BMT Cordah Limited
ENVIRONMENTAL CONSULTANCY
AND INFORMATION SYSTEMS

Air Quality Study in the Vicinity of RAF Lossiemouth and RAF Kinloss

A Report for Moray Council

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Glossary

CO	Carbon Monoxide
DMRB	Design Manual for Roads and Bridges Screening Model (v1.0g)
EAC	Effective Area Coverage
EAL	Environmental Assessment Level
H1	Horizontal Guidance Note IPPC H1: Integrated Pollution Prevention and Control Environmental Assessment and Appraisal of BAT
GC/MS	Gas chromatography-mass spectrometry
HDV	Heavy Duty Vehicles (Includes Rigid & Articulated HGVs, Buses and Coaches)
HSE	Health and Safety Executive
IPPC	Integrated Pollution Prevention and Control
LAQM	Local Air Quality Management
LDV	Light duty vehicle
NAEI	National Atmospheric Emissions Inventory
NAQS	National Air Quality Strategy
NETCEN	National Environment Technology Centre (AEA Environmental Technology)
NO_2	Nitrogen Dioxide
OEL	Occupational Exposure Limits
OTV	Odour Threshold Value
PM_{10}	Particulate matter with an (equivalent aerodynamic) diameter of ten microns (10µm) or less
SO_2	Sulphur Dioxide
TLV	Threshold Limit Value
VOC	Volatile Organic Compounds

Units	
m/s	Metres per second
ng	Nanogrammme ($1x10^{-9}$ grammes)
ppb	parts per billion
$\mu g/m^3$	Microgramme per metre cubed ($1x10^{-6}$ grammes per metre cubed)

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ACKNOWLEDGEMENTS

BMT Cordah Limited would like to thank Moray Council for their assistance in the monitoring programme and provision of data throughout the duration of the study.

BMT Cordah Limited would also like to thank representatives from RAF Lossiemouth and RAF Kinloss for their attendance at meetings and their co-operation in providing permission to locate sampling equipment at site boundaries and for the provision of data.

Finally we would also wish to thank local residents who provided access and permission to locate sampling equipment on their property.

EXECUTIVE SUMMARY

BMT Cordah Limited was commissioned by Moray Council to undertake an assessment of air quality in the areas surrounding RAF Lossiemouth and RAF Kinloss. The study was in response to residential complaints to determine the potential risks to human health and odour nuisance due to emissions from aircraft and other on-site activities. The pollutants investigated were nitrogen dioxide (NO_2), fine particulate matter (PM_{10}) and volatile organic compounds (VOCs).

Baseline air quality monitoring was undertaken in the vicinity of the RAF bases over 6-months (November 2003 to April 2004) to determine NO_2 and total VOC concentrations. In addition, specific VOC species were identified and quantified and compared to recommended human health and odour nuisance air quality criteria. The monitoring programme also included a study to examine the likelihood of dust nuisance in the vicinity of each air base.

The results indicated that NO_2 levels were not influenced by variations in aircraft movements at either air base and were greatest at sites predominantly influenced by road traffic in Lossiemouth. 6-month mean concentrations at monitoring sites without traffic influences were typical of background levels for the Moray area. The dust sampling results showed the highest values occurring at Gilmour Crescent and Stotfield Road (Lossiemouth); both sites are influenced by road traffic. Dust levels at all sites were below typical levels that would cause dust nuisance complaints.

VOC measurements indicated a range of different species at varying concentrations at each site. Not all species were detected at each site and during each month. Mean monthly VOC levels showed an exceedence of the long-term environmental assessment level (EAL) and the odour threshold value (OTV) for acetic acid at Westerfolds Farm. There was also an OTV exceedence for 1-butanol at Stotfield Road, which coincided with the exceedence at Westerfolds Farm. OTV exceedence provides evidence to verify odour complaints in the vicinity of RAF Lossiemouth. There were also three sites (Westerfolds Farm, Crash Gate 4 and RAF Kinloss), which recorded concentrations of hexane within 10% of the long-term EAL. These exceedences were only evident during 1-month and the 6-month mean concentrations at all sites were significantly below relevant human and EAL.

During February the total VOC concentrations at Crash Gate 4 and Westerfolds Farm showed an exceedence of the long-term EAL for toluene, concentrations at Stotfield Road and the Station Commanders House in Kinloss showed levels within 10% of the long-term EAL for toluene, which is used as a proxy assessment level for total VOCs.

Results do not show a clear link between the number of aircraft movements and the total VOCs measured on a monthly basis. It is possible that changes in air base activities and types of aircraft, in addition to local agricultural and traffic sources have a greater impact on VOC concentrations, than simply the number of flight movements.

Specific VOC levels at RAF Lossiemouth present in both the aircraft fuel and the atmosphere during routine operations were not detected in the samples collected during a no-fly period. During this period un-combusted aviation fuel VOCs were not detected at 4 monitoring sites around Lossiemouth. The total VOCs recorded during the no-fly period at each site were below the 6-month mean concentration recorded at each site. The mean NO_2 concentration during the no-fly period indicated that road traffic emissions may have a greater impact than RAF base activities on levels at some sites.

A modelling assessment for benzene at Stotfield Road indicated that a source other than road traffic was contributing to monitored levels. It is therefore possible that the activities at RAF Lossiemouth may be contributing to the ambient concentrations. However, monitored levels were below relevant EAL indicating that there is no significant impact to human health in the vicinity of the air base.

1 INTRODUCTION

BMT Cordah Limited was commissioned by Moray Council to undertake an assessment of air quality in the areas surrounding the RAF bases at Lossiemouth and Kinloss. The study was undertaken in response to complaints from local communities to determine if there was any risk to human health or the likelihood of an odour nuisance at sensitive receptors in each area due to emissions from aircraft and other on-site activities.

The study included the following elements:

- Literature review – to determine the typical pollutants emitted to atmosphere from military and commercial air bases;
- Conduct a DMRB Assessment of Stotfield Road within the vicinity of RAF Lossiemouth to determine contributions of benzene, NO_2 and PM_{10} from road traffic;
- Development of a monitoring strategy – including a review of existing air quality monitoring, local meteorological data and complaints history;
- A six-month monitoring programme for VOCs and NO_2;
- A short-term monitoring exercise for particulates; and
- Comparison of measured concentrations with human health criteria, odour threshold values and occupational exposure limits.

2 LITERATURE REVIEW

A review of information in the public domain was undertaken in an attempt to obtain emission factors for the different types of aircraft operating from RAF Lossiemouth and RAF Kinloss. The aim was to establish which pollutants identified at ground level could be attributed to emissions from the air bases and aircraft in flight in the vicinity of the air bases.

The National Atmospheric Emissions Inventory (NAEI) (Ref. 1) provides estimates of emissions from military aircraft based on their fuel consumption. The aviation fuel data contains fuel used overseas. Takeoff and landing data for military aircraft are not generally available so the estimates are based on fuel consumption data and cruise emission factors for small jet aircraft, so estimates are therefore approximate.

Methodologies to develop emission inventories for civilian airports and air force bases in the USA were reviewed (Ref. 2). This provided equations to calculate emissions from a number of activities associated with military air bases including landing and take-off cycles, refuelling activities, maintenance and fire fighting activities and a number of other ground support operations associated with the activities of the air base.

In order to compile an emissions inventory substantially more information is required than is known about the operations at the air bases of concern in this project (e.g. number of movements, fuel type, fuel consumption, engine specification and performance, taxi-time) however, such a task was not within the scope of this study.

The emissions inventory methodologies reviewed and available emission factors only enable the calculation of emissions of total non-methane VOCs and methane. Therefore the determination of the specific sources of the individual VOC species detected during the monitoring study was not possible.

The review of available emission factors and methodologies for emission inventories relating to airports and airbases concluded that available techniques were not suitable for the assessment of ambient air quality outside RAF Kinloss and RAF Lossiemouth. It was determined that the assessment of ambient air quality in the vicinity of the two RAF bases would focus on monitored concentrations of NO_2, particulates and VOCs, which are associated with aviation emissions and data available for influencing factors such as meteorological data, complaints history and flight patterns.

3 MONITORING STRATEGY

The monitoring programme was designed to determine the ambient concentrations of NO_2, particulates and VOCs within the vicinity of RAF Lossiemouth and RAF Kinloss over a 6-month period. The analysis of VOCs included concentrations for both total VOCs and for individual VOC species.

Several factors, which may influence or provide an indication of ambient air quality, were investigated prior to finalising the monitoring strategy. These were:

- Background concentrations;
- Current air quality monitoring data available for Moray;
- Air quality complaints history for the locality;
- Meteorological data; and
- Available flight pattern data from RAF Lossiemouth and RAF Kinloss.

3.1 Background Monitoring Data

A review of available background concentrations in the Moray Council area was undertaken. The National Environmental Technology Centre (NETCEN) (Ref. 3) has mapped estimated annual mean background concentrations of all pollutants specified in the National Air Quality strategy (NAQS) (Ref. 4) for 2001 and respective assessment years for each pollutant. Average background concentrations were calculated for NO_2, PM_{10} and benzene for Moray using the methodologies set out in the technical guidance LAQM.TG(03) (Ref. 5). Predicted results are indicative of likely background concentrations.

3.1.1 NO_2

The estimated annual mean NO_x concentration for 2001, 2005 and 2010 was below 20µg/m^3. The maximum predicted NO_x concentration, taken from the NETCEN 1 x 1 km^2 background concentration database for Moray in 2001 was 10.9µg/m^3. Future concentrations of NO_2 were calculated using the factors supplied in Box 6.6 of the Technical Guidance LAQM.TG (03) (Ref. 5). The NO_2 component of total NO_x was predicted to be below 10µg/m^3 for all areas of Moray during 2001. However, it is predicted to fall to below 8µg/m^3 for the whole of the Council area by 2005.

3.1.2 PM_{10}

The average PM_{10} concentration, calculated from the NETCEN databases for background concentrations (Ref. 3) for Moray is 15.2µg/m^3 for 2001. Using the factors of 0.955 for secondary particulates and 0.954 for primary particulates, provided in Box 8.7 of the technical guidance LAQM.TG (03) (Ref. 5), to forward predict PM_{10} concentrations for 2003 allowed an estimated value of 14.5µg/m^3 to be calculated.

3.1.3 Benzene

The average benzene concentration, calculated from the NETCEN databases for background concentrations (Ref. 3) for Moray is 0.05µg/m^3 for 2001. Using the factor of 0.875, provided in Box 3.3 of the technical guidance LAQM.TG (03) issued to local authorities for the purposes of LAQM (Ref. 5), to forward predict benzene concentrations for 2003 allowed an estimated value of 0.046µg/m^3 to be calculated.

3.2 Existing Monitoring and LAQM Reports Conducted by Moray Council

Previous air quality reports conducted by Moray Council as part of the Review and Assessment process have concluded that there is unlikely to be an exceedence of the NAQS objectives for NO_2, SO_2, benzene, CO, 1,3-butadiene or lead (Ref. 6). Moray Council is currently conducting a Detailed Assessment of PM_{10} from road traffic emissions at Queen Street Roundabout in Elgin. The area of Detailed Assessment is not within the vicinity of either RAF Lossiemouth or RAF Kinloss, where it was concluded in previous reports (Ref. 6) that there was unlikely to be an exceedence of the NAQS objectives for PM_{10}.

Moray Council do not undertake any routine monitoring of particulates, benzene or any other VOCs as part of the LAQM process.

Moray Council monitors NO_2 at a number of sites within the area, all of which have been operational since 1999. Monitoring is undertaken using passive diffusion tubes. The same method was used for the additional monitoring undertaken in this study. The site locations, and descriptions, of the Council monitoring sites are presented in Table 1.

Table 1 NO_2 Diffusion Tube Monitoring Sites in Moray since 1999

Site	Location	Classification	Ordnance Survey Grid Reference
Elgin 1	Lamp Post West Park Court	Kerbside	NJ212626
Elgin 2	Junction East & Maisondieu Rd	Kerbside	NJ224627
Elgin 3	99-101 Maisondieu Road	Roadside	NJ223627
Elgin 4	26-28 Priory Place	Urban Background	NJ223626
Elgin 5	Main Street New Elgin	Kerbside	NJ223618
Fochabers 1	50A High Street	Kerbside	NJ345588
Fochabers 2	Sunndach George Street	Urban Background	NJ343587
Forres	Tolbooth, High Street	Roadside	NJ034587
Keith 1	106 Moss Street	Roadside	NJ433507
Keith 2	87 Moss Street	Roadside	NJ432507

The monitoring locations were selected to provide monitoring data from several key areas within Moray:

- Monitoring at the most heavily trafficked roads within Elgin town centre (e.g. Elgin 1, Elgin 2, Elgin 3 and Elgin 5);
- Urban background concentration (e.g. Elgin 4 and Fochabers 2); and
- Monitoring on the main roads through the other towns and villages within Moray (e.g. Fochabers 1, Forres, Keith 1 and Keith 2).

The NO_2 concentrations measured at these sites are presented in Table 2.

Table 2 NO_2 Monitoring Results

Monitoring Site	Annual Mean NO_2 Concentration ($\mu g/m^3$)		
	2000	2001	2002
Elgin 1	19.8	17.1	23.4
Elgin 2	13.8	12.3	15.9
Elgin 3	9.5	7.6	10.5
Elgin 4	7.0	6.2	6.9
Elgin 5	20.7	9.1	14.1
Fochabers 1	16.6	16.1	21.6
Fochabers 2	4.9	4.3	4.1
Forres	11.1	10.6	12.6
Keith 1	15.0	14.8	18.6
Keith 2	14.0	12.0	15.5

The monitoring results indicate that the NO_2 concentrations are well below the NAQS (Ref. 4) annual mean objective for NO_2 of 40µg/m^3. There was no overall downward trend in NO_2 concentration between 2000 and 2002. The concentrations monitored at the kerbside and roadside monitoring sites on the arterial routes in Moray have increased, whilst the concentrations measured at the background sites and those at the outlying towns and villages have remained fairly constant.

The Technical Guidance LAQM.TG (03) (Ref. 5) suggests that meeting the 2005 annual NO_2 mean objective is expected to be more demanding than meeting the hourly mean objective. No hourly monitoring data is available for Moray. As the annual mean objective is currently not exceeded it is considered unlikely that the hourly mean objective will be exceeded.

The annual NO_2 mean concentration is expected to decrease by a further 9% between 2002 and 2005 at roadside and kerbside locations, mainly due to improvements in motor vehicle engine efficiency and technology (Ref. 5).

3.3 Review of Complaints History

Moray Council Environmental Services Department provided information on areas with frequent complaints of fuel related odours and letters from members of the general public who had raised concerns about the potential health effects of emissions from the RAF bases. In summary, the main areas where complaints arose due to fuel related odours in the vicinity of RAF Lossiemouth were:

- Woodlands Walk, Inchbroom Avenue;
- Elgin Road;
- Stotfield Road;
- Sunbank; and
- Prospect Terrace.

Complaints of fuel deposits on windows and washing were also received from James Street and Commerce Street.

A number of complaints regarding fuel odours were recorded from a resident in the village of Covesea and letters were received from a resident in Glebe Road, Kinloss raising a

number of concerns and questions regarding the potential health risks of emissions from RAF Kinloss including complaints of fuel odours.

3.4 Review of Local Meteorological Conditions

BMT Cordah obtained 10-years of statistical meteorological data for the station operated by the Meteorological Office at RAF Kinloss for the period 1987-1996. More recent hourly data for 2002 and 2003 were also purchased by Moray Council for their ongoing LAQM projects. A wind rose for each dataset is shown in Figures 1 to 3 (Appendix A).

The data shows that the prevailing wind is typically south-westerly in the range 3 to 8 m/s for the 10-year dataset and typically south west in the range 3 to 5 m/s for both 2002 and 2003. The wind regime during 2003 at Kinloss exhibited a significant proportion of easterly and south easterly winds. The wind speed recorded during 2003 showed a similar distribution pattern to the 2002 wind speed recordings, however there were greater numbers of high wind speeds (>6 m/s) recorded during 2003.

From the data supplied by RAF Lossiemouth, for the duration of the study, it was evident that the prevailing wind direction was typically south-westerly although winds of similar frequencies were recorded from south-easterly to south-westerly during November 2003. The mean wind speed was most often in the range 5.5 to 8 m/s. From the data supplied by RAF Kinloss, for the duration of the study, the prevailing wind direction was typically south-south-westerly to south westerly. The mean wind speed was 4.5 m/s.

3.5 Review of Aircraft Base Activities

RAF Lossiemouth provided data showing areas of different activities including runways, taxi paths, aircraft maintenance areas, paint spraying facilities and fuel storage areas. These sites were considered when choosing the most appropriate monitoring location at the RAF Lossiemouth site boundary.

Information was obtained from each aircraft-base regarding type and frequency of aircraft movements on a monthly basis. This information was assessed in order to examine whether there was a correlation between the total number of movements at the aircraft-bases and pollutant concentrations measured at the monitoring sites.

3.5.1 RAF Lossiemouth

Monthly flight movements and weather data recorded at RAF Lossiemouth were supplied by RAF Lossiemouth for the duration of the study. There was a no-fly period between 20th December 2003 and 4th January 2004 inclusive with the exception of emergency operations.

3.5.2 RAF Kinloss

Monthly flight movements and weather data recorded at RAF Kinloss were supplied by RAF Kinloss for the duration of the study.

3.6 Selection of Monitoring Sites

A visit to areas surrounding each base and a site visit to RAF Lossiemouth was undertaken by BMT Cordah personnel on 24th September 2003 in order to review the suitability of a number of proposed monitoring sites and discuss the project with representatives from each RAF base.

Subsequent to the site visit and consideration of all the other information collected, the monitoring sites were chosen. A summary of each site and their reason for selection is detailed in Sections 3.6.1 and 3.6.2

The site locations are shown in Figures 4 and 5 (Appendix A) and a photograph of each sampling location is shown in Appendix B.

3.6.1 RAF Lossiemouth

Four monitoring sites were selected in the vicinity of RAF Lossiemouth. These were:

- Site 1 – Covesea to the north of the base. The site is a known air sensitive receptor from where complaints have been received and is near to the flight path for aircraft landings.
- Site 2 – Crash Gate 4 is situated at the site boundary closest to emissions from ground based activities (e.g. take off, taxi, engine testing and maintenance).
- Site 3 - Opposite the Skerry Brae public house in Stotfield Road in Lossiemouth. The site was chosen to monitor typical levels of NO_2 and VOCs at a roadside location influenced by road traffic. The site also acts as a comparison with those nearer the aircraft base and in rural locations. Traffic flow data were obtained for Stotfield Road so that the predicted VOC and NO_2 concentrations from the DMRB model (Ref. 7) could be compared with the actual monitored concentrations so that the proportion likely to be due to traffic emissions could be established. The monitoring equipment was vandalised during the first month of the study and was subsequently moved to another location on Stotfield Road at the junction with the B9040 and is shown as Site 3b on Figure 4 (Appendix A).
- Site 4 – Westerfolds, near the site boundary and flight take off path at the south-west of the site. The site is likely to experience some influence of agricultural related VOCs. The site therefore provides a useful reference figure for VOC and NO_2 concentrations from both agricultural and aircraft sources. This site in particular can be compared with the one in Lossiemouth.

3.6.2 RAF Kinloss

Two sites were selected in the vicinity of RAF Kinloss. These were:

- Site 5 – RAF Kinloss at the Station Commander's house on the B9011. There is minimal risk of public exposure to pollution at the site however; the site is underneath the take-off flight path and a useful reference unlikely to be affected by other emission sources.
- Site 6 - Glebe Road residential location. This is a sensitive receptor from where complaints have been received and is near to on-site ground level activities.

4 MONITORING METHODOLOGY

The monitoring equipment and analysis was supplied by Clyde Analytical, a UKAS accredited laboratory based in Greenock. The full QA/QC procedures for the methods used in the study are detailed in Appendix C.

The on-site assembly, collection and change-over of sampling equipment was undertaken by BMT Cordah personnel on a monthly basis. A representative of the Environmental Services Department of Moray Council changed the equipment that was exposed for 24-hour periods.

4.1.1 NO_2

NO_2 was measured using diffusion tubes at each site. Each tube was attached to a lamppost, fencepost or similar arrangement and exposed for 6 consecutive periods of one month duration. Additional tubes were located at sites 1 - 4 for a shorter period to correspond with the no-fly period at RAF Lossiemouth from 20th December 2003 to 4th January 2004 inclusive to act as control readings. For the two weeks monitoring during the no-fly period the results are likely to be indicative rather than exact due to the variation in sample period compared to the rest of the study.

4.1.2 Particulates

It was not anticipated that PM_{10} concentrations in the vicinity of the aircraft bases would breach any standards for human health. However, there was a perception of dust nuisance. Particulate sampling was therefore undertaken by sticky plate samplers exposed for 24-hours at 12 locations in the vicinity of the aircraft bases.

Sticky plate samplers have been used by local authorities and industry since the early 1980's as a simple and robust method of assessing indicative dust fallout from a variety of sources. Each plate has an exposed and covered control area and the sticky plate is assembled vertically around a lamppost or fencepost at each location with wind directions marked on it to produce a directional system. After exposure the sampler is covered and returned to the laboratory and scanned using computer technology. The results from the exposed area are compared with those on the control area and the data collected are calculated as daily effective area coverage (EAC) and compared with typical levels for different environments and public response levels.

The sampling took place for 24-hours from 3/4/04 to 4/04/04. The locations were the same 6 sites as detailed above plus six additional sites including a reference background site and sensitive receptors near each base. The sites were:

- Sites 1-6 as described above;
- At RAF Kinloss (NGR 308062, 862853), influenced by RAF Kinloss and road traffic;
- Gordonstoun Gate (NGR 319327, 869576), a rural background site near Lossiemouth;
- Junction of the B9012/Duffus Castle Road (NGR 317598, 866993), influenced by traffic and agriculture;
- Silver Sands Caravan Park (NGR 320553, 870852), a background site near Lossiemouth influenced by sea spray and traffic;
- Gilmour Crescent (NGR 323286, 869958), an urban background site in Lossiemouth; and

- Priory Place in Elgin (NGR 322241, 862662), an urban background site.

4.1.3 VOCs

The concentration of VOCs was measured using tubes packed with the adsorbent, Tenax TA. A measured volume of sample air was drawn through the tube, concentrating organic materials in the tube to the level at which they can be detected. Samples are thermally desorbed in the laboratory and the vapours are then analysed by gas chromatography-mass spectrometry (GC/MS). The technique separates the samples into individual species and provides identification for a wide range of organic compounds. Each tube was exposed for six consecutive monthly periods at the sites listed above.

Additional tubes were located at sites 1 - 4 for a shorter period to correspond with the no-fly period at RAF Lossiemouth to act as control readings. For the two weeks monitoring during the no-fly period the results are likely to be indicative rather than exact due to the variation in sample period compared to the rest of the study.

Two additional sites were introduced in the final month at James Street and Inchbroom in Lossiemouth in response to complaints from the public regarding odour nuisance.

In order to measure short-term peaks in VOC concentrations, which may result in odour episodes, two additional tubes were exposed for 24-hours in two locations, where the maximum monthly concentrations were recorded. These sites were at Site 1- Covesea and Site 3 – Stotfield Road.

RAF Lossiemouth provided a sample of the aviation fuel Jet A-1 for analysis by GC/MS in the laboratory in an attempt to identify if any of the VOCs present in the uncombusted fuel were resident in the atmosphere in the vicinity of the air bases. The assessment was purely indicative of the source of atmospheric VOCs, the fuel was assessed in an uncombusted form and VOCs measured in the atmosphere originating from aviation sources will primarily consist of VOCs present in combusted fuel. The presence of VOCs found in uncombusted fuel does not provide evidence of their presence in combusted fuel, which are likely to be significantly different. Therefore the presence of VOCs found in uncombusted aviation fuel may not be wholly representative of the total quantity of VOCs likely to have originated from the RAF bases, but will provide an indication of fugitive emissions from RAF air base activities. The results of the 24-hour analysis are discussed in Section 5.3.3.

5 RESULTS AND COMPARISONS WITH AIR QUALITY ASSESSMENT CRITERIA

5.1 Monitoring Results for NO_2

The results of the diffusion tube analysis for NO_2 are shown for each monitoring period of the survey in Table 3 and Figure 6 (Appendix A).

Table 3 Monthly Average Concentrations of NO_2 (µg/m^3)

	RAF Lossiemouth				RAF Kinloss	
Site	Site 1 Covesea	Site 2 Crash Gate 4	Site 3 Stotfield Road*	Site 4 Westerfolds	Site 5 Kinloss Flight Path	Site 6 Glebe Road
November	12.3	4.9	Missing	9.9	11.7	16
December	9.5	<4.0	<4	10.5	8.6	10.5
December No Fly Period	7.7	7.7	13.2	<6		
January	5.3	4.2	23.5	<4	24.3	35.1
February	5.3	10.1	21.2	5.3	10.1	11.3
March	6.4	5.3	12.8	4.8	7.1	7.8
April	4	4	6.3	4	4	4
6-month Mean	**7.1**	**5.7**	**16**	**6.9**	**11**	**14**

** This site was originally located opposite the Skerry Brae Pub in Stotfield Road in November but was relocated to the junction with the B9040 on Stotfield Road from December onwards due to vandalism.*

Note: The variation in concentrations between sites is due to a range of variables (e.g. meteorology, pollution source contribution)

The highest 6-month mean concentration of NO_2 was recorded at Stotfield Road in Lossiemouth, followed by Glebe Road in Kinloss; however no measurement exceeded the NAQS annual mean objective value of 40µg/m^3. At the remaining sites, the 6-month mean was less than or comparable with typical background levels of NO_2 for the area. It is therefore unlikely that there will be any impact to human health of concentrations of NO_2 in the vicinity of either aircraft base.

In order to compare the recorded NO_2 concentrations measured at Stotfield Road, which is influenced by local road traffic with the predicted concentration that would be expected from the traffic flow on that road, a simple screening calculation using the DMRB model designed for use in LAQM projects by local authorities was undertaken. The objective was to identify if the measurements were influenced by other potential sources i.e. RAF base activities. The results of the exercise are discussed in Section 5.1.1.

5.1.1 NO_2 Results for the DMRB Road Traffic Assessment at Stotfield Road

Traffic flow data for the 2-week period 20/11/03 to 3/12/03 was supplied by Moray Council on Stotfield Road (Appendix D). The 24-hour count was 2679 for week 1 and 2597 for week 2. The average flow of 2638 was input to the model. The average vehicle speed for each week was 30 mph and the standard vehicle split of 90% light duty vehicles (LDV) and 10% heavy duty vehicles (HDV) was assumed.

The DMRB model calculates the concentration at the sensitive receptor depending on its distance from the centre of the road. The road width varies along Stotfield Road but it was assumed that the kerbside where the risk of public exposure occurs was 5m from the centre of the road. The DMRB calculation is shown in Appendix D.

The results of the assessment show that the expected annual mean concentration at a sensitive receptor along Stotfield Road was calculated to be 12.4µg/m^3. This is similar to the 6-month mean concentration recorded during the monitoring study, therefore indicating that the variations in ambient NO_2 concentrations along Stotfield Road are likely to be primarily dependent on traffic emissions.

5.2 Monitoring Results for Particulates

The complete analytical report from Clyde Analytical is included in Appendix E and the results are summarised in Table 4 and can be compared with 'typical' values, provided by Clyde Analytical, in Table 5.

Table 4 Dust Analysis - Percentage Effective Area Coverage (EAC)/day

Location	% EAC/day			
	North	East	South	West
a) Site 5-RAF Kinloss	0.04	0.08	0.08	0.04
b) Site 6 – Glebe Road Kinloss	0.08	0.08	0.08	0.08
c) Kinloss Speed Limit Sign	0.04	0.08	0.04	0.04
d) Site 1-Covesea Village	0.04	0.04	0.04	0.04
e) Gordonstoun Gate	0.04	0.08	0.04	0.08
f) Junction B9012 Duffus Castle Road	0.08	0.12	0.08	0.08
g) Site 4 – Westerfolds	0.08	0.04	0.08	0.04
h) Site 2 – Crash Gate 4	0.16	0.12	0.12	0.12
i) Site 3 – Stotfield Road	0.16	0.16	0.16	0.16
j) Silver Sands Caravan Park	0.04	0.04	0.08	0.04
k) Gilmour Crescent. Lossiemouth	0.20	0.20	0.16	0.16
l) Priory Place, Elgin	0.04	0.08	0.08	0.08

Table 5 Typical Levels of Dust Provided by Clyde Analytical

Situation	%EAC/day
Rural	0.01
Suburban/small towns	0.02
Urban	0.3-0.4
Rural Summertime	0.5
Industrial	0.8-1
Public Response	**%EAC/day**
Noticeable	0.2
Possible complaints	0.5
Objectionable	0.7
Probable Complaints	2
Serious Complaints	5

The results show that the highest EAC/day values occur at the Gilmour Crescent and Stotfield Road sites in Lossiemouth which are both urban locations influenced by road traffic. It can be seen however, that all values are below the typical levels that result in potential dust nuisance complaints.

5.2.1 PM_{10} Results for the DMRB Road Traffic Assessment at Stotfield Road

The DMRB assessment of road traffic on Stotfield Road calculated an annual mean road traffic contribution of less than 1µg/m^3 of PM_{10}. When added to the typical background concentration of PM_{10} of 14.5µg/m^3 for the Lossiemouth area, it is unlikely that there will be any breach of NAQS health based objectives for PM_{10} in the vicinity of RAF Lossiemouth.

5.3 Monitoring Results for VOCs

5.3.1 Monthly Analysis

The monthly results of the exposed samples for each monitoring site are presented in Result Tables 1 to 6 (Appendix A).

Assessment of human health impacts is conducted by comparison of measured pollutant concentrations with the relevant long and short-term assessment criteria. Comparisons were made with EALs specified in the Integrated Pollution Prevention Control (IPPC) horizontal guidance note H1 (Ref. 8). The long-term EALs are derived from the Health & Safety Executive (HSE) EH40/2002 Occupational Exposure Limits Supplement 2003 (Ref. 9) 8-hour reference period converted to annual mean limits. The short-term EALs are derived from the HSE EH40/2002/3 (Ref. 9) OELs 15-minute reference period converted to an hourly mean.

An assessment of odour nuisance was conducted by comparison of measured pollutant concentrations with the relevant odour assessment criteria. Odour assessment is subjective due to the individual responses to a specific odour from each person. Odour assessment criteria generally take the form of Odour Threshold Values (OTVs) or Odour Threshold Limit Values (TLVs). The OTVs for each pollutant are taken from Woodfield and Hall (Ref. 10) as listed in the IPPC horizontal guidance note for odour H4 Part 1 - Regulation and Permitting (Ref. 11), with the exception of the value for methyl isobutyl ketone, which was taken from Odour Control - A Concise Guide (Ref. 12).

The OTVs are derived from established methods and correspond to the concentration of a pollutant that constitutes one odour unit of that specific species. One odour unit is defined as the concentration of a specific pollutant that is detectable by 50% of an olfactometry panel. The definitive OTV for a substance is a statistically derived value that represents an ’average‘ response from 50% of trained observers (Ref. 12).

The TLVs are time-weighted mean concentrations of a specific species equivalent to the exposure gained during a typical 8-hour working day or a 40-hour working week. The TLV for a particular species corresponds to the concentration to which nearly all humans may be exposed without detrimental effects to health or comfort (Ref. 12). The TLVs represent long-term assessment criteria for odour and are therefore comparable with the monthly and 6-monthly mean concentrations recorded. The TLVs used in this assessment are taken from Odour Control - A Concise Guide (Ref. 12).

Monthly mean and 6-monthly mean VOC concentrations were compared with the long-term EALs and TLVs in the absence of other suitable criteria. The 24-hour mean VOC concentrations were compared with the short-term EALs and OTVs. EALs, OTVs and TLVs are not available for all VOC species therefore analysis has been conducted for identified VOC species with relevant assessment criteria.

The total VOCs, expressed as the sum of all identified VOCs, are shown at the bottom of Result Tables 1 to 6 (Appendix A). The results are summarised in Figure 7 (Appendix A). In the absence of air quality limits for total VOCs, previous practice has been to compare the total VOCs recorded to the long-term EAL for toluene as a reference pollutant. The long-term EAL for toluene is 1910µg/m^3.

The full speciation analysis was not undertaken for April. Analysis for the individual species of benzene, toluene, xylene and total VOCs was carried out. The total VOC concentration derived using this method is the same as it would have been with the full speciation by

GC/MS when measured as parts per billion (ppb) but as there is no available result for each individual species a conversion to standard SI units of $\mu g/m^3$ is not possible. Thus the total VOCs recorded for the month of April in Result Tables 1 to 6 (Appendix A) is the sum of toluene, xylene and benzene only and does not account for any other VOCs that may have been present.

Extra tubes were exposed at James Street and Inchbroom in Lossiemouth for April in response to complaints from the public regarding fuel odours. The sample at James Street, Lossiemouth was damaged (i.e. wet weather) and therefore no data were returned for this site. The sample from Inchbroom recorded a total VOC concentration of 27.1ppb.

On examination of the flight movement data; the flight movements at Lossiemouth were lower in February than in most other months and the January flight frequency is typical of most months. At Kinloss, the February flight count is higher than the January count but flight movements during both months were either below or about the average for the 6-month study period. March had the highest number of flight movements at each base while the total VOC concentration for March at all sites was less than $138\mu g/m^3$.

Concentrations of hexane recorded at three sites (RAF Kinloss, Crash gate 4 and Westerfolds) during February were elevated to within 10% of the long-term EAL, however all three sites recorded a 6-month mean concentration significantly below the relevant assessment levels. One exceedence of the long-term EAL and the OTV for acetic acid was recorded at Westerfolds during November. The 6-month mean acetic acid concentration is significantly below the long-term EAL but did exceed the OTV; thus indicating that there is some evidence to support complaints of odour at this site. One exceedence of the OTV for 1-butanol was recorded at Stotfield Road during February. This was a one off incident as no further exceedences of 1-butanol concentrations were experienced at any monitoring site and the 6-month mean for Stotfield Road did not indicate an exceedence of the OTV for 1-butanol.

Concentrations of C_{10}-C_{15} aliphatic hydrocarbons were particularly high during February, in comparison to concentrations recorded during other months, at four sites namely RAF Kinloss, Glebe Road, Westerfolds and Crash Gate 4. There are no available environmental or human health assessment criteria for this species of VOC so it is not possible to determine the effect of these elevated concentrations.

During February the total VOC concentrations at Crash Gate 4 and Westerfolds Farm showed an exceedence of the long-term EAL for toluene, concentrations at Stotfield Road and the Station Commanders House in Kinloss showed levels within 10% of the long-term EAL for toluene. These exceedences or near exceedences were only evident during February and were not evident in the 6-month mean concentrations.

The data showed no obvious link between the number of aircraft movements and the total VOCs measured on a monthly basis. It is possible that changes in ground level activities or types of aircraft movements as well as agricultural and road traffic sources may influence the presence and concentrations of a range of individual VOC species. It can be seen from Result Tables 1 to 6 that not all species were detected at each site and that the presence of a particular VOC in one month did not determine its presence in subsequent months. Further information and detailed study would be required in order to deduce the origin of specific species.

5.3.2 24-Hour Exposure Analysis

Odour complaints usually arise when individuals are exposed to short-term peaks in concentrations of a particular substance. In order to examine the VOC levels over a shorter duration, VOC monitoring was undertaken at Site 1-Covesea and Site 3 – Stotfield Road for a 24-hour period in April. Odours can occur over seconds, minutes and hours and are generally short lived; therefore 24-hour sampling can at best be indicative of potential odour problems.

The full speciation analysis by GC/MS was not undertaken for samples collected during the final month; however the total VOC and benzene, toluene and xylene concentrations were recorded. As for the monthly samples in April the total VOC concentration is only available in $\mu g/m^3$ as the sum of benzene, toluene and xylene or as the total VOCs in ppb. The total VOC concentration for Stotfield Road and Covesea were 771 ppb and 516 ppb respectively. These values were higher than any of the monthly totals and potentially illustrate that peaks in concentration may occur over much shorter time periods. The recorded short-term concentrations for benzene, toluene and xylene did not exceed the short-term EALs, but the odour threshold value was close to being exceeded for xylene. The exercise was repeated in June for the same sites and the samples were analysed for individual species of VOCs. The results of the repeat sampling over 24-hours are shown in Result Table 7 (Appendix A).

The results show that no short-term EALs or OTVs were exceeded at either Covesea or Stotfield Road. The quantities of dichloromethane and C_8-C_{12} aliphatic hydrocarbons recorded over the 24-hour period were relatively high in comparison to the levels recorded during the 6-month monitoring period. The quantity of dichloromethane measured at Covesea exceeded the long-term EAL but was below the short-term EAL limit. The presence of isopropanol was detected during the 24-hour period of monitoring; however this was not detected at any site during the 6-month monitoring period. The quantities of toluene at Stotfield Road and hexane at Covesea recorded for the 24-hour monitoring period were comparable with the quantities recorded over the 6-month period indicating that these may represent background levels. The total VOC levels recorded at Covesea over the 24-hour period are approximately 9 times the level recorded as a 6-month mean. For Stotfield Road this factor was less with levels of total VOCs recorded during the 24-hour monitoring period approximately twice those recorded for the 6-month mean.

Results indicate that it is unlikely that there is any human health impacts from the VOC concentrations measured over short periods in the vicinity of the RAF bases, but there is some evidence that complaints of odours are substantiated. Further sampling for short-term periods would be required to fully determine the likelihood of complaints.

5.3.3 Control Readings

RAF Lossiemouth informed Moray Council and BMT Cordah that there would be a no-fly period between 20th December 2003 and 4th January 2004 inclusive, when all flight and ground level activities would cease with the exception of search and rescue operations as required by emergencies. This provided a good opportunity to take control readings at the monitoring sites in order to compare pollutant concentrations during periods of low and normal operation.

Additional VOC and NO_2 tubes were therefore exposed for this shorter control period and were analysed by the same methods as the regular monthly samples in the laboratory. In addition, a sample of aviation fuel supplied by RAF Lossiemouth, Jet-A1, was supplied to

the laboratory for GC/MS analysis. Studies indicated that during the no-fly period VOCs associated with uncombusted aviation fuel were not detected at the 4 monitoring sites around RAF Lossiemouth.

The comparison between total VOC concentrations for December and the no-fly period, illustrated in Figure 7 (Appendix A), shows that with the exception of Site 1- Covesea, the total VOC concentration increased during the no-fly period. It would be expected that a reduction in flight activity at the RAF base would lead to a reduction in total VOC concentrations within the vicinity of the air base. The results of the no-fly period analysis indicates that the ambient VOC concentrations at Stotfield Road, Westerfold Farm and Crash Gate 4 are influenced by sources other than the RAF bases or that atmospheric residency times are greater than two weeks. The detection level of each VOC species for the 2-week no-fly sample period is higher than for the monthly analysis and the methodology for sampling VOCs using tenax tubes is not accredited for period of 2-weeks. Therefore the results provided by the analysis for the no-fly period are probably less reliable than the monthly results.

The total VOCs recorded during the no-fly period at each site were, however, below the 6-month mean concentration recorded at each respective site during the monitoring period. Therefore the total VOC concentrations measured during the no-fly period were below the expected ambient atmospheric concentrations at each monitoring site.

The mean NO_2 concentration increased during the no-fly period at Site 2 - Crash Gate 4 and Site 3 - Stotfield Road and decreased at Site 1 - Covesea and Site 4 - Westerfolds when compared with the total monthly concentration for December. These results indicate that road traffic emissions may have a greater influence on NO_2 concentrations at Sites 2 and 3, however at Sites 1 and 4 aircraft emissions may have a greater influence on NO_2 concentrations.

5.3.4 Benzene Results of the DMRB Road Traffic Assessment at Stotfield Road

The DMRB assessment of road traffic on Stotfield Road calculated an annual mean of 0.02µg/m^3 of benzene due to traffic emissions. When added to the typical background concentration of benzene of 0.07µg/m^3 for the area, provided by NETCEN (Ref. 3), the benzene concentration at Stotfield Road was predicted to have an annual mean of less than 0.1µg/m^3. The 6-month mean benzene concentration measured at Stotfield Road was 3.74µg/m^3. The difference between modelled and monitored benzene concentrations at Stotfield Road suggests that it is possible that the site is recording emissions of benzene from another local source which may possibly be related to activities at RAF Lossiemouth. Further source apportionment studies would be required to determine the contribution of benzene from RAF activities. Nevertheless, it should be noted that there are no predicted or recorded exceedences of the NAQS annual mean objective for benzene of 5 ppb or the EALs. It is therefore unlikely that there will be any adverse impacts on human health due to benzene at the Stotfield Road site.

6 CONCLUSIONS

Monitoring was undertaken in the vicinity of RAF Lossiemouth and RAF Kinloss in Moray for a 6-month period from November 2003 to April 2004 in order to quantify the ambient concentrations of NO_2 and total VOCs. In addition the monitoring methodology was designed in order to identify and quantify the different species of VOCs present in the atmosphere. The measured VOC concentrations were compared with established EALs to examine the potential impact on human health and with odour assessment criteria to examine the potential for odour nuisance. The monitoring programme also included a short-term exercise to examine the likelihood of dust nuisance in the vicinity of each air base.

The results of the study show that there are no recorded exceedences of the NAQS annual mean concentration of 40µg/m^3 for NO_2 in any month or as a 6-month average concentration at any of the monitoring sites. The results show that the ambient concentrations of NO_2 do not appear to be influenced by variations in aircraft flight movements at either site and were highest in the locations most influenced by road traffic in Lossiemouth. The 6-month mean concentration at the other sites was typical of background concentrations across the Moray area.

The dust sampling results showed that the highest values occurred at the Gilmour Crescent and Stotfield Road sites in Lossiemouth, which are both urban locations influenced by road traffic. It was discernable, however, that the monitored values at all sites were below the typical levels that result in dust nuisance complaints.

The results of the VOC analysis indicated that there were a range of different substances which were detected in varying quantities at each site. Not all species were detected at each site and the presence of a particular VOC in one month did not always occur in subsequent months. The monthly mean concentrations of each species recorded one exceedence of the long-term EAL and OTV for acetic acid at Westerfolds Farm during November. During February there was one exceedence of the OTV for 1-butanol at Stotfield Road in Lossiemouth, which indicates that there was some evidence to verify the complaints of odours in the vicinity of RAF Lossiemouth. There were also three sites, Westerfolds Farm, Crash Gate 4 and RAF Kinloss, which during February recorded concentrations of hexane within 10% of the long-term EAL. Each of these exceedences or recorded concentrations were only evident during one month and results for the 6-month mean concentrations at all sites were significantly below relevant human and EAL.

There does not appear to be a clear link between the number of aircraft movements and the total VOCs measured on a monthly basis. It is possible that changes in ground level activities or types of aircraft movements in addition to agricultural and traffic sources may have a greater influence on presence and concentrations of a range of individual VOC species than purely number of flight movements. Further information and detailed study would be required in order to investigate this matter further and provide a full source apportionment assessment.

Control readings, recorded at RAF Lossiemouth demonstrate that the specific VOCs that were detected in both the aircraft fuel Jet A-1 and the exposed monitoring equipment during routine operations in November were not present in the samples collected during the no-fly period. This result indicates that during the no-fly period VOCs associated with uncombusted aviation fuel were not detected at the 4 monitoring sites around RAF Lossiemouth.

The comparison between total VOC concentrations for December and the no-fly period shows that, with the exception of Site 1- Covesea, the total VOC concentration increased

during the no-fly period. The total VOCs recorded during the no-fly period at each site are, however, below the 6-month mean concentration recorded at each respective site during monitoring period. Therefore the total VOC concentrations measured during the no-fly period are below the expected ambient atmospheric concentrations at each monitoring site.

The mean NO_2 concentration recorded during the no-fly period indicated that road traffic emissions may have a greater influence than RAF base activities on NO_2 concentrations at Sites 2 and 3, however at Sites 1 and 4 aircraft emissions may have a greater influence on NO_2 concentrations.

The DMRB assessment for benzene at Stotfield Road indicated that a source other than road traffic may be contributing to monitored levels. It is therefore possible that the activities at RAF Lossiemouth are contributing to the ambient benzene concentrations in the vicinity. However, monitored levels of benzene are below relevant EALs indicating that there is no significant impact to human health from benzene in the vicinity of RAF Lossiemouth.

In summary, the air base activities may influence specific VOC species present in the ambient air in the vicinity of the air bases, however the total VOC concentration is not influenced by the number of flight movements alone.

7 REFERENCES

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