



Occupational health studies in pilot study 2006 and the rubber asphalt project 2007 – 2009 commissioned by the Swedish Road Administration

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Summary

This report has been prepared on a commission by the Swedish Road Administration. It deals with the impact on the work environment at the asphalt plant, when mixing rubber granules from recycled car tires with bitumen, and at the construction site, when laying the rubber asphalt mix. The complete study includes a pilot study during 2006 and production studies during 2007 - 2009.

Measurements of the 16 most common PAHs indicate that the staff/operator exposure to PAHs is very low when working with rubber asphalt. The operators, working with the rubber mixing equipment connected to the asphalt plant, experienced lower exposure than those operators, working on or next to the asphalt paver, where the wind direction determines which operator is most exposed. The staff/operator exposure to both benzo(a)pyrene and naphthalene is well below the level limit values and in most cases the exposure is below the detection limit for benzo(a)pyrene.

The maximum exposure to benzo(a)pyrene, measured in this project is $0,03 \mu\text{g}/\text{m}^3$, which means 1,5 % of the level limit value. At the asphalt paving a heating machine and a remixer were used. Sampling from material around the augers of the paver also shows that the highest contents of PAHs are obtained during laying with the heating machine and the remixer. For all measurements the exposure to naphthalene has been very low with a maximum value of 0,012 % of the level limit value. Any mobile exposure measurement of the aniline content has not been carried out, but at the ladder of the paver and on the same level as respiratory air of the paver levellers the aniline content was $30 \mu\text{g}/\text{m}^3$, which is less than 1 % of the level limit value.

The measurements show that the benzothiazole and aniline emanate from the additive of rubber granules, since it was not possible to detect these substances at laying of asphalt without rubber (ABS11). Any significant difference in PAH-evaporation, due to different rubber granules suppliers, was not possible to measure.

Irritations of the respiratory passages and nausea, as reported at laying of rubber asphalt (6) under adverse conditions with almost no wind and very high air temperatures, are hardly caused by the aldehydes, but rather by the exposure of benzothiazole and its unpleasant smell. This presumption needs to be confirmed by further measurements.

The addition of a deodorising agent to the bitumen did not decrease but rather increased the benzothiazole content around the augers. The paver operators did not perceive any difference in smell.

Provoked laboratory studies show that, when rubber granules are mixed at temperatures raised from above 164 °C to about 180 °C, the emission of PAHs in the air inside the bitumen mixer is heavily increased. This is probably due to the rubber additive and the elevated temperature.

The PAH-content at the augers of the asphalt paver increases very little when laying of the rubber asphalt mix GAP 11 at temperature 150-160 °C or 135-140 °C is compared with laying of ABS 11 at temperature 145-155 °C. The difference in PAH-content from GAP 11 between 150-160 °C and 135-140 °C was negligible. Laying of the open-graded rubber asphalt mix GAÖ 8/11 (145-150 °C) with a heating machine increases the PAH-content at the augers slightly compared with GAP 11, but in the case of benzothiazole the increase is multiplied. When a heating machine was used for laying of the open-graded mix, the result can be influenced by the open-graded mix and the use of heater.

The results from the laboratory measurements and from the measurements above suggest that when the asphalt is heated above about 170 °C, the PAH-emission increases significantly. Further measurements should be carried out in a laboratory with controlled external conditions.

A fan, mounted on the paver, reduces the PAH exposure somewhat, but the operators on and around the paver were uncertain of the effect, as they did not perceive any difference. Again further measurements should be carried out and in so with fewer external variables.

In summary, it can be concluded that the work environment will not become worse in a decisive way due to the added rubber, provided that the asphalt temperature does not exceed about 170°C.

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Introduction

This report is a compilation of studies, commissioned by the Swedish Road Administration, to study the influence on the occupational health, when adding rubber granules from car tyres to asphalt mixes. The studies began with a pilot study in laboratory scale 2006 and continued with a study in half a large laboratory scale. Then the studies have been carried out under production until September 2009, dealing with occupational health issues associated with the production.

Objectives

The studies in this report have been carried out to increase the knowledge about the occupational health at working with rubber asphalt and to decide whether addition of rubber granules leads to substantially more dangerous working environment than asphalt work without addition of rubber. The studies have been directed towards measurements of polycyclic aromatic hydrocarbons (PAH), as those pilot studies, commissioned by SRA (1,2), have demonstrated that PAHs are emitted at gasification of rubber asphalt. Benzothiazole is a substance, which gives rise to the typical rubber smell, has been studied in lesser extent in this report, as an occupational exposure limit value for this substance is missing. Besides from the fact that benzothiazole can cause contact allergy, the only possible symptoms at inhalation are smarting pains in eyes, nose and throat and cough. There are no studies, proving that exposure to benzothiazole has resulted in some great health risks, despite the fact that exposure to benzothiazole has occurred during all years of manufacture of rubber products. On the other hand it is very plausible that the smell of benzothiazole can be so unpleasant that it may cause indisposition.

Rubber asphalt

In this project "Rubber asphalt" is defined as an asphalt mix, where the bitumen phase has been modified by rubber granules, produced by fragmentation and sieving of recycled tyres. At a temperature of 165-175°C standard bitumen and rubber granules (0-1 mm) are mixed with a rubber content in the binder of 17-20 % by mass. While slow stirring the rubber and bitumen will react during 45-60 minutes and a rubber modified bitumen is obtained, which then is mixed with the aggregate to an asphalt mix. The rubber content of the finished asphalt mix/pavement is 1,5-2,0 % by mass.

2006 - PILOT STUDY

Measurement of polycyclic aromatic carbons (PAH) from rubber modified bitumen

BACKGROUND

To improve the technical properties of the road pavements some countries have started to mix rubber granules into the bitumen at the asphalt production plant. There is a justified suspicion that this rubber addition can result in increased health risks to the staff, exposed to the smoke from the bitumen-rubber mixture. Therefore, the Swedish Road Administration (SRA) decided to measure in the laboratory the quantity of polycyclic aromatic hydrocarbons, emitted from some bitumen binders with and without addition of rubber granules respectively. AB Previa was commissioned to measure in a laboratory environment the polycyclic aromatic hydrocarbons, emitted from bitumen-rubber mixtures and carry out comparative measurements with and without addition of rubber respectively.

SAMPLING AND TESTING

Sampling of the polycyclic aromatic hydrocarbons is carried out by sucking air and smoke from the top of the bitumen mixer through a brass pipe, roughly 40 cm long, and further by a glass fibre filter in a XAD-pipe, serving as an adsorption pipe, where the polycyclic aromatic hydrocarbons are captured. (See the pictures on page 44).

Sampling begins, when the temperature of the binder mixture has reached 150 – 165°C, and it continues then during 4 hours with an air-flow through the adsorption pipe of 0,2 l/min, except for experiment 2 and 3, where the air-flow during some part of the sampling time decreased a little. All samples were taken in SRAs asphalt laboratory in Jönköping, where the bitumen mixtures are run in a non-corrosive container, equipped with stirrer and heating device.

ANALYSES

After each mixing the mixer is cleaned with pure bitumen B 70/100. The adsorption pipe from each experiment is plugged up and sent to Analytica AB, Täby, for analysis of the most common PAHs with combined gas chromatography and mass spectrometry (GC-MS). Analytica AB has in turn delegated the analysis to GBA, Flensburger Strasse 15, 254 21 PINNEBERG, Germany, which is an accredited laboratory by the German accreditation body DAR.

SAMPLING DATA

EXPERIMENT 0 2006-11-10

Sampling time 4 hours

Sampling volume 48 liters

Bitumen Ready-mixed bitumen 70/100 from Norrköping and produced 2005

Sampling starts at 150 °C. After 15 min the temperature is 160°C. Then the temperature is 158 – 164°C during the sampling.

EXPERIMENT 1 2006-11-13

Sampling time 4 hours

Sampling volume 48 liters

Bitumen Nypol 50/100-75 from Nynäs

The sampling starts at 150 °C. After 15 min the temperature is 160 °C. Then the temperature is 160 – 166 °C during the sampling. A liquid is condensed in the adsorption tube.

EXPERIMENT 00 2006-11-15

Sampling time 4 hours

Sampling volume 48 liters

Bitumen Mixture of 65% bitumen 50/70 + 35% bitumen 160/220 from the depot

The sampling starts at 150 °C. After 15 min the temperature is 160 °C. Then the temperature is 158 – 164 °C during the sampling. A liquid is condensed in the adsorption tube.

EXPERIMENT 2 2006-11-20

Sampling time 4 hours

Sampling volume 43,2 liters

Bitumen Mixture of 65 % bitumen 50/70 + 35 % bitumen 160/220 from the depot + rubber granules 0-0,8 mm.

The sampling starts at 165 °C, when some part of the rubber granules has been added. After 5 min the remaining part of the rubber granules is added. After 15 min the temperature is 175 °C. Then the temperature is 172 – 178 °C during the sampling. The air-flow at the sampling decreases down to 0,15 l/min after about 3 h, but is adjusted again to the target value of 0,2 l/min. A liquid is condensed in the adsorption tube.

EXPERIMENT 3 2006-11-23

Sampling time 4 hours

Sampling volume 45,6 liters

Bitumen Mixture of 65 % bitumen 50/70 + 35 % 160/220 from the depot + rubber granules R+

The sampling starts at 165 °C, when some part of the rubber granules has been added. After 5 min the remaining part of the rubber granules is added. After 15 min the temperature is 175 °C. Then the temperature is 172 – 178 °C during the sampling. The stirring in the mixing container is stopped after about 120 min, when the temperature reached 182 °C during 5 min, before the stirring was restarted. The air-flow at the sampling decreases down to 0,15 l/min after 2 h, but is adjusted again to the target value of 0,2 l/min. A liquid is condensed in the adsorption tube.

2006 - SUBTOTALS Pilot study

PAH		Experi- ment 0 ≤164°C	Experi- ment 1 ≤166°C	Experi- ment 00 ≤164°C	Experi- ment 2 ≤178°C	Experi- ment 3 ≤182°C	Occupational exposure limit value	Note
Naphtalene	µg/m ³	190	1100	600	1100	1100	LLV=50 000 STV=80 000	
Acenaphthylene	µg/m ³	1,6	5,8	7,9	67	81	--	
Acenaphthene	µg/m ³	13	29	56	280	140	--	
Fluorene	µg/m ³	10	18	42	250	160	--	
Phenantrene	µg/m ³	9	19	58	760	390	--	
Anthracene	µg/m ³	0,63	1,7	5,4	39	55	--	
Fluoranthene	µg/m ³	1,4	1,3	3,1	58	48	--	
Pyrene	µg/m ³	1,1	1,4	6,3	150	140	--	
Benzo(ah)anthracene	µg/m ³	<0,4	<0,4	0,73	5,3	4,8	--	C
Chrysene	µg/m ³	<0,4	<0,4	1,8	11	9,4	--	C
Benzo(b)fluoranthene	µg/m ³	<0,4	<0,4	0,77	3,5	3,1	--	C
Benzo(k)fluoranthene	µg/m ³	<0,4	<0,4	<0,4	0,53	0,64	--	C
Benzo(a)pyrene	µg/m ³	<0,4	<0,4	0,48	2,5	2,1	LLV=2 STV=20	C, R, H
Dibenzo(ah)anthracene	µg/m ³	<0,4	<0,4	<0,4	<0,5	<0,4	--	C
Benzo(ghi)perylene	µg/m ³	<0,4	<0,4	<0,4	1,5	1,3	--	
Indeno(123cd)pyrene	µg/m ³	<0,4	<0,4	<0,4	<0,5	<0,4	--	C

LLV=Level limit value

STV=Short-term value

C=Carcinogenic

R=Reproduction inconvenient

H=Easily absorbed by the skin

The PAHs in the table above are arranged according to molecular weight with increasing weights downwards in the table. Stated PAH-contents of $< 0,4 \mu\text{g}/\text{m}^3$ and $< 0,5 \mu\text{g}/\text{m}^3$ respectively in the table mean that the measured values fall below the detection limit. To get more precise values new experiments with longer sampling times have to be carried out.

From the table above it is evident that bitumens from different sources (experiment 0 and 00) have yielded different results, where the binder in experiment 00, consisting of a mixture of 65 % bitumen 50/70 + 35 % bitumen 160/220 from the depot, contains more PAHs than the binder in experiment 0, consisting of bitumen 70/00 from Norrköping and produced 2005.

The bitumen mixture/binder (PMB) in experiment 1, which contains polymers, emits more naphthalene than the binder in experiment 00, but emits lesser quantities of the other PAHs than the binder in experiment 00.

Considering experiment 2 and 3 with addition of rubber granules and elevated temperature all PAH-contents increase in comparison with experiment 00 (same bitumen but without rubber granules). However, for some PAHs the values in all of the three experiments are below the detection limit, meaning that now differences can be recorded.

The measurement results show that addition of rubber granules in the bitumen mixture and elevation of the temperature from $164 \text{ }^\circ\text{C}$ to $178\text{-}182 \text{ }^\circ\text{C}$ the benzo(a)pyrene content in the air above the bitumen mixture increases and exceeds $2 \mu\text{g}/\text{m}^3$, which is about 5 times greater than the content at the lower temperature, when rubber has not been added. It is also evident from the measurements results (for measured values above the detection limit) that the contents of the other carcinogenic PAHs also increase about 5 times, when the temperature has been elevated and rubber granules have been added to the bitumen mixture.

Occupational exposure limit values according to AFS 2005:17 exist for benzo(a)pyrene and naphthalene of the measured PAHs. The level limit value, i.e. worst tolerable average content (time-weighted mean) of benzo(a)pyrene in respiratory air during a working day is $2 \mu\text{g}/\text{m}^3$ and the short term value, which is the time-weighted mean of exposure during 15 min, is $20 \mu\text{g}/\text{m}^3$. For naphthalene the level limit value is $50\ 000 \mu\text{g}/\text{m}^3$ and the short term value $80\ 000 \mu\text{g}/\text{m}^3$.

Comparisons with occupational exposure limit values must be done with great care, as the samples were taken in the air directly above the bitumen mixture and not in respiratory air at actual exposure. To conclude if the occupational exposure limit value for benzo(a)pyrene is exceeded the samples have to be taken in respiratory air under normal working conditions. In addition to this the health risks from other PAHs have to be considered.

2006 - PARTIAL SUMMARY Pilot study

AB Previa, commissioned by the head office of SRA, has measured the content of polycyclic aromatic hydrocarbons (PAHs), emitted at heating of different bitumen mixtures. At 178-182 °C and addition of rubber granules about 5 times higher contents of carcinogenic PAHs were measured in the air directly above the hot bitumen mixtures than at 164 °C with the corresponding bitumen without rubber granules. With rubber granules in the bitumen mixture and elevated temperature a quantity of 2,1 – 2,5 µg/m³ benzo(a)pyrene was measured above the mixture. The occupational exposure limit value for benzo(a)pyrene is at present 2 µg/m³. In comparison with the limit value for naphthalene the measured contents are very low. For other PAHs occupational exposure limit values are missing. To find out if the occupational exposure limit value for benzo(a)pyrene is exceeded, further measurements have to be carried out, but in that case under normal “bitumen work” conditions and with sampling in respiratory air.

2007 –MEASUREMENT 1

Exposure to PAHs at manufacture of the ‘Asphalt Rubber’-binder in half a large laboratory scale

BACKGROUND

At the pilot study in November 2006 in SRAs asphalt laboratory in Jönköping the measurements of the polycyclic aromatic hydrocarbons (PAHs) at addition of rubber granules to bitumen were based on samples, taken directly above the hot bitumen mixture. Therefore, these measurement results for benzo(a)pyrene cannot be compared with the occupational exposure limit value, since this limit value is based on the exposure, i.e. benzo(a)pyrene content in respiratory air. Therefore Measurement 1 is a further development of the former one, as the sampling-measurement now is carried out in respiratory air.

SAMPLING AND TESTING

The samples of the polycyclic aromatic hydrocarbons (PAHs) are taken by capturing the respiratory air and bringing it through a glass-fibre filter in a XAD-tube, which is the adsorption tube for the PAHs. As a matter of precaution the sampling is duplicated by connecting two adsorption tubes in respiratory air. Moreover it is decided to take a sample at a fixed measuring point about 1 m from the bitumen mixer.

The bitumen is mixed in SRAs asphalt laboratory in Jönköping, but in a spacious hall with a large ceiling height (lorry garage type) but without mechanical in and out air-flow/air ventilation and without any point suction fan. The sampling starts when the pre-heated 70/100-bitumen is poured into the mixer and the temperature is raised to 175 °C. Then the rubber granules are added, giving the mix proportions 83 % bitumen and 17 % rubber granules by mass. The laboratory manager Gustav Petersson, who is the person most exposed to the smoke, has the measuring equipment with the two adsorption tubes in respiratory air. He adds the rubber granules and measures repeatedly the temperature at the viscosity measurements, carried out outside the bitumen mixer. When the mixture is ready, he draws off a part of it into tin containers and seals them with lids. The remaining part of the binder is mixed with aggregate, forming an asphalt mix. Then Marshall test specimens are prepared for strength testing in the ordinary asphalt laboratory. During this preparation the air-pump on the fixed measuring point is turned off.

All sampling was cancelled during lunch, but is resumed after lunch, when a new bitumen mixture with rubber granules is manufactured. Also in this case several viscosity measurements are carried out, and the prepared mixture is finally drawn off into a number of tin containers with lids, while the sampling continues.

SAMPLING DATA

2007-04-24 Indoors in a garage building and in SRA's asphalt laboratory, Jönköping

Sampling points PAHs	Sampling time (min)	Sampling volume (liters)
Mobile 1 - respiratory air	319	63,8
Mobile 2 - respiratory air	319	63,8
Fixed measuring point about 1 m from the mixer	266	52,2

ANALYSES

When the sampling is concluded, the adsorption tubes are plugged and sent to Analytica AB, Täby for analysis of the 16 most common PAHs. Analytica AB has in turn delegated the analysis to GBA, Flensburger Strasse 15, 254 21 PINNEBERG, Germany, which is an accredited laboratory by the German accreditation body DAR. The analysis is carried out with combined gas chromatography and mass spectrometry (GC-MS).

2007 - SUBTOTALS Measurement 1

PAH		Mobile 1	Mobile 2	Fixed measuring point	Occupational exposure limit value	Note
Naphtalene	µg/m ³	<0,4	<0,4	<0,4	LLV=50 000 STV=80 000	
Acenaphtylene	µg/m ³	<0,4	<0,4	<0,4	--	
Acenaphtene	µg/m ³	<0,4	<0,4	<0,4	--	
Fluorene	µg/m ³	<0,4	<0,4	<0,4	--	
Phenanthrene	µg/m ³	<0,4	<0,4	<0,4	--	
Anthracene	µg/m ³	<0,4	<0,4	<0,4	--	
Fluoranthene	µg/m ³	<0,4	<0,4	<0,4	--	
Pyrene	µg/m ³	<0,4	<0,4	<0,4	--	
Benzo(a)anthracene	µg/m ³	<0,4	<0,4	<0,4	--	C
Chrysene	µg/m ³	<0,4	<0,4	<0,4	--	C
Benzo(b)fluoranthene	µg/m ³	<0,4	<0,4	<0,4	--	C
Benzo(k)fluoranthene	µg/m ³	<0,4	<0,4	<0,4	--	C
Benzo(a)pyrene	µg/m ³	<0,4	<0,4	<0,4	LLV=2 STV=20	C, R, H
Dibenso(ah)anthracene	µg/m ³	<0,4	<0,4	<0,4	--	C
Benzo(ghi)perylene	µg/m ³	<0,4	<0,4	<0,4	--	
Indeno(123cd)pyrene	µg/m ³	<0,4	<0,4	<0,4	--	C

LLV=Level limit value

STV=Short-term limit value

C=Carcinogenic

R=Reproduction inconvenient

H=Easily absorbed by the skin

The PAHs in the table above are arranged according to molecular weight with increasing weights downwards in the table. All stated PAH-contents of <0,4 µg/m³ and <0,5 µg/m³ in the table fall below the detection limit. To get more precise values new experiments should be carried out with even longer sampling times.

Occupational exposure limit values according to AFS 2005:17 exist only for benzo(a)pyrene and naphtalene of the measured PAHs. The level limit value, i.e. worst tolerable average content (time-weighted mean) of benzo(a)pyrene in respiratory air during a working day is 2 µg/m³ and the short term value, which is the time-weighted mean of exposure during 15 min, is 20 µg/m³. The measurement results show that the exposure to this substance is less than 20 % of the level limit value.

2007 - PARTIAL SUMMARY Measurement 1

AB Previa, commissioned by SRA, has measured the content of polycyclic aromatic hydrocarbons (PAHs), emitted during addition of rubber granules into bitumen. The measurement has been carried out, partly in respiratory air during working with the bitumen mixture, partly about 1 m from the bitumen mixer, mounted indoors in a spacious hall (lorry garage type) without mechanical in and out air-flow/air ventilation. The contents of all 16 studied PAHs were below the detection limit, i.e. less than $0,4 \mu\text{g}/\text{m}^3$. The measurement results also showed that the exposure to benzo(a)pyrene was less than 20 % of the level limit value. To find out the actual exposure the measurements have to be carried out during a longer time period.

2007 – MEASUREMENT 2

PAHs in the pugmill of the asphalt plant and exposure to PAHs and benzothiazole at addition of rubber granules and laying of rubber asphalt

BACKGROUND

Measurements of the polycyclic aromatic hydrocarbons (PAHs) at addition of rubber granules to bitumen were carried out in laboratory scale with sampling in the mixer in November 2006. Exposure measurements of PAHs have also been carried out at addition of rubber to bitumen and production of rubber asphalt in half a large laboratory scale in April 2007. In this study measurements of both PAHs and benzothiazole have been carried out at the addition of rubber at the asphalt plant and at laying of rubber asphalt in full scale.

SAMPLING AND TESTING

The polycyclic aromatic hydrocarbons (PAHs) were sampled by capturing the air. The air was brought through a glass-fibre filter in a XAD-tube of OVS-type, which was the adsorption tube for the PAHs. These adsorption tubes are larger than those, used in previous measurements in this project. The reason for this was that only SP (Technical Research Institute of Sweden) was capable to carry out the analyses of both PAHs and benzothiazole. So SP decided which type of adsorption tube should be used. The sampling of benzothiazole was carried out with Tenax-tubes and during asphalt paving duplicate samples of benzothiazole were taken in respiratory air of two persons.

At the beginning of the sampling PAH-samples were only taken at a fixed sampling point in the pugmill at the asphalt plant in Forserum. During the sampling asphalt with added rubber/rubber asphalt was produced, but asphalt without rubber was also produced during the measurements.

Next sampling was carried out at the asphalt plant in Dalby, where both the contents of PAHs and benzothiazole were measured in respiratory air of the binder mixing operator, managing the mechanical equipment for the rubber addition (in the report called batcher) and working on top of the container, when rubber was added to the bitumen mixture.

During the same day as the measurements were carried out at the asphalt plant in Dalby, measurements were also carried out during asphalt paving on Ringvägen in Malmö. There mobile samples were taken in respiratory air of the binder mixing operator and the two paver levellers and moreover stationary samples were taken above the augers of the paver somewhat to the left of the grid floor to the asphalt paver. Samples of both PAHs and benzothiazole were taken.

During the sampling on the asphalt paver the wind was strong from north and the paver was driven westwards, which implies that the pollutants from the asphalt paving were brought from the right to the left.

SAMPLING DATA

2007-08-15 Asphalt plant in Forserum

Sampling point PAHs	Sampling time (min)	Sampling volume (liters)
Fixed measuring point in the pugmill	236	236

2007-09-03 Asphalt plant in Dalby

Sampling point PAHs	Sampling time (min)	Sampling volume (liters)
Batcher rubber granules (mobile)	392	400

Sampling point PAHs	Sampling time (min)	Sampling volume (liters)
Batcher rubber granules (mobile)	30	3,0

2007-09-03 E6/E20/E22 Yttre Ringvägen Malmö. The paver running towards the west

Weather observations: Cloudy with sunny intervals. Wind 2-7 m/s N. Temp 15 – 20°C

	Sampling time (min)	Sampling volume (liters)
Sampling point PAHs		
Paver operator (mobile)	343	360
Left paver leveller (mobile)	365	365
Above the auger (fixed measuring point)	347	354
Right paver leveller (mobile)	353	371
Sampling point benzothiazole		
Paver operator (mobile)	20	2,0
Paver operator (mobile)	38	3,8
Left paver leveller (mobile)	47	4,7
Left paver leveller (mobile)	20	2,0
Above the auger (fixed measuring point)	20	2,1
Right paver leveller (mobile)	61	6,1

ANALYSES

All the samples, taken in Dalby and Malmö, were the next day delivered to SP, Technical Research Institute of Sweden in Borås, for analysis.

2007 - PARTIAL SUMMARY Measurement 2

PAH		Forse- rum	Asphalt paving Ringvägen Malmö				Dalby	Occupational exposure limit value
		Pug- mill	Paver opera- tor	Left paver leveller	Above the augers	Right paver leveller	Batcher	
Naphtalene	µg/m ³	1,8	<0,1	1,1	0,2	<0,1	0,1	LLV=50000 STV=80000
Acenaphtylene	µg/m ³	<0,1	<0,1	<0,1	0,5	<0,1	<0,1	
Acenaphtene	µg/m ³	<0,1	<0,1	<0,1	2,7	<0,1	<0,1	
Fluorene	µg/m ³	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	
Phenanthrene	µg/m ³	1,7	0,2	2,5	8,0	0,2	<0,1	
Anthracene	µg/m ³	0,2	<0,1	0,3	1,0	<0,1	<0,1	
Fluoranthene	µg/m ³	0,3	<0,1	0,4	1,4	<0,1	<0,1	
Pyrene	µg/m ³	0,5	<0,1	0,8	2,5	<0,1	<0,1	
Chrysene	µg/m ³	0,1	<0,1	<0,1	0,2	<0,1	<0,1	
Benzo(a)anthracene	µg/m ³	0,4	<0,1	0,5	1,2	<0,1	<0,1	
Benzo(b)fluoranthene	µg/m ³	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	
Benzo(k)fluoranthene	µg/m ³	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	
Benzo(a)pyrene	µg/m ³	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	LLV=2 STV=20
Benzo(ghi)perylene	µg/m ³	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	
Dibenzo(ah)anthracene	µg/m ³	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	
Indeno(123cd)pyrene	µg/m ³	<0,2	<0,2	<0,2	<0,2	<0,2	<0,2	
Total of measurable PAH	µg/m ³	4,9	0,2	5,6	17,6	0,2	0,1	

LLV=Level limit value

STV=Short-term limit value

Occupational exposure limit values according to AFS 2005:17 exist only for benzo(a)pyrene and naphthalene of the measured PAHs. The level limit value, i.e. worst tolerable average content (time-weighted mean) for benzo(a)pyrene in respiratory air during a working day is 0,002 mg/m³ or 2 µg/m³, and the short term value, which is the time-weighted mean of exposure during 15 min, is 20 µg/m³. The measurement results show that the exposure to this substance is less than 5 % of the level limit value and the analysis laboratory could not detect any benzo(a)pyrene in any of the samples.

It is evident from the results that the highest measurable PAH-contents were naturally measured directly above the augers of the paver. The left positioned paver leveller was the most exposed person, owing to the wind direction.

At the last measurement, carried out in April 2007, when rubber was added to bitumen in half a large laboratory scale, the detection limit was 0,4 $\mu\text{g}/\text{m}^3$ for PAH and at all measuring points the exposure was less than 0,4 $\mu\text{g}/\text{m}^3$. The results of this measurement show that operators, working as paver levellers in the wind direction from the augers of the paver and the newly laid asphalt, are exposed to higher contents of e.g. naphthalene, phenanthrene, fluoranthene, pyrene and benzo(a)anthracene. At the addition of rubber granules at the asphalt plant the exposure of these substances seems to be definitely lower, which may be due to the wind direction. Since many of the detected PAHs are carcinogenic or suspected carcinogenic and several of them can cause eczema at exposure to UV-light, the exposure should be minimized, if the addition of rubber granules will be a usual method?.

		Asphalt paving Ringvägen Malmö				Dalby
		Paver operator	Left paver leveller	Above the auger	Right paver leveller	Batcher
Benzothiazole						
Sampling 1	$\mu\text{g}/\text{m}^3$	3,5	285	133	12	4,0
Sampling 2	$\mu\text{g}/\text{m}^3$	1,8	26			
Mean	$\mu\text{g}/\text{m}^3$	2,7	156			

The sampling of benzothiazole was carried out during 20-61 min and constitutes by that a spot sample of the exposure. At the two measuring points, where duplicate samples were taken, the exposure varies considerably over time. For benzothiazole there is no limit value, but it is a substance, which may induce contact allergy.

2007 - PARTIAL SUMMARY Measurement 2

AB Previa, commissioned by SRA, has measured the contents of polycyclic aromatic hydrocarbons (PAHs), emitted from bitumen/asphalt, added with rubber. Measurements of PAHs exclusively have been carried out at a fixed sampling point in the pugmill at the asphalt plant in Forserum during production of so called 'rubber asphalt'. Furthermore the contents of PAHs and benzothiazole have been measured in respiratory air of the binder mixing operator for the rubber addition at the asphalt plant in Dalby. The contents of PAH and benzothiazole have also been measured during laying of so called 'rubber asphalt' on Ringvägen outside Malmö. The samples were in this case taken from respiratory air of the paver driver/operator and the screed staff and also above the augers of the paver. The highest PAH-contents were measured above the augers of the paver and somewhat lower contents in respiratory air of that paver leveller, who often was in the wind direction from the paver. Even in the pugmill of the asphalt plant in Forserum measured high contents of PAH.

Considering benzothiazole, there is no occupational exposure limit value to compare the measured values to, but the highest contents were measured above the augers of the paver and in respiratory air on the paver leveller, being in the wind direction from the paver. In spite of the fact that occupational exposure limit values are missing for the measured PAHs, the exposure is recommended by way of precaution to be minimized.

2008 - MEASUREMENT 1-6

PAHs at the asphalt plant and exposure to PAHs at batching of rubber granules and laying of rubber asphalt with rubber from different suppliers and laying with remixer and heater

BACKGROUND

Measurements of polycyclic aromatic hydrocarbons (PAH) at the addition of rubber have been carried out in laboratory scale with sampling in the mixer in November 2006. Exposure measurements of PAHs have also been carried out at addition of rubber to bitumen and production of rubber asphalt in half a large laboratory scale in April 2007. In August 2007 the PAHs were measured at the production of rubber asphalt in the pugmill of the asphalt plant in Forserum and in September 2007 PAH-measurements were carried out on the paving staff, when laying rubber asphalt on Ringvägen in Malmö. At the same time exposure measurements were carried out on one of the employees, adding rubber granules to the bitumen at the asphalt plant in Dalby.

SAMPLING AND TESTING

To increase the knowledge of the influencing factors on the exposure to PAHs when laying rubber asphalt, the exposure measurements have continued in 2008 and measurements have in all been carried out at six different occasions. Apart from mobile exposure measurements on the paver driver/operator and the two paver levellers, measurements have been carried out on one of the plant operators, batching rubber granules into the bitumen. Moreover, measurements have been carried out directly above the augers of the paver. At NCCs asphalt plant in Spillepengen, Malmö, PAHs in the smoke from the bitumen-rubbermixture /‘Asphalt Rubber’ (Measurement 1) were also measured.

The sampling of the polycyclic aromatic hydrocarbons (PAH) was carried out by capturing the air and bringing it through a XAD-tube of OVS-type, which was the adsorption tube for the PAHs. The air flow through the adsorption tube was around 2,0-2,5 l/m.

SAMPLING DATA

Measurement 1. 2008-06-11

E6/E22 Vellinge – Petersborg and the asphalt plant Spillepengen, Malmö

Eximlink

Weather observations: Showers of rain in the middle of the day – sun in the evening.

Wind 2-11 m/s W – SW. Temp 20 – 27°C

	Sampling time (min)	Sampling volume (liters)
Sampling point PAHs		
Asphalt plant Spillepengen (fast mätpunkt)	403	814
Paver operator (mobile)	290	595
Above the auger (fixed measuring point)	295	596
Left paver leveller (mobile)	253	506
Right paver leveller (mobile)	296	607

Measurement 2. 2008-08-06

Road 31/127 Västerleden, Vetlanda

Genan, remixing, heater

Weather observations: Slight rain during the morning, but sun in the afternoon.

Wind 0-4 m/s SW. Temp 14 – 23° C

	Sampling time (min)	Sampling volume (liters)
Sampling point PAHs		
Paver operator (mobile)	324	729
Above the auger (fixed measuring point)	337	691
Left paver leveller (mobile)	298	685
Right paver leveller (mobile)	318	747

Measurement 3. 2008-08-19/20

Road 262 Edsberg – Danderyd

Genan, heater

Weather observations: Cloudy intervals. Precipitation < 1 mm. Wind 3 m/s SO – SW. Ca 15° C

	Sampling time (min)	Sampling volume (liters)
Sampling point PAHs		
Batcher rubber granules Vällstaverk (mobile)	571	1435
Paver operator (mobile)	392	1064
Above the auger (fixed measuring point)	391	968
Left paver leveller (mobile)	387	964
Right paver leveller (mobile)	388	976

Measurement 4. 2008-08-20/21

Road 262 Edsberg – Danderyd

Eximlink, heater

Weather observations: Cloudy intervals. Precipitation < 5 mm. Wind 3 m/s S – SW. Ca 15° C

	Sampling time (min)	Sampling volume (liters)
Sampling point PAHs		
Batcher rubber granules Vällstaverk (mobile)	699	1789
Paver operator (mobile)	427	1076
Above the auger (fixed measuring point)	356	891
Left paver leveller (mobile)	422	1074
Right paver leveller (mobile)	420	1057

Measurement 5. 2008-08-22/23

Road 262 Edsberg – Danderyd

Genan (Road+), heater

Weather observations: Cloudy intervals. Precipitation < 1 mm. Wind 2 m/s NO. Ca 10° C

	Sampling time (min)	Sampling volume (liters)
Sampling point PAHs		
Batcher rubber granules Vällstaverk (mobile)	761	1863
Paver operator (mobile)	428	1042
Above the auger (fixed measuring point)	427	1024
Left paver leveller (mobile)	427	1056
Right paver leveller (mobile)	427	1065

Measurement 6. 2008-10-06

E22 Söderleden, Norrköping

RTW, heater

Weather observations: Cloudy with sunny intervals. Wind 0-4 m/s W. Temp 9 - 14° C

	Sampling time (min)	Sampling volume (liters)
Sampling point PAHs		
Batcher rubber granules Luddenverk (mobile)	246	517
Paver operator (mobile)	324	680
Above the auger (fixed measuring point)	317	666
Left paver leveller (mobile)	331	670
Right paver leveller (mobile)	323	678

ANALYSES

After the sampling the adsorption tubes were dispatched as soon as possible to SP, Technical Research Institute of Sweden in Borås, for analysis.

2008 - SUBTOTALS Measurement 1-6

Rubber supplier Note	Measurement 1 2008-06-11					Measurement 2 2008-08-06					Occupational exposure limit value (µg/m ³)
	Eximlink					Genan					
	Spille- pengen	E6/E22 Petersborg - Vellinge				Road 31/127 Västerleden, Vetlanda					
		Asphalt plant NCC (µg/m ³)	Paver operator (µg/m ³)	Above the auger (µg/m ³)	Left paver leveller (µg/m ³)	Right paver leveller (µg/m ³)	Paver operator (µg/m ³)	Above the auger (µg/m ³)	Left paver leveller (µg/m ³)	Right paver leveller (µg/m ³)	
PAH											LLV=50000 STV=80000
Naphtalene	0,42	0,46	4,10	0,62	2,15	2,4	2,5	1,4	0,91		
Acenaphtylene	<0,008	<0,008	<0,008	<0,008	<0,008	0,47	2,5	0,22	0,11		
Acenaphtene	<0,008	<0,008	<0,008	<0,008	<0,008	2,6	11	1,9	0,98		
Fluorene	<0,008	<0,008	<0,008	<0,008	<0,008	1,6	11	1,1	0,6		
Phenanthrene	0,08	0,120	2,4	0,185	0,79	3,6	35	2,5	1,4		
Anthracene	<0,008	<0,008	0,39	0,02	0,13	0,34	3	0,22	0,12		
Fluoranthene	0,02	0,03	0,89	0,05	0,3	0,85	8	0,53	0,29		
Pyrene	0,07	0,07	2,44	0,13	0,74	0,87	10	0,57	0,3		
Benzo(a)anthracene	<0,008	<0,008	<0,008	<0,008	<0,008	0,08	0,81	0,04	0,03		
Chrysene	<0,008	<0,008	<0,008	<0,008	<0,008	0,25	0,69	0,07	0,04		
Benzo(b)fluoranthene	<0,008	<0,008	<0,008	<0,008	<0,008	0,06	0,46	0,02	0,02		
Benzo(k)fluoranthene	<0,008	<0,008	<0,008	<0,008	<0,008	0,01	0,44	<0,008	<0,008		
Benzo(a)pyrene	<0,008	<0,008	<0,008	<0,008	<0,008	0,03	0,15	0,012	<0,008		LLV=2 STV=20
Dibenso(ah)anthracene	<0,008	<0,008	<0,008	<0,008	<0,008	0,015	0,04	<0,008	<0,008		
Benzo(ghi)perylene	<0,008	<0,008	<0,008	<0,008	<0,008	0,03	0,16	<0,008	<0,008		
Indeno(123cd)pyrene	<0,008	<0,008	<0,008	<0,008	<0,008	0,015	0,05	<0,008	<0,008		
Total of measurable PAH	0,59	0,68	10,22	1,01	4,11	13,22	85,80	8,58	4,80		

Rubber supplier Note	Measurement 3 2008-08-19/20					Measurement 4 2008-08-20/21					Occupational exposure limit value ($\mu\text{g}/\text{m}^3$)
	Genan					Eximlink					
	Heater					Heater					
	Vällsta	Road 262 Edsberg - Danderyd				Vällsta	Road 262 Edsberg - Danderyd				
PAH	Asphalt plant Batching ($\mu\text{g}/\text{m}^3$)	Paver operator ($\mu\text{g}/\text{m}^3$)	Above the auger ($\mu\text{g}/\text{m}^3$)	Left paver leveller ($\mu\text{g}/\text{m}^3$)	Right paver leveller ($\mu\text{g}/\text{m}^3$)	Asphalt plant Batching ($\mu\text{g}/\text{m}^3$)	Paver operator ($\mu\text{g}/\text{m}^3$)	Above the auger ($\mu\text{g}/\text{m}^3$)	Left paver leveller ($\mu\text{g}/\text{m}^3$)	Right paver leveller ($\mu\text{g}/\text{m}^3$)	
Naphtalene	0,41	1,6	2,3	1,1	1,3	0,42	2,4	4,5	1,8	2,3	LLV=50000 STV=80000
Acenaphtylene	0,015	0,13	2,199	0,1	0,11	0,02	0,19	2,3	0,16	0,2	
Acenaphtene	0,07	0,54	7	0,52	0,52	0,02	0,2	1,7	0,17	0,19	
Fluorene	0,05	0,32	7	0,35	0,35	0,03	0,27	5,5	0,27	0,3	
Phenanthrene	0,09	0,59	17	0,84	0,83	0,06	0,64	16	0,8	0,98	
Anthracene	0,01	0,06	1,4	0,08	0,09	0,01	0,07	1,5	0,08	0,1	
Fluoranthene	0,01	0,14	3,1	0,17	0,16	0,01	0,15	3	<0,008	0,21	
Pyrene	0,02	0,25	5,2	0,28	0,27	0,02	0,4	8,4	0,45	0,537	
Benzo(a)anthracene	<0,008	0,03	0,34	0,02	0,02	<0,008	0,04	0,05	<0,008	0,03	
Chrysene	<0,008	0,04	1,1	0,02	0,03	<0,008	0,07	0,62	0,03	0,11	
Benzo(b)fluoranthene	<0,008	0,02	0,14	0,01	0,01	<0,008	0,02	0,18	<0,008	0,02	
Benzo(k)fluoranthene	<0,008	<0,008	0,02	<0,008	<0,008	<0,008	<0,008	0,23	<0,008	<0,008	
Benzo(a)pyrene	<0,008	<0,008	0,06	<0,008	<0,008	<0,008	<0,008	0,09	<0,008	0,01	LLV=2 STV=20
Dibenso(ah)anthracene	<0,008	<0,008	0,01	<0,008	<0,008	<0,008	<0,008	0,015	<0,008	<0,008	
Benzo(ghi)perylene	<0,008	<0,008	0,03	<0,008	<0,008	<0,008	<0,008	0,05	<0,008	<0,008	
Indeno(123cd)pyrene	<0,008	<0,008	<0,008	<0,008	<0,008	<0,008	<0,008	0,015	<0,008	<0,008	
Total of measurable PAH	0,68	3,72	46,90	3,49	3,69	0,59	4,32	44,15	3,76	4,99	

Rubber supplier Note	Measurement 5 2008-08-22/23					Measurement 6 2008-10-06					Occupational exposure limit value (µg/m ³)
	Genan (Road +)					RTW					
	Heater					Heater					
	Vällsta	Road 262 Edsberg - Danderyd				Ludden	E22 Söderleden Norrköping				
PAH	Asphalt plant Batching (µg/m ³)	Paver operator (µg/m ³)	Above the auger (µg/m ³)	Left paver leveller (µg/m ³)	Right paver leveller (µg/m ³)	Asphalt plant Batching (µg/m ³)	Paver operator (µg/m ³)	Above the auger (µg/m ³)	Left paver leveller (µg/m ³)	Right paver leveller (µg/m ³)	
Naphtalene	0,74	1,35	4,5	0,92	1,3	0,15	1,6	4,5	0,89	0,89	LLV=50000 STV=80000
Acenaphtylene	0,025	0,08	0,85	0,05	0,1	0,012	<0,008	<0,008	<0,008	<0,008	
Acenaphtene	0,11	0,32	7,13	0,31	0,85	<0,008	<0,008	<0,008	<0,008	<0,008	
Fluorene	0,08	0,2	5	0,18	0,52	0,02	0,13	0,97	0,17	0,14	
Phenanthrene	0,16	0,51	11	0,42	1,3	0,07	0,25	3,1	0,59	0,48	
Anthracene	0,02	0,05	0,96	0,05	0,12	<0,008	0,025	0,27	0,06	0,04	
Fluoranthene	<0,008	0,09	1,9	0,07	0,25	0,01	0,07	0,71	0,16	0,12	
Pyrene	0,04	0,15	3	0,12	0,38	0,03	0,25	1,9	0,42	0,34	
Benzo(a)anthracene	<0,008	0,01	<0,008	<0,008	<0,008	<0,008	0,02	0,08	0,015	0,01	
Chrysene	0,01	<0,008	0,46	<0,008	<0,008	<0,008	0,18	0,57	0,08	0,07	
Benzo(b)fluoranthene	<0,008	<0,008	0,07	<0,008	<0,008	<0,008	0,02	0,05	0,01	<0,008	
Benzo(k)fluoranthene	<0,008	<0,008	<0,008	<0,008	<0,008	<0,008	<0,008	<0,008	<0,008	<0,008	
Benzo(a)pyrene	<0,008	<0,008	0,03	<0,008	<0,008	<0,008	<0,008	0,02	<0,008	<0,008	LLV=2 STV=20
Dibenso(ah)anthracene	<0,008	<0,008	<0,008	<0,008	<0,008	<0,008	<0,008	<0,008	<0,008	<0,008	
Benzo(ghi)perylene	<0,008	<0,008	0,015	<0,008	<0,008	<0,008	<0,008	<0,008	<0,008	<0,008	
Indeno(123cd)pyrene	<0,008	<0,008	<0,008	<0,008	<0,008	<0,008	<0,008	<0,008	<0,008	<0,008	
Total of measurable PAH	1,19	2,76	34,92	2,12	4,82	0,29	2,55	12,17	2,40	2,09	

The results show that for the majority of PAHs the highest average contents were obtained at the paving works in Vetlanda, when both heater and remixer were used and the wind was also weak. The highest benzo(a)pyrene content was at that time measured above the augers of the paver, where $0,15 \mu\text{g}/\text{m}^3$ benzo(a)pyrene was obtained and in respiratory air of the plant operator $0,03 \mu\text{g}/\text{m}^3$ benzo(a)pyrene was measured. In comparison with the occupational exposure limit value, where the level limit value is $2 \mu\text{g}/\text{m}^3$, the exposure of the plant operator to benzo(a)pyrene is in spite of this on a low level, as the exposure to benzo(a)pyrene was 1,5 % of the level limit value. Without heater or remixer the exposure to benzo(a)pyrene has been below the detection limit, i.e. $< 0,008 \mu\text{g}/\text{m}^3$, but this observation is based on only one measurement in Malmö, when the wind was strong. Considering naphthalene max $4,5 \mu\text{g}/\text{m}^3$ has been measured above the augers and max $2,4 \mu\text{g}/\text{m}^3$ has been measured in respiratory air, which means 0,005 % of the level limit value for naphthalene. The current level limit value for naphthalene is $50\ 000 \mu\text{g}/\text{m}^3$.

As mentioned above the highest PAH-contents (shaded background in the data table) were measured, when remixer and heater have been used. Two PAHs – naphthalene and chrysene - have yielded deviating results, because the highest chrysene content was measured above the augers of the paver, when testing 'Genam'-rubber in Stockholm, and the highest naphthalene content was obtained at trials in both Stockholm and Norrköping, when only heater was used.

The measurements results indicate that more PAHs will be emitted with increasing temperature of the asphalt mix, and the asphalt temperature has probably greater influence on the PAH-emission than the added rubber granules. To prove this presumption comparative laboratory measurements need to be carried out with and without rubber granules and with different asphalt temperatures respectively.

The wind velocity is naturally of great importance to the resulting exposure intensity. As an example the lowest contents were measured at the measurement in Malmö, when the wind velocity varied between 2 and 11 m/s. The wind direction is obviously also of great importance, which was clearly demonstrated by the measurements, carried out in 2007. Generally the measurements results indicate that those, operating the addition of rubber at the asphalt plant, are exposed to lower PAH-contents than the paver operator and paver leveller.

2008 - PARTIAL SUMMARY Measurement 1-6

AB Previa, commissioned by SRA, has measured the PAH-contents, emitted from bitumen/asphalt with rubber addition at six different days/nights in 2008. The measurements have been carried out in respiratory air of the paver operator and the two paver levellers and above the augers of the paver. At four of the six different days/nights measurements have also been carried out in respiratory air of one of the employees, operating the addition of rubber granules to the bitumen at the plant. The results of the measurements show that the greatest PAH-contents are obtained directly above the augers of the paver. Concerning the exposure to benzo(a)pyrene max $0,03 \mu\text{g}/\text{m}^3$ has been measured in respiratory air, which is 1,5 % of the level limit value of $2 \mu\text{g}/\text{m}^3$. For naphthalene max $2,4 \mu\text{g}/\text{m}^3$ has been measured, which means 0,005 % of the level limit value.

From the results of the measurements it can be concluded that more PAHs are emitted, when the asphalt is heavily heated using heater, and in particular, when remixing is performed. The results of the measurements also show that the exposure to PAHs is lower for those, working with addition of rubber granules at the plant than for those, working on the paver. The wind direction and the wind velocity together with the temperature of the asphalt mix seem to be those factors, which to a great extent determine the exposure level at the paver.

2009 - MEASUREMENT 1-5

Measurement of PAHs, benzothiazole and aniline and assessment of smell

BACKGROUND

Measurements of polycyclic aromatic hydrocarbons (PAH) at the addition of rubber have been carried out in laboratory scale with sampling in a laboratory mixer in November 2006. Exposure measurements of PAHs were also carried out at addition of rubber to bitumen and production of rubber asphalt in half a large laboratory scale in April 2007. In August 2007 the PAHs were measured at the production of rubber asphalt at the asphalt plant in Forserum and in September 2007 PAH- measurements were carried out on the paving staff, when laying rubber asphalt on Yttre Ringvägen in Malmö. At the same time exposure measurements were carried out at addition of rubber granules at the asphalt plant in Dalby. In 2008 exposure measurements of PAHs were carried out on the paving staff and the PAH-emission above the augers of the paver at six different occasions (E6 Vellinge – Trelleborg, Road 31 Vetlanda with heater and remixing, Road 262 Edsberg – Danderyd three nights with heater, E22 Norrköping with heater and open-graded mix). Moreover, exposure measurements were carried out at four occasions on staff, operating the addition of the rubber granules.

SAMPLING AND TESTING

During 2009 the rubber asphalt project has continued with measurements of PAHs, benzothiazole, aniline and aldehydes to get answers to the following questions:

Measurement 1- Issues:

Will a fan on the paver reduce the exposure of the paver levellers and operator/driver to air pollutants as PAHs and aldehydes from the asphalt?

Irritations of the respiratory passages and nausea have been reported during laying of rubber asphalt (6). Are they caused by exposure to aldehydes?

SAMPLING DATA

Measurement 1a

GAP16 with Dynapac F161-8W equipped with a post-mounted fan

2009-05-18 at 15 – 17 on E6/E22 south towards Vellinge

Weather observations: Sun and almost clear. W – WSW wind 2-5 m/s. Temp 18,5 – 21,5°C

and 2009-07-01 at 8.20 – 12.30 on E6/E20/E22 Yttre Ringvägen Malmö with the paver on the road northwards ahead of exit towards Sallerupsvägen

Weather observations: Sun and totally clear – almost totally clear. NO wind 0-2 m/s. Temp 23 – 26°C

Sampling position PAHs	Sampling time (min)			Sampling volume (liters)		
	18 maj	1 juli	Totalt	18 maj	1 juli	Totalt
Paver operator	114	242	356	285	605	890
Right paver leveller	112	232	344	281	582	863
Left paver leveller	-	239	239	-	598	598
Above the auger on the paver	105	245	350	260	608	868

2009-07-01 at 8.00 - 11.20 duplicate samples were taken on **aldehydes** according to the following

Sampling pos. aldehydes	Sampling time (min)	Sampling volume (liters)
Left paver leveller	60	63
Above the auger on the paver	63	66

Measurement 1b

GAP16 with Dynapac F161-6W without fan

2009-05-19 at 7.10 – 15.15 on E6/E22 south towards Vellinge

Weather observations: Sun and totally clear – almost totally clear. S wind 0-5 m/s. Temp 13 – 21°C

Sampling position PAHs	Sampling time (min)	Sampling volume (liters)
Paver operator	480	1176
Left paver leveller	479	1150
Right paver leveller	416	990
Above the auger on the paver	477	1145

2009-05-19 at 12.05 - 13.30 duplicate samples were taken on **aldehydes** according to the following

Sampling pos. aldehydes	Sampling time (min)	Sampling volume (liters)
Left paver leveller	85	85
Above the auger on the paver	84	84

Measurement 1c

GAP16 with Dynapac F161-6W without fan

2009-05-18 at 11.45 – 17.15 on E6/E22 south towards Vellinge

Weather observations: Sun and almost totally clear. W-WSW wind 2-5 m/s. Temp 18,5 – 21,5°C

Sampling position PAHs	Sampling time (min)	Sampling volume (liters)
Above the auger on the paver	323	791

Measurement 2 – Issues:

Will deodorising agents reduce the content of benzothiazole or is the smell disguised?

In view of the complaints from neighbours next to the asphalt plant what contents of benzothiazole have been measured at the site boundary and in the wind direction to the asphalt plant?

Measurements of the benzohtiazole were carried out during laying of rubber asphalt, partly without addition of a deodorising agent on 17 June 2009, partly with addition of a deodorising agent on 23 June 2009. To minimize the influence of the wind, the samples were taken directly above the augers of the paver.

SAMPLING DATA

Measurement 2a

GAP16 without deodorising agents

2009-06-17 at 10.45 – 11.45 on E6/E20/E22 Yttre Ringvägen Malmö. The paver heading west just before the exit to Lockarp

Paver: Dynapac F161-6W

Weather observations: Sun and partly cloudy – almost totally clear. Wind WSW 0-4 m/s. Temp 17°C

Sampling position	Sampling time (min)	Sampling volume (liters)
Above the auger on the paver (duplicate samples)	13,5	2,025
Above the auger on the paver (duplicate samples)	40,0	6,0

Measurement 2b

GAP16 without deodorising agents by the asphalt plant

2009-06-17 at 13.00 – 13.35 NCC Asfaltverk Spillepengen Malmö

Sampling position	Sampling time (min)	Sampling volume (liters)
Land border asphalt plant (duplicate samples)	35	5,25

Measurement 2c

GAP16 with deodorising agents

2009-06-23 at 10.45 – 11.40 on E6/E20/E22 Yttre Ringvägen Malmö. The paver heading NO after exit to road 101

Paver: Dynapac F161-6W

Weather observations: Sun and totally clear – partly cloudy. NW wind 0-7 m/s. Temp 20,5°C

Sampling position	Sampling time (min)	Sampling volume (liters)
Above the auger on the paver (duplicate samples)	13,5	2,025
Above the auger on the paver (duplicate samples)	40,0	6,0

Measurement 3 – Issues:

How looks/is the PAH-emission at laying of GAP 11 with rubber granules from RagnSells

Aniline was detected at analysis of benzothiazole from the rubber asphalt above. How high contents are emitted?

SAMPLING DATA

Measurement 3

Night between 2009-08-19 - 20 at 22.30– 04.30 on E6/E20 heading north after Ullevimotet in Gothenburg

Paver: Wirtgen Vögele Super 1800-2

Weather observations: No precipitation. S wind 0-1 m/s. Temp 16 – 17,5 °C

Sampling position PAHs	Sampling time (min)	Sampling volume (liters)
Paver operator	362	909
Left paver leveller	266	660
Right paver leveller	280	725
Above the auger on the paver	287	729

Sampling position benzothiazole and aniline	Sampling time (min)	Sampling volume (liters)
Above the auger on the paver	30	4,5
Above the auger on the paver	30	4,5
Near the ladder on the paver	50	10,0

Measurement 4 – Issues:

Is ABS 11 without added rubber emitting lower quantities of PAHs than GAP 11 with added rubber?

Are benzothiazole and aniline emitted from ABS 11 without added rubber?

Are asphalt mixes with low temperature (about 140 °C) and added wax emitting lower quantities of benzothiazole, aniline and PAHs than GAP 11 with added rubber?

SAMPLING DATA

Measurement 4

The evening and night between 2009-09-08 - 09 at 18.00 to 04.15 on the road 180 Alingsås in north-westerly direction towards the center

Paver: Wirtgen Vögele Super 1800-2

Weather observations: No precipitation. S wind 4-6 m/s. Temp 15 – 20,5 °C

Measurement 4a

ABS11 without addition of rubber 18.00 – 21.30

Surface temperature directly after the paver 145 – 155 °C

Sampling position PAHs	Sampling time (min)	Sampling volume (liters)
Above the auger on the paver	147	394
Above the auger on the paver	147	390

At 18.05 -19.30 Temperature 19 – 20,5°C

Sampling position	Sampling time (min)	Sampling volume (liters)
benzothiazole and aniline		
Above the auger on the paver	30	6,00
Above the auger on the paver	51	8,93

Measurement 4b

GAP11 with addition of rubber 23.45 - 02.55

Surface temperature directly after the paver 150 – 160 °C

Sampling position PAHs	Sampling time (min)	Sampling volume (liters)
Above the auger on the paver	189	507
Above the auger on the paver	188	508

At 23.50 -01.15 Temperature 15 – 16°C

Sampling position	Sampling time (min)	Sampling volume (liters)
benzothiazole and aniline		
Above the auger on the paver	30	6,00
Above the auger on the paver	50	8,75

Measurement 4c

GAP11 with addition of rubber and wax Sasobit 21.30-22.50 and 03.00-04.15

Surface temperature directly after the paver 135 – 140 °C

Sampling position PAHs	Sampling time (min)	Sampling volume (liters))
Above the auger on the paver	153	409
Above the auger on the paver	153	416

At 21.30 -22.50 Temperature 15°C

Sampling position	Sampling time (min)	Sampling volume (liters)
benzothiazole and aniline		
Above the auger on the paver	32	6,40
Above the auger on the paver	51	8,93

Measurement 5 – Issues:

Is 'open graded asphalt' with added rubber (GAÖ 8/GAÖ 11), Vetfix AP17 and heater emitting more pollutants in terms of benzothiazole, aniline and PAHs than GAP 11?

SAMPLING DATA

Measurement 5

2009-09-21 at 09.00-15.15 on road 180 Alingsås in SSW direction from the centre

Paver: Wirtgen Vögele Super 1800-2

Weather observations: Cloudy with a rain shower. Wind 0-7 m/s from WSW. Temp 7,5 – 13 °C

Heater

Surface temperature directly after the paver 145 – 150 °C

Sampling position PAHs	Sampling time (min)	Sampling volume (liters)
Above the auger on the paver	233	592
Above the auger on the paver	233	592

At 09.10 -10.00 Temperature 7,5 - 9°C

Sampling position benzothiazole and aniline	Sampling time (min)	Sampling volume (liters)
Above the auger on the paver	50	8,75
Additional 2 samples but the analysis failed		

SAMPLING TECHNIQUE AND CHEMICAL ANALYSES

PAHs: Samples are taken with XAD-2-tubes and an air velocity of about 2,5 l/min. The tubes are extracted with toluene, after which the extract is analysed by a chromatograph, equipped with MS-detector.

Aldehydes: Collection is carried out with a DNPH-filter and an air velocity about 1,0 l/min. The filters are extracted in the laboratory with acetonitrile, after which the extract is analysed by fluid chromatograph, equipped with MS-detector.

Benzothiazole and aniline: In this case Tenax-tubes and the air velocity 0,15-0,20 l/min are used. After the thermal desorption of the Tenax-tubes gas chromatographic analysis is carried out, where mass spectrometry is used to identify the substances and a flame-ionisation detector is used to determine the quantity.

All analyses have been carried out at SP (Technical Research Institute of Sweden in Borås).

**ESTIMATION OF SMELL, INCONVENIENCIES AND INTERVIEWS
RELATED TO SMELL**

Date	At measurement	Rubber asphalt	Note	Estimation smell/incon- veniences	Inter- view
2009-07-01	1a	GAP16	Paver with fan	X	X
2009-06-17	2a	GAP16	No deodorising agent	X	
2009-06-23	2b	GAP16	Deodorising agent	X	
2009-08-20	3	GAP11	First contact with rubber asphalt	X	
2009-09-08	4	GAP11	Addition of wax Sasobit	X	
2009-09-21	5	GAÖ8/11	Addition of vetfix AP17	X	

The form for assessment of smell and inconveniences is given on page 16 in the annex.

2009 SUBTOTALS

Measurement 1a – c

	1a				1b				1c	
	Malmö E6/E20/E22									
	GAP16								ABS16	
	Eximlink				Eximlink					
	Fan				Without fan				Without fan	
	Paver operator	Right paver leveller	Left paver leveller	Above the auger	Paver operator	Right paver leveller	Left paver leveller	Above the auger	Above the auger	Occupational exposure limit value (µg/m³)
PAH	(µg/m³)	(µg/m³)	(µg/m³)	(µg/m³)	(µg/m³)	(µg/m³)	(µg/m³)	(µg/m³)	(µg/m³)	
Naphtalene	0,82	0,69	0,52	3,58	1,5	1,9	2,9	3,0	1,71	LLV=50000 STV=80000
Acenaphtylene	0,04	0,03	<0,03	0,36	0,40	0,15	0,16	0,7	0,34	
Acenaphtene	0,02	0,01	<0,03	0,15	0,23	0,10	0,11	0,07	0,47	
Fluorene	0,04	0,03	<0,03	0,36	0,30	0,15	0,16	0,80	1,05	
Phenanthrene	0,14	0,11	0,10	1,30	1,20	0,50	0,55	2,95	3,34	
Anthracene	0,02	0,02	<0,03	0,20	0,19	0,07	0,07	0,43	0,73	
Fluoranthene	0,08	0,06	<0,03	0,70	0,68	0,25	0,26	1,65	1,68	
Pyrene	0,13	0,14	0,19	1,30	1,33	0,51	0,54	3,32	1,25	
Benzo(a)anthracene	<0,03	<0,03	<0,03	<0,03	0,04	<0,03	<0,03	0,07	0,19	
Chrysene	<0,03	<0,03	<0,03	<0,03	0,13	0,06	0,05	0,25	0,21	
Benzo(b)fluoranthene	<0,03	<0,03	<0,03	<0,03	0,04	<0,03	<0,03	0,06	0,09	
Benzo(k)fluoranthene	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	0,02	
Benzo(a)pyrene	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	0,03	LLV=2 STV=20
Dibenso(ah)anthracene	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	
Benzo(ghi)perylene	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	
Indeno(123cd)pyrene	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	
Total of measurable PAH	1,29	1,09	0,81	7,95	6,04	3,69	4,80	13,30	11,11	

2009 SUBTOTALS

Measurement 1a-b

	1a		1b		Occupational exposure limit value (µg/m³)
	Malmö E6/E20/E22				
	GAP16				
	Eximlink				
	Fan		Without fan		
Left paver leveller	Above the auger	Left paver leveller	Above the auger		
Aldehydes and ketones	(µg/m³)	(µg/m³)	(µg/m³)	(µg/m³)	
Formaldehyde	<20	<20	<20	<20	LLV=600 CLV=1 200
Acetaldehyde	55	670	120	520	LLV=45 000 STV=90 000
Acroleine	<20	<20	<20	<20	LLV=200 STV=700
Acetone	<20	<20	<20	<20	LLV=600 000 STV=1200 000
Propionaldehyde	<20	<20	<20	80	
Crotonaldehyde	<20	<20	<20	<20	
Butyraldehyde	<20	240	40	170	
Benzaldehyde	<20	30	<20	25	
Isovaleraldehyde	<20	60	<20	40	
Valeraldehyde	<20	150	33	120	
Tolualdehyde	<20	<20	<20	<20	
Hexaldehyde	<20	<20	<20	<20	
Dimethylbenzaldehyde	<20	<20	<20	<20	
Total of measureable aldehyde	55	1150	193	955	

**Asphalt mix
Rubber supplier
Note**

2009 SUBTOTALS

Measurement 2a – c

	2a		2b	2c		
	Malmö E6/E20/E22		Spille- pengen	Malmö E6/E20/E22		
Asphalt mix	GAP16					
Rubber supplier	Eximlink					
Note	Without deodorising agents			Deodorising agents		Occupational exposure limit value (µg/m ³)
	Above the auger (µg/m ³)	Above the auger (µg/m ³)	SW of the plant (µg/m ³)	Above the auger (µg/m ³)	Above the auger (µg/m ³)	
BENZOTHIAZOLE	3600	1000	<50	6800	4200	
Benzothiazole mean	2300			5500		
ANILIN	700	200	<50	900	1600	LLV=4 000 STV=8 000
Aniline mean	450			1250		

2009 SUBTOTALS

Measurement 3

Asphalt mix

Rubber supplier

Gothenburg E6/E20

GAP11

RagnSells

	Paver operator	Right paver leveller	Left paver leveller	Above the auger	Near the ladder	Above the auger	Above the auger	Occupational exposure limit value
PAH	(µg/m³)	(µg/m³)	(µg/m³)	(µg/m³)	(µg/m³)	(µg/m³)	(µg/m³)	(µg/m³)
Naphtalene	3,15	3,86	5,90	4,77				LLV=50 000 STV=80 000
Acenaphtylene	0,09	<0,03	0,04	0,23				
Acenaphtene	0,07	<0,03	0,03	0,13				
Fluorene	0,13	<0,03	0,04	0,27				
Phenanthrene	0,43	0,15	0,2	1,48				
Anthracene	0,06	<0,03	<0,03	0,17				
Fluoranthene	0,24	0,09	0,13	0,61				
Pyrene	0,75	0,29	0,42	1,95				
Benzo(a)anthracene	<0,03	<0,03	0,04	0,16				
Chrysene	0,16	0,20	0,26	1,17				
Benzo(b)fluoranthene	<0,03	<0,03	0,04	0,17				
Benzo(k)fluoranthene	<0,03	<0,03	<0,03	<0,03				
Benzo(a)pyrene	<0,03	<0,03	<0,03	<0,03				
Dibenso(ah)anthracene	<0,03	<0,03	<0,03	<0,03				
Benzo(ghi)perylene	<0,03	<0,03	<0,03	<0,03				
Indeno(123cd)pyrene	<0,03	<0,03	<0,03	<0,03				
Total of measurable PAH	5,08	4,59	7,10	11,11				
BENZOTHAZOL					320	2120	2120	
ANILINE					30	170	180	LLV=4000 STV=8000

2009 SUBTOTALS

Measurement 4a-c, 5

	4a		4b		4c		5		
	Alingsås Road 180								
Asphalt mix	ABS11		GAP11		GAP11 Cold		GAÖ8 GAÖ11		
Rubber supplier	RagnSells								
Note							Heater		
	Above the auger	Above the auger	Above the auger	Above the auger	Above the auger	Above the auger	Above the auger	Above the auger	Occupational exposure limit value
	(µg/m ³)	(µg/m ³)	(µg/m ³)	(µg/m ³)	(µg/m ³)	(µg/m ³)	(µg/m ³)	(µg/m ³)	(µg/m ³)
PAH									LLV=50 000 STV=80 000
Naphtalene	8,60	6,45	8,63	9,15	6,85	10,5	4,80	6,14	
Acenaphtylene	0,04	0,04	0,06	0,12	0,07	0,15	0,30	0,4	
Acenaphtene	0,10	0,13	0,08	0,15	0,09	0,18	0,50	0,72	
Fluorene	0,15	0,17	0,13	0,25	0,15	0,28	0,55	0,70	
Phenanthrene	0,44	0,53	0,58	1,05	0,55	0,96	2,50	0,84	
Anthracene	0,06	0,08	0,07	0,14	0,07	0,13	0,40	0,40	
Fluoranthene	0,06	0,06	0,18	0,33	0,13	0,26	0,75	0,84	
Pyrene	0,19	0,19	0,53	1,00	0,40	0,79	2,40	2,67	
Benzo(a)antracene	0,03	0,04	0,05	0,08	0,03	0,06	0,2	0,2	
Chrysene	0,23	0,26	0,31	0,53	0,20	0,39	1,3	1,2	
Benzo(b)fluoranthene	<0,03	0,03	0,03	0,06	<0,03	0,05	0,2	0,2	
Benzo(k)fluoranthene	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	
Benzo(a)pyrene	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	LLV=2 STV=20
Dibenso(ah)anthracene	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	
Benzo(ghi)perylene	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	
Indeno(123cd)pyrene	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	<0,03	
Total of measurable PAH	9,90	7,98	10,65	12,86	8,54	13,71	13,90	14,31	
Mean	8,94		11,76		11,13		14,11		

2009 SUBTOTALS

Measurement 4a-c, 5

	4a		4b		4c		5	
	Alingsås Road 180							
Asphalt mix	ABS11		GAP11		GAP11 Cold		GAÖ8 GAÖ11	
Rubber supplier	RagnSells							
Note							Heater	
	Above the auger	Above the auger	Above the auger	Above the auger	Above the auger	Above the auger	Above the auger	Occupational exposure limit value
	(µg/m³)	(µg/m³)	(µg/m³)	(µg/m³)	(µg/m³)	(µg/m³)	(µg/m³)	(µg/m³)
BENZOTHIAZOLE	<20	<20	260	400	230	280	1600	
Benzothiazole mean	<20		330		255			
ANILINE	<10	<10	20	20	20	10	25	LLV=4000 STV=8000
Aniline mean	<10		20		15			

2009 –SUBTOTALS

Assessment/estimation of smell and inconveniencies

To assess smell and inconveniencies due to smell a form was used (annex page 20), where undersigned asked how the smell, based on the scale in the form, was perceived that day.

Occupation	Fan on the paver	
	Smell intensity	Inconvenience intensity
	2009-07-01	
Paver operator	2	0
Left paver leveller		
Right and left leveller	2	0
Roller driver	3	0
Roller driver	2	0

Occupation	No deodorising agent		Deodorising agent		Difference smell intensity	Note
	Smell intensity	Inconvenience intensity	Smell intensity	Inconvenience intensity		
	2009-06-17		2009-06-23			
Paver operator	2	0	2	0	0	Person allergic to pollen
Left paver leveller	3	0	3	0	0	
Right paver leveller	2	0	3	0	+1	
Roller driver, near the paver	0	0	1	0	+1	
Roller driver, distant from the paver	0	0	0	0	0	
Tack coating operator	3	0	-	-	-	
Batcher rubber	1	0	1	0	0	
Batcher rubber	1	0	0	0	-1	
Paver operator	3	0	1	0	-2	
Loader driver etc	3	0	-	-	-	
Loader driver etc	-	-	1	0	-	
			Total		-1	

Occupation	First run with rubber asphalt		GAP 11 Cold		GAÖ8/GAÖ11 with vetfix	
	Smell intensity	Inconvenience intensity	Smell intensity	Inconvenience intensity	Smell intensity	Inconvenience intensity
	2009-08-20		2009-09-08		2009-09-21	
Paver operator	2	0	2	0	1,5	0
Left paver leveller	2	0	1	0	1	0
Right and left leveller	3	0	2	0	1	0
Roller driver	0	0				
Roller driver	1	0				

Smell scale

0 = No smell

1 = Hardly perceptible smell

2 = Weak smell

3 = Clear smell

4 = Strong smell

5 = Very strong smell

6 = Unbearable smell

2009 - Interview replies to the question if any effect of the fan on the paver is noticed?

”Don’t know what I’ll to . The fan does some good, I suppose. Reclaimed mixes smell considerably stronger” (Paver driver)

”I have not noticed any difference. The fan may be effective to the smell, rising straight upwards, if the fan has an effect at all. AG-mixes smell much worse. Can be the mere smell from a refuse tip.
(Paver leveller)

”I have not noticed any difference with or without a fan on the paver. One thinks about the carcinogenic substances will induce cancer in the long run” (Casual roller driver)

”I smell rubber but it is not perceived in the cabin of the roller” (Roller driver)

2009 –COMMENTS

Measurement 1

The results show that the PAH-contents are reduced considerably at all measuring points using fan on the paver. It is true that the wind conditions differ; when laying with fan the wind blows diagonally from right and when laying without fan direct headwind. If the measurements with and without fan during 2008 are compared with each other, it is obvious that fan on the paver reduces the exposure to PAHs.

Regarding aldehydes no improvement can be observed above the augers of the paver with fan. The aldehyde contents are in this case in stead somewhat higher with fan. However, the aldehyde contents decrease significantly for the left paver leveller, when fan is used.

The operators answered in the interviews that they did not notice any effect of the fan and that it is not evident that the fan is useful. As man has no sensory organs, capable of perceiving PAHs or aldehydes of very low contents, the replies are consequently the expected.

The exposure to aldehydes is very low and is for the majority of the aldehydes below the detection limit. For acetaldehyde, possible to detect in respiratory air, the content is between 1-3 ‰ of the level limit value. Therefore, the measured contents of aldehydes can hardly explain reported inconveniencies in terms of irritations in the respiratory passages and nausea (6). However, the sampling time for the aldehydes is short and based on very few samples. Further sources of error are that the measured aldehyde contents to some extent can arise from the exhaust gas from the engine of the own paver or the exhaust gases from the vehicular traffic around the paver.

Measurement 2 incl. assessment of smell and interview replies

The results from the measurements of benzothiazole above the augers of the paver, when laying asphalt mixes with and without deodorising agent (limonene), show unambiguously that the deodorising agent does not reduce the benzothiazole content above the augers of the paver. In stead the measurement results show a higher content of both benzothiazole and aniline above the augers of the paver with deodorising agent, and this is difficult to explain as limonene is a hydrocarbon without sulphur as in benzothiazole or nitrogen or as in aniline. The deodorising agent can hardly react with benzothiazole to decrease the content, but it can probably only disguise the smell.

Regarding the staff estimations of the smell with and without deodorising agent respectively, there is no significant difference, and only those knowing the existence of deodorising agents that perceive a reduced smell.

When analysing benzothiazole SP also detected aniline in the samples with benzothiazole and the aniline content is about 20 % of the measured benzothiazole content.

The measurement results from the boundary site of the asphalt plant show that benzothiazole and aniline in the air are not detectable. This fact does not imply that the smell of benzothiazole is not perceptible, as the smell threshold of benzothiazole is very low.

Measurement 3

At the measurements in Gothenburg it was almost windless, when Ragnsell's rubber granules were used, and the PAH-contents were about the same as in Malmö, when Eximlink's rubber granules were used and the laying was carried out with a Dynapac-paver without fan. However, the exposure to naphthalene deviates and is the strongest, measured in the project, but in comparison with the level limit value it is despite this fact very low or 0,012 % of the limit value.

The benzothiazole contents above the augers of the paver are about 2100 $\mu\text{g}/\text{m}^3$ and about 300 $\mu\text{g}/\text{m}^3$ at the ladder of the paver, and the aniline content is about 1/10 of the benzothiazole content. The exposure to aniline for those working near or on the paver should not be stronger than the exposure that was measured at the ladder on the paver, i.e. 30 $\mu\text{g}/\text{m}^3$, which means 1 % below the level limit value.

Measurement 4

During the measurements in Alingsås it was windy, but during the three initial measurements (sampling 4a-c) the conditions are directly comparable, as they were carried out with the same paver and with the paver in the same direction, which means that the wind direction had the same influence in these cases.

The measurements results show that the PAH-contents above the augers of the paver is somewhat lower with ABS 11 (without rubber) in comparison with GAP 11 (with rubber) and "cold" GAP 11 with addition of wax and lower mix temperature. The measurement results from the Malmö study with ABS 16 (measurement 1c), i.e. without added rubber, and GAP 16 (measurement 1b) show that the PAH-contents above the augers of the paver are somewhat lower, when the asphalt mix does not contain rubber.

The benzothiazole and aniline contents are according to the measurements 4b-4c in Alingsås generally low, but in sample 4a without added rubber neither benzothiazole or aniline can be detected, which confirms that these substances actually arise from the rubber.

Sampling 4c with GAP 11 and low temperature (135 – 140°C after the paver) and added wax leads hardly to any noticeable reduction of either PAHs or aniline in comparison with GAP 11 at the temperature 150 – 160°C after the paver. However, considering benzothiazole the difference is significant.

Measurement 5

One additional measurement was carried out in Alingsås on an open-graded rubber asphalt with added Vetfix AP17 and preheated with heater. During the measurement it was windy and relatively cool and there was also a shower of rain. Although the mix had relatively low temperature, the PAH-contents above the augers of the paver were somewhat higher. This indicates that the heater contributes to an increase of the PAH-contents, which also was observed during the measurements last year. Also the benzothiazole content is considerably higher in comparison with the other measurements in Alingsås, than but not as high as during the measurements in Gothenburg, where it was almost windless. The aniline content above the augers of the paver is insignificantly higher than that was measured in Gothenburg.

Estimations of smell

Discussions with paving staff and their estimation of smell/inconveniencies indicate that they after a while do not think about the rubber smell, if they know what is smelling and also got information on what is smelling and the health risks.

2009 - PARTIAL SUMMARY Measurement 1-5 including estimations and interviews

Fan on the paver leads to a reduction of the PAH-exposure, but several investigations need to be carried out on one and the same paver with fan on and off respectively during similar weather conditions to confirm this effect.

The exposure to aldehydes is very low and can hardly be the reason for those irritations of the respiratory passages and the indisposition, which have been reported during paving of rubber asphalt (6). Aniline has a lower smell limit of around 2000 µg/m³ and could not even be measured above the augers of the paver. So aniline can neither hardly be the reason for the reported inconveniences.

The addition of deodorising agents as limonene to the rubber asphalt neither reduces the benzothiazole content nor the aniline content.

Benzothiazole and aniline are not possible to detect at the site boundary in the wind direction from the asphalt plant.

Ragnsell's rubber granules yield the same PAH-contents as Eximlink-granules.

ABS 11 (without rubber) emits somewhat lower PAH-contents compared with both GAP 11 (with rubber) and the so called 'cold GAP 11 (with added rubber and wax). Any difference in PAH-emission between the latter could hardly be observed. When laying the open-graded mix GAÖ 8/GAÖ 11 with Vetfix in combination with pre-heating, the PAH-emission and the benzothiazole content increased, which also can be owing to the use of heater?

Discussion

Field measurements can be influenced by a number of external factors as wind-force, wind direction, air temperature, weather (sun, rain etc.), production rate, asphalt paver, traffic and not the least the asphalt temperature. At the measurements 4a-4c the external factors were varying very little except the asphalt temperature and the mix type. The PAH-emission above the augers of the paver from GAP 11 without added wax was/is slightly higher than the emission from “cold” GAP 11 with wax. For ABS 11 without added rubber, the reduction compared to GAP 11 was somewhat more evident, but the differences should generally be greater with lower wind forces at the time for the measurement.

The greatest PAH-contents were measured when laying rubber asphalt with both heater and remixer, which anyhow indicate that the temperature of the mix has a great influence. At the pilot study 2006 the first conclusion drawn was that the PAH-emission increases due to the addition of rubber.

However, the increased PAH-emission can also be caused by the higher temperature (178-182°) at the trials with rubber granules compared with those trials that were run without rubber granules (162-164°).

All results from the field measurements in this project and the measurable carcinogenic PAH-contents above the augers of the paver are compiled in the following table:

Field measurements	Rubber asphalt	Rubber asphalt	Rubber asphalt	No rubber asphalt
	No heater	Heater	Heater remixer	No heater
Ringvägen Malmö 2007	1,4			
Measurement 1 Malmö 2008	0			
Measurement 2 Vetlanda 2008			2,64	
Measurement 3 Danderyd 2008		1,67		
Measurement 4 Danderyd 2008		1,2		
Measurement 5 Danderyd 2008		0,56		
Measurement 6 Norrköping 2008		0,72		
Measurement 1b Malmö 2009	0,38			
Measurement 1c Malmö 2009				0,54
Measurement 3 Gothenburg 2009	1,5			
Measurement 4a Alingsås 2009				0,28
Measurement 4b Alingsås 2009	0,53			
Measurement 4c Alingsås 2009 *	0,37			
Measurement 5 Alingsås 2009 **		1,65		
Mean µg/m³	0,70	1,16	2,64	0,41

* GAP 11 ”cold” with Sasobit wax

** GAÖ 8/GAÖ 11 with Vetfix API7

The results in the table above indicate that the temperature of the asphalt determines to a great extent the amount of emitted carcinogenic PAHs. The influence of the added rubber becomes less important, if the asphalt temperature is kept at a reasonable level.

The emission of benzothiazole is also influenced by the temperature, since benzothiazole is a fluid at room temperature and boiling at only 228°C.

Conclusions and recommendations

As benzo(a)pyrene is the most carcinogenic PAH (Reference 7, Annex page 50), it has often been regarded as an indicator for other PAHs (5). When laying rubber asphalt the exposure to benzo(a)pyrene is in the range from non-detectable to maximum 1,5 % of the level limit value for benzo(a)pyrene. The results of the measurements have also shown that the addition of rubber increases the exposure to PAHs very little and is on a very low level, when laying rubber asphalt. Thus, rubber asphalt mixes will not make the working environment essentially more dangerous than conventional asphalt mixes.

The conclusions above must not stop the efforts to reduce the exposure to PAHs, benzothiazole, aldehydes, aniline and other chemical substances. So it is recommended to continue the work with increased temperature control and systems, which minimize the risk for over-heating of the asphalt mix at the asphalt plants. The development of so called 'cold mix' should also continue, as lower temperature results in decreased emission of air pollutants. If further measurements with fewer external variables can verify that fan above the augers of the paver reduces the exposure to PAHs, investments in such equipped pavers are also recommended.

References

1. Chemical comparison of laboratory generated fumes from straight run vacuum distilled and two different crumb rubber modified bitumens.

Prepared for Swedish Road Administration. Anthony J. Kriech, Heritage Research Group 2007
2. Chemical comparison of laboratory generated fumes crumb rubber modified bitumens – a laboratory prepared versus production prepared product.

Prepared for Swedish Road Administration. Anthony J. Kriech, Heritage Research Group 2008
3. Utlakning av polycykliska aromatiska kolväten (PAH) ur asfalt och förorenad mark.

IVL-rapport Annika Perhans 2003 (in Swedish)
4. Arbetsmiljöverkets författningssamling 2005:17 Hygieniska gränsvärden (in Swedish)
5. Polyaromater i arbetsmiljön Arbeta och hälsa 1980:1 Gösta Lindstedt och Jan Sollenberg (in Swedish)
6. Asfaltarbetarens skräck: asfalt med gummiinblandning? SEKO-Tidningen 2008 (in Swedish)
7. Kemiska ämnen. Prevents web-databas 2009 (in Swedish)

Annex

Compilation of toxicological and physical data on PAHs (7)

	LD₅₀ orally; rat/mouse mg/kg = substance mass in mg per kg body mass, when 50 % of the rats/mice die when eating it		Relative carcinogenic potential cp. benzo(a)pyrene	Melting- point °C	Boiling- point °C
Naphtalene	490		Non-carcinogenic	80	218
Acenaphtylene	1 760	(mouse)	Non-carcinogenic	92-93	217
Acenaphtene	10 000		Non-carcinogenic	96	279
Fluorene	> 2000		Non-carcinogenic	116-117	295
Phenanthrene	700		Non-carcinogenic	101	340
Anthracene	3 200		Non-carcinogenic	217	342
Fluoranthene	2 000		Non-carcinogenic	109-111	384
Pyrene	2 700		Non-carcinogenic	156	393
Benzo(a)anthracene			0,014 - 0,145	161	438
Chrysene			0,001 - 0,1	255-256	448
Benzo(b)fluoranthene			0,141 - 1	168	357
Benzo(k)fluoranthene			0,01 - 0,1	217	480
Benzo(a)pyrene	> 15		1	178	495
Benzo(ghi)perylene			Not a confirmed carcinogenic	277	550
Dibenzo(ah)anthracene			0,89 - 5	266	524
Indeno(123cd)pyrene			0,067 - 0,232	163	536

Annex



Pictures – Bitumen mixer used at the pilot study and Measurement 1 - 2007

Annex



Remixer at Measurement 2 – 2008 Vetlanda

Annex

Assessment of smell and possible other inconveniencies from asphalt

Date 2009-

Name _____

Occupation: _____

Grade on a scale 0-6 how strong
the rubber asphalt mix smells **today** where

- 0 = No smell
- 1 = Hardly perceptible smell
- 2 = Weak smell
- 3 = Clear smell
- 4 = Strong smell
- 5 = Very strong smell
- 6 = Unbearable smell

Do you experience **other** inconveniencies of the rubber asphalt mix **today**?
If so, specify these inconveniencies

Grade on a scale 0-6 the intensity of the inconveniencies
the rubber asphalt mix smells **today** where

- 0 = No inconveniencies
- 1 = Hardly perceptible
- 2 = Weak
- 3 = Clear
- 4 = Strong
- 5 = Very strong
- 6 = Unbearable