DERBY CITY COUNCIL

DETAILED ASSESSMENT FOR BENZENE

(Photograph courtesy of Derby Daily Telegraph Ltd)

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Produced by Derby City Council

SUMMARY

There are two health-based objectives for benzene, above which relevant public exposure is considered to pose a risk to human health. The 2003 and 2010 National Air Quality Objectives have respective annual average benzene concentration limits of 16.25µg/m^3 and 5µg/m^3.

These objectives for benzene relate to the building facades of dwellings, nurseries and schools, where the public may be regularly exposed to benzene over the course of a year. The health of people in the work place is controlled through health and safety legislation.

The need for a Detailed Assessment for Benzene was identified by Derby City Council's 2004 Updating and Screening Assessment (USA). As part of the ongoing process of the Review and Assessment of local air quality, benzene emissions from the Acetate Products factory in Spondon were assessed.

The USA concluded that although the 2003 benzene objective was being met, the 2010 annual average benzene objective of 5µg/m^3 might be exceeded at both the Anglers Lane and White House Nursery (north) monitoring sites. As a result a Detailed Assessment for benzene was required.

The purpose of this Detailed Assessment is to determine whether an exceedence of the 2010 annual average benzene objective is likely at dwellings, nurseries and schools within the vicinity of Acetate Products. If this proves to be the case, the magnitude and location of a benzene Air Quality Management Area (AQMA) will need to be determined.

The methodology chosen for this Detailed Assessment relies upon the monitoring results obtained from an extended and upgraded benzene monitoring network. This network consists of a pumped tube sampler, 17 co-located BTEX diffusion tubes and an Opsis analyser.

Dispersion modelling was deemed unsuitable for the purpose of this Detailed Assessment, due to the fugitive nature of the benzene emissions from Acetate Products. The vast majority of Acetate Products industrial-related benzene emissions arise from fugitive sources.

Results from the upgraded monitoring network have been provided for both the 5-month period between August to December 2004, and the calendar year January to December 2005. In order to put these results in context, previous year's results from the original benzene-monitoring network have also been provided.

Analysis is undertaken of all the results presented within this report, together with an assessment as to the likelihood of Acetate Products being able to reduce their emissions sufficiently to enable compliance with the 2010 benzene objective.

The Detailed Assessment concludes that at this stage an Air Quality Management Area for Benzene is not required. This is in consequence of the work that has been and continues to be undertaken by Acetate Products, the Environment Agency and Derby City Council, to ensure that the 2010 objective is met.

The benefit of joint working between stakeholders is demonstrated by the downward trend in annual average off-site benzene concentrations over the last 5 years. In order to ensure that this trend continues, Acetate Products authorisation was varied in February 2006. This authorisation, which soon be upgraded to a Permit, now provides a formal commitment to ensuring compliance with the 2010 annual average benzene objective.

Progress towards meeting the 2010 objective will be kept under constant review, using the monitoring results obtained from the benzene-monitoring network. This review will be formalised through the City Council's Progress Reports, which are submitted to the Department for Environment, Food and Rural Affairs (Defra) for approval.

Should at any time it be considered likely that the 2010 annual average benzene objective will be breached, the City Council will consult with all relevant stakeholders. This will be with a view to declaring an Air Quality Management Area for benzene in the vicinity of Acetate Products.

If an Air Quality Management Area is declared, the City Council would be under a duty to produce an associated Action Plan. This would be with the aim of ensuring that the 2010 objective is met at nearby receptors, again in consultation with stakeholders.

However, it is anticipated that Acetate Products' Permit can be varied with time, to ensure that the 2010 objective is met. This will involve continuation of the programme of effective joint working between Acetate Products, the Environment Agency and Derby City Council.

This approach aims to ensure that the annual average benzene objective of 5µg/m^3 is met at all dwellings, nurseries and schools by 2010. If successful, it will avoid the future need to declare an Air Quality Management Area for benzene.

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1.0 INTRODUCTION

Derby is a city of almost 250,000 people. It is situated in the heart of the East Midlands and is surrounded by primarily rural districts. The urban conurbation of Derby is the responsibility of the unitary authority of Derby City Council.

Under the Environment Act 1995, Derby City Council is under a duty to continually review and assess whether the concentrations of 7 pollutants will exceed the associated National Air Quality Objectives. The pollutants in question are benzene, 1,3-butadiene, carbon monoxide, lead, nitrogen dioxide (NO_2), particulate matter (PM_{10}) and sulphur dioxide.

This report is a detailed assessment for industrial-related benzene associated with the Acetate Products factory in Spondon.

Benzene (C_6H_6) is a Volatile Organic Compound (VOC). It is also a genotoxic human carcinogen. Studies of industrial workers exposed to benzene, have demonstrated that there is an increased risk of leukaemia associated with their working lifetime exposure (Reference 14).

National Air Quality Objectives have been set for benzene for the objective years of 2003 and 2010, based upon benzene concentrations that are considered to pose an exceedingly small risk to human health.

As is shown in Table 1, the 2003 National Air Quality Objective for benzene was an annual average concentration 16.25µg/m^3. The 2010 National Air Quality Objective for benzene is an annual average concentration of 5µg/m^3.

Table 1

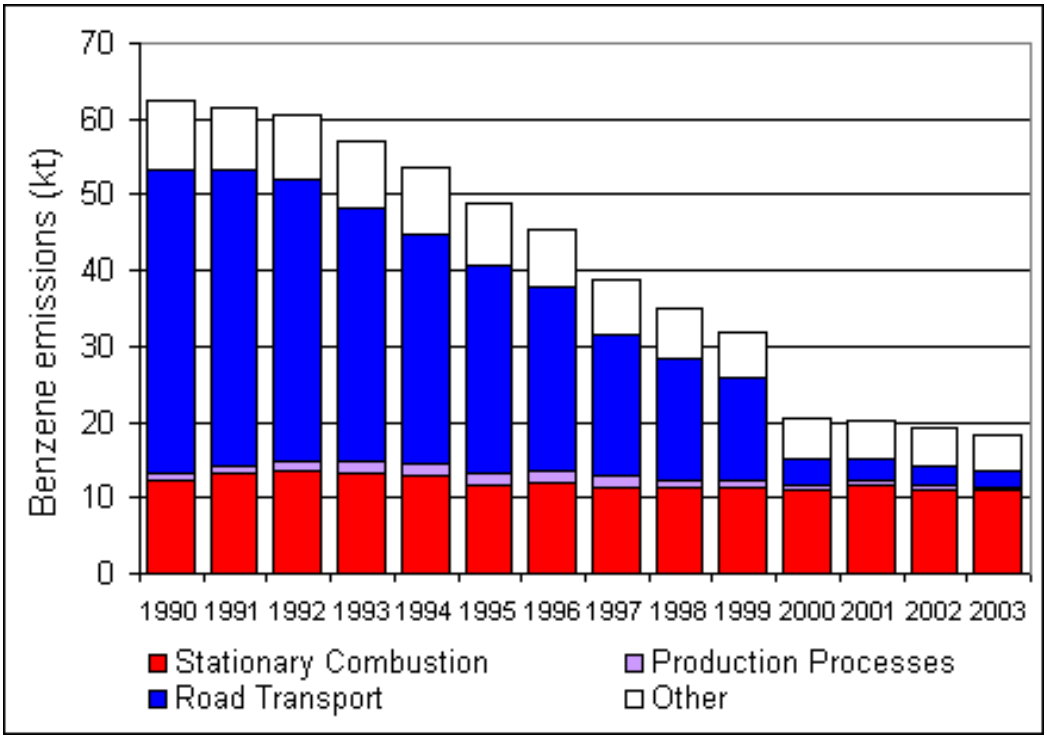
Summary of the National Air Quality Objectives for Benzene

Pollutant	Concentration	Measurement	Target Date
Benzene	16.25µg/m^3	Annual mean	31 Dec 2003
	5µg/m^3	Annual mean	31 Dec 2010

Atmospheric benzene is present almost entirely as a result of human activities. With the exception of a few industrial processes, the main source of atmospheric benzene emissions in the UK is from the refining, distribution and combustion of petrol.

As is shown in Graph 1, benzene emissions have been steadily decreasing since 1990.

Graph 1, UK Benzene Emissions 1990 - 2003



The decrease in annual average UK benzene emissions over the last 13 years is due to the following:

1) In 1993, petrol driven cars were fitted with catalytic converters.

2) In 2000, the Auto-Oil Directive reduced the limit on the benzene content of petrol from 5% to 1%.

3) In the late 1990s, Stage 2 vapour recovery systems were introduced at petrol stations.

4) Emissions from the domestic and industrial sectors have also been reduced over the same period.

The result of the year-on-year reduction in UK benzene emissions, has been a gradual reduction in urban background benzene concentrations. Taking into account that 2003 was a high year for pollution, as is shown in Table 2, this reduction has however now levelled out. Further substantial reductions in urban background benzene concentrations are therefore considered unlikely.

Table 2

Annual Average Benzene Concentrations for the Non-Automatic Hydrocarbon Network (17)

Year	Average Benzene Concentration ($\mu g/m^3$)
2002	1.66
2003	1.79
2004	1.63
January - August 2005	1.59

As a result of the introduction of Stage 2 vapour recovery, petrol stations are no longer a significant source of benzene emissions. This was confirmed by the 2004 Updating and Screening Assessment, which screened out all petrol stations within Derby as being unlikely to cause an exceedence of either the 2003 or 2010 benzene objective.

On a national basis, Plymouth has the only benzene-related Air Quality Management Area (AQMA). This is as a result of the close proximity of a school playground to a petrol station forecourt. There is no industrial-related benzene Air Quality Management Area (AQMA) in the UK (1).

The continual process of Review and Assessment of local air quality requires local authorities to determine the likelihood of an exceedence of National Air Quality Objectives. Members of the public need to be regularly present for the averaging period of the objective.

In the case of the annual mean objective, this requires assessment at the building facades of dwellings, nurseries, schools and hospitals. The health of people in the work place is addressed through health and safety legislation.

Derby City Council undertook its first Review and Assessment of local air quality in 2000. This was a four-stage review of the National Air Quality Objectives. It used a combination of monitoring and detailed dispersion modelling, to establish the likelihood of exceedences of the National Air Quality Objectives.

The 2000 Review and Assessment screened out benzene, determining that it would be unlikely to cause a breach of the relevant National Air Quality Objectives. At the same time, it identified specific problems with both road-traffic based nitrogen dioxide (NO_2) and industrial based particulate matter (PM_{10}). These issues are the subject of separate Detailed Assessments.

Although benzene was screened out by the initial Review and Assessment, ambient benzene monitoring was undertaken. Four benzene diffusion tubes were located in the vicinity of the Acetate Products factory at Spondon, with a fifth urban background diffusion tube being located at the Council House air quality monitoring station.

In 2002, Derby City Council commenced its second Review and Assessment of local air quality. This relies upon a 2-stage process, involving an initial Updating and Screening Assessment (USA) and then Detailed Assessments to consider identified local air quality issues in more depth.

Derby City Council's Updating and Screening Assessment was approved by Defra in March 2004. It identified a need for 3 Detailed Assessments in relation to industrial-based benzene and road-traffic based NO_2 and PM_{10}.

The need for a Detailed Assessment for Benzene was based upon the monitoring results obtained from the network of benzene diffusion tubes. The 2001 and 2002 annual average diffusion tube results for both Anglers Lane and White House Nursery (north) exceeded the 2010 objective of 5µg/m^3.

This Detailed Assessment for Benzene contains a review of the initial Updating and Screening Assessment. It also provides an overview of the relevant industrial processes undertaken by Acetate Products, it discusses the application of dispersion modelling and describes the benzene monitoring network.

Following on from this, the Detailed Assessment provides a detailed investigation into the likelihood of an exceedence of the 2010 annual average benzene objective at dwellings, nurseries and schools. There are no hospitals in the vicinity, so this receptor type is excluded from this Detailed Assessment.

The results from the upgraded benzene-monitoring network are provided for both the 5-months between August to December 2004, and the calendar year January to December 2005. In order to place these results in context, previous year's results from the original benzene-monitoring network have also been provided.

Analysis is undertaken of all the results presented within this report, together with a subjective assessment as to the likelihood of Acetate Products being able to reduce their emissions sufficiently to ensure that the 2010 benzene objective can be achieved.

Finally, the outcomes of this Detailed Assessment for Benzene are presented.

2.0 ACETATE PRODUCTS

Acetate Products was formerly known as both 'Acordis' and 'Courtaulds.' It operates an organic chemicals factory on Holme Lane in Spondon, producing cellulose acetate flake. This acetate flake is then spun to create fibres, which are used in both cigarette filter tow and 'Clarofoil' plastic film.

Acetate Products are regulated for atmospheric emissions by the Environment Agency, under Authorisation AK2335. By 31 March 2006, Acetate Products are required to apply to upgrade this Authorisation to a Permit, by means of an 'A1' IPPC application to the Environment Agency.

Once issued, the Permit will address a range of environmental impacts. In addition to atmospheric emissions, the Environment Agency will also have responsibility for regulating noise and odour from the Installation.

With regard to their future Permit, it has been deemed that Acetate Product's primary activity is Cellulose Acetate Flake Manufacture. This production of organic materials, falls under section 4.1 A(1)(a)(viii) of the Pollution Prevention and Control Regulations 2000.

The company also undertakes 2 ancillary activities: Acetic Anhydride manufacture falls under section 4.1A(1)(a)(ii) of the Regulations, and Acetone Distillation falls under section 5.4 A(1)(a).

Benzene forms an integral part of the industrial operation at Spondon. It is used in the Acetyls Plant, as a co-solvent in the recovery of acetic acid from a weak acid waste stream. It is also used in the Flake Plant, in the cracking of acetic acid to acetic anhydride.

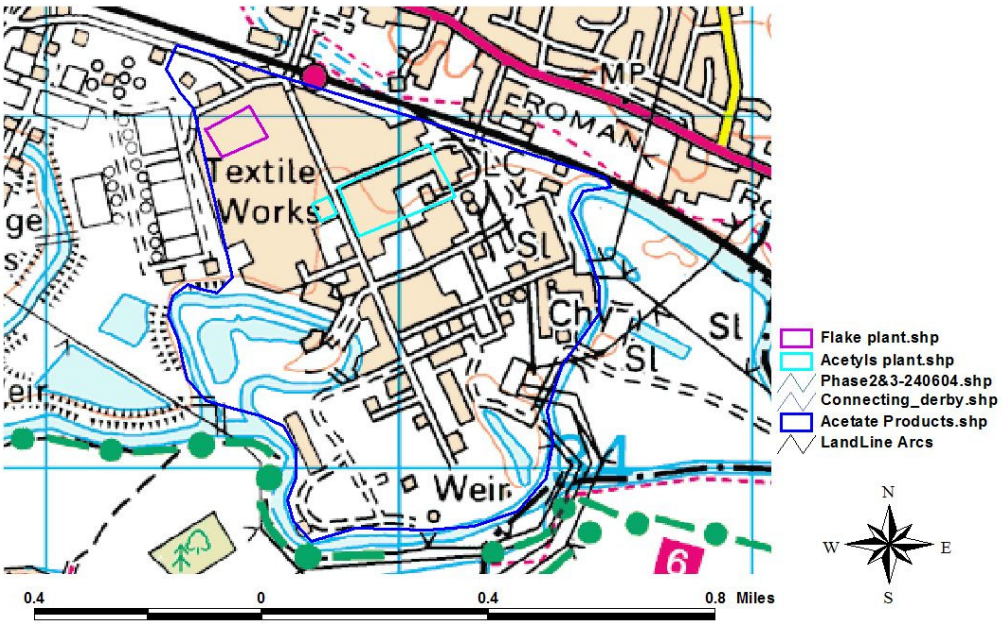
2.1 Acetyls Plant

The Acetyls Plant is located along the north-eastern boundary of Acetate Product's Spondon site, close to Anglers Lane, as is shown in Map 1. It carries out two basic processes:

(i) It concentrates the weak acetic acid effluent from the flake plant for reuse. The acetic acid is extracted from the weak acid solution using a solvent of ethyl acetate and benzene. It is then separated from the solvent by distillation.

(ii) Acetic acid is cracked at high temperature to acetic anhydride, which is then used in the production of cellulose acetate flake. A benzene solvent is then used to quench the product steam from the furnace, to improve the yield from the reaction.

Map 1
Acetyls & Flake Plant at Acetate Products



2.2 Flake Plant

The Flake Plant is located at the entrance to the site, off Megaloughton Lane, as is shown in Map 1.

Within the Flake Plant, shredded wood pulp is mixed with acetic acid and a sulphuric acid catalyst, as well as acetic anhydride from the Acetyls Plant. Minute traces of residual benzene from the acetic anhydride process are present in this acetic anhydride.

The cellulose in the wood pulp reacts with the acetic anhydride to give cellulose triacetate, which is then hydrolysed to give diacetate dope.

Cellulose acetate flake is precipitated from the diacetate dope, by adding 10% dilute acetic acid. The precipitated flake is washed with water, to remove the remaining acetic acid and dried. The weakened acetic acid is recovered and sent to the Acetyls Plant to be concentrated and recycled.

2.3 Benzene Emissions

Atmospheric emissions of benzene from the Flake Plant arise from the following emission points (see Map 2):

1) C3 - Flake Plant scrubber located on 7 extension, A roof

2) C7 - Flake Plant fugitive releases from the buildings 8 ext and 9 ext

The primary source of benzene emissions is however from the following emission points in the Acetyls Plant (see Map 2):

1. C12 - Acetyls Plant VOC abatement scrubber

2. C17 - Acetyls Plant x 6 benzene tank atmospheric vents (SS5, SS7, SS10, SS15, SS6 and DS5)

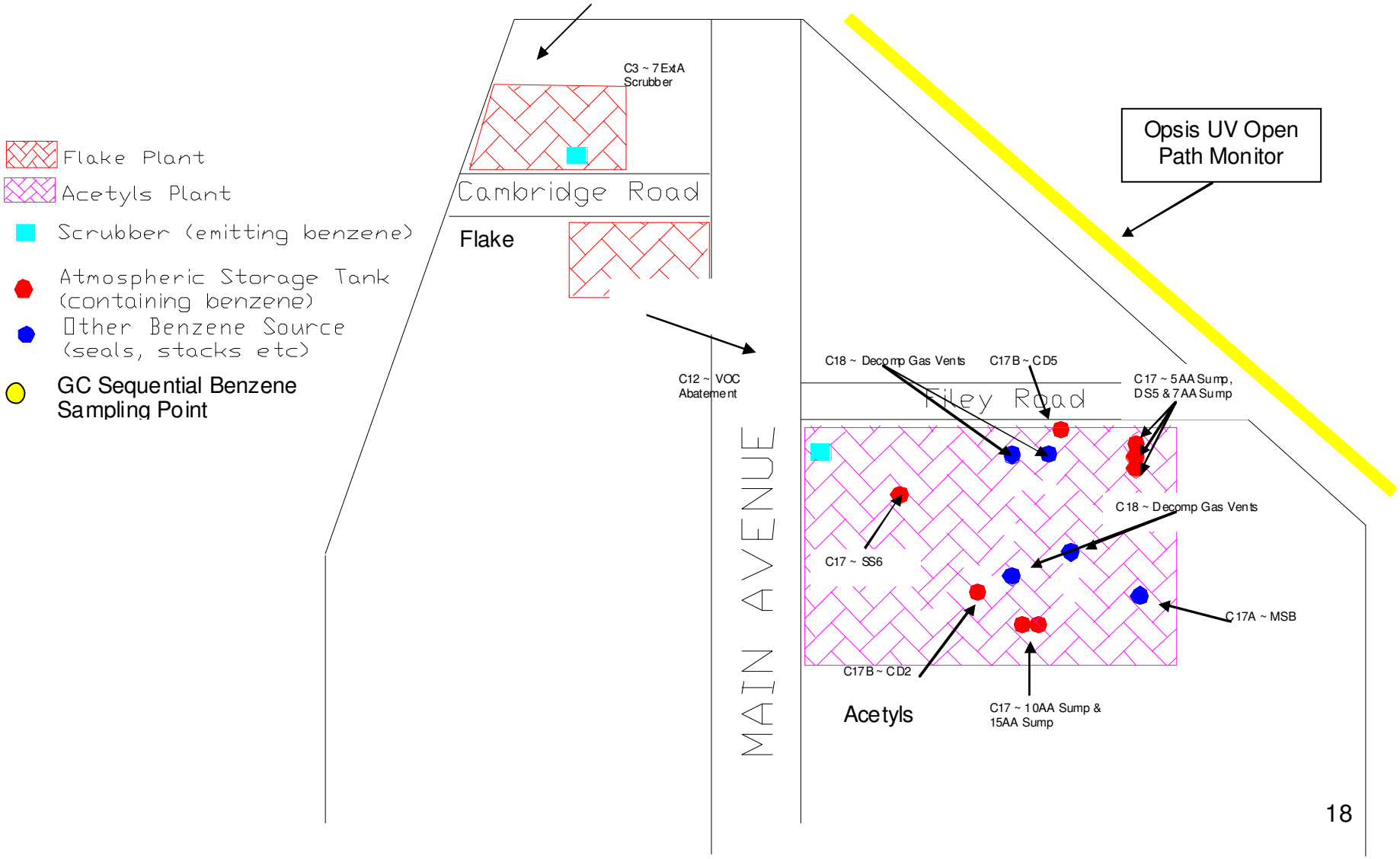
3. C17B - Acetyls Plant crucible drainage tanks (CD2 and CD5)

4. C18 - Acetyls plant decomposition gas (waste gas containing benzene), which is vented through 4 vents during the start-up of the anhydride units.

5. Extract hot condensate wash. The Opsis monitoring recently identified this to be the largest remaining point source. This is both in terms of the amount of benzene released and the duration over which the emissions take place. As compared to the relatively short-lived decomposition gas emissions of around 20 minutes, the extract hot condensate wash can emit low levels of benzene for several days at a time. Approximately 20 hot condensate washes take place each year.

6. Fugitive emissions

Map 2, Benzene Release Points



In accordance with the requirements of the existing authorisation, Acetate Products produced an Improvement Plan to address the benzene emissions arising from all of these Acetyls and Flake Plant sources. An integral part of this plan was the establishment of the Benzene Emissions Reduction Team (BERT), which meets every 6 weeks to consider progress with 3 key work streams:

1) Leak Detection and Repair (LDAR)

Best Available Technique (BAT) for reducing fugitive VOC emissions, is an ongoing programme of Leak Detection and Repair (LDAR). Rather than attempting to quantify the fugitive benzene emissions from this extensive and very complicated process, Acetate Products decided to implement the BAT of LDAR from the outset.

The ongoing programme of Leak Detection and Repair involves a continuous programme of walk-about surveys with a photo-ionisation detector. This means that all joints and pipe work will be surveyed for benzene leaks in a systematic manner. The majority of the leaks are able to be eliminated during the survey and if not, are scheduled in for future action. This is generally achieved with minimal expenditure.

A second photo-ionisation detector has now been purchased, to provide back-up support for this LDAR programme. It is anticipated that by December 2006, the survey of the highest risk plant will have been completed, with around half of the total relevant plant having been surveyed.

2) Elimination of Significant Point Sources

Acetate Products have systematically reduced and eliminated a number of their point source emissions, over a period of several years.

In accordance with Requirement 29 of their authorisation, Acetate Products have modified the decomposition gas system (C18) to minimise the normal venting of decomposition gas during start-ups. Further work on this venting is scheduled, in an attempt to eliminate this source of benzene emissions by the end of April 2006.

The main benzene storage tank (C17A) is no longer a source of benzene emissions, due to back venting works completed in 2004.

These improvements have resulted in a significant reduction in the estimated annual mass benzene emissions, as shown in Table 3. This is despite a year on year increase in production of flake from the Spondon site.

Table 3
Estimated Annual Mass Benzene Emissions

Year	Emission (tonnes)	Production (tonnes of flake)
1994	18.1	-
1995	12.5	-
1996	8.1	-
1998	8.0	-
1999	5.3	38,012
2000	4.6	37,031
2001	4.3	44,947
2002	4.2	49,841
2003*	4.7	51,952
2004	3.8	53,535
2005	2.9	57,375

** Increase in accuracy of method of recording mass benzene emissions (Reference 15 & 20)*

The annual mass benzene emissions in Table 3 provide an estimate of benzene emissions from all point sources, fugitive emissions inside buildings and all storage tanks.

Importantly however, the annual mass benzene emissions do not account for benzene emissions from external pipe work, which are considered to be a significant source of fugitive benzene emissions from site.

This is perhaps why, despite the significant and worthwhile reduction in these annual mass benzene emissions, the off-site annual average benzene concentrations continue to exceed the 2010 objective.

Work is continuing to eliminate significant point sources. Recent analysis of the Opsis monitoring data identified the Extract Hot Condensate Wash as the most significant point source of benzene emissions. Abatement of this significant point source has now been highlighted for action by September 2006.

It is anticipated that the necessary reduction in benzene emissions from the hot condensate wash will be able to be achieved procedurally. If capital spend is however required, the timescale of September 2006 may need to be extended.

C3 (flake plant scrubber) and C12 (acetyls plant VOC scrubber) are not considered significant sources of benzene emissions. In the case of C3, this point source is also located a considerable distance away from the site's north-eastern boundary. Consequently, neither C3 nor C12 are considered any further at this stage.

3) Elimination of Process Activity Emissions

Behavioural change has been critical to the identification and elimination of process activity emissions. The introduction by Acetate Products of an Opsis real-time analyser along the north-eastern site boundary in March 2005, facilitated this change.

The relay of continuous Opsis monitoring data to Acetate Product's control room, has increased employee awareness and as a result, employees are more proactive in identifying process activities which impact upon benzene concentrations at the site boundary. This enables action to be taken to eliminate or reduce the benzene emissions on a daily basis.

This approach has helped to change the culture of the organisation, with there now being a drive to make benzene emission reductions an integral part of day to day activities.

For example, rather than LDAR being classed as a special project, it is now an operational responsibility. The Operations Team review the Opsis monitoring data on a daily basis, in the context of the ongoing LDAR survey.

At the same time, the Benzene Emissions Reduction Team (BERT) now has time to deal with benzene emission reductions from the hot condensate wash as a stand-alone project.

3.0 EVALUATION OF UPDATING & SCREENING ASSESSMENT

Derby City Council's Updating and Screening Assessment (USA) was completed in March 2004. It considered 7 pollutants with National Air Quality Objectives, of which benzene is one.

Specifically in relation to benzene emissions, the USA considered all possible sources of benzene and locations of relevant public exposure. This was in accordance with the following checklist, which is provided by Technical Guidance LAQM TG(03):

Table 4
Summary of the Previous Updating and Screening Checklist for Benzene

Section	Source, location or data that need to be assessed	Detailed Assessment required?
A	Monitoring data	Yes
B	Very busy roads or junctions in built up areas	No
C	Industrial sources	No
D	Petrol stations	No
E	Major fuel storage depots	No

The USA concluded that it was possible that the 2010 annual average benzene objective of 5µg/m^3 may be exceeded at both the Anglers Lane and White House Nursery (north) monitoring sites. As a result, it was necessary to undertake a Detailed Assessment for Benzene.

The first stage of this Detailed Assessment for Benzene, is a review of the 2004 Updating and Screening Assessment. This involves reconsideration of both Sections A and C above, which relate to 'Monitoring Data' and 'Industrial Sources.'

3.1 Monitoring Data

Based on the results shown in Table 5, the USA concluded that in both 2000, 2001 and 2002, the Anglers Lane monitoring site exceeded the 2010 annual average benzene objective of 5µg/m^3. In 2001 and 2002, the White House Nursery (north) monitoring site also exceeded the 2010 annual average benzene objective.

Table 5
Annual Mean Benzene Concentrations (µg/m^3)

	Annual Mean 2000	Annual Mean 2001	Annual Mean 2002
Council House	3.7	3.5	3.1
White House Nursery (Nottingham Road)*	4.1	5.3	5.2
Anglers Lane	7.4	10.7	7.8
Asterdale Primary School	3.8	3.9	2.8
St John Fisher Primary School	2.8	3.1	2.8

** new site started in March 2000*

None of the benzene diffusion tube sites were found to exceed the 2003 annual average objective of 16.25µg/m^3.

In accordance with the guidance, the benzene concentrations were not corrected to future years. This is because there is no accurate means of predicting future exceedences from an industrial process. A subjective assessment of future benzene concentrations is however provided in this Detailed Assessment.

It was rightly concluded that, on the basis of the monitoring data provided in the USA, there was a need to proceed to a Detailed Assessment for industrial-related benzene.

3.2 Industrial Sources

Acetate Products was identified by the USA as being an industrial process that emits benzene. As a result, information was obtained on both the total annual emission of benzene and the stack parameters.

Although the 2002 annual mass emission of 4.2 tonnes was correct, the information relating to the stack parameters was not. The stack height of 107 metres was a significant over-estimate. This data presumably relates to the old power station stack, which is not a source of benzene. The highest benzene-emitting stack is the Acetyls Plant VOC abatement scrubber (C12), which is only 24 metres high.

The situation was further complicated by the benzene emissions from Acetate Products not originating from a single stack. Indeed, the majority of their benzene emissions are fugitive in nature. It is for this reason that it was not possible to use the nomograms provided in Technical Guidance LAQM TG(03).

In accordance with the same guidance, it was therefore necessary to proceed to a Detailed Assessment for Benzene due to 'Industrial Sources.' This was in contrast to the Updating and Screening Assessment, which concluded that this was only necessary due to 'Monitoring Data.'

3.3 Other Aspects of the USA

It is important to note that by undertaking the USA, all other potential sources of benzene in the vicinity have been able to be discounted as insignificant. This includes road-traffic exhaust emissions, the railway that runs adjacent to the north-eastern boundary of Acetate Products and Erewash Valley Service Station, 50 Nottingham Road, Spondon.

This view that Acetate Products is the only significant source of benzene in the Spondon area, is supported by the company's analysis of the initial Opsis monitoring data. This analysis concluded that Acetate Products was the main contributor to elevated off-site benzene concentrations in Spondon (6).

The need for a Detailed Assessment for Benzene in relation to Acetate Products, is supported by the company's own Management Plan. This plan was submitted to the Environment Agency in 2003 and concluded that where Acetate Products operate under normal conditions, it is possible that a breach of the 2010 objective for benzene will occur at nearby dwellings (7).

Having confirmed that a Detailed Assessment for Benzene was required, a suitable methodology has been produced. This methodology is described in following sections. It aims to determine the likelihood of a breach of the 2010 annual average benzene objective at dwellings, nurseries and schools in the vicinity of Acetate Products.

4.0 DISPERSION MODELLING

Dispersion modelling is a technique used to model the atmospheric dispersion of pollutants from industrial, commercial, domestic and traffic sources. In order to achieve this with an acceptable degree of accuracy, the assumptions used within the model need to make a reasonable representation of reality.

Dispersion modelling is advantageous, in that it is able to estimate pollution concentrations at locations at which it may not be physically or financially practical to place monitoring equipment. It also has the advantage of being able to predict pollutant concentrations into future years, taking into account both emission controls and changes to source emissions.

In the case of Acetate Products and this Detailed Assessment, dispersion modelling is however considered to be inappropriate. This is because dispersion models are better suited to use with either point sources or well-defined fugitive emissions.

Acetate Products benzene emissions cannot be accurately defined for 2 reasons:

1) A significant proportion of the Acetyls Plant is located outdoors. This means that the fugitive benzene emissions from this plant are not emitted from the volume source of buildings but rather from a large number of undefined sources on external structures.

2) With the exception of SS7 vent, seven of the eight benzene storage tanks (C17 and C17B) are considered to be fugitive emission sources. These tanks account for a significant proportion of the benzene emissions but cannot be accurately modelled. This is because the design of these tanks means that they cannot be defined as either area or volume sources.

All 7 of the benzene storage tanks vent into ground level bunds, as is shown in Photograph 1. This is with the exception of SS7 vent, which is a small vent on the top of the storage tank.

Photograph 1
Benzene Storage Tanks C17 and C17B - Venting Into Bunds

In the case of C17, 5 of the 6 tanks not only vent into bunds but also vent from down pipes:

Photograph 2
Benzene Storage Tanks C17 - Vent for Down Pipe

The venting arrangements for these benzene storage tanks mean that these fugitive emission sources do not represent area sources, as the benzene emissions arise from the vents and not the tanks. They also do not represent ground level point sources, due to the bunds inhibiting benzene dispersion.

The difficulty in accurately quantifying Acetate Product's fugitive emissions is further shown by the company's decision to implement the LDAR programme, rather than quantify emissions and set timetabled target reductions.

Even with a mass balance calculation to estimate the total fugitive loss from the process, the size and complex nature of the plant means that it would still be impossible to accurately attribute these emissions to specific points, areas and volumes.

The unsuitability of dispersion modelling is further demonstrated, by an assessment of the percentage split between fugitive and point source benzene emissions from Acetate Products.

A series of graphs have been produced of the 15-minute 2005 Opsis benzene monitoring data from the company's north-eastern boundary. This data has been restricted to the wind direction of 190 to 280 degrees, so as to only account for those times where there was a south-westerly wind. This wind direction blows benzene from the Acetyls Plant, directly towards the Opsis analyser.

Using this monitoring data for the prevailing wind direction, a number of 15-minute benzene concentrations have been linked with specific fugitive and point source benzene releases on site.

For the period between 11 March and 31 December 2005, of the 12,117 time periods, 90 have been linked to point source emissions. This means that based on this approximation, there is a 99.26% and 0.74% split between fugitive and point source emissions.

Of this very small point source contribution recorded by the Opsis analyser, given that it has been picked up at the site boundary, it will in any case behave as a fugitive emission once it crosses the site boundary towards relevant points of public exposure.

Although the calculation of point source and fugitive emissions is likely to be an over-estimate of fugitive emissions, it does provide further evidence of the significant fugitive element of the benzene emissions from Acetate Products.

The reasons for the likely over-estimate in the above calculation are twofold:

1. All unidentified emissions have by default been recorded as fugitive emissions. Some of these emissions are likely to be due to either point source emissions or background suburban benzene concentrations.

2. Several of the point source benzene emissions have significantly higher concentrations than those associated with fugitive benzene emissions. No account has been able to be taken of the relative size of the 15-minute benzene concentrations.

Even if dispersion modelling were to be undertaken of the relatively small 0.74% point source contribution, this could not be done to a sufficient degree of accuracy for 2 reasons:

1) The stacks are generally either horizontal or inverted. Dispersion modelling is unable to accurately account for the resultant effect of these stacks on inhibiting dispersion.

2) Acetate Products' site contains a large number of buildings and many high temperature processes. Again, these issues significantly reduce the accuracy of dispersion modelling.

The decision not to use dispersion modelling as part of the methodology for this Detailed Assessment is supported by the Modelling Helpdesk (Reference 11), the Environment Agency (12) and Acetate Products (13). Supporting letters from both the Environment Agency and Acetate Products are included as Appendices 1 and 2.

In summary, dispersion modelling is only worthwhile, if the modelled predictions are accurate enough to assist in determining the geographical extent of any Air Quality Management Area.

This is not considered to be the case in this instance. Consequently, the outcome of this Detailed Assessment will rely upon a combination of the data obtained from the extended and upgraded benzene monitoring network and professional judgement.

5.0 MONITORING

The City Council has monitored ambient benzene concentrations in the vicinity of Acetate Products since 1999. It was as a result of this monitoring data, that the 2004 Updating and Screening Assessment concluded there was a need for a Detailed Assessment for Benzene.

In Spring 2004, a fundamental review was undertaken of the existing benzene monitoring network. This was with a view to creating a benzene-monitoring network, which would provide an extensive range of high quality benzene monitoring data, for the purpose of enabling a decision to be made as the geographical extent of any necessary Air Quality Management Area.

Critical to this monitoring network, was therefore the ability to use the monitoring data to determine the likelihood of a breach of the 2010 annual average benzene objective of 5µg/m^3. This is in relation to dwellings, nurseries and schools in the vicinity of Acetate Products

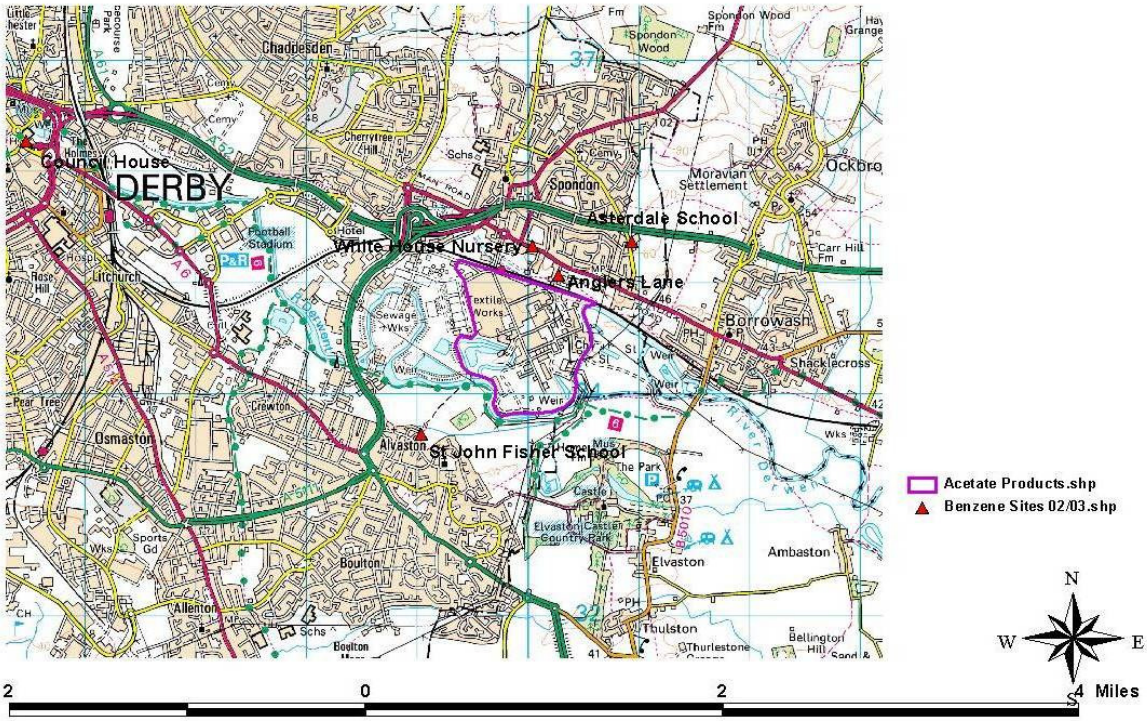
The need for an extensive high quality benzene-monitoring network is further underlined by the fact that dispersion modelling is unsuitable for this particular Detailed Assessment.

5.1 Existing Monitoring Strategy

Between 2000 and August 2004, a network of 5 benzene diffusion tubes was used to assess ambient benzene concentrations in Spondon. Four of these tubes were located at dwellings close to the Acetate Products and the fifth was located at the Council House, representing an urban background site.

All of the tubes were collected on a fortnightly basis. These diffusion tubes were then analysed by Casella UKAS accredited laboratories.

Map 3
2003 Benzene Tube Locations



In addition to the City Council's network of diffusion tubes, Acetate Products provided co-located tubes at both the Anglers Lane and White House Nursery (north) sites. They also maintained their own network of on-site benzene diffusion tubes.

The 2 off-site diffusion tubes were used to help validate the benzene monitoring data for Anglers Lane and White House Nursery (north). This issue was complicated by possible laboratory bias, due to the City Council and Acetate Products using different UKAS accredited laboratories to undertake their analysis.

Acetate Products used their network of on-site diffusion tubes to assist in their benzene emissions reduction programme.

5.2 New Monitoring Strategy

Acetate Products is a large industrial process, with a number of dwellings in close proximity along its north-eastern boundary.

The majority of the benzene emissions from Acetate Products are emitted from its Acetyls Plant, which is located close to its north-eastern boundary. The prevailing south-westerly wind carries these benzene emissions in the direction of the nearby dwellings for a substantial proportion of the time.

The factory is located on the flood plain of the River Derwent. As a result, the factory is at a lower altitude than many of the nearby dwellings, with a noticeable increase in altitude with distance from the factory's north-eastern boundary.

The combination of benzene emissions close to dwellings, the prevailing south-westerly wind and the gradient, makes the resultant atmospheric dispersion of benzene difficult to predict. This is especially so, given that the majority of the benzene emissions are from fugitive sources and therefore cannot be linked back to specific stacks.

The long averaging period of a year in the objective, means that the annual average peak off-site benzene emission is likely to occur within the direction of the prevailing wind. What was then unknown, was the distance at which this peak level would occur from the site boundary. This was due to uncertainty regarding the relative impact of fugitive and point source benzene emissions.

It was evident that, for the purpose of this Detailed Assessment, the existing network of 5 benzene diffusion tubes and 2 co-located tubes was insufficient. Only by significantly increasing the size of the network, would it be possible to accurately predict those points of relevant public exposure at risk of exceeding the 2010 objective.

In addition to problems with the size of the existing benzene-monitoring network, inadequacies were also identified with the monitoring network itself.

The monitoring network at that time consisted entirely of benzene diffusion tubes. A local bias correction factor could not be applied, in the absence of a co-location study of triplicate tubes with a recognised reference analyser. In effect, there was therefore no means of determining the accuracy of the indicative diffusion tubes.

The benzene diffusion tubes themselves were only co-located at the Anglers Lane and White House Nursery (north) sites. Even at these sites, the use of different laboratories meant that the accuracy was reduced, due to possible laboratory bias. Furthermore, Technical Guidance LAQM TG(03) recommends the use of more accurate BTEX diffusion tubes, rather than benzene diffusion tubes.

BTEX diffusion tubes have the advantage that in addition to benzene, they also measure toluene, ethylbenzene and the xylene concentrations. This information increases the accuracy of the data ratification process, through analysis of their respective ratios.

As a result of this critical analysis of the existing benzene-monitoring network, a new benzene-monitoring network was commissioned in August 2004. This network consists of 17 co-located BTEX diffusion tubes and a co-location study of triplicate BTEX diffusion tubes with a pumped tube sampler.

At the same time as the upgrade to the existing off-site monitoring network, Acetate Products also upgraded their on-site network. More recently, in March 2005 an Opsis analyser was sited along Acetate Product's north-eastern site boundary. This continuous analyser replaced the indicative network of BTEX diffusion tubes.

5.2.1 BTEX Diffusion Tubes

The Council's revised network of 18 monitoring locations was commissioned in August 2004. These locations are listed in Table 6. With the exception of the Council House, all of the new monitoring locations are also shown in Maps 4 and 5.

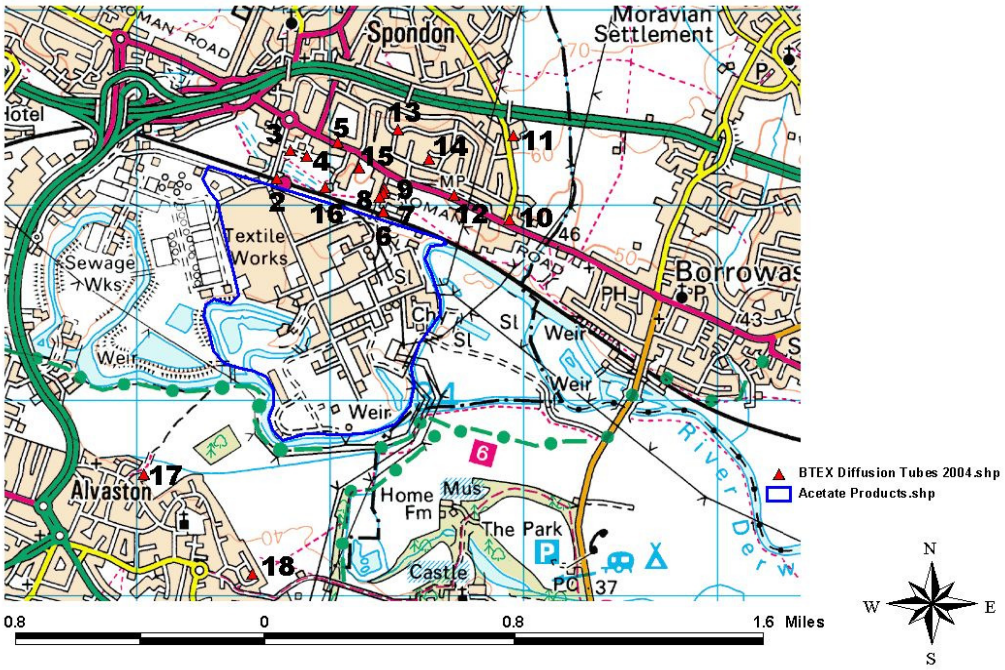
Table 6 - Part 1
2005 Benzene Monitoring Locations - see Maps 4 & 5

Tube Number	Description
1	Council House *(not shown on Map 2)*
2	Station House
3	8 Oakfields Grove
4	33 Willowside Green
5	White House Nursery (north)
6	43 Anglers Lane (Pumped tube sampler)
7	41 Anglers Lane
8	Telegraph pole opposite 37 Anglers Lane
9	Lamp post north of 37 Anglers Lane
10	354 Borrowash Road
11	Asterdale Primary School

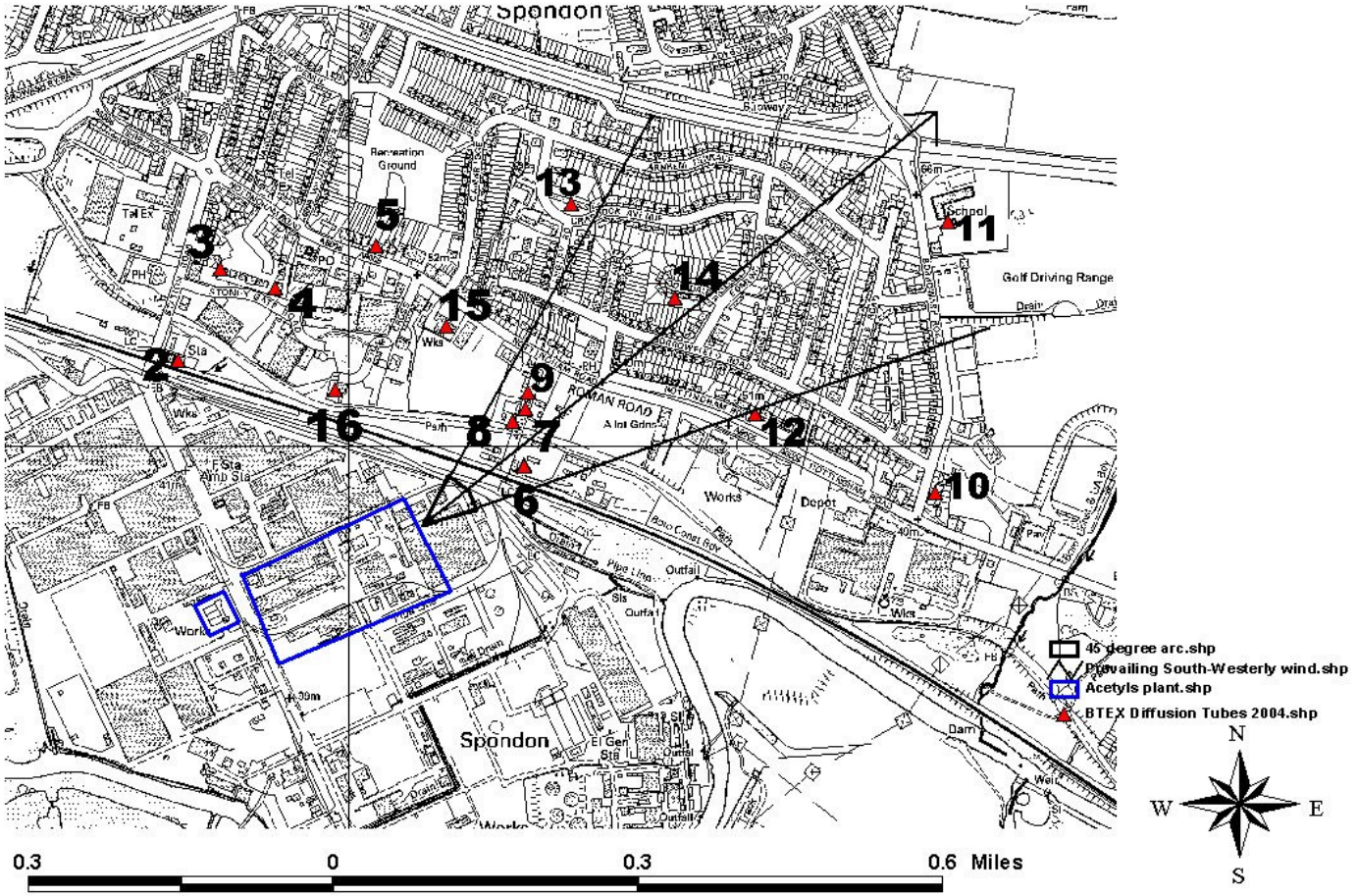
Table 6 - Part 2
2005 Benzene Monitoring Locations

Tube Number	Description
12	197 Nottingham Road
13	17/19 Craddock Avenue
14	15 Dovedale Road
15	White House Nursery (south)
16	24 Stoney Cross
17	St John Fisher Primary School
18	Caroline Close

Map 4
2004 & 2005 BTEX Tube Locations



Map 5
2004 & 2005 BTEX Tube Locations for Tubes 2 to 16



The 18 monitoring locations were carefully chosen to represent a sample of those dwellings, nurseries and schools that may be affected by benzene emissions from Acetate Products. The Council House represents an urban background-monitoring site.

These monitoring locations also represent a variety of distances and elevations from the Acetate Products factory. They are primarily located within a 45-degree arc of the prevailing south-westerly wind, using the north-eastern boundary as the base of this arc (see Graph 2 wind rose).

In order to confirm the significant effect of the prevailing wind upon off-site benzene concentrations, monitoring locations outside of the 45 degree arc and to the south of the site, were chosen at St John Fisher School and Caroline Close.

Following the identification of possible monitoring locations, on-site surveys were conducted to determine the practicalities of each location. Consideration was given to accessibility, the risk of vandalism and the willingness of people to have the box shown in Photographs 3 and 4, located on their facade.

Photographs 3 and 4
BTEX Tubes in Enclosures

The enclosure for the co-located BTEX diffusion tubes, reduces the risk of rainwater affecting the results. Wire gauze filters on the sampling ends of the tubes, reduce the risk of contamination of the tubes.

Until December 2005, the financing of the off-site network of BTEX diffusion tubes was shared between Derby City Council and Acetate Products. Employees from both organisations were also involved in the fortnightly changing of the BTEX tubes.

The diffusion tube survey is now managed by the City Council, with Acetate Products supplying 4 of the BTEX diffusion tubes. Acetate Products now finance and operate the Opsis analyser.

Analysis of all the off-site and on-site BTEX tubes has been undertaken by the National Physical Laboratory (NPL), since August 2004. The pumped tube sampler is also maintained and annually serviced by NPL. Previously, Casella and CERAM analysed the City Council and Acetate Products diffusion tubes respectively.

For quality assurance purposes, a blank BTEX tube is provided by NPL every fortnight. Analysis of this tube is used to demonstrate that the tubes themselves are not a source of benzene contamination.

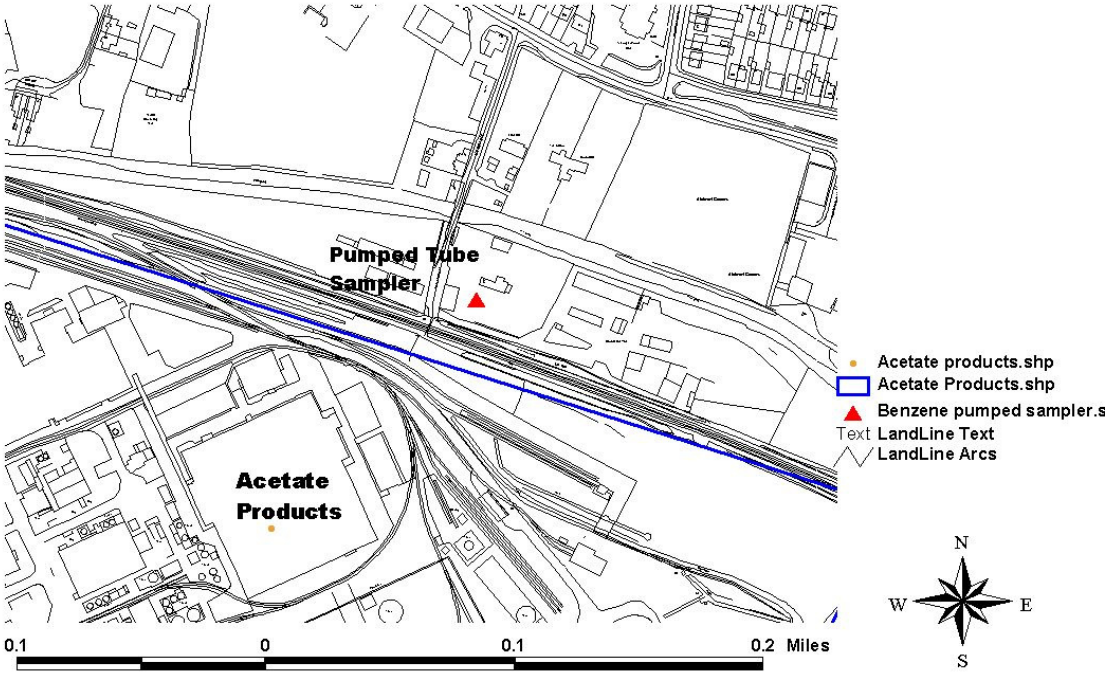
In terms of data validation and ratification, a precautionary approach has been employed. Unless there is reasonable confidence that a diffusion tube result is invalid, it has therefore been included. In this way, the diffusion tube monitoring results are not positively or negatively skewed.

Finally, a decision was made to maintain the fortnightly sampling period , as this provides more detailed and therefore accurate monitoring data than monthly analysis.

5.2.2 Pumped Tube Sampler

In August 2004, a benzene pumped tube sampler was commissioned, together with a co-location study of triplicate diffusion tubes. It is located in the rear garden on the façade of 43 Anglers Lane (see Map 6, Photographs 5 & 6):

Map 6
Pumped Tube Sampler at 43 Anglers Lane



Photographs 5 and 6
Pumped Tube Sampler

The need for a reference sampler is identified by technical guidance LAQM TG(03). Following advice from Defra's Air Quality Monitoring Helpdesk, a pumped tube sampler was deemed to be the most appropriate monitor available (Reference 3). Pumped tube samplers have been used by the UK Hydrocarbon Network since 2001.

Pumped tube samplers are recognised as meeting the requirements of BS EN 14662-1:2005 "Ambient Air Quality - Standard Method for Measurement of Benzene Concentrations - Part 1: Pumped Sampling Followed by Thermal Desorption and Gas Chromatography."

Pumped tube samplers are also due to be included in the European Committee for Standardisation's (CEN) list of standard methods to be used to comply with EU Directives (18).

The advantage of employing a pumped tube sampler with off-site gas chromatography, is that it is relatively inexpensive. As the benzene Air Quality Objective is an annual average, it is sufficient to obtain an average measurement for the same fortnightly sampling periods as the BTEX diffusion tubes.

The pumped tube sampler is inherently more accurate than the indicative BTEX diffusion tubes, which rely on the natural uptake rate of the tube and are therefore affected by both wind and moisture. In comparison, the pumped tube samples air at a pre-determined flow rate alternately through 2 absorption tubes. At the end of the sampling period, the tubes are sent to the NPL laboratory for analysis, which is UKAS accredited.

Laboratory analysis uses thermal desorption gas chromatography to measure the mass of pollutants measured. Using the recorded volume of atmospheric gas sampled, the fortnightly average concentrations of benzene, toluene, ethylbenzene and xylene are then calculated.

The use of two tubes enables measurement repeatability to be checked, with an average difference between analysed duplicate tubes of approximately 3.1%. The estimated overall uncertainty in the benzene measurements from the pumped tube sampler is +/-12% at the 95% confidence limit (Reference 4). BTEX diffusion tubes have an estimated uncertainty of +/-21% at the 95% confidence limit (Reference 5).

Subsequently, an annual average bias correction factor can be calculated using the results of the triplicate BTEX diffusion tube co-location study. This bias correction factor is then applied to the rest of the BTEX diffusion tube network.

In terms of quality assurance, a blank BTEX tube is provided every 2 months, which is not exposed. This provides the benzene exposure level, as a result of the handling, storage and analysis of the pumped tubes. This in turn informs the process of data validation and ratification.

On the advice of both NPL and the Monitoring helpdesk, no account needs to be taken of laboratory bias when validating and ratifying the results for the benzene-monitoring network (Reference 16 & 17).

The rear façade of 43 Anglers Lane was chosen as a suitable location for the pumped tube sampler, due to this property only being 75 metres to the north-east of the Acetyls Plant. It is the closest property to this part of the site, where the majority of the benzene is believed to originate. Consequently, with a predominant south-westerly wind, 43 Anglers Lane represents a likely worst-case location for relevant public exposure.

This monitoring location also has a number of inherent advantages. The rear garden of 43 Anglers Lane is enclosed, so there is a low risk of vandalism. Most importantly, the Council also had the support and co-operation of the residents of 43 Anglers Lane. This was essential in terms of providing an electricity supply for the analyser, locating the analyser at a property façade and regularly accessing the analyser for analysis and maintenance purposes.

Derby City Council wishes to express its gratitude to the occupants of 43 Anglers Lane for their continued co-operation in this survey.

5.2.3 On-Site Monitoring

Acetate Products established its on-site benzene-monitoring network, in order to increase its understanding of its fugitive and point source benzene emissions. In this way, it can employ cost-effective abatement techniques, in order to ensure compliance with the 2010 objective for benzene.

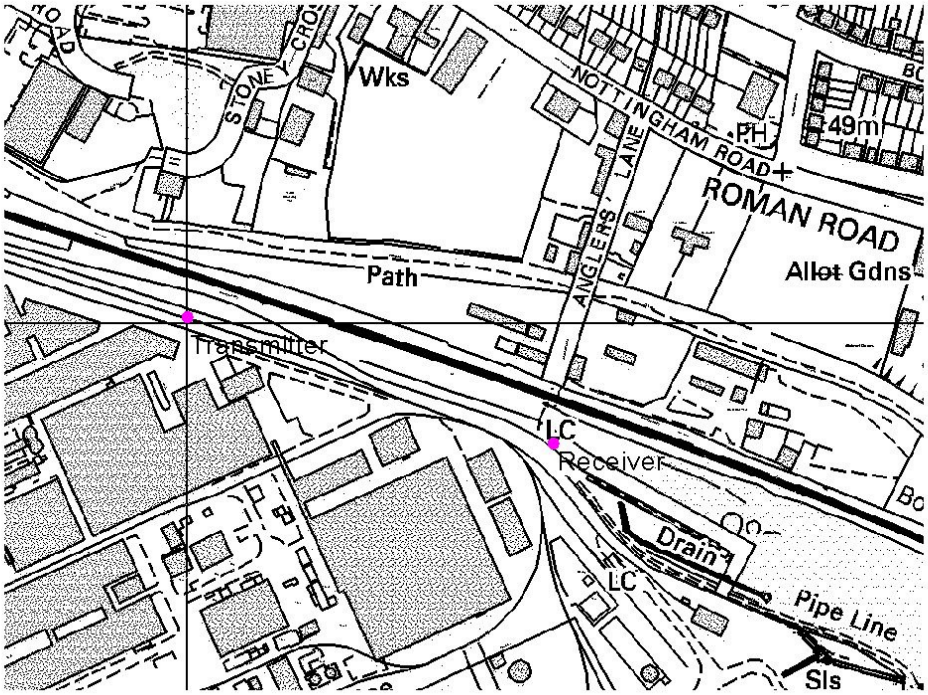
The on-site monitoring network was upgraded in August 2004, from benzene diffusion tubes to BTEX diffusion tubes. This change coincided with the improvements made to the off-site benzene-monitoring network and, for the sake of consistency with the Council, NPL were also contracted to provide and analyse the new network.

In March 2005, Acetate Products invested in a real-time Opsis analyser and associated meteorological station. This equipment is sited along the company's north-eastern boundary, at the southern end of Anglers Lane (see Map 7, Photographs 7-9).

The real-time Opsis monitoring data provides more accurate benzene monitoring data than the indicative BTEX diffusion tubes, enabling on-site activities to be linked to off-site benzene concentrations with a high degree of confidence. This is why at the end of 2005, Acetate Products discontinued on-site diffusion tube monitoring, instead concentrating its efforts on interpreting the Opsis monitoring data.

Opsis monitors use open-path monitoring. This involves a beam of light being sent from a transmitter to a receiver, in this case over a distance of 253 metres. Differential Optical Absorption Spectroscopy (DOAS) is then used to calculate how much the light has been distorted and therefore the BTEX concentrations.

Map 7
Opsis Analyser



Photographs 7 and 8
Opsis Analyser

Photograph 9
Meteorological Station for the Opsis Analyser

In contrast to the pumped tube sampler, which is located at 43 Anglers Lane, the Opsis analyser has a number of inherent advantages.

1) It gathers data every 2 minutes and therefore has a better time resolution than the pumped tube sampler.

2) The real-time nature of the results makes the Opsis analyser suitable for correlating boundary benzene concentrations with on-site activities.

3) It simultaneously measures BTEX gases, which facilitates investigative work.

4) The path of several hundred metres provides a substantial amount of averaging and thus a more representative measurement than traditional point measurement techniques. This makes the Opsis analyser ideal for this type of 'fence line' boundary monitoring.

Although the Opsis analyser has advantages over a pumped tube sampler, it cannot be used for the purpose of the co-location study in this Detailed Assessment. This is because:

1. Pumped tube samplers are the reference sampler for benzene.

2. The Opsis analyser is not located at points of relevant exposure.

1. BTEX diffusion tubes cannot physically be co-located with an Opsis analyser. This is because the benzene is measured as an average concentration along an integrated path, rather than at a single measurement point.

6.0 MONITORING RESULTS

In terms of validation and ratification of the data, a number of checks have been made.

Each BTEX diffusion tube is deployed in the field for a fortnight. Consequently, no information is provided on maximum and minimum benzene concentrations during this fortnightly averaging period. This means that a precautionary approach has been adopted for data ratification purposes, whereby results are only considered to be invalid when this can be confidently assumed.

The results of the October 2004, February 2005 and January 2006 pumped tube sampler audits have been used to scale the recorded data. Since the last service was undertaken on 24 January 2006, all of the benzene results reported in this Detailed Assessment are considered to be fully validated and ratified.

Cross-referencing between co-located tubes, other tubes in the network and the pumped tube sampler has also taken place. This is within the context of a measurement uncertainty of +/-12% for the pumped tube sampler and +/-21% for the BTEX diffusion tubes.

Account has been taken of the ratios of benzene, toluene, ethylbenzene, (m + p)-xylene and o-xylene recorded at each BTEX tube. Where there has been a marked variation in the ratio of pollutants normally observed, further consideration has been given to the validity of the data.

Blank tubes have been used with both the diffusion tubes and the pumped tube sampler, in order to provide further confidence in the results obtained. Finally, reference has been made to the pumped sampler and BTEX tubes logbooks. In this way, account has been able to be taken of problems with data collection and/or analysis.

In relation to the validated and ratified results, pumped tube samplers are a more accurate means of measuring ambient benzene concentrations than diffusion tubes. This is why the pumped tube co-location study results have been used in Table 7, to correct the BTEX diffusion tube results.

Table 7
Co-Location Study Results for 43 Anglers Lane

Data	Grid Ref	17 August 2004 - 31 December 2004	1 January 2005 - 31 December 2005
C_m = Benzene Concentration at Pumped Tube Sampler (µg/m^3)	440280 334969	13.1	7.43
Data Capture for Pumped Tube Sampler	N/A	67%	92%
D_m = Benzene Concentration for 3 BTEX Diffusion Tubes (µg/m^3)	440280 334969	9.8	4.9
Bias Correction Factor (C_m/D_m)	N/A	1.34	1.52
Diffusion Tube Bias ($D_m - C_m/C_m$)	N/A	- 25.2%	-34.1%

Based on the co-location study results in Table 7, bias correction factors of 1.34 and 1.52 have been applied to the BTEX diffusion tube results in Table 8.

The difference between the values for C_m in Table 7 and the benzene concentration for 43 Anglers Lane in Table 8 - Part 1, arises from C_m only representing the period when the co-located pumped tube data was available. As is shown by the data capture rates, the co-location study was operational for 67% and 92% of the sampling periods in question.

The bias correction factors of 1.34 and 1.52 are broadly similar to those used by NPL, although no formal work has been published in this respect.

In 2002, NPL undertook an internal quality control check for 24 monitoring sites. For 4 sites this was over a 12-month period and for the remaining 20 sites, it was over a 1 to 3 month period. The average bias correction factor across all of these sites was found to be 1.22 (Reference 17).

This 1.22 bias correction factor supports the results obtained from the City Council's own co-location study at 43 Anglers lane, demonstrating that BTEX diffusion tubes consistently under-read.

This under-read is within the upper range of acceptability, given that at the 95% confidence limit, BS EN ISO 16017-2: 2003 provides overall uncertainties of +/-30% for BTEX diffusion tubes. Although NPL's own uncertainty for BTEX measurements is +/-21%, there is also a +/-12% uncertainty associated with the pumped tube sampler (Reference 4 & 5).

Table 8 - Part 1

Average of Co-Located BTEX Diffusion Tube Results for New Monitoring Locations

Monitoring Location	Grid Reference	Distance to Acetate Products' boundary (metres)	Monitoring Location	Bias Adjusted Benzene Concentrations 17 August 2004 - 31 December 2004 ($\mu g/m^3$)	Bias Adjusted Benzene Concentrations 1 January 2005 - 31 December 2005 ($\mu g/m^3$)
43 Anglers Lane (pumped tube)	440280 334969	43	Facade	12.1	8.3
Station House	439730 335139	47	Kerbside	2.7	2.5
8 Oakfields Grove	439796 335282	189	Facade	2.6	2.6
33 Willowside Green	439886 335251	196	Facade	3.1	3.1
41 Anglers Lane	440261 335040	100	Facade	12.1	8.4

Table 8 - Part 2
Average of Co-Located BTEX Diffusion Tube Results for New Monitoring Locations

Monitoring Location	Grid Reference	Distance to Acetate Products' boundary (metres)	Monitoring Location	Bias Adjusted Benzene Concentrations 17 August 2004 - 31 December 2004 ($\mu g/m^3$)	Bias Adjusted Benzene Concentrations 1 January 2005 - 31 December 2005 ($\mu g/m^3$)
Telegraph pole opposite 37 Anglers Lane	440282 335056	129	Kerbside	10.7	12.8*
Caravan adjacent to 43 Anglers Lane	440282 334964	53	Facade	-	7.1*
354 Borrowash Rd	440926 334928	352	Facade	2.8	2.2
197 Nottingham Rd	440644 335054	237	Facade	4.5	3.4

*Change in monitoring location on 2 March 2005, from Telegraph Pole opposite 37 Anglers Lane, to caravan adjacent to 43 Anglers Lane. The results for the telegraph pole represent a 2 month monitoring period when the ambient benzene concentrations were high.

Table 8 - Part 3
Average of Co-Located BTEX Diffusion Tube Results for New Monitoring Locations

Monitoring Location	Grid Reference	Distance to Acetate Products's boundary (metres)	Monitoring Location	Bias Adjusted Benzene Concentrations 17 August 2004 - 31 December 2004 ($\mu g/m^3$)	Bias Adjusted Benzene Concentrations 1 January 2005 - 31 December 2005 ($\mu g/m^3$)
17/19 Craddock Avenue	440352 335384	460	Facade	4.3	3.2
15 Dovedale Road	440518 335233	370	Facade	4.7	3.8
White House Nursery (south)	440155 335193	216	Facade	6.1	4.8
24 Stoney Cross	439977 335092	80	Facade	4.1	4.7
Caroline Close	439612 333113	707	Kerbside	1.5	1.5

Table 8 provides benzene concentrations for the period 17 August 2004 to 31 December 2004, as well as 2005 annual average benzene concentrations.

The 2005 annual average concentrations are for an entire calendar year and therefore account for seasonal variations in pollution concentrations. The 2004 concentrations do however only represent a 4 month averaging period.

In order to convert the short-term 2004 monitoring data for the new monitoring sites, into an estimate of the 2003 annual average benzene concentrations, use has been made of the methodology provided in Box A1.3 in Technical Guidance LAQM.TG(03) (see Table 8).

The resultant adjustment is considered appropriate, based on the fact that patterns in pollutant concentrations usually affect a wide region. Thus if a 3-month period is above average at one location, it will almost certainly be above average at other locations in the region.

Although this approach is less appropriate to industrial-based benzene than road-traffic based NO_2, it is the best approach available and is in accordance with advice from the Monitoring Helpdesk.

Three long-term automatic monitoring sites have been chosen from the national network, namely Leamington Spa, Stoke and Barnsley. All 3 of these sites are urban background sites, with similar characteristics to the Spondon area.

Table 9
Adjustment to Estimate Annual Average 2003 Benzene Concentrations

Long Term Site	Annual Mean 2003 ($\mu g/m^3$) (A_m)	Period Mean August - December 2004 ($\mu g/m^3$) (P_m)	Ratio (A_m/P_m)
Leamington Spa	1.27	1.2	1.058
Stoke-on-Trent	1.8	1.44	1.25
Barnsley	0.98	0.69	1.42
		Average Ratio	1.243

As a result of this approximation, a factor of 1.243 is used in Table 10, to convert the 2004 short-term benzene concentrations into 2003 annual average benzene concentrations.

Table 10 - Part 1
Estimated 2003 Annual Average Benzene Concentrations

Monitor	Grid Ref.	Bias Adjusted Measured Benzene Concentrations 17 August 2004 - 31 December 2004 ($\mu g/m^3$)	Estimated Annual Average Benzene Concentrations 1 January 2003 - 31 December 2003 ($\mu g/m^3$)
43 Anglers Lane (pumped tube)	440280 334969	12.1	15.0
Station House	439730 335139	2.7	3.4
8 Oakfields Grove	439796 335282	2.6	3.2
33 Willowside Green	439886 335251	3.1	3.9
41 Anglers Lane	440261 335040	12.1	15.0
Telegraph pole opposite 37 Anglers Lane	440282 335056	10.7	13.3
354 Borrowash Road	440926 334928	2.8	3.5
197 Nottingham Road	440644 335054	4.5	5.6
17/19 Craddock Avenue	440352 335384	4.3	5.3

Table 10 - Part 2
Estimated 2003 Annual Average Benzene Concentrations

Monitor	Grid Ref.	Bias Adjusted Measured Benzene Concentrations 17 August 2004 - 31 December 2004 ($\mu g/m^3$)	Estimated Annual Average Benzene Concentrations 1 January 2003 - 31 December 2003 ($\mu g/m^3$)
15 Dovedale Road	440518 335233	4.7	5.8
White House Nursery (south)	440155 335193	6.1	7.6
24 Stoney Cross	439977 335092	4.1	5.1
Caroline Close	439612 333113	1.5	1.9

For the 5 former benzene diffusion tube locations, the benzene diffusion tubes were upgraded to BTEX diffusion tubes in August 2004. Since these benzene diffusion tubes were on site for the whole of the 2004 calendar year, there is no need to estimate annual average benzene concentrations for 2003.

The 2004 annual average benzene concentrations are shown in Table 11. The bias corrected BTEX diffusion tube results for 17 August to 31 December 2004 have been combined with the benzene diffusion tube results for 7 January 2004 to 18 August 2004.

The pumped tube sampler was not commissioned until 17 August 2004, so a bias correction factor has been unable to be applied to the January to August 2004 element of these results.

Table 11
2004 Annual Average Benzene Concentrations

Monitor	Grid Ref	Distance to Acetate Products' boundary (metres)	Monitoring location	Benzene Diffusion Tubes 7 Jan 2004 - 4 August 2004 ($\mu g/m^3$)	Bias Adjusted BTEX Diffusion Tube Results 17August - 31 Dec 2004 ($\mu g/m^3$)	Time- Weighted 2004 Annual Average Benzene ($\mu g/m^3$)
Lamp post north of 37 Anglers Lane*	440279 335087	152	Kerbside	5.7	9.9	7.3
White House Nursery (north)	440045 335320	307	Facade	2.9	3.4	3.1
Asterdale Primary School	440948 335356	641	Facade	1.5	2.4	1.9
St John Fisher School	439043 333619	711	Facade	1.2	1.6	1.5
Council House	435473 336253	4,018	Urban background	1.4	2.0	1.6

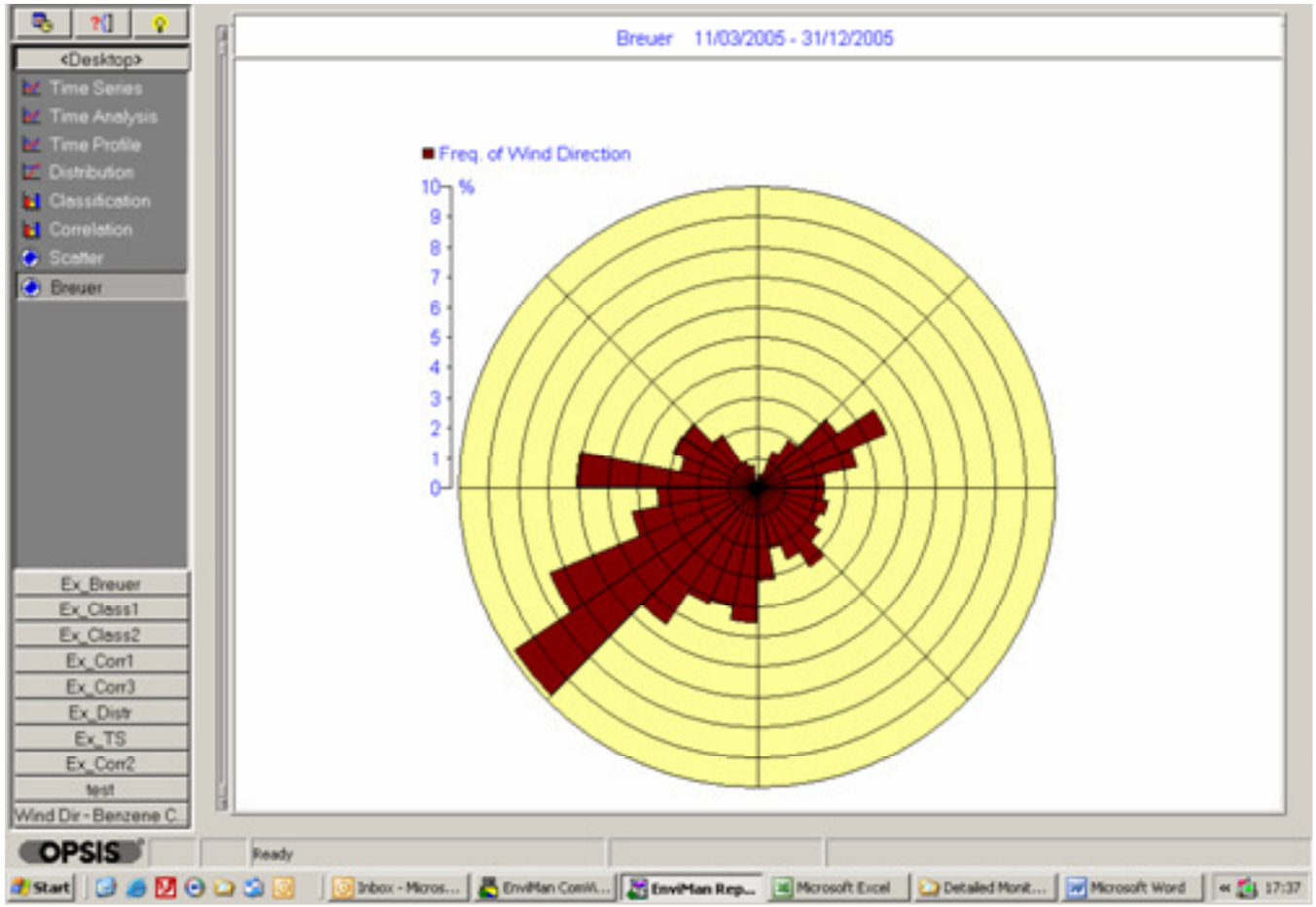
Change of monitoring location in summer 2003, a few metres north of original monitoring location, to lamp post at grid reference 440270 33506,

Table 12
Original Monitoring Locations, Annual Average Benzene Diffusion Tube Results (µg/m^3)

Monitoring Location	Grid Reference	2000	2001	2002	2003	2004#	2005@
Lamp post north of 37 Anglers Lane	440279 335087	7.4	10.7	7.8	5.4*	7.3	7.3
White House Nursery (north)	440045 335320	4.1	5.3	5.2	3.6	3.1	3.4
Asterdale Primary School	440948 335356	3.8	3.9	2.8	2.0	1.9	2.4
St John Fisher Primary School	439043 333619	2.8	3.1	2.8	2.5	1.5	1.3
Council House	435473 336253	3.7	3.5	3.1	1.9	1.6	1.6

* Change of monitoring location in summer 2003, to lamp post slightly further north at grid reference 440270 335068
# 2004 annual mean combines benzene and BTEX diffusion tube measurements
@ Bias correction factor of 1.53 has been applied to 2005 annual mean

Graph 2 - Wind Rose for Opsis Analyser, 11 March to 31 December 2005



This wind rose confirms that there is a prevailing south-westerly wind in the vicinity of Acetate Products.

7.0 ANALYSIS OF MONITORING RESULTS

1) Benzene levels in Spondon currently meet the 2003 annual average National Air Quality Objective for Benzene of 16.25µg/m^3.

2) Between 2000 and 2005, a number of exceedences of the 2010 annual average National Air Quality Objective for Benzene of 5µg/m^3, have occurred at a number of points of relevant public exposure.

3) Within the context of the monitoring results recorded to date and the 2010 objective of 5µg/m^3, all monitoring locations on Anglers Lane consistently exceed the 2010 objective.

4) The monitoring locations at 24 Stoney Cross, White House Nursery (South), 15 Dovedale Road, 197 Nottingham Road and 17/19 Craddock Avenue also periodically exceed the 2010 objective. No exceedences were however recorded during 2005, which was the first calendar year for the more accurate and comprehensive BTEX diffusion tube network.

5) The 2003 estimated benzene concentrations are high in comparison to other years. This may be due to:

   - The predictions being based on just 6 months of 2004 benzene monitoring data. By their very nature, predictions will be less accurate than actual monitoring data. This is particularly so, given that they also rely upon national trends in urban background benzene concentrations. This trend may differ from the local trend in industrial benzene emissions.

   - During 17 August to 31 December 2004, the data capture rate for the pumped tube sampler was only 67%. This means that the bias correction factor is based on co-location study results that, in effect, were for significantly less than 6 months.

The data capture rate of 67% is less than the 90% recommended by technical guidance LAQQM TG(03). It was caused by technical problems with the analyser, which were unable to be highlighted until subsequent analysis of its BTEX pumped tubes.

- 2003 is considered to be a poor but not exceptional year for pollution. In the case of benzene, which is a volatile organic compound (VOC), the effect of the summer heat wave is likely to have been significant.

  Nevertheless, based on the Precautionary Principle, the 2003 estimated annual average concentrations have been taken to be valid. This means that the predicted benzene concentrations for both 41 and 43 Anglers Lane of 15µg/m^3 were only just below the 2003 objective of 16.25µg/m^3. They were also 3 times the 2010 objective of 5µg/m^3.

6) Through validation and ratification of the monitoring data, it is evident that the network of a pumped tube samplers and BTEX diffusion tubes is inherently accurate.

7) The results for the pumped tube sampler co-location study for 2004 and 2005, found the BTEX diffusion tubes to consistently under-read by between 25% and 34.1%. The resultant application of bias correction factors of 1.34 and 1.52 significantly increase the resultant benzene concentrations from the benzene-monitoring network.

   These large bias correction factors are deemed to be appropriate, falling within the upper range of accepted errors from these sampling methods. The pumped tube sampler has a measurement uncertainty of +/-12%, whilst NPL's BTEX diffusion tubes have an uncertainty of +/-21% (4 & 5).

8) The Council House, St John Fisher School and Caroline Close recorded no exceedences of the 2010 objective between 2000 and 2005.

This confirms the Council House's status as an urban background site, with low annual average benzene concentrations in common with other urban background sites across the country.

The monitoring sites at St John Fisher School and Caroline Close are sufficiently distant from Acetate Products and upwind, to represent suburban background sites. Benzene monitoring was therefore discontinued at these locations in January 2006.

9) In 2003, the Council House monitoring location recorded an annual average benzene concentration of 1.9µg/m^3, whilst Asterdale School recorded an annual average of 2.0µg/m^3. This school is sufficiently distant from Acetate Products, for the annual average benzene concentrations to have reduced to urban background levels.

10) In relation to the results obtained from the 5 original monitoring locations, these sites have existed since 2000. This means that it is possible to determine whether a trend exists within that period:

There has been a significant year on year reduction in benzene concentrations. Importantly however, this downward trend is evident at both the urban background site at the Council House and at the 4 monitoring locations in the vicinity of Acetate Products.

This means that the downward trend in the vicinity of Acetate Products is likely to be due to a combination of the national reduction in background benzene concentrations and Acetate Products' year on year reductions in benzene emissions. Evidence of the latter is provided in Table 3.

The results for the Non-Automatic Hydrocarbon Network in Table 2, as well as the Council House results in Table 12, provide evidence as to the relative effect of national reductions and abatement actions undertaken by Acetate Products.

From 2003 onwards, the reduction in measured benzene concentrations in Spondon, is almost entirely due to abatement actions undertaken by Acetate Products. This is encouraging, if further reductions in ambient benzene concentrations are to be achieved by Acetate Products.

11) In relation to the 2003 predictions and the 2004/2005 data, the highest ambient benzene concentrations were recorded at 43 and 41 Anglers Lane. In 2005, the respective annual average benzene concentrations at 41 and 43 Anglers Lane were 8.4 and 8.3µg/m^3.

This is in consequence of 43 and 41 Anglers Lane being the closest dwellings to the Acetyls Plant at Acetate Products, from which the majority of the benzene is emitted. These dwellings are also located downwind, as is shown in Map 5.

12) The diffusion tube located at the caravan adjacent to 43 Anglers Lane, recorded an average benzene concentration for March to December 2005 of 7.1µg/m^3. This is slightly less than the concentrations recorded at 43 and 41 Anglers Lane, possibly due to it being further to the east and therefore not being directly downwind.

13) Further north along Anglers Lane and at greater distance from Acetate Products, benzene concentrations continue to exceed the 2010 annual average objective for benzene.

The diffusion tube located on the telegraph pole opposite 37 Anglers Lane, recorded an estimated 2003 annual average benzene concentration of 13.3µg/m^3. The 2-monthly average concentration of 12.8µg/m^3 for January and February 2005 was again high, but coincided with 2 months of elevated benzene concentrations across the network.

The monitoring location on Anglers Lane at the lamppost north of number 37 Anglers Lane, is the most northerly of the monitoring locations on Anglers Lane. An exceedence of the 2010 objective was recorded at this monitoring location every year between 2000 and 2005. The 2005 annual average concentration was 7.3µg/m^3.

14) Further still from Acetate Products but again downwind from it, several other monitoring locations recorded exceedences of the 2010 objective in 2003, although not in 2005.

White House Nursery (South) was estimated to have a 2003 annual average benzene concentration of 7.6µg/m^3. 15 Dovedale Road, 197 Nottingham Road and 17/19 Craddock Avenue were estimated to have 2003 annual average benzene concentrations of 5.8µg/m^3, 5.6µg/m^3 and 5.3µg/m^3.

The 2003 elevated benzene concentrations recorded at these locations are not considered to arise from the grounding of point source emissions at points of higher altitude. They are more likely to be due to the natural dilution with distance of benzene from the Acetyls Plant, within the context of a prevailing south-westerly wind.

This is because analysis of the Opsis data, has shown that the point source emissions are evident along its measurement path and therefore reach ground level prior to crossing the site boundary. Once off-site, these point source emissions behave as fugitive emissions, combining with the significant proportion of fugitive emissions that arise from site.

15) Evidence of reduced benzene concentrations with distance from Anglers Lane and the effect of the prevailing wind, is supported by the monitoring results for Stoney Cross, Station House, Oakfields Grove, Willowside Green, Borrowash Road and White House Nursery (north). All of these monitoring locations are outside of the 45-degree arc shown in Map 5.

24 Stoney Cross is situated to the west of Anglers Lane. Here the 2003 annual average benzene concentration was predicted to be 5.1µg/m^3 and therefore to exceed the 2010 objective. The 2005 annual average concentration was however 4.7µg/m^3, which meets with the 2010 objective.

Station House is located close to Acetate Products but even further to the west. Here the estimated 2003 and 2005 annual average benzene concentrations were 3.4µg/m^3 and 2.5µg/m^3. The 2010 objective was also met at 8 Oakfields Grove, 33 Willowside Green, White House Nursery (north) and 354 Borrowash Road.

16) It can be seen that the combination of proximity to the Acetyls Plant and the prevailing south-westerly wind, directly affect the annual average benzene concentrations recorded at dwellings, nurseries and schools in the vicinity of Acetate Products.

17) Although fluctuating wind directions in different meteorological years affect the precise location of the maximum predicted concentration, 41 and 43 Anglers Lane represent the locations of worst-case relevant public exposure.

8.0 OUTCOME OF DETAILED ASSESSMENT

Analysis of the results from the benzene-monitoring network has determined that at dwellings, nurseries and schools within Spondon, the air quality meets the 2003 annual average benzene objective of 16.25µg/m^3.

However, based on 2000 to 2005 monitoring data, the air quality at specific receptors in Spondon, does not currently meet the 2010 annual average benzene objective of 5µg/m^3.

Several monitoring locations on Anglers Lane consistently failed to meet the 2010 objective between 2000 and 2005. 24 Stoney Cross, White House Day Nursery (south), 15 Dovedale Road, 197 Nottingham Road and 17/19 Craddock Avenue have also periodically exceeded the 2010 objective.

If this scenario were to predominate until the end of 2010, an Air Quality Management Area for Benzene would need to be declared. This would be for an area that would include Anglers Lane, Stoney Cross, part of Nottingham Road, Craddock Avenue, Chester Court, Vincent Avenue, part of Borrowfield Road and Silverhill Road.

It is however unlikely that the benzene concentrations will remain as high, even during a 'poor' pollution year, with there being likely to be a further reduction in the annual average benzene concentrations by 2010. This is on the basis that:

1) There is a lead-in period of 5 years until 31 December 2010. This means that there is sufficient time within which Acetate Products can work to implement appropriate benzene emission reductions, prior to 2010.

   If the proposed European Directive on Ambient Air Quality lengthens the 5µg/m^3 Objective compliance period from 2010 to 2015, this would almost double the lead-in time. This is however only a proposal, so it has not been taken into account at this stage.

2) A considerable amount of work has already been undertaken by Acetate Products to reduce benzene emissions from the site. As described in Chapter 2, the Benzene Emissions Reduction Team (BERT) has undertaken and continues to undertake significant work in relation to Leak Detection and Repair (LDAR), elimination of significant point sources and elimination of process activity emissions.

   This has already resulted in a reduction in fugitive benzene emissions from pipes, elimination of the main benzene storage tank (C17A) as a source of benzene emissions and during 2006, minimisation is also scheduled of the Extract Hot Condensate Wash, as the most significant source of benzene emissions remaining on site.

   The short-term effects of remediating the tar pits on site have been discounted from the 2010 predictions, since the associated benzene emissions are scheduled to take place before 2010.

3) Between 2000 and 2005, the 4 long-term monitoring stations in the vicinity of Acetate Products each recorded a significant downward trend in off-site annual average benzene concentrations. This is due to a combination of abatement measures undertaken by Acetate Products and a year-on-year national reduction in urban background benzene concentrations.

   From 2003 onwards, this reduction in annual average benzene concentrations in Spondon, is due almost entirely to abatement measures undertaken by Acetate Products. This is encouraging, as further abatement measures undertaken by Acetate Products will therefore be likely to significantly reduce off-site benzene concentrations.

4) Acetate Products commissioned a real-time Opsis analyser in March 2005. This has significantly increased the company's understanding of the benzene emissions from site, ensuring that benzene leaks are detected and eliminated more quickly. With time this understanding is likely to improve still further, so enabling completion of further targeted and cost-effective benzene abatement measures.

5) Acetate Products has imposed upon itself a target annual average benzene concentration at its north-eastern site boundary, below which it can be confident that off-site compliance with the 2010 objective will be achieved. This target value has been calculated through correlation of the Opsis results with both off-site benzene concentrations and the 2010 objective of 5µg/m^3.

6) The EU Air Quality Framework and Daughter Directives place the UK under a legal obligation to meet the specified limit values for individual pollutants by the required dates. In the case of Acetate Products, the company is the only source of elevated benzene concentrations in the vicinity.

   This means that should benzene releases from Acetate Products result in or be predicted to result in a breach of the EU 2010 limit value, then the company is required to go beyond Best Available Technique (BAT) in order to achieve compliance. In effect, this means that regardless of how much investment is required in abatement techniques, achievement with the 2010 objective is still required.

   It is anticipated that Acetate Products will however not need to go beyond BAT, in order to achieve compliance with the 2010 annual average benzene objective. Nevertheless, should this be necessary, it is the Environment Agency's duty as regulator to enforce this.

In consultation with both the City Council and Acetate Products, the Environment Agency has recently varied the site authorisation to include the following Improvement Condition:

The operator shall improve the authorised process in order to ensure that no emissions from that process could cause a breach of the National Air Quality Objective, of a maximum benzene annual average of 5µg/m3, at all points of relevant public exposure (as defined by the DEFRA Technical Guidance LAQM TG (03).

In 2006/2007, Acetate Product's authorisation will, in any case, need to be upgraded to a Permit. This means that in Spring 2006, Derby City Council will be formally consulted on the Permit application.

It is envisaged that the Environment Agency will impose detailed Permit conditions for further benzene abatement work and investment by Acetate Products. This will be with the benefit of additional Opsis monitoring data, which will have further increased understanding of the benzene emissions from site.

The resultant Permit conditions appropriate to the 2010 benzene objective will be kept under constant review. In this way, it is anticipated that the Environment Agency's formal Improvement Programme will ensure that Acetate Products will be able to reduce their emissions sufficiently for the 2010 National Air Quality Objective for benzene to be met.

There are also 3 confounding factors, which have been accounted for in the assessment of the likelihood of achieving the 2010 annual average benzene objective:

1) Acetate Products plan to increase production at their Spondon site over the next few years. This may lead to an increase in benzene emissions. However, Table 3 shows that despite a year-on-year increase in flake production, a reduction in total benzene emissions from site has so far been achieved.

2) Variations in meteorological conditions mean that some future years may be 'poor' pollution years. This happened in 2003 and, although the summer heat-wave meant that pollutant concentrations were generally higher, DEFRA has advised that this was not outside the boundaries of normal year to year variations.

3) The land to the north-east of Acetate Products is currently subject to a number of new and proposed developments, some of which are for residential purposes.

   Environmental Health will continue to advise Derby City Council Planning Committee on the impacts of local industry and poor air quality on future site occupants, as well as any environmental impacts arising from the developments themselves.

On the basis of all of the above information, the City Council has concluded that over the next 5 years, the necessary reduction in annual average benzene concentrations at nearby receptors is likely to be achieved. This will enable the 2010 annual average benzene objective to be achieved at all dwellings, schools and nurseries in the vicinity of Acetate Products.

It is therefore concluded that an Air Quality Management Area for benzene is not required at this stage.

The City Council has reached this conclusion in its capacity as the responsible authority for Local Air Quality Management. This judgement has been based on 5 years of benzene monitoring data, the reasons stated above and ongoing consultation with the Review and Assessment Helpdesk, Acetate Products and the Environment Agency.

The Review and Assessment Helpdesk supports the conclusion that an Air Quality Management Area is not required at this stage (8). This is on the basis that the situation is kept under constant review. The Council therefore intends to continue with its off-site benzene-monitoring network for the foreseeable future.

The Environment Agency is committed to ensure compliance with the 2010 objective via the Permitting process. This is evident through its willingness to vary the existing site authorisation, as well as its supporting letter in Appendix 1.

Acetate Products are also committed to a programme of benzene emissions reduction, which it believes will ensure compliance with the 2010 objective. This commitment has been formalised through the Environment Agency regulated Authorisation, as well as in its supporting letter shown in Appendix 2. This will continue the programme of effective joint working between Acetate Products, the Environment Agency and Derby City Council.

Progress towards meeting the 2010 objective will be kept under constant review, using data obtained from the benzene-monitoring network. This review will be formalised through the City Council's Progress Reports, which will be submitted to the Department for Environment, Food and Rural Affairs (Defra) for approval.

Should at any time it be considered likely that the 2010 annual average benzene objective will be breached, the City Council will consult with all relevant stakeholders. This will be with a view to declaring an Air Quality Management Area for Benzene in the vicinity of Acetate Products.

If an Air Quality Management Area were to be declared, the City Council would be under a duty to produce an associated Action Plan to reduce levels below the 2010 objective, again in consultation with stakeholders.

9.0 REFERENCES

1) Claire Beattie, Review and Assessment Helpdesk, 27 September 2005

2) Ellesmere Port and Neston Borough Council,
Detailed Assessment for Benzene, December 2004

3) E-mail from Brian Jones of the Monitoring Helpdesk, 15 April 2004

4) NPL Leaflet on Controlled Flow Air Samplers

5) E-mail from David Butterfield of NPL, 18 March 2005

6) Acetate Products, Detailed Benzene Monitoring Report, June 2005

7) Acetate Products, Air Quality management Plan, December 2003

8) E-mail from Dr Clare Beattie, Review & Assessment Helpdesk, 6 Jan 2006

9) Plymouth City Council, Detailed Assessment for Benzene, April 2004

10) North Lincolnshire Council, Detailed Assessment for Benzene, May 2004

11) E-mail from Yvonne Brown of the Modelling Helpdesk

12) Meeting with Simon Paterson, Environment Agency's inspector for
Acetate Products, 7 December 2005

13) Meeting with Colin Wilkinson and Kelly Barratt of Acetate Products,
3 November 2005

14) Defra, Report on the Review of the National Air Quality Strategy -
Proposals to Amend the Strategy, 13 January 1999

15) E-mail from Acetate Products, 13 February 2006

16) E-mail from Dr Beth Conlan of the Modelling Helpdesk, 9 February 2006

17) Conversation with David Butterfield of NPL, 13 February 2006

18) Netcen, Air Pollution in the UK: 2003

19) http://www.naei.org.uk/pollutantdetail.php

20) www.environment-agency.gov.uk/maps

Appendix 1

Letter from the Environment Agency

Mr Jeff Laidler
Environmental Health & Trading Standards
Derby City Council
Derby City Council,
Celtic House
Heritage Gate
Friary Street
Derby
DE1 1QX.

Our ref: AK2335
Your ref:

Date: 10 February 2006

Dear Mr Laidler

Derby City Council Detailed Assessment For Benzene

Thank you for the draft Detailed Assessment For Benzene, dated February 2006 that you sent me. I confirm that I agree with the contents and findings of the assessment, and that the Environment Agency will continue to work with the council with the aim that the national air quality objectives for Benzene will not be breached.

Yours sincerely

Simon Paterson
Process Industry Regulatory Officer
Environment Agency
Direct dial 0115 846 2604
Direct e-mail simon.paterson@environment-agency.gov.uk

Appendix 2

Letter from Acetate Products

Acetate Products

Environmental Health & Trading Standards
Derby City Council
Celtic House,
Heritage Gate,
Friary Street
Derby.
DE1 1QX

FAO Mr J Laidler

13th February 2006

Dear Jeff

With regard to the National Air Quality Strategy for benzene emissions. We are committed to meeting the requirements of the National Air Quality Objective for 2010.

Therefore we will continue to make improvements to our process, which will minimise emissions that have an effect the local air quality.

Yours faithfully,

Colin Wilkinson
Environmental Specialist