot function for the mean PM_{2.5} concentration plotted against temperature at the Eskom Ezamokuhle Station for the period (4/02/21)

3 METHODOLOGY

The effect of air pollution on the environment, economic and health of the people in an affected community cannot be overemphasized (Anderson et al., 2012; Anenberg et al., 2010; Jian et al., 2016; Krall et al., 2013; Schwartz et al., 2017; Tao et al., 2011). It must be noted that some of these pollutants sources occur naturally in the environment (biogenic) whilst other sources are due to man-made activities (anthropogenic).

ARM recognize that Ezamokuhle is characterised by a myriad of agricultural, commercial, industrial and residential land use activities which are all located in close proximity to one another. Thus there is a broad spectrum of emission sources impacting on this area. This includes *inter alia*: industrial emissions, domestic fuel burning, vehicle tailpipe emissions, biomass burning, agricultural activities and numerous other fugitive sources. Thus for the *Rapid in-situ assessment* of Ezamokuhle, ARM utilised a combination both ground and aerial based in-situ assessments.

3.1 ETHICAL APPROACH TO THE STUDY

Ms Nokwethemba Khumalo, communications officer for Eskom, obtained permission from the Ezamokuhle Leadership for ARM to conduct both the ground-based and aerial assessment in Ezamokuhle. None of the methods employed required direct contact with the community and no interviews were conducted with any community members.

- *Ground-based assessment*

During the drive-through, photos were discreetly & respectfully taken. The team remained cautious of raising concerns in the community by their presence.

- *Aerial-based assessment*

All relevant parties were duly informed including SAPS, the Civil Aviation Authority of South Africa and the Community Leadership.

3.2 GROUND-BASED IN-SITU ASSESSMENT

3.2.1 DAWN TO DUSK BOUNDARY

ARM conducted a civil dawn to civil dusk drive through Ezamokuhle where all potential pollution sources were documented, ARM utilised civil twilight to define the boundary limits for civil dawn (Figure 13) and civil dusk (Figure 14). Civil twilight is the period when enough natural light remains that artificial light is not needed. Morning civil twilight begins when the geometric center of the sun is 6° below the horizon and ends at sunrise. Evening civil twilight begins at sunset and ends when the geometric center of the sun reaches 6° below the horizon.

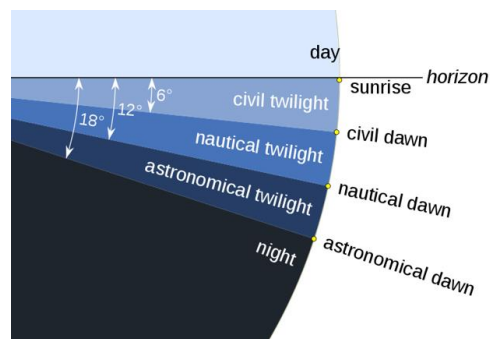


Figure 13: Civil Dawn

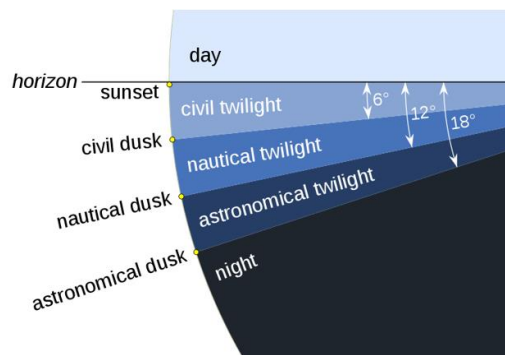


Figure 14: Civil dusk

3.2.2 IN-SITU DRIVE THROUGH GRIDS

- *Outer grid*

ARM first drove on the outer perimeter of Ezamokuhle (Figure 15) at a speed of 4km/hr. The team started at 5:30am from Bree street and moved in a clockwise direction in order to identify all sources of air pollution that may potentially have an impact on the Ezamokuhle airshed. The questionnaires (Annexure 1) were employed to identify, evaluate & document these air quality sources & issues.



Figure 15: Outer grid for Ezamokuhle

- *Inner grid*

Once the outer grid was completed, ARM then drove on the inter-leading inner streets of Ezamokuhle. Ezamokuhle was further sub-divided into 9 distinct zones (Figure 16). The corresponding wards for each zone is shown in Table 1. The team completed all accessible streets in a particular Zone and logged all air quality sources utilizing the questionnaires (Annexure 1). This process will be repeated for each consecutive zone until all 9 zones were completed & documented with the questionnaire.

Table 2: Ward allocation to Zone

Ward	Associated zone
Phumala	Zone 2
China 2	Zone 1 and 3
Jabavu	Zone 9
Roestein	Zone 5, 6, 7, 8
Smallville	Zone 4

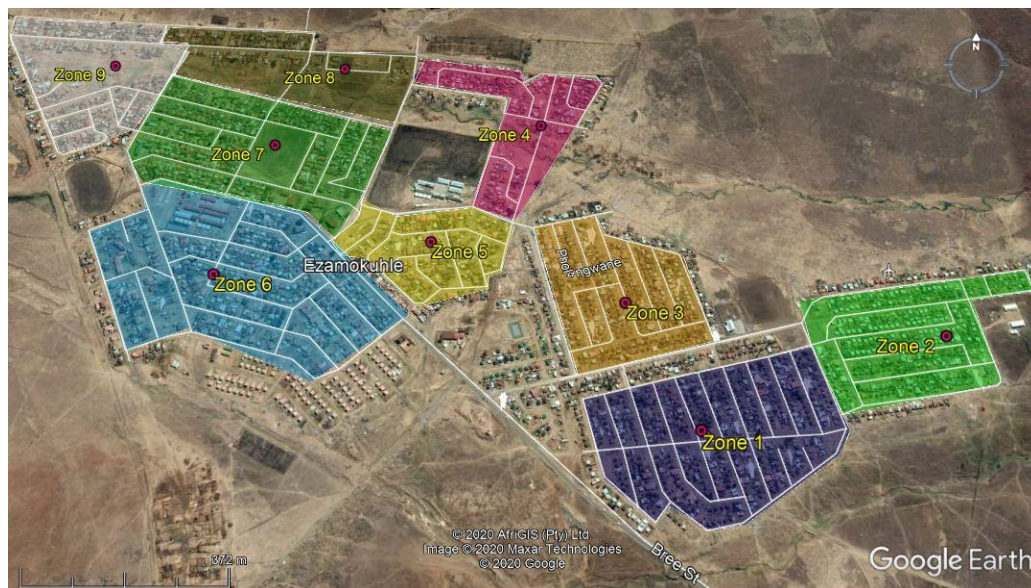


Figure 16: Inner Grid

3.2.3 REPEATABILITY OF OBSERVATIONS

In order to create a robust and reliable data set, the drive-through for both the outer and inner grids (3.2.2) were repeated for 3 separate occasions on the day (morning, midday and afternoon). This was done to ensure all possible sources including those that might have been previously omitted were captured. Additionally by employing this approach, the team was able to document the temporal change in emission sources over the day.

3.3 AERIAL BASED IN-SITU ASSESSMENT

A drone is an air plane or a helicopter-shaped flying object which flies by radio waves as unmanned aerial vehicle (UAV) or remotely piloted aircraft. Two UAV (Mavic Pro 2 & SenseFly eBeeX) were flown to conduct an aerial assessment for Ezamokuhle. The UAVs flew at an altitude of 150m above Ezamokuhle for the pre-determined flight path (Figure 17). The Mavic Pro 2 drone (Figure 18) took off at 7:30am for a rapid fly-over using a video, and a second fixed wing SenseFly eBeeX drone (Figure 19) was launched at 09:00 am to record high-resolution imagery for Ezamokuhle.

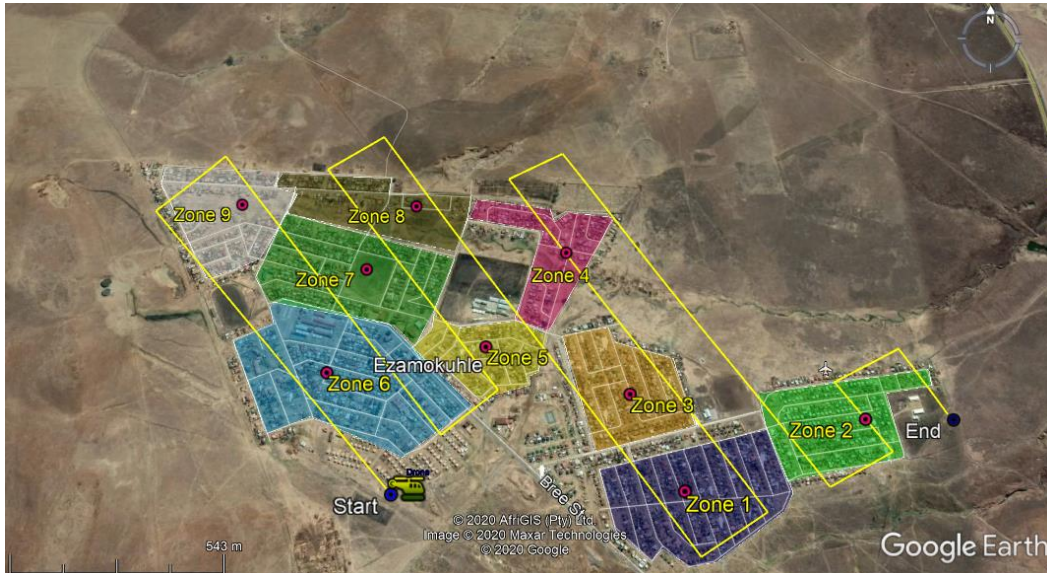


Figure 17: UAV Flight Path



Figure 18: Mavic Pro 2 UAV



Figure 19: SenseFly eBeeX UAV

3.4 DATA ANALYSIS

The UAV images were stitched to provide a high resolution aerial map at 2.5cm/pixel. The aerial video recording provided a rapid assessment of the area and is available on request to Eskom. For the drive-through & UAV assessment, data from the questionnaire sheets were captured by the assessors and the consolidated findings are reported in the next section.

4 RESULTS & DISCUSSION

For the *Rapid in-situ assessment* of Ezamokhule, ARM utilised a combination both ground and aerial based in-situ assessments.

Based on these in-situ assessments, the study has identified three categories of air pollution sources: historical, current and potential future sources of air pollution. Historical emission sources have been identified based on evidence indicating a historical air pollution episode, for example a veld burn scar indicating a historic veld fire burning emissions incident. Current air pollution sources were identified based on active and visible atmospheric emissions captured by the in-situ assessments. Potential future sources of air pollution were identified on the basis that whilst the source was dormant and in-active on the day of the in-situ assessment, the source had the potential to be an active emission source in the future. For example a number of waste dumps were identified in the assessment, whilst these waste dumps were not burning of the day of the assessment, they have the potential during combustion to be a significant atmospheric pollutant emission source unless the waste herein is removed.

Figure 20 presents an overview of the evidence of historical, current and forthcoming (future) air quality problems that were document in the assessment. The following section unpacks these areas in detail.



Figure 20: Overview of air pollution sources documented in Study

4.1 HISTORICAL AIR POLLUTION SOURCES

The only historical air pollution source category identified in the assessment was historic waste burning.

4.1.1 WASTE BURNING

Three historic waste burning sites were identified in Ezamokuhle (Figure 21 and 22). The ground based assessment showed presence of mainly “new” waste which could be attributed either to a recent litter and waste cleaning campaign. There were no clear indications of ash residues from waste burning in the streets. Thus it didn’t appear that waste burning was prolific in Ezamokuhle.



Figure 21: Map showing the location of historic waste burning sites



Figure 22: Historic waste burning site located adjacent to the Brick-works

4.2 CURRENT AIR POLLUTION SOURCES

Figure 23 provides an overview of the current air pollution source categories that were identified.



Figure 23: Map showing the location of current air pollution sources documented in the Study

The following current air pollution source categories were identified in the assessment:

4.2.1 RESIDENTIAL FUEL BURNING

In total approximately 20 household chimneys were emitting smoke at any one time during the day in Ezamokuhle. At around 9am the drone images show on average 4 stack plumes in each zone (Figure 24), adding up to 36 plumes in total in Ezamokuhle. During the day and at the end of the day the smoking stack numbers did not increase visibly. Due to excessive rain one reason could be lack of available, dry fuels. Note that from both a drive-through and drone assessment, only visible smoke from stacks can be counted and at this point of the project it is unknown if the smoke originates from coal, wood or cow dung. Where cleaner fuels and good quality coal is used, smoke is only visible during the upstart of fires, and even wood burning emits less plume once the fire is hot, hence the chimney count of active stacks could be an under estimation.

The residential fuel burning emissions emitted from the household chimneys have a low plume momentum and buoyancy thus result in high ground level concentrations. The impact of this localised impact is seen in Figure 25, where the non-buoyant residential fuel burning poorly diluted looping plume impacts directly on the neighbouring households. It was interesting to note that besides the households who conduct residential fuel burning, visible smoke stack emissions were also recorded for the local primary school (Figure 26). Additionally the UAV identified sporadic incidents of residential fuel burning occurring in burn barrels (steel drums) (Figure 27).

- *Residential Fuel Burning Households*

It was interesting to note that every house in Ezamokuhle had a visible chimney. Further it appears that all these houses have electricity based on the presence of overhead electricity cables and satellite dishes (Figure 28 & 29). In total 1138 RDP houses were counted from the UAV survey (Table 2). There was no well-defined suburb that contains informal dwellings (shacks) only. Instead, almost every RDP house in Ezamokuhle has one or two informal households on the property either attached to the main house or a few meters away. Each informal dwelling contained a chimney indicating a potential pollution source when fuel is burned. From the drone aerial views, the exact ratio of RDP houses to informal dwellings can be determined, which is 1 to 2.3 (Table 1). There are in total 2663 informal dwellings in Ezamokuhle. These informal households are mainly built from corrugated iron with a corrugated iron roof. There are visible electricity cables attached to every RDP house and extended to these adjacent informal dwelling/s (Figure 30).

Table 3: Number of households in Ezamokuhle based on UAV survey

Ward	Zone	RDP houses	Stand-alone RDP Houses	RDP Housing with backyard dwelling	Mud Houses	Self-built Houses	Stand alone Big House	Big Houses with backyard Dwelling	Informal dwellings	Stand-alone informal dwelling	Informal with backyard	Houses with Satellite dish's	TOTAL
China 2	1	328	119	209	1	90	6	84	272	14	258	177	692
	3	276	66	210	1	62	15	57	286	22	286	145	597
Jabavu	9	5	0	5	16	70	2	68	227	18	227	65	318
Phumala	2	213	39	174	2	42	7	35	250	14	250	135	507
Roestein	5	11	0	11	0	132	6	126	119	10	119	59	255
	6	228	74	154	7	139	29	110	268	4	268	78	642
	7	50	10	40	9	210	17	193	144	17	144	75	421
	8	0	0	0	2	58	1	57	95	5	95	19	151
Smallville	4	24	0	24	0	104	3	101	129	6	129	62	257
TOTAL		1138			38	887			2663				4726



Figure 24: Residential fuel burning household emissions emitted through chimneys



Figure 25: Residential fuel burning looping plume impacting on neighbouring households



Figure 26: Residential fuel burning in burn barrel (plume on left)



Figure 27: Residential fuel burning household emissions from the local primary school



Figure 28: Satellite dish connections to households

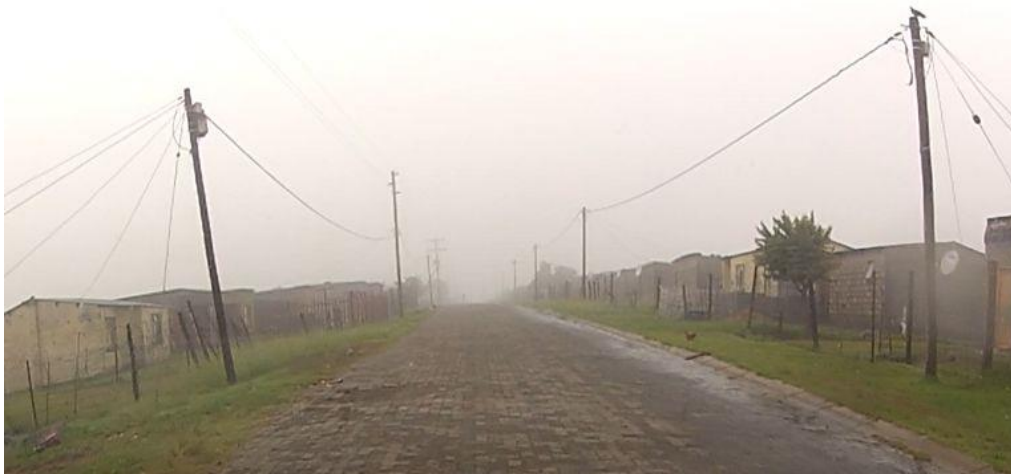


Figure 29: Electricity connections to RDP households



Figure 30: Electricity connection between RDP housing and informal household

4.2.2 INDUSTRIAL EMISSIONS

Very few industrial activities were detected in Ezamokuhle, with the exception of the clay brick and paving manufacturer located in Roestein (Figure 31 & 32). Kanabkaew and Buasing (2021) have demonstrated that air pollutants, i.e. particulate matters (PM), carbon monoxide (CO) and sulphur dioxide (SO₂) are mainly emitted during the brick firing process. With the substantial low release height of these pollutant emissions, the nearby communities and primary school (Figure 33) would be exposed to the adverse environmental and health impacts from this facility.



Figure 31: Brickworks in Roestuin



Figure 32: Spatial extent of Brickworks



Figure 33: Close proximity of the Brickworks to the local Primary School

4.2.3 VEHICULAR EMISSIONS

The traffic density even during peak hours is low (Figure 34). The majority of vehicles are taxis and then followed by private vehicles and a few small trucks. It's noteworthy that the taxis are generally in a very good condition, either Mercedes Benz Sprinter Inkanyezi (23-seater) taxi or Toyota Ses'fikile 16-seater taxis (Figure 35), but neither were filled up more than half with passengers.



Figure 34: Low traffic density in Ezamokuhle



Figure 35: Taxis operating in Ezamokuhle

4.2.4 MAJUBA POWER-STATION

The Majuba Power Station is not visible from Ezamokuhle and is approximately 15km away on the south western side, obscured by a hill. At least a dozen coal trucks per hour were observed passing through Amersfoort at the entrance to Ezamokuhle on the N11 thoroughfare to the east, crossing Bree Street towards Majuba Power Station and that can contribute to air pollution levels for both PM and SO₂ in Ezamokuhle. Additionally the *Activity 1: Status Quo Assessment Report* conducted by ARM has highlighted the impact of the Majuba Power Station (SO₂ and NO₂) emissions in Ezamokuhle.

4.2.5 ODOURS

No odours were detected except in close proximity to chimneys that were operational from coal or wood burning. The lack of sewer odours is probably due to the absence of long-drops and presence of French drains or a reticulation system. A sewerage reticulation project sign board (Figure 36) indicated that at least some extensions are due for expanding sewerage reticulation in the township.



Figure 36: Reticulation Project sign board in Ezamokuhle

4.2.6 WASTE BURNING

No waste burning was observed during the assessment. This could also be ascribed to the wet weather prevalent in the area on the day of the assessment. A single black bin was visible at most of the RDP houses and during Thursday afternoon 4 February 2021, waste collection was observed by the local municipality truck and workers in Jabavu. The process of waste removal explains why no significantly large waste disposal or waste dump heaps were found inside the township.

4.2.7 DUST ON PAVED, TARRED & UNPAVED ROADS

On the perimeter of Ezamokuhle, the main roads are either paved or tarred (Figure 37). There are no sidewalks (Figure 38) along the roads and they do not carry heavy traffic. The inner roads of the township are all dust roads and the quality varied from good to bad (Figure 39). Due to the recent rain and floods, some roads were completely inaccessible due to mud and were not surveyed. No observations of dust were made due to the heavy rainfall in previous days, but road dust is expected during dry seasons.



Figure 37: Paved main road in Ezamokuhle



Figure 38: Roads in Ezamokuhle lacking side-walks



Figure 39: Ezamokuhle inner roads

4.2.8 FORMAL & INFORMAL TRADERS

Informal shops, sometimes opening from an RDP house, were open from the early hours of the morning. Inside some of the shops, wood was visible and for sale. From the drive-through, none of these shops appeared to be major sources of air pollution judged by the chimney emissions which were absent, resulting in the assumption that during summer mainly electricity is used. However outside one of these shops a burn barrel was spotted which was utilised for residential fuel burning (Figure 40). Informal traders along the main routes were not apparent, probably due to the rainy conditions experienced during the survey and preceding days.



Figure 40: Burn barrel utilized by trader

4.2.9 TYRE BURNING

No observations of tyre burning were documented.

4.2.10 VELD FIRES

No observations were documented but the tall grass along the roads suggest that veld fires will be common in the dry season.

4.2.11 ESKOM EZAMOKUHLE AMBIENT AIR QUALITY STATION

ARM visited the Eskom Ezamokuhle Air Quality Monitoring Station which is located on the southern grounds of the Hlelimfundo high School (Figure 41). It's noteworthy that 9 motor vehicles were parked within a 30m radius of the station (Figure 42). The tailpipe emissions from these vehicles result in elevated short-term peak concentrations of NO₂ and PM been logged at the station. Additionally the station is located within a close proximity to the road, hence the NO₂ signals are directly impacted by vehicular emissions.



Figure 41: Eskom Ezamokuhle Ambient Air Quality Station



Figure 42: Vehicular emission sources parked within a close proximity to the Eskom Ezamokuhle Ambient Air Quality Station

4.3 POTENTIAL FUTURE SOURCES OF AIR POLLUTION

Figure 43 provides an overview of the potential future sources of air pollution that were identified.



Figure 43: Map showing the location of potential future sources of air pollution documented in the Study

The following potential future sources of air pollution were identified in the assessment:

4.3.1 RESIDENTIAL FUEL BURNING

During the survey the ambient temperatures ranged between 19°C and 29°C. However, during winter, power-interruptions and lower ambient temperatures it is anticipated that more wood, coal and dung burning will occur for purposes of space heating, bathing and cooking. These changes will be monitored in the subsequent *Eskom PMV Project* activities such as door-to-door surveys and in-door monitoring.

- *Wood & Coal Merchants*

One potential firewood merchant was identified in Smallville wherein the yard was stacked with white fertilizer bags used for packing of the firewood (Figure 44 & 45). Otherwise, only a few yards contained a small pile of coal, probably only for use by the home owner. Some of the local spaza shops were selling wood just inside the door, and a bakkie load of wood (unmarked) also entered Ezamokuhle from Amersfoort. One small truck entered Ezamokuhle from Amersfoort, loaded with coal and the trade name Emangweni appeared on the door, which could be a potential coal merchant. *Activity 8* of the *Eskom PMV Project* will further explore the coal and other fuel supply chains.



Figure 44: Firewood merchant in Smallville



Figure 45: Firewood packed in bags for sale

4.3.2 WASTE BURNING

Waste and litter appear along all the streets in Ezamokuhle. ARM identified several communal areas where waste dumping was more prevalent (Figure 46). At all the sites, the waste was only a single layer thick and consisted of the following in almost equal quantities by volume: cardboard boxes (20%), polystyrene packaging (20%), plastic (bags and high-density polyethylene - 40%) and disposable nappies (20%).

At two sites (Roestein and China 2) there were skips visible, but at both sites the skips were rusted (Figure 46 & 47) to such an extent that they were not useable and cannot be loaded onto a truck. Waste was lying around the skips but not a large quantity, probably two skip loads were strewn around each area.

The accumulation of waste during summer is prone to burning during a subsequent dry period e.g. winter. A veld fire can easily reach the waste area and result not only in air emissions from grass burning, but also from the burning of plastic bags and bottles, polystyrene packaging, cardboard boxes and disposable nappies resulting in an increased emissions profile, more

opaque smoke, longer smouldering and odours, than the average veld fire. Additionally Laban (2018) demonstrated that the open burning of anthropogenic waste resulted in elevated ozone concentrations.



Figure 46: Potential future waste burning sites



Figure 47: Waste dumping in China 2



Figure 48: Rusted Waste Skip located in Roestuin next to a "no dumping" sign

4.3.3 FUGITIVE DUST EMISSIONS

Significant atmospheric dust arises from the mechanical disturbance of granular material exposed to the air. Dust generated from these open sources is termed "fugitive" because it is not discharged to the atmosphere in a confined flow stream. The sources of fugitive dust for Ezamokuhle include paved roads, unpaved roads and open sports fields.

As sidewalks are absent along the roads and it will result in the re-entrainment of dust emissions due to pedestrian traffic. Additionally the inner roads of the township are all dust roads which compound the impact of particulate emissions. It's anticipated that at the intersection of paved/tarred roads and unpaved roads there will be abrasion & re-entrainment of dust emissions which will be exacerbated by the dry season. The UAV assessment has identified the sport fields in Ezamokuhle as having inadequate vegetative cover (Figure 49) and thus susceptible to abrasion and entrainment of fugitive dust particles.



Figure 49: Potential fugitive dust emission source

4.3.4 VELD FIRES

The prevalence of tall grass along the roads suggest that veld fires will be common in the dry season. Biomass burning is seasonal and occurs almost exclusively during the winter and into spring, from July to September (Silva et al., 2002). These will result in elevated PM, CO, NO_x and VOC emissions (DEFF, 2012).

5. CONCLUSION

In summary study has identified historic; current and potential future air pollution source for Ezamokuhle. The only historical air pollution source category identified in the assessment were three historic waste burning sites. Current air pollution source categories identified in the assessment included: residential fuel burning; brick manufacturing facility; traffic emissions; odours and formal traders. The potential future sources of air pollution identified in the study include: residential fuel burning; waste burning and fugitive dust emissions for paved roads, unpaved roads and open sports fields.

Air quality offset intervention targeted for waste burning and fugitive dust from open sport fields are potentially low-hanging fruit opportunities. For example, a clean-up exercise to remove the waste in the identified communal areas (Figure 46) offers a simple cost-effective air pollution reduction intervention to prevent the future burning of these waste dumps. Similarly for the open soccer pitch (Figure 49), an improvement of the drainage system may result in an increase in grass cover thereby reducing fugitive dust emissions.

Both the ground based and aerial assessment identified that the households in Ezamokuhle had a visible chimney. This indicates the proliferation on residential fuel burning in Ezamokuhle. This household residential fuel burning is further exacerbated during: lower ambient temperatures, power-interruptions and winter which result in elevated ambient air quality pollutant concentrations. Thus there is an opportunity herein to reduce human exposure to harmful levels of air pollution by reducing emissions from residential burning. Thus supporting the roll-out of Eskom's PMV air quality offset intervention project in Ezamokuhle

6. ACKNOWLEDGEMENTS

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ANNEXURE 1: QUESTIONNAIRES

WASTE BURNING

Table 4: Questionnaire

Variable	Information (tick all that are applicable)	Additional Comments
Zone		
Exact Time	<input type="radio"/>	
Time of day	<input type="radio"/> Morning <input type="radio"/> Midday <input type="radio"/> Afternoon	
GPS Location		
Street Name		
Photo	<input type="radio"/> Yes <input type="radio"/> No	
Photo id		
Air quality issue	<input type="radio"/> Historic <input type="radio"/> Current <input type="radio"/> Future	
1.1 Emission Source		
1.1.1 Waste Burning		
Details of area where waste burning is located	<input type="radio"/> Front of household <input type="radio"/> Behind household <input type="radio"/> Open field (details in comments) <input type="radio"/> Edge of township <input type="radio"/> Traffic Circle <input type="radio"/> Road servitude <input type="radio"/> Open stand <input type="radio"/> Other	
Proximity of waste burning to households	<input type="radio"/> Near (within 10m) <input type="radio"/> Intermediate (10 to 50m) <input type="radio"/> Far (more than 50m away)	
Frequency of burning	<input type="radio"/> Continuous <input type="radio"/> Intermittent <input type="radio"/> Ad hoc <input type="radio"/> Unknown	
Complete or incomplete Combustion	<input type="radio"/> All waste material burnt <input type="radio"/> Some waste material remains unburnt (Specify % unburnt in comments ___%)	
Waste segregation and % for waste heap	<input type="radio"/> Paper (___%) <input type="radio"/> Leather/Rubber (___%) <input type="radio"/> Textile/Fibre ((___%) <input type="radio"/> Plastic (___%) <input type="radio"/> Vegetation (___%) <input type="radio"/> Organic (___%) <input type="radio"/> Glass (___%) <input type="radio"/> Metal (___%)	

Activity 3: Rapid In-situ Assessment for Ezamokuhle



	<ul style="list-style-type: none"> ○ Ceramic (___%) ○ Wood (___%) ○ Electronic goods (___%) ○ Other (___%) 	
Method of transport of waste to waste heap	<ul style="list-style-type: none"> ○ Thrown adhoc by hand (littering) ○ Wheelbarrow ○ Vehicle ○ Other 	
Odour	<ul style="list-style-type: none"> ○ No odour ○ Mild odour ○ Strong odour 	
Size of waste heap	<ul style="list-style-type: none"> ○ Small (radius up to 3m) ○ Medium (3m to 10m) ○ Large (>10m) 	
Waste Skips Present	<ul style="list-style-type: none"> ○ Yes ○ No 	
Number of Waste Skips Present	<ul style="list-style-type: none"> ○ 	
Waste segregation and % for Waste Skip (if Present)	<ul style="list-style-type: none"> ○ Paper (___%) ○ Leather/Rubber (___%) ○ Textile/Fibre ((___%) ○ Plastic (___%) ○ Vegetation (___%) ○ Organic (___%) ○ Glass (___%) ○ Metal (___%) ○ Ceramic (___%) ○ Wood (___%) ○ Electronic goods (___%) ○ Other (___%) 	

General Comment

TRANSPORT EMISSION SOURCES

5: Questionnaire

Variable	Information (tick all that are applicable)	Additional Comments
Zone		
Exact Time	<input type="radio"/>	
Time of day	<input type="radio"/> Morning <input type="radio"/> Midday <input type="radio"/> Afternoon	
GPS Location		
Street Name		
Photo	<input type="radio"/> Yes <input type="radio"/> No	
Photo id		
Air quality issue	<input type="radio"/> Historic <input type="radio"/> Current <input type="radio"/> Future	

1.2 Transport Emissions		
Emission source	<input type="radio"/> Cars <input type="radio"/> SUV <input type="radio"/> Taxi (minibus) <input type="radio"/> Taxi (other eg, Avanza) <input type="radio"/> Bus <input type="radio"/> Truck	
Loading of vehicle	<input type="radio"/> Loaded <input type="radio"/> Unloaded (only driver)	
Number of occupants	<input type="radio"/>	
Speed of vehicle	<input type="radio"/> Slow (less than 20km) <input type="radio"/> Fair (20km to 50km) <input type="radio"/> Fast (greater than 50km)	
Type of emissions	<input type="radio"/> Exhaust emissions <input type="radio"/> Dust (Comment on impact of dust, eg. where pavement, road, reentrainment?) <input type="radio"/> Other	
Vehicle condition & maintenance	<input type="radio"/> Poor (vehicle exhaust smoking visibly black/grey smoke) <input type="radio"/> Good (no visible smoke from exhaust)	
Number of vehicles at location	<input type="radio"/> Quiet (1-3 vehicles) <input type="radio"/> Intermittent (3 to 10 vehicles) <input type="radio"/> Busy (more than 10 vehicles)	
Visibility	<input type="radio"/> Poor (Dust and Exhaust plume impacts visibility) <input type="radio"/> Good (Visibility is clear)	

Activity 3: Rapid In-situ Assessment for Ezamokuhle



Type of Road	<input type="radio"/> Tar <input type="radio"/> Paved <input type="radio"/> Gravel <input type="radio"/> Other	
Condition of Road	<input type="radio"/> Poor <input type="radio"/> Good	
Pedestrian on Roads	<input type="radio"/> Yes <input type="radio"/> No	
Pavement/Sidewalk on Road	<input type="radio"/> Yes <input type="radio"/> No	
Emissions from lack of a sidewalk/pavement	<input type="radio"/> Yes <ul style="list-style-type: none"> <input type="radio"/> If yes specify in comments <input type="radio"/> No	

General Comment

INFORMAL VENDOR EMISSION SOURCES

6: Questionnaire

Variable	Information (tick all that are applicable)	Additional Comments
Zone		
Exact Time	<input type="radio"/>	
Time of day	<input type="radio"/> Morning <input type="radio"/> Midday <input type="radio"/> Afternoon	
GPS Location		
Street Name		
Photo	<input type="radio"/> Yes <input type="radio"/> No	
Photo id		
Air quality issue	<input type="radio"/> Historic <input type="radio"/> Current <input type="radio"/> Future	

1.3 Informal Vendor Emissions		
Food item sold	<input type="radio"/> Maize <input type="radio"/> Meat <input type="radio"/> Other (Please specify) <input type="radio"/> _____	
Type of fuel	<input type="radio"/> Coal <input type="radio"/> Wood <input type="radio"/> Parrafin <input type="radio"/> Other (Please specify)	
Visibility of plume	<input type="radio"/> Yes <input type="radio"/> If yes, color of smoke <input type="radio"/> No	
Magnitude of impact	<input type="radio"/> Near (radius of less than 3m) <input type="radio"/> (radius of 3m to 5m) <input type="radio"/> Far (greater than 5m)	
Severity of emissions	<input type="radio"/> Low <input type="radio"/> High	

General Comment

ESKOM EZAMOKUHLE MONITORING STATION

7: Questionnaire

Variable	Information (tick all that are applicable)	Additional Comments
Zone		
Exact Time	<input type="radio"/>	
Time of day	<input type="radio"/> Morning <input type="radio"/> Midday <input type="radio"/> Afternoon	
GPS Location		
Street Name		
Photo	<input type="radio"/> Yes <input type="radio"/> No	
Photo id		
Air quality issue	<input type="radio"/> Historic <input type="radio"/> Current <input type="radio"/> Future	

1.4 Ezamokuhle Monitoring Station		
Emission Sources surrounding station	<input type="radio"/> Vehicles (Details) <input type="radio"/> Roads (Details) <input type="radio"/> Households (Details) <input type="radio"/> Dust (Details) <input type="radio"/> Other (Details)	
Visible plumes impacting station	<input type="radio"/> Yes <input type="radio"/> If yes, details <input type="radio"/> No	
Trees around station	<input type="radio"/> Yes <input type="radio"/> If yes, is an obstruction to station results <input type="radio"/> No	
Buildings around station	<input type="radio"/> Yes <input type="radio"/> If yes, is an obstruction to station results <input type="radio"/> No	
Ground cover where station is sited	<input type="radio"/> No Vegetation <input type="radio"/> Limited Vegetation <input type="radio"/> Vegetation present	

General Comment

VELD FIRES

8: Questionnaire

Variable	Information (tick all that are applicable)	Additional Comments
Zone		
Exact Time	<input type="radio"/>	
Time of day	<input type="radio"/> Morning <input type="radio"/> Midday <input type="radio"/> Afternoon	
GPS Location		
Street Name		
Photo	<input type="radio"/> Yes <input type="radio"/> No	
Photo id		
Air quality issue	<input type="radio"/> Historic <input type="radio"/> Current <input type="radio"/> Future	

1.6 Veld fires		
Burn area size	<input type="radio"/> Small (less than 5m ²) <input type="radio"/> Intermediate (5 -15m ²) <input type="radio"/> Large (>15m ²)	
Vegetation type	<input type="radio"/> Grassland <input type="radio"/> Trees <input type="radio"/> Other (Please specify)	
Visibility of plume	<input type="radio"/> Yes <input type="radio"/> If yes, color of smoke <input type="radio"/> No	
Severity of emissions	<input type="radio"/> Low <input type="radio"/> High	

General Comment

ODOURS

9: Questionnaire

Variable	Information (tick all that are applicable)	Additional Comments
Zone		
Exact Time	<input type="radio"/>	
Time of day	<input type="radio"/> Morning <input type="radio"/> Midday <input type="radio"/> Afternoon	
GPS Location		
Street Name		
Photo	<input type="radio"/> Yes <input type="radio"/> No	
Photo id		
Air quality issue	<input type="radio"/> Historic <input type="radio"/> Current <input type="radio"/> Future	

1.7 Odours		
Source	<input type="radio"/> Sewage drains <input type="radio"/> Animal Carcass <input type="radio"/> Other (Details)	
Intensity	<input type="radio"/> None <input type="radio"/> Moderate <input type="radio"/> Intense	
Localised odour to location	<input type="radio"/> Yes <input type="radio"/> No	

General Comment

COAL STOCKYARD

10: Questionnaire

Variable	Information (tick all that are applicable)	Additional Comments
Zone		
Exact Time	<input type="radio"/>	
Time of day	<input type="radio"/> Morning <input type="radio"/> Midday <input type="radio"/> Afternoon	
GPS Location		
Street Name		
Photo	<input type="radio"/> Yes <input type="radio"/> No	
Photo id		
Air quality issue	<input type="radio"/> Historic <input type="radio"/> Current <input type="radio"/> Future	

1.8 Coal Stock Yard		
Size	<input type="radio"/>	
Operation	<input type="radio"/> Busy <input type="radio"/> Quite	
Visible emissions	<input type="radio"/> Yes <input type="radio"/> No	
Fugitive emissions	<input type="radio"/> Localised impact (only stock yard) <input type="radio"/> Impact on surrounding area	
Transport of coal from stock yard	<input type="radio"/> Trucks <input type="radio"/> Taxi <input type="radio"/> Other	

General Comment

GENERAL: GREENING

11: Questionnaire

Variable	Information (tick all that are applicable)	Additional Comments
Zone		
Exact Time	<input type="radio"/>	
Time of day	<input type="radio"/> Morning <input type="radio"/> Midday <input type="radio"/> Afternoon	
GPS Location		
Street Name		
Photo	<input type="radio"/> Yes <input type="radio"/> No	
Photo id		
Air quality issue	<input type="radio"/> Historic <input type="radio"/> Current <input type="radio"/> Future	

2.0 Greening		
Trees on stand	<input type="radio"/>	
Number	<input type="radio"/>	
Type	<input type="radio"/> Fruit <input type="radio"/> Shade <input type="radio"/> Recreation <input type="radio"/> Other	
Location	<input type="radio"/> Sidewalk <input type="radio"/> Parks <input type="radio"/> Schools <input type="radio"/> Churches <input type="radio"/> Other	

General Comment

OTHER SOURCES

12: Questionnaire

Variable	Information (tick all that are applicable)	Additional Comments
Zone		
Exact Time	<input type="radio"/>	
Time of day	<input type="radio"/> Morning <input type="radio"/> Midday <input type="radio"/> Afternoon	
GPS Location		
Street Name		
Photo	<input type="radio"/> Yes <input type="radio"/> No	
Photo id		
Air quality issue	<input type="radio"/> Historic <input type="radio"/> Current <input type="radio"/> Future	

2.1 Other Emission Source		
Source	<input type="radio"/>	
Severity of the air quality incident	<input type="radio"/>	
Magnitude of the air quality incident	<input type="radio"/>	
Nature of the air quality incident	<input type="radio"/>	

General Comment

ANEXURE 2

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