a year long study of ambient air concentrations of benzene around a service station

Prepared for CONCAWE's Health Management Group by:

S.J. Lewis

B.J. Simpson (Technical Coordinator)

ABSTRACT

This report describes the results obtained from measurements of ambient benzene levels around a single service station in the UK over a one year period. Continuous sampling was achieved using diffusion tubes and results compared with those from intermittent active sampling using pumps and adsorption tubes. Results obtained around the service station were compared with those from a corresponding "green field site" in the same local area.

KEYWORDS

Benzene, gasoline, diffusion monitoring, active monitoring, service station.

ACKNOWLEDGEMENT

The survey described in this report would not have been possible without the full cooperation of the personnel at the site at which the sampling was undertaken. CONCAWE therefore wishes to thank the following personnel and companies who assisted and took part in the survey:

D. Butler
R. Butler
BP
Exxon

CONTENTS

SUMMARY

In 1990-1992, a series of measurements of benzene-in-air were taken around 12 service stations in Europe. [1] As a follow up, a more detailed one year study has been conducted at a single, semi-rural, self-service station without Stage 2 recovery, to gain more insight into sources, magnitude and variability of the ambient benzene levels at the site.

Sampling positions were selected so as to distinguish between the service station activities and other factors, such as emissions from motor vehicles. This involved positioning samplers around the service station, and at equivalent positions around a "green field" site, where the effect of passing road traffic was judged to be similar.

Continuous ambient air samples were taken at nine locations over 26 consecutive, two week periods, using diffusive monitors. Four were around the service station to indicate the annual average benzene concentrations at this site, four around the "green field site" and a further sample at a remote "background site".

A statistical sampling exercise was carried out during the same period at the same sites to establish the feasibility of utilising a limited sampling protocol in order to compute annual average concentrations. Active samplers were employed, every 30th day, to obtain 12 air samples at the same nine sampling positions.

The results from diffusive monitoring indicated that the mean annual benzene-in-air concentration around the service station was 3.8 µg/m^3 (range of the means was 1.6 - 6.9 µg/m^3). The individual two-week samples gave benzene levels in the range <1.0 - 10.6 µg/m^3.

The equivalent mean annual benzene-in-air concentration for the four points at the "green field site" was 1.4 µg/m^3 (range of means 1.0 - 1.8 µg/m^3). The corresponding individual two-week samples gave benzene levels in the range <1.0 - 10.7 µg/m^3.

The annual mean benzene-in-air level at the "background site" was <1.0 µg/m^3.

The statistical review of the data suggested that the results obtained from the active and diffusive techniques were from similar distributions. The mean of the active 30th day samples was approximately 20% higher than that obtained from the diffusive monitoring data.

The diffusive monitoring results suggest that service station activities contribute approximately 2.4 µg/m^3 (65%) to the overall mean benzene-in-air concentration at the service station, adjacent road traffic contributes 0.5 µg/m^3 (15%) and the remaining 0.9 µg/m^3 (20%) can be attributed to the background.

A simple comparison between the two sampling studies indicates that the associated costs of conducting them are similar.

1. INTRODUCTION

In 1994 CONCAWE published a report of a preliminary study [1] of ambient benzene-in-air concentrations around several service stations and distribution terminals in Europe. In the study a series of measurements were taken over 24 hour periods during summer and winter. The study showed there was a variation in benzene-in-air levels between sites and there was more than one source of benzene around a service station e.g. venting from storage tanks, refuelling of cars and exhaust emissions from passing cars.

CONCAWE initiated a follow-up study in order to establish:

- the annual average benzene-in-air concentration at several points around one service station,
- the local contribution of a service station to benzene-in-air concentrations.

The follow-up study was also designed to test whether a statistical sampling protocol could be used to predict annual ambient air benzene levels from short period, monthly monitoring data.

2. SELECTION OF SERVICE STATION AND SAMPLING LOCATIONS

In order to satisfy the objectives of the study, it was necessary to select a service station which was away from interfering sources of benzene including other service stations, major roads and industrial areas. In addition, the service station needed to be sited on a straight road with no major junction within 300 metres. The same criteria were applied to a "green field site" and a remote "background site", the former being under the influence of the road traffic, the latter under no specific or identifiable influence.

The siting of the air samplers would enable an assessment of the contribution of the service station to the ambient air benzene levels.

The service station selected was in the United Kingdom and was open daily from 0700 to 2200, except for Christmas day. The total gasoline storage capacity was 113,000 litres, with no vapour recovery on delivery and no Stage 2 recovery on vehicle refuelling. The grades of gasoline fuel sold were Premium leaded (97 RON), Europremium unleaded (95 RON) and Superplus unleaded (98 RON).

Ventilated sampling boxes attached to poles at a height of 1.5 metres were fixed at 4 locations around the service station. These sampling positions (designated S samples) reflect the influence of the service station and emissions from passing cars.

A further 4 boxes were sited in the same configuration at a "green field site", located 300 metres away from the station. These sampling positions (designated N sites) reflect the influence of emissions from passing cars and, as there were no junctions between this site and the service station, the number of cars passing both sites was assumed to be the same. In addition, a ninth box was sited away (C site) from the road and service station to reflect the background benzene-in-air concentrations.

A detailed layout of the service station configuration is shown in **Figure 1**.

3. SAMPLING AND ANALYSIS TECHNIQUES

3.1. DIFFUSIVE SAMPLING

This involved continuous (over 336 hours) ambient air sampling for 26 consecutive two-week periods over one year. The samplers were thermal desorption tubes packed with 200 mg of Chromosorb 106, fitted with diffusive heads containing a silicone membrane. The sampling began on 4 February 1993 and was completed on 3 February 1994.

3.2. ACTIVE SAMPLING

This involved taking 12 hour samples every thirtieth day starting at a random hour throughout a 24 hour period. Air was drawn at approximately 20 ml/min through 2 tubes connected in series each containing 200 mg of Chromosorb 106. The full sampling and analytical techniques are given in CONCAWE Report No. 94/53. [1]

3.3. ANALYSIS

The diffusive and active samples were analysed by gas chromatography following thermal desorption.

3.4. CALCULATION OF RESULTS

For both types of sampling, blank samples were taken and the benzene results calculated by subtracting the blank values from the exposed values. For convenience all values below 1.0 µg/m^3 are quoted as <1.0 µg/m^3 in the tables in this report. However, the "true" values have been used in the calculations of the mean benzene-in-air concentrations.

3.5. OTHER DATA

Details of the fuel deliveries, fuels usage, benzene content and meteorological data were recorded for each of the active and diffusive sampling periods.

4. RESULTS

4.1. DIFFUSIVE SAMPLING

All the results from the benzene-in-air two-week diffusive sampling measurements are shown in **Appendix 1**. A summary of the data is given below in **Table 1**. The data are also represented graphically in **Figures 2** and **3**.

Table 1 : Summary of the ambient benzene-in- air concentrations from diffusive monitoring

Sampling Position	Number of samples	Benzene-in-air Concentration (µg/m^3)	
		Range	Annual Mean
Background			
C1	26	<1.0 - 2.7	<1.0
Roadside Control Site			
N1	26	<1.0 - 2.6	1.4
N2	24	<1.0 - 2.8	1.0
N3	25	<1.0 - 10.7	1.8
N4	26	<1.0 - 3.5	1.2
Service Station Site			
S1	25	<1.0 - 10.6	6.9
S2	25	<1.0 - 8.6	2.4
S3	24	<1.0 - 9.8	3.8
S4	25	<1.0 - 5.5	1.6

4.2. ACTIVE SAMPLING

All the results from the benzene-in-air 12 hour active sampling measurements are shown in **Appendix 1**. A summary of the data is given below in **Table 2** and are represented graphically in **Figures 4** and **5**.

Table 2 : Summary of ambient benzene-in-air concentrations from active monitoring

Sampling Position	Number of samples	Benzene-in-air Concentration (µg/m^3)	
		Range	Mean
Background			
C1	12	<1.0 - 12.4	2.1
Roadside Control Site			
N1	12	<1.0 - 4.0	1.5
N2	12	<1.0 - 4.5	1.1
N3	12	<1.0 - 6.0	2.3
N4	12	<1.0 - 6.2	2.1
Service Station Site			
S1	12	<1.0 - 23.8	7.6
S2	12	<1.0 - 3.0	1.3
S3	12	<1.0 - 30.5	6.4
S4	12	<1.0 - 8.8	3.1

4.3. FUEL DATA

The mean gasoline throughput for a two week period for the collection of the diffusive samples was 109 872 litres. The mean gasoline throughput during the collection of the 12 hour active samples was 4224 litres with a range of 416-7211 litres.

A summary of the data standardised to gasoline throughput per hour of sampling is given in **Table 3**.

Table 3 : Summary of the gasoline sales standardised to volume (litres) throughput per hour sampled

	Diffusive	Active
Mean gasoline throughput (litres per hour sampled)	327	352
Range of throughput (litres per hour sampled)	269-385	35-601
Standard deviation (litres per hour sampled)	34	167

This indicates that the mean volume throughputs per hour were similar, but there was a greater variation during the active sampling periods. This was a consequence of the service station being closed for some of the time during certain active sampling periods.

The means and ranges of benzene content and volumes sold during the year for the 3 grades of gasoline are given in **Table 4**.

Table 4 : Means and ranges of benzene content and volumes of gasoline sold during the study

Fuel	Mean Benzene content for the study (% v/v)	Range of monthly Benzene contents (% v/v)	Total volume sold (litres)
Premium leaded (97 RON)	1.02	0.46 - 1.95	1 147 506
Europremium Unleaded (95 RON)	0.85	0.32 - 4.02	1 374 986
Superplus Unleaded (98 RON)	1.04	0.25 - 3.80	333 522

4.4. OTHER DATA

Figure 6 shows the simplified wind rose for the locality during the year of the study. **Figure 7** gives wind directions during each of the diffusive sampling periods. This indicates that the wind direction was mainly from either the south west or north east.

5. PROCESSING OF RESULTS

5.1. SIMPLE PROCESSING

A simple comparison of the means of the benzene-in-air results obtained from the active and diffusive sampling is shown in **Table 5**. Where appropriate, certain of the annual means have been rounded up to the nearest 0.1 µg/m^3.

Table 5 : Comparison of the mean ambient benzene-in-air concentrations

Position of measurement	Benzene-in-air concentrations (µg/m^3)		Difference between diffusive and active sampling results (%)
	Annual Mean of active samples	Annual Mean of diffusive samples	
Background			
C1	2.1 (1.2*)	0.9	- 64 (-33*)
Roadside Control Site			
N1	1.5	1.4	- 18
N2	1.1	1.0	- 23
N3	2.3	1.8	- 25
N4	2.1	1.2	- 43
Service Station Site			
S1	7.6	6.9	- 10
S2	1.3	2.4	+ 60
S3	6.4	3.8	- 43
S4	3.1	1.6	- 52

* If high result during sampling period 5 is ignored

5.2. STATISTICAL PROCESSING

5.2.1. General

The diffusive sampling protocol involves the collection of data over the entire study period, whereas, the active sampling only collects data for a small proportion (1.6%) of the one year study. A bootstrapping technique [2-4] (See 5.2.2. below) was used to assist in the evaluation of the data from the survey.

5.2.2. Bootstrapping

Bootstrapping is a statistical method that is used to estimate the mean and variation of data from ill-defined or unknown distributions. Because of the wide variation in ambient conditions, and the nature of the measurements, the monitoring data have a poorly defined distribution and are therefore, amenable to the bootstrapping process. The process was separately applied to the benzene-in-air data derived from both the active and diffusive monitoring at each of the three locations. The estimates reported in the following tables are based on distributions from 10 000 bootstrap sampling replications.

5.2.3. Bootstrapping results

The mean results from the bootstrapping for the diffusive and active sampling is shown in **Table 6**.

Table 6 : Actual benzene-in-air data versus mean benzene-in-air results obtained from the bootstrapping

Location	Mean from bootstrapped diffusive data (µg/m^3)	Mean from actual diffusive data (µg/m^3)	Mean from bootstrapped active data (µg/m^3)	Mean from actual active data (µg/m^3)
Service station	4.0	3.8	4.7	4.7
Green field site	1.4	1.4	1.7	1.8
Control site	<1.0	<1.0	1.2	2.1

In addition, the results from the statistical analysis also indicated that:

- the data from the 12 hour active samples were approximately 20% higher than those from two week diffusive samples,
- the 12 hour active samples were more variable than the data generated by the diffusive technique and
- the relative shape of the distributions is similar for the 4 comparison locations.

6. DISCUSSION

Diffusive data (Year Long Study)

Figure 2 shows all the benzene-in-air data for the "background" and "green field" sites. Inspection indicates that the measurement at N3 taken during sampling period 12 is much higher than the airborne concentration of benzene for the rest of the N3 and other N sets. As a consequence of this discrepancy, a review of the sampling and analytical data was undertaken to find any deviations that may have occurred. The review showed no deviation from the norm and therefore, the period 12 result was retained.

Active data (30th Day Study)

Inspection of **Figure 4** indicates that the benzene-in-air concentration at C1 during sampling period 15 is much higher than for the rest of the C and N sets. A review of the sampling and analytical data showed no reasons for this discrepancy and therefore, the result was retained.

Overall the benzene-in-air concentrations at S2 sample are low as this sampling position is generally upwind of the service station and sheltered, being approximately 4 metres below the level of the service station. S1 is close to the connection points for deliveries and the tank vents. The tank vents were 4 metres above ground level. S3 is a predominantly downwind sample.

Comparison of the active and diffusive benzene-in-air data

The benzene-in-air results from the two sampling techniques were slightly different, but this is not unexpected since the sampling periods were different. However, the following points should be noted.

Whilst it was necessary to subtract one "blank" value from the diffusive samples, two "blank" values were subtracted from the results of the active sampling as 2 tubes were used during the active sampling.

The 'active data' are more variable because the fuel throughput was more variable and these samples were more influenced by short-term emissions, e.g. during deliveries and small spillages.

Data derived from simple and statistical processing indicate that the diffusive monitoring results were, in general, lower than the active sampling results. A possible reason for this may be the relative periods of time that the service station was open and the fuel throughput during the times of sampling. During the diffusive sampling the station was open from 0700 to 2200, which is 63% of the sampling time, whereas for the active sampling the station was open for 83% of the time. This difference may explain the slightly higher results given by the active sampling.

The average fuel throughput was lower during the period of diffusive sampling, i.e. 327 litres per hour compared to 352 litres per hour for the active sampling.

Comparison of results with the previous study [1]

The benzene-in-air levels obtained during this study were lower than those reported in the previous CONCAWE study. The latter concentrated on urban service stations whereas the service station in the present study is considered to be semi-rural.

Influence of gasoline throughput

It would be expected that the greater the gasoline throughput, the higher the levels of benzene-in-air around the service station, all other factors being identical. However, as there was little variability in the monthly gasoline consumption, it was considered inappropriate to compare gasoline throughput from month to month with the measured levels from the diffusive samplers.

Figure 8, on the other hand, compares gasoline throughput with mean benzene-in-air levels at the service station sites as measured using active samplers. Whilst there is no clear correlation, the lowest throughput did correspond to the lowest benzene-in-air level.

Influence of service station on green field sites

The "green field" site was approximately north east of the service station. If the service station emissions affected the "green field" site, elevated levels would have been expected when there were predominantly south westerly winds. **Figure 9** shows the ratio of the sum of the benzene levels measured around the green field sites to the sum of the benzene levels measured around the service station with the percentage of time of south westerly winds superimposed. There was no indication of any direct correlation between the results at the service station and those at the "green field" site.

General

The major influence on each sampler appears to originate from local activity, i.e. within a few metres. Consequently any correlation with sample S3 is likely to be associated with cars parked close to the sampler during the inflation of tyres, rather than with other activities at the site.

Cost Comparison

A comparison of costs associated with the two sampling protocols is given in **Appendix 2**. This indicates, for this study, that even though the active sampling protocol only covered 1.6% of the year, the total sampling and analytical costs were similar.

7. CONCLUSIONS

Using diffusive monitoring, this CONCAWE study established the annual average benzene-in-air concentrations at several points around a service station. These ranged from 1.6 - 6.9 µg/m^3, with a mean annual average benzene-in-air concentration from the four sampling points of 3.8 µg/m^3 .

The diffusive monitoring results indicated that the service station activities contributed approximately 2.4 µg/m^3 (65%) to the overall mean benzene-in-air concentration at the service station, 0.5 µg/m^3 (15%) arose from adjacent road traffic and 0.9 µg/m^3 (20%) was associated with the background.

The simple processing and the "bootstrapping" technique employed to compare the two different sampling techniques suggest that it may be possible to employ limited sampling to predict long term averages. The statistical review of these data suggested that the results obtained from the active and diffusive techniques were from similar distributions. The mean of the active 30th day sampling was approximately 20% higher than that obtained from the diffusive monitoring data, although there were clear differences between the prevailing conditions that may account for this.

A cost comparison between the two sampling studies indicated that the associated costs were similar.

8. REFERENCES

1. CONCAWE (1994) A preliminary study of ambient air concentrations of benzene around service stations and distribution terminals in Europe. Report 94/53. Brussels: CONCAWE

2. Diaconis, P. and Efron, B. (1983) "Computer Intensive Methods in Statistics", *Scientific American*, *248, 116-130*

3. Efron, B. (1982) "The Jackknife, The Bootstrap and Other Resampling Plans", Soc. Industrial & Applied Mathematics, Philadelphia

4. Efron, B. and Tibshirani, R. (1991) "Statistical Data Analysis in the Computer Age", *Science*, *253*, *390-395*

TABLE 1 Results of Two Week Diffusive Sampling (µg/m^3)

Start date	4/2/93	18/2/93	4/3/93	18/3/93	1/4/93	15/4/93	29/4/93	13/5/93	27/5/93
S1	8.2	9.8	8.1	6.2	4.5	6.6	2.3	4.4	9.3
S2	3.1	1.8	1.7	1.4	1.4	1.1	1.2	1.5	1.8
S3	6.7	3.9	3.8	3.3	4.4	2.9	6.7	3.5	4.1
S4	3.6	4.8	3.3	<1.0	2.4	1.6	1.7	1.6	2.5
N1	2.5	1.8	1.9	1.4	1.2	2.6	<1.0	1.1	1.5
N2	2.8	1.3	1.3	<1.0	<1.0	<1.0	<1.0	1.0	<1.0
N3	3.1	1.3	1.6	1.1	1.2	1.0	1.1	<1.0	1.7
N4	2.6	1.6	1.5	1.8	1.4	1.4	1.0	1.2	2.0
C1	2.3	<1.0	1.5	1.0	1.2	<1.0	<1.0	<1.0	<1.0
Average gasoline throughput per hour (litres)	279	310	316	269	364	328	368	348	385
Number of deliveries	3	4	3	4	4	4	4	4	4

Start date	10/6/93	24/6/93	8/7/93	22/7/93	5/8/93	19/8/93	2/9/93	16/9/93	30/9/93
S1	8.1	10.0	10.6	9.0	8.4	7.9	4.0	7.5	8.4
S2	1.7	2.2	2.5	<1.0	3.7	6.6	1.1	8.6	Void
S3	3.2	Void	3.1	<1.0	Void	5.5	3.8	4.8	4.9
S4	1.0	1.9	<1.0	<1.0	Void	1.0	1.5	<1.0	1.9
N1	2.3	2.2	1.3	<1.0	1.1	1.0	<1.0	<1.0	<1.0
N2	<1.0	2.2	<1.0	Void	<1.0	<1.0	<1.0	Void	<1.0
N3	1.8	2.4	10.7	<1.0	1.3	1.3	1.2	1.1	<1.0
N4	1.6	3.5	1.5	<1.0	<1.0	<1.0	<1.0	<1.0	1.2
C1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.7	<1.0
Average gasoline throughput per hour (litres)	335	360	358	366	376	365	354	324	308
Number of deliveries	5	4	4	5	4	4	5	4	4

Start date	14/10/93	28/10/93	11/11/93	25/11/93	9/12/93	23/12/93	6/1/94	20/1/94	
S1	9.0	8.2	6.3	Void	8.1	8.4	7.5	<1.0	
S2	1.5	4.9	7.1	2.8	<1.0	2.1	2.1	<1.0	
S3	7.3	9.8	6.1	3.8	<1.0	2.9	2.8	1.9	
S4	2.0	2.7	5.5	1.9	<1.0	1.7	<1.0	<1.0	
N1	2.1	1.1	2.2	1.6	1.1	1.6	<1.0	<1.0	
N2	1.4	1.5	2.5	1.5	<1.0	1.2	1.8	1.3	
N3	1.6	2.1	2.5	Void	1.5	1.1	3.6	1.8	Average for the year
N4	<1.0	2.1	2.1	1.5	<1.0	1.5	<1.0	<1.0	
C1	<1.0	1.5	1.4	1.4	<1.0	<1.0	<1.0	<1.0	
Average gasoline throughput per hour (litres)	318	290	293	293	326	281	290	296	327
Number of deliveries	4	4	3	4	5	4	3	3	

TABLE 2 Results of the 30th day Active Sampling (μg/m^3)

Date	10/2/93	12/3/93	11/4/93	11/5/93	10/6/93	10/7/93
Start time	8:00	1:00	7:00	2:00	18:00	7:00
S1	5.3	2.1	1.5	<1.0	14.7	23.8
S2	3.0	<1.0	2.1	<1.0	2.8	1.1
S3	<1.0	30.5	3.7	8.1	<1.0	3.6
S4	8.8	7.2	8.4	2.7	3.3	<1.0
N1	4.0	2.8	<1.0	1.5	3.6	1.6
N2	4.5	<1.0	1.1	1.8	<1.0	<1.0
N3	4.3	2.5	<1.0	2.5	<1.0	1.6
N4	6.2	5.3	1.2	1.3	1.7	<1.0
C1	4.0	2.0	1.2	1.6	12.4	<1.0
Average gasoline throughput per hour (litres)	441	302	601	274	136	610
Number of deliveries	0	1	0	0	0	0

Date	9/8/93	8/9/93	8/10/93	7/11/93	7/12/93	6/1/94	
Start time	13:00	20:00	12:00	12:00	4:00	4:00	
S1	19.6	<1.0	<1.0	Void	15.5	9.6	
S2	1.3	1.5	1.1	<1.0	1.4	2.0	
S3	<1.0	<1.0	5.6	14.2	2.1	12.2	
S4	<1.0	<1.0	5.4	<1.0	<1.0	2.6	
N1	2.2	<1.0	<1.0	<1.0	1.8	1.5	
N2	3.0	<1.0	1.0	<1.0	1.4	1.3	
N3	6.0	<1.0	1.2	5.8	1.3	1.9	Average for the year
N4	1.1	<1.0	3.8	2.3	<1.0	1.5	
C1	<1.0	<1.0	1.2	2.1	<1.0	<1.0	
Average gasoline throughput per hour (litres)	447	35	415	335	315	308	352
Number of deliveries	0	0	0	1	0	0	

APPENDIX 2 COMPARISON OF COSTS FOR ACTIVE AND DIFFUSIVE SAMPLING

There are two variable cost considerations when undertaking this comparison, i.e. time and analysis cost. The cost of pre-survey organisation, setting up sampling sites etc. is considered to be the same for each exercise. The cost of each exercise, expressed in man-hours, is outlined below.

1. DIFFUSIVE SAMPLING (26, two week periods, 100% of the year)

1.1 Time

There were 26 sampling periods requiring a competent person on site for 3 hours (setting up equipment, exchanging samplers, gathering fuel data etc.). In addition, for this site there was 4 hours travelling time required. Therefore the total number of hours required were 189 (7 x 27) hours.

1.2 Analysis (excluding quality control samples)

Each diffusive sampling exercise generates 9 sampling tubes and therefore there are 234 (9 x 26) samples for analysis. Assuming 1 hour per analysis, the cost would be 234 hours.

2. ACTIVE SAMPLING (12, twelve hour periods, 1.6% of the year)

2.1 Time

There were 12 sampling periods requiring personnel on site for 15 hours (setting up equipment, deploying samples, checking flow rates, gathering fuel data etc.). Travelling time was 4 hours. Therefore the total number of hours required were 228 (12 x 19) hours.

2.2 Analysis (excluding quality controls samples)

The active sampling method employs two tubes in series at each point and therefore, each active sampling exercise generates 18 sampling tubes. This results in 216 (18 x 12) samples for analysis. Assuming 1 hour per analysis, the cost would be 216 hours.

3. SUMMARY OF COSTS

Table A-1: Summary of cost (man-hours) for the two sampling protocols

Type of sampling	Diffusive	Active
Time (hours)	189	228
Analysis (samples)	234	216
Total	423	444

4. Conclusion

The costs of the two types of study are similar.

FIGURE 1 **SERVICE STATION CONFIGURATION**

FIGURE 2 **GRAPHICAL REPRESENTATION OF THE DIFFUSIVE RESULTS AT THE "BACKGROUND" AND "GREEN FIELD SITES"**

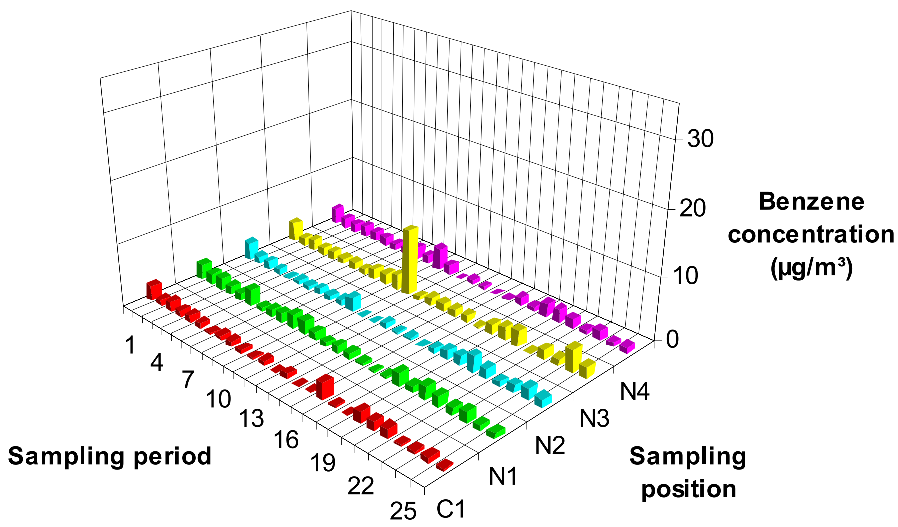

FIGURE 3 **GRAPHICAL REPRESENTATION OF THE "SERVICE STATION" DIFFUSIVE RESULTS**

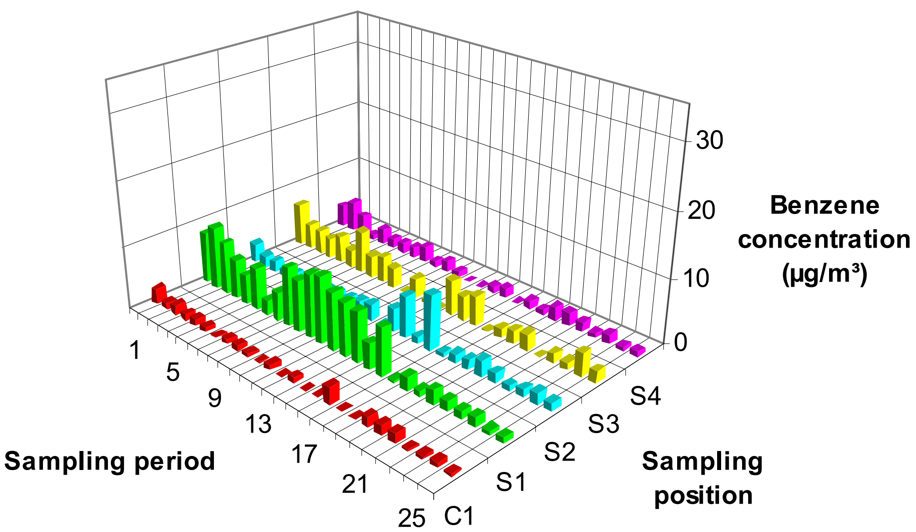

FIGURE 4 **GRAPHICAL REPRESENTATION OF THE ACTIVE RESULTS AT THE "BACKGROUND" AND "GREEN FIELD" SITES**

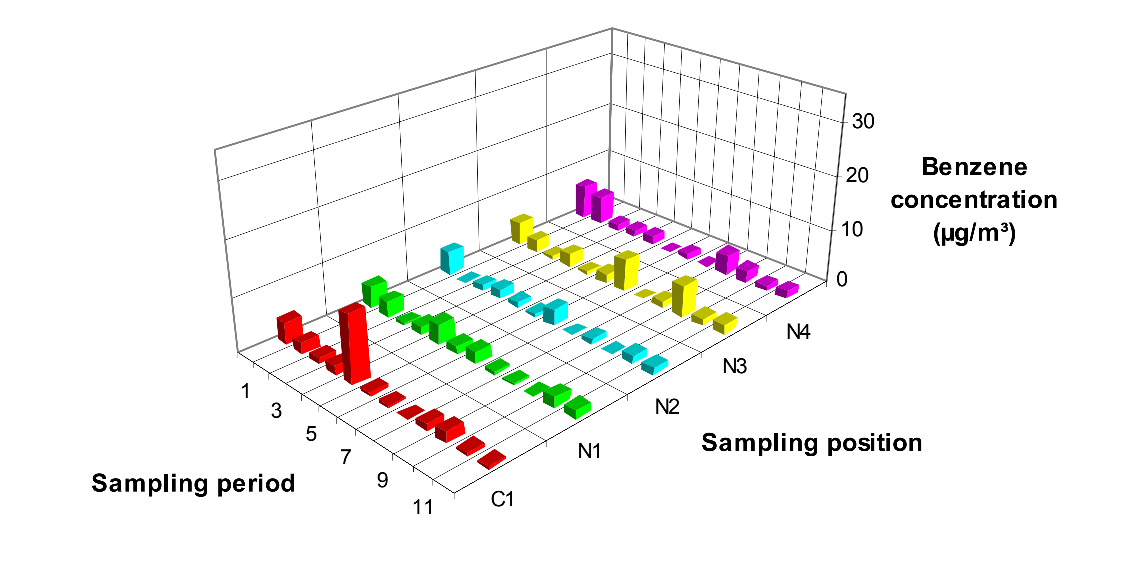

FIGURE 5 **GRAPHICAL REPRESENTATION OF THE ACTIVE RESULTS AT THE "SERVICE STATION" SITES**

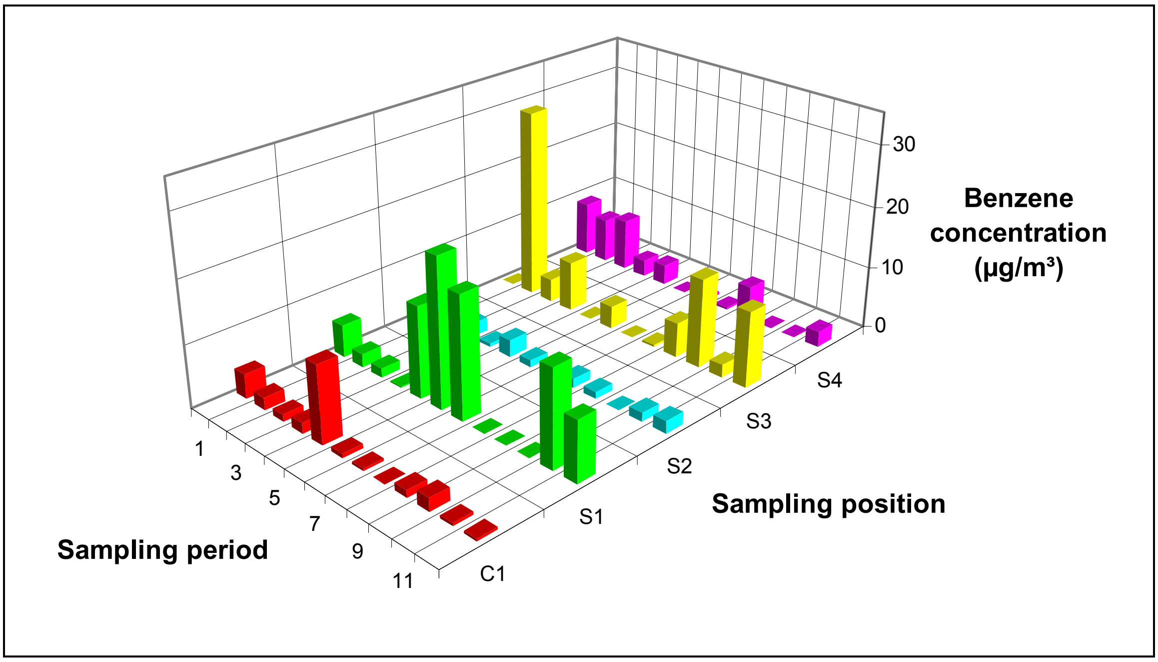

FIGURE 6 **SIMPLE WIND ROSE FOR YEAR LONG STUDY**

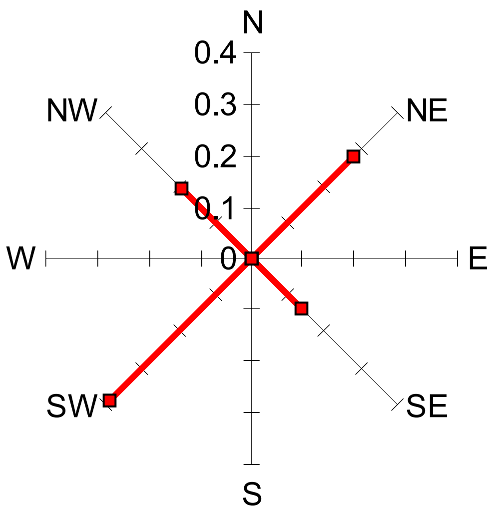

FIGURE 7 **WIND DATA FOR DIFFUSIVE SAMPLING PERIODS**

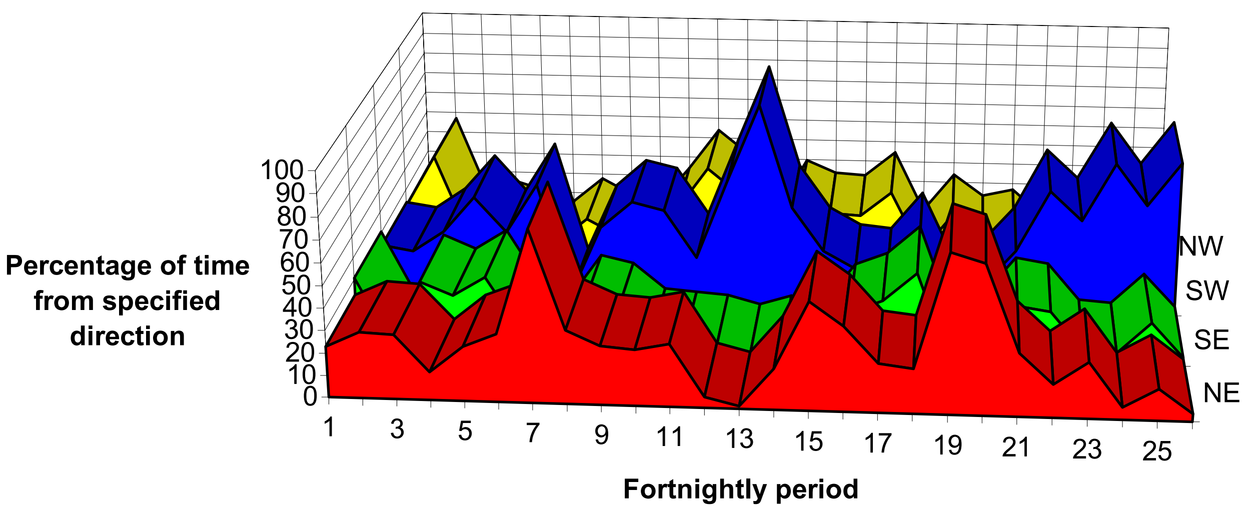

FIGURE 8 **COMPARISON OF GASOLINE SOLD AND MEAN BENZENE-IN-AIR LEVELS FOR SERVICE STATION LOCATIONS DURING THE ACTIVE SAMPLING PERIODS**

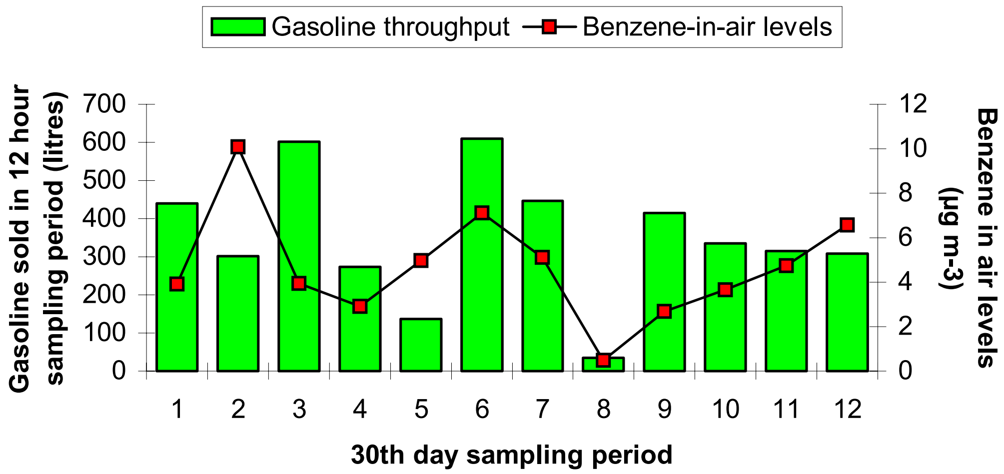

FIGURE 9 **COMPARISON OF THE RATIO OF THE SUM OF THE NON-SERVICE STATION AND THE SUM OF THE SERVICE STATION LEVELS VERSUS THE PERCENTAGE OF TIME OF SOUTH WESTERLY WINDS**