BTX passive sampling to characterise traffic restriction effects

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BTX diffusive sampling to characterise traffic restriction effects

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Abstract: On September 22 of each year a large number of French and European towns reduce the motor vehicle traffic in their city centre. Diffusive sampling of benzene, toluene and xylene during periods of 10 hours was used to characterise the improvement of the air quality due to these traffic restrictions. Despite the short sampling duration the use of diffusive sampling led to results consistent with the reduction of the number of motor vehicles and the measured concentrations of carbon monoxide. While under normal traffic conditions most benzene roadside concentrations measured during the day under low wind speed conditions exceeded the European limit value of 5 $\mu g/m^3$, these concentrations decreased to an average of 1.5 $\mu g/m^3$ under restricted traffic conditions with only 2 out of 10 measurement sites showing concentrations exceeding the French air quality target value of 2 $\mu g/m^3$.

1 Introduction

Following the example of La Rochelle in 1997 a large number of French towns decided in 1998 to drastically reduce the motor vehicle traffic in their city centres on a demonstration day. This operation is repeated every year on the 22nd of September, and is now implemented in a large number of European countries. In 1998, for the first national occurrence of 'En ville sans ma voiture' (traffic-free day), the French Ministry of Environment asked INERIS to characterise the improvement in air quality by measuring the decrease in roadside benzene, toluene and xylene (BTX) concentrations due to these traffic restrictions. In association with the local Air Quality Monitoring Network AIRLOR, with whom a previous study had been conducted [1], we carried out a 3 day campaign in the centre of Nancy, one of the largest cities in north-east of France. The city of Nancy was chosen because the traffic restrictions were imposed over a large area. Measurements were taken using sampling on diffusion tubes [2], followed by GC-FID analysis. Diffusive sampling appeared to be the best method to fulfil the aims of the operation because :

- diffusive samplers allow a quasi-simultaneous sampling at different sites
- the method is lightweight and therefore easy to use in multi-site applications
- the integration time covers well the period of interest.

2 Experimental

In order to compare the pollutants' concentrations with and without traffic under similar meteorological conditions and to compare them with other available data (traffic counts, CO monitoring), BTX were sampled at 10 different sites over periods of 10 hours on each of the 3 days including the 'traffic-free day'. The sampling points chosen were typical roadside sites close to the kerbside. Aluminium shelters were placed at sampling heights of 1.7 to 2.6 m, depending on the available support.

Passive samplers were Perkin Elmer tubes loaded with 130 mg of Carbotrap B [3]. The diffusion path length with the Perkin Elmer diffusion head is typically 21 mm. Each day of the campaign the tubes were opened early in the morning, placed in the shelters, and closed at the end of the day. On September 22 it was ensured that all the tubes were closed before the traffic started again at 7 p.m. It can be assumed that the amount of compounds trapped during a period of typically 10 hours, especially during the traffic-free day, would be small. Therefore the tube blanks had all been carefully checked before going to the site, and the analyses were done shortly after return of the samples to the laboratory. Tubes were thermally desorbed in a Perkin Elmer ATD400 and analysed in a Chrompack CP 9002 gas chromatograph with an FID and a CP-SIL 5 CB column.

3 Results and discussion

3.1 Measurement results

Concentrations for benzene, toluene and xylenes are given in Table 1.

Table 1 : BTX concentrations, µg/m^3

	Sampling site n°									
09/21/98	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Benzene	7.43	3.40	3.06	4.23	3.57	2.39	4.74	2.46	2.38	2.31
Toluene	15.85	4.74	6.18	8.68	6.90	6.01	6.19	4.35	4.34	2.60
(m+p)-Xylene	11.67	3.70	4.61	6.50	5.00	3.61	4.47	3.17	4.58	1.52
o-Xylene	3.99	1.38	1.60	2.35	1.66	1.19	1.78	1.49	1.07	0.59
09/22/98										
Benzene	2.70	0.79	2.09	1.00	2.29	0.67	1.97	1.11	1.29	1.36
Toluene	2.85	1.26	2.73	1.65	1.69	1.64	3.19	1.13	1.19	1.68
(m+p)-Xylene	1.97	1.07	1.41	0.53	1.35	1.01	1.08	0.83	0.85	1.08
o-Xylene	0.75	0.00*	0.61	0.00*	0.60	0.00*	0.70	0.56	0.50	0.32
09/23/98										
Benzene	7.99	3.52	6.04	6.72	6.12	5.32	6.92	3.68	5.58	3.01
Toluene	20.23	7.29	8.57	15.44	14.08	12.20	16.91	8.97	13.07	5.47
(m+p)-Xylene	16.22	5.07	5.86	11.73	9.88	8.59	11.57	6.46	9.63	4.02
o-Xylene	5.58	1.73	2.49	4.14	3.62	3.21	4.07	2.47	3.60	1.58

* *concentrations were below detection limits*

AIRLOR supplied the meteorological data. Typical wind speeds and directions for the three days of the campaign are represented in Figure 1. The weather was sunny and warm, with a light N-E wind of 4 m/s on September 21 and 22, decreasing to less than 2 m/s on the 23rd. The data were recorded in the suburb of Nancy on an open terrain : wind speeds were lower in the streets of the centre, though these are not typical canyon streets because buildings are not high. Influence of wind speed and direction is therefore not predominant. Nevertheless, higher BTX concentrations on September 23 than on September 21 are due to a smaller dispersion. Figures 2 to 5 represent the BTX concentrations for each day of the campaign. It is evident that these concentrations are much lower on September 22 than on the other two days due to the traffic restriction.

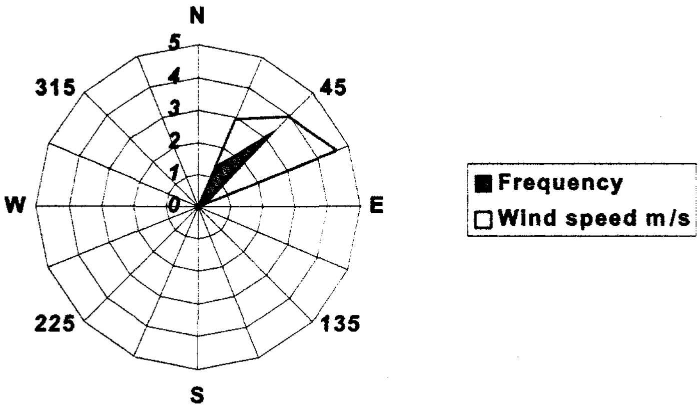

Figure 1 : wind rose for September 22

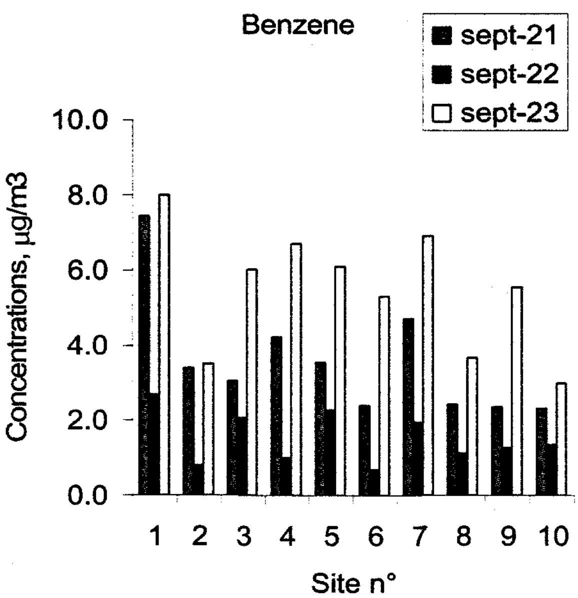

Figure 2 : Benzene concentrations

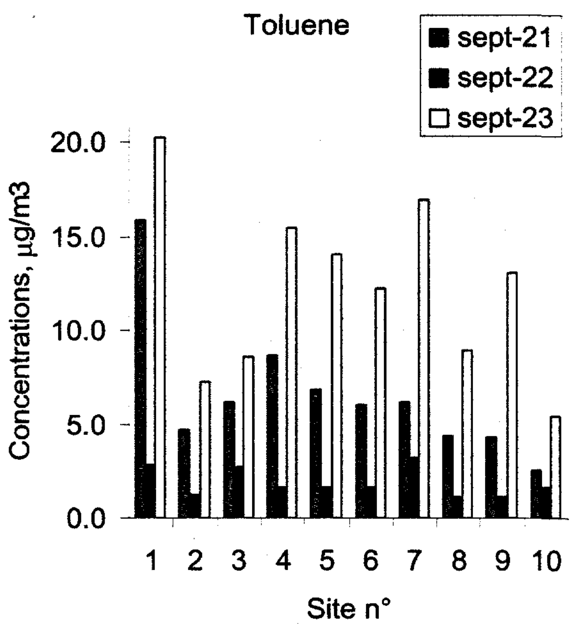

Figure 3 : Toluene concentrations

With normal traffic, and specially when wind speed is low, nearly all the sites show benzene concentrations exceeding the limit value of 5 µg/m^3 imposed by the recent European Directive [4] although the centre of Nancy does not have a heavy traffic (below 5,000 vehicles/day in most locations). All the values exceed the French target air quality value [5] of 2 µg/m^3. With traffic restrictions, benzene concentrations fulfil the European Directive and are very close to the French target value.

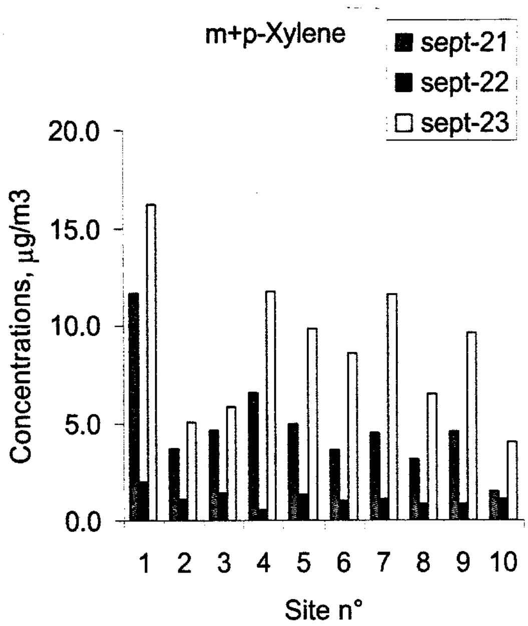

Figure 4 : m+p-Xylene concentrations

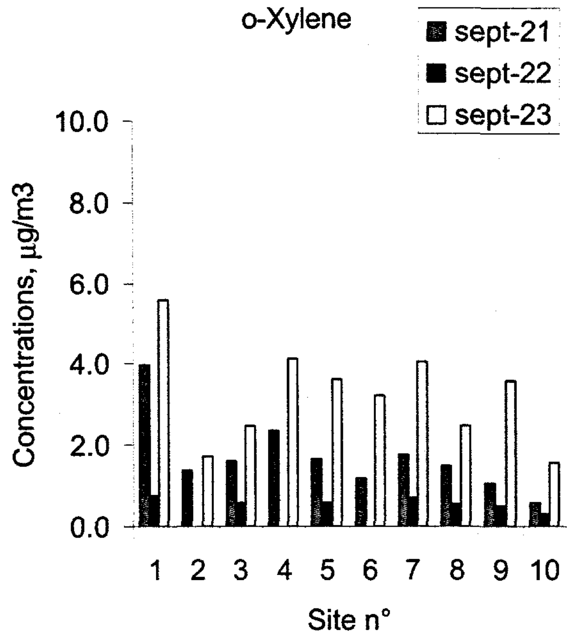

Figure 5 : o-Xylene concentrations

3.2 Correlation with other data

We have calculated the decrease in BTX concentrations for different sites as

$$d(\%) = \left(1 - \frac{C_B}{C_A}\right) \times 100$$

where C_B is the concentration in µg/m^3 of a compound on September 22 and C_A is the concentration on September 21 or 23 . Extreme and mean values for each compound are given in Table 2. We also report variations observed in traffic : number of vehicles and continuously monitored carbon monoxide in the same area. These data were supplied by AIRLOR.

Table 2 shows that traffic restrictions reduce both the BTX and CO concentrations in a same order of magnitude as the number of vehicles. This correlation clearly indicates that traffic is the major source of BTX [6]. The larger difference between September 22 and 23 comes from a smaller dispersion on September 23 due to the lower wind speed.

Table 2: decreases in concentrations and traffic on September 22 relatively to September 21 and 23

	Decrease of 22nd/21st, %			**Decrease of 22nd/23rd, %**		
Compound or traffic	Min	Max	Mean	Min	Max	Mean
Benzene	32	77	56	55	87	72
Toluene	35	82	67	68	91	83
m+p-Xylene	29	92	72	73	95	85
o-Xylene	46	100	73	76	100	87
Traffic, 2 busy streets*	65			No data available on 23rd		
CO monitored in the area*	60 to 70			70 to 80		

3.3 Influence of wind direction

Table 3/Figure 6 represents benzene concentrations measured during the 3 days of the campaign at 2 different sites located on the diagonal axis of a crossroad. With the rather high wind speed on September 21 and 22, the concentrations are 2 to 3 times higher downwind than upwind due to the accumulation effects and the influence of the crossroad source. The effect of traffic reduction is dramatic at these sites which were situated close to the kerbside. On September 23, due to the low wind, the benzene concentrations are comparable on the two sides of the crossroad, indicating no dispersion or accumulation effects.

Benzene concentrations, $\mu g/m^3$		
Day	Site n°6 (upwind)	Site n° 7 (downwind)
September 21	2.39	4.74
September 22	0.67	1.97
September 23	5.32	6.92

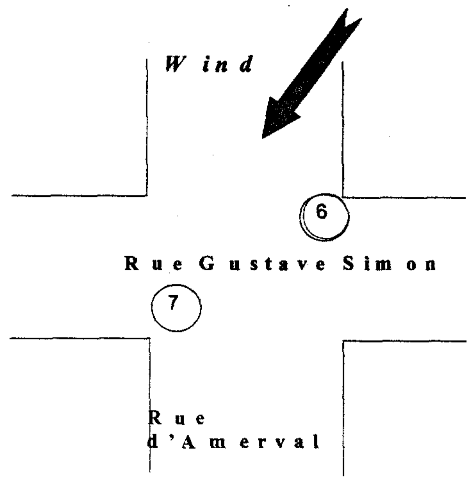

Table 3 / Figure 6: Effects of wind direction

3.4 Influence of sampling height

Measured BTX concentrations were plotted the measured BTX concentrations against the sampling heights for each day of the campaign. The correlation coefficient of the linear regression is poor because the sampling height is not the only parameter influencing the concentrations at roadside locations : topography, type of traffic and local turbulence vary from one site to another. Nevertheless there is a strong tendency : slopes are all negative for the normal traffic days, indicating that concentrations are higher nearer the ground and that the major source of BTX is the vehicle traffic. On September 22 concentrations are higher at elevated sampling points indicating that the measured BTX concentrations come from another source than the local traffic.

Table 4 : influence of sampling height on BTX concentrations

	Slopes : concentration vs. sampling height		
	September 21	September 22	September 23
Benzene	-0.168	0.374	-1.33
Toluene	-1.18	0.149	-5.17
m+p-Xylene	-1.27	0.552	-4.43
o-Xylene	-0.311	0.139	-1.53

4 Conclusions

Results show that, despite a short sampling duration, the use of diffusive samplers was appropriate to this study. Decreases in BTX concentrations on the traffic-free day were consistent with the reduction in the number of vehicles and the CO concentrations monitored at a roadside location. Finally, under normal traffic conditions, most benzene roadside concentrations measured over daytime periods in the centre of Nancy, under low wind speed conditions, slightly exceed the European Limit value of 5 $\mu g/m^3$. With traffic restrictions, however, these concentrations decrease to an average of 1.5 $\mu g/m^3$, and only 2 sites out of 10 show values which exceed the French Air Quality Target of 2 $\mu g/m^3$.

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