D12

FINAL REPORT

ON

SOCIO-ECONOMIC IMPACTS

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An important study for the health and safety of workers was achieved during the project:

Concerning the Action C2, hazard assessment was performed to produce specific measurements of PAH (polycyclic aromatic hydrocarbons) on different configurations of jobsite.

Two goals for this study: the values of PAH are needed to establish the life cycle analysis (LCA) as part of impacts in the air and may be used to adapt the protection to the risk for health and safety for workers in jobsites.

We extracted it from a USIRF database of hazard assessment, CIMAROUT.

The specific study on PAH on jobsites allowed to have a reference table which can be used both for LCA and for protection of workers.

Activities and results

Hazard assessment was performed on 51 jobsites in 2014 and 2015 to produce specific measurements of PAH on different configurations of jobsite (rural road, tunnel, warm mix asphalt, hot mix asphalt…). The study was performed by Grenoble Hospital University and 2 reports have been done (one in 2015 and one in 2016).

These results are shared with EAPA (European Asphalt Pavement Association), to be disseminated in asphalt companies all over Europe. Some recommendations have been done for health and safety workers: the best available technique is warm mix asphalt today.

The values of PAH are used in the LCA as impacts in the air and may be used to adapt the protection to the risk for health and safety.

Table 1 of the final report for LCA – Data on bitumen fume emissions during asphalt laying (from the study on PAH)

Data	Unit	Values for 1 m² of pavement	Source
Fluoranthene	kg	4.28E-08	Calculation
Pyrene	kg	2.87E-08	
Benzo(a)anthracene	kg	1.36E-09	
Chrysene	kg	6.22E-09	
Benzo(b)fluoranthene	kg	3.34E-09	
Benzo(j)fluoranthene	kg	1.24E-09	
Benzo(k)fluoranthene	kg	1.41E-09	
Benzo(a)pyrene	kg	1.98E-09	
Benzo(e)pyrene	kg	4.75E-09	
Dibenzo(a,h)fluoranthene	kg	7.92E-10	
Benzo(ghi)perylene	kg	2.54E-09	
Indeno(1,2,3-cd)pyrene	kg	1.02E-09	
Naphthalene	kg	5.30E-03	
Acenaphthene	kg	1.12E-03	
Fluorene	kg	6.20E-04	
Phenanthrene	kg	1.11E-03	
Anthracene	kg	5.17E-05	
Fluoranthene	kg	6.91E-05	
Pyrene	kg	4.18E-05	

Data	Unit	Values for 1 m² of pavement	Source
Benzene	kg	9.90E-05	
Cyclopentane	kg	1.13E-04	
n-Hexane	kg	2.83E-04	
Toluene	kg	7.92E-04	
Styrene	kg	5.66E-05	
Xylenes	kg	2.09E-02	
Ethylbenzene	kg	1.98E-02	
Formaldehyde	kg	5.66E-05	

This study allowed to bring a better definition for the risk evaluation in our job:
Comprehensive approach vs specific approach

An article was written by Christine Leroy and Georges Balavoine (Expert with the Health-Safety Committee of Usirf) about these two approaches:

As part of the preparation of the Single Risk Assessment Document (DUER), each employer much characterize the exposure of his employees to asphalt binder emissions.
To do this, the collective assessment report and the ruling of Anses “Evaluation of the health risks linked to the occupational use of asphalt products and their additives” very clearly proposes to implement two approaches in parallel:

- “A comprehensive approach on the one hand, quantifying the major classes of pollutants present in the emissions (VOC, dust, etc.), relevant within the framework of a comparative risk prevention approach.”
  Henri Molleron provides an excellent description of it in his article “Case of asphalt fumes: historical context”. This method, developed by the INRS (National institute for research and safety for the prevention of work accidents and occupational illnesses), was recently published and put into application on some fifty projects. It has started to prove itself and it will very likely become the reference method, as soon as the work of comparison with the German method is completed.

- “A specific approach on the other hand, targeting certain well-identified pollutants (B[a]P, PAH, etc.), and useful in an approach of characterization of the toxicological profiles of the asphalt binders and their emissions. While awaiting additional new tracers, the measurement of the PAHs remains the current reference.”

That is why the members of Usirf (Union of French Road Industry Associations) also wanted to carry out on the same projects monitored by the INRS and the Carsats (Pension and occupational health insurance funds) in 2014 and 2015 series of measurements of PAHs (polycyclic aromatic hydrocarbons) and assigned this study to the Toxicology Department of the Grenoble University Hospital Center, which is a reference on the national level in terms of industrial and environmental toxicology. This study, which concerns in particular the evaluation of exposure to asphalt fumes through the analysis of 17 gaseous and particle PAHs, was supplemented at the request of a few companies by the analysis of 13 metabolites of these PAHs. It is presented in the article “Occupational exposure to asphalt fumes”, signed by Laurence Boulangé, Erick Lemonnier, Franck Ollivier, Lionel Bobeau and Jean-Pierre Baud.

It also highlights the efficacy of collective prevention measures: the use of warm asphalt mixes, the use of finishers with windshields and systems for aspiration of asphalt fumes, etc.

This article was completed by another collective article about the study lead by the Grenoble Hospital University, written by member of USIRF:

Occupational exposure to asphalt fumes
Main conclusions of the 2015 national campaign
The national campaign carried out by Usirf on asphalt fumes in 2014 and 2015 continues on from other studies devoted to the evaluation of occupational risks. It covers the evaluation of exposure to fumes through the analysis of 17 PAHs in respiratory exposure and of 13 metabolites of these PAHs.

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The various studies carried out since 2001 by the road construction sector, in conjunction with the Occupational Health Service, the Carsats (Pension and occupational health insurance funds) and the CHSCT (Health, safety and working conditions committees) of companies, have always demonstrated that the levels of exposure were well below the regulatory or recommended threshold values and that the means of prevention implemented had led over time to the continuous lowering of the levels of exposure of employees of the road construction industry to PAHs (polycyclic aromatic hydrocarbons).
The national campaign carried out by Usirf (Union of French Road Industry Associations) in 2014 and 2015 continues the evaluation of occupational risks. It was carried out with the Toxicology Department of the Grenoble University Hospital Center, recognized on the national level as the reference in terms of industrial and environmental toxicology. This study

covers the evaluation of exposure to fumes through the analysis of 17 PAHs in respiratory exposure and 13 metabolites of these PAHs.

Methodology

In the ruling of Anses (National Agency for Food, Environment and Occupational Health & Safety) concerning the evaluation of the health risks linked to the occupational use of asphalt products and their additives[4], it was recommended that users of asphalt products implement two analysis strategies to evaluate the exposure of employees to asphalt fumes:

- the first one, referred to as comprehensive, which is part of a preventive approach to reduce exposure, is the subject of the work of the working group of INRS (National institute for research and safety for the prevention of work accidents and occupational illnesses) – Profession;
- the other one, referred to as specific, which remains indispensable in an approach involving toxicological investigation and characterization of PAH mixtures, is the subject of the voluntary campaign of Usirf initiated in 2014 and broadly continued in 2015.

Analysis of asphalt fumes

In the so-called comprehensive approach, a working group was formed including representatives of the profession (Usirf and Asphalt Office), the INRS, the OPPBTP (Organisation for Prevention of Occupational Hazards in the Construction Industry), the GNMST-BTP (Multi-disciplinary national consortium for health in the workplace in construction and public works), Eurobitume, the CNAM (National health insurance fund) and the DGT (Directorate-General for Labour). The goal of this working group was to define a comprehensive method to allow for measurement of the emission of carbonated compounds between C9 and C36 (beyond the PAH tracers alone and all of the VOC (volatile organic compounds)), with the understanding that the concentrations measured could not be associated with any health effect because of the globalization of the mixture measured.

With this objective, a method, developed by the exposure metrology laboratory of the INRS led to the publication of Métropol 123, accessible on the INRS site.
Within the framework of this specific approach, 17 PAHs were measured and analyzed, of which 5 gaseous PAHs, 2 PAHs in gas and particle form and 10 PAHs in particle form. Based on a proposal from the Grenoble University Hospital Center, 2 PAH isomers of benzo[a] pyrene (BaP) were also analyzed.
This exposure study is the largest one ever carried out, both in terms of the number of samples and the number of tracers taken into consideration. It supplements the preceding Usirf study of 2014. The results presented in this article concern the 2015 campaign. Within the framework of this study, all of the PAHs emitted led to exposure values and biometric monitoring.
Within the framework of this study, the notion of toxic equivalent was proposed by the Grenoble University Hospital Center in order to integrate all of the carcinogenic particle PAH values classified C1B by the European Union that don't have occupational exposure limit values (OELV) and to associate with them a toxic equivalent (Toxic Equivalent Factor (TEF) published by Ineris).

–Table 1–
PAH studied in atmospheric surveillance.
For the European Union, the substances classified 1B are substances that must be considered carcinogenic substances.
For the CIRC, the substances classified 1 are carcinogenic, 2A: probably carcinogenic and 2B: possibly carcinogenic.

HAP		Classe EU[1]	Classe CIRC[2]	Seuils	Seuils de quantification
HAP gazeux	**Naphtalène (Naph)** CAS 91-20-3, CE 202-049-5	2	2B	VLEP* = 50 mg/m³	0,30 ng / tube
	Acénaphtylène (Acen) CAS 208-96-8, CE 205-917-1	-	-	-	0,20 ng / tube
	Fluorène (Fluo) CAS 86-73-7, CE 201-695-5	-	-	-	0,10 ng / tube
	Phénanthrène (Phe) CAS 85-01-8, CE 201-581-5	-	-	-	0,10 ng / tube
	Anthracène (ant) CAS 120-12-7, CE 204-371-1	-	-	-	0,05 ng / tube
HAP gazeux et particulaires	**Fluoranthène (G-Flua)** CAS 206-44-0, CE 205-912-4	-	-	-	0,10 ng / tube 0,10 ng / filtre
	Pyrène (G-Pyr) CAS 129-00-0, CE 204-927-3	-	-	-	0,10 ng / tube 0,05 ng / filtre
HAP particulaires	**Benzo[a]anthracène (BaA)** CAS 56-55-3, CE 200-280-6	1B	2B	-	0,10 ng / filtre
	Chrysène (Chr) CAS 218-01-9, CE 205-923-4	1B	2B	-	0,10 ng / filtre
	Benzo[b]fluoranthène (BbF) CAS 205-99-2, CE 205-911-9	1B	2B	-	0,10 ng / filtre
	Benzo([k]fluoranthène (BkF) CAS 207-08-9, CE 205-916-6	1B	2B	-	0,05 ng / filtre
	Benzo[a]pyrène (BaP) CAS 50-32-8, CE 200-028-5	1B	1	Valeur recommandée par la CNAMTS** = 150 ng/m³	0,05 ng / filtre
	Indéno(1,2,3-cd)pyrène (IP) CAS 193-39-5, CE 205-893-2	2	-	-	0,20 ng / filtre
	Dibenz[a,h]anthracène (DahA) CAS 53-70-3, CE 200-181-8	1B	2A	-	0,10 ng / filtre
	Benzo[ghi]perylène (BghiP) CAS 191-24-2, CE 205-883-8	-	-	-	0,10 ng / filtre
	Benzo(j)fluoranthène (BjF) CAS 205-82-3, CE 205-910-3	1B	-	-	0,05 ng / filtre
	Benzo(e)pyrène (BeP) CAS 192-97-2, CE 205-892-7	1B	-	-	0,05 ng / filtre

* VLEP : valeurs limites d'exposition professionnelle
** CNAMTS : Caisse nationale d'assurance maladie des travailleurs salariés

Measurement protocol

The measurements of professional exposure to asphalt fumes took into account the respiratory and cutaneous routes:

- To take into account exposure via the respiratory route, 2 pumps were installed simultaneously on several employees working at the site in order to draw atmospheric samples, one for the PAHs (specific approach), the other one for the comprehensive approach.

–Photo 1–
Installation of sensors for the measurement of the atmospheric exposure of the employees (finisher driver, screedman and rake operator).

- To take into account the possible cutaneous exposure to PAHs, urinary samples were drawn from volunteers after a medical prescription from the occupational health physician and then a consultation and prior information from the Health, Safety and Work Conditions Committees involved. The individual results were only sent to the occupational health physicians who were in charge of notifying the employees of the results obtained.
  This campaign was covered by study agreements between the Grenoble CHU and the Eurovia and Eiffage Infrastructures Prevention Departments on the one hand and Usirf on the other. The results were sent in the form of an anonymous summary report which gives the various levels of PAHs and their metabolites dosed in the urine at the beginning and the end of the shift.

The analyses of the urinary metabolites of the PAHs involved 1-hydroxypyrene and urinary 3-hydroxybenzo(a)pyrene as well as 11 metabolites of gaseous PAH (1- and 2-naphtols, 1- 2- 3- 4- 9- phenanthrols and 1- 2- 3- 9-fluorenols).
For this biological study, the individual parameters, such as tobacco use or the consumption of smoked foods or barbecue grilled meat, were also taken into account.
Atmospheric samples were taken:

- For the PAHs, by two samplers on asphalt mix laying work sites after training by the team of the Grenoble CHU;
- For the comprehensive approach, by agents of the participating Carsat laboratories. Their role was to draft the sampling sheets in accordance with the good practice recommendations of the French Occupational Health Society (SFMT).
  Technical questionnaires concerning the descriptions of and conditions for the carrying out of the work, the events that occurred during the metrology days and the

temperatures of the asphalt mixes were systematically used. These questionnaires were produced in the form of sheets:

- A descriptive sheet for the work site giving the conditions defined in advance before the project;
- A sheet for atmospheric samples giving the actual conditions observed on the day of the drawing of the atmospheric samples;
- A sheet for event information (time of arrival of the supply trucks, etc.). For this study, various work site typologies representative of the activity of the road construction industry were inventoried and proposed: mechanized work with hot or warm asphalt mixes, manual laying, semi-enclosed work sites (tunnel or parking lot), mechanized work site with finisher that might or might not be equipped with a capture system (photos 2 and 3).

–Photo 2–
Configuration in tunnel.

* OELV: Occupational exposure limit values
** CNAMTS: National health insurance fund for salaried employees

The temperature of the asphalt mixes was recorded for each truck at the level of the worm feeder of the finisher using a thermocouple. An arithmetic average was then calculated, the minimum and maximum temperatures were noted, allowing for verification of the temperature set points given during the manufacturing of the asphalt mixes at the asphalt mix plant and to ensure the proper coherency of the project typologies proposed. The asphalt fume capture systems on the finishers were checked using an anemometer at the beginning of and during the work (photo 4).
Lastly, potential PAH emitting sources, such as the exhaust gases coming from the fleet of trucks and the finisher, were taken into account in the study.

–Photo 3–
Installation of sensors for the environmental reference.

Results

Conditions of application of asphalt mixes

The application conditions for the asphalt mixes are summarized in table 2.
During the campaign, the outside air temperature varied between 5 and 21 °C, with an average of 13.2 °C. We also note a work site in an enclosed area (tunnel), for which the temperature was 30 °C.
The wind, the precipitation and the degree of sunlight on the various days of measurement were taken into account: wind speed and orientation (4 situations/23 involved moderate to high winds, or 23.2% of the samples), precipitations (8 work sites/23, or 31.6% of the samples). Overall, little precipitation was observed for the work sites studied. The measurements made are thus representative of a summer/autumn exposure. 5 projects were done at night and 3 were carried out in semi-enclosed areas (tunnel or parking lot).

Respiratory exposure

Comprehensive approach

The campaign carried out over the 2014-2015 period in conjunction with the Carsat and the INRS allowed for the collection of 259 individual measurements and testing of the Métropol 123 protocol. The values expressed in mg/m3, although they cannot be correlated with a health effect, can serve as indicators to evaluate the overall efficacy of the means of prevention. All of this work will be presented in an article in the near future.

Specific approach

In all, 88 atmospheric samples of gaseous PAHs and 88 atmospheric samples of particle PAHs were taken.

–Photo 4–
Monitoring of the fume capture system on the finisher.

–Table 2–
Summary of the conditions of application of asphalt mixes during the Usirf voluntary campaign.

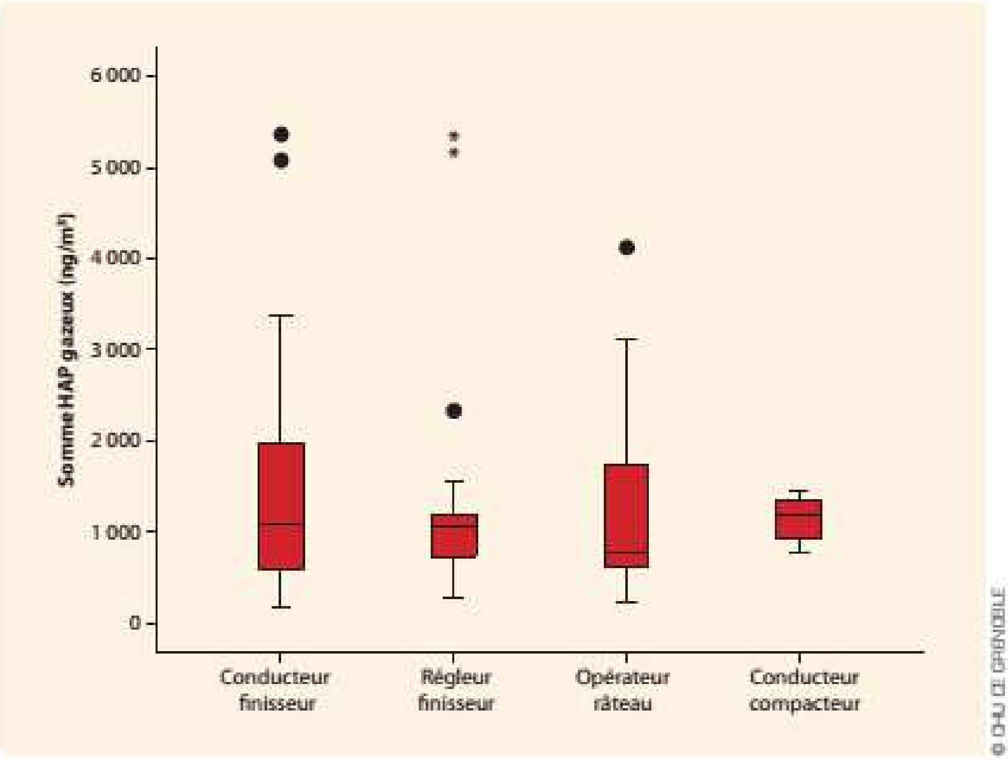
	Température de l'enrobé (°C)	% de liant bitumineux	% de recyclés d'enrobés	Tonnage d'enrobés appliqué par finisseur	Nombre de camions de chantier
Moyenne	157,9	5,1	11,6	464,3	31,4
Médiane	160	5,1	10,0	330	18
Écart-type	10,3	0,52	8,2	507,3	30,7
Minimum	136	4,1	0	15	0
Maximum	175	6,1	25	2 100	111

67 individual samples (76.1%) and 21 surrounding samples (23.9%) corresponding to standard reference sample on work site boundary were taken (standard reference sample on work site boundary positioned at a distance, upstream from the work site). The gaseous PAH values (naphthalene, acenaphthylene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene), which correspond to the sum of each of the PAHs, are given by work station in table 3 and in figure 1.
The highest geometric value and the highest maximum value are for the roller driver station.

–Table 3–
Sum of the gaseous PAHs (ng/m3) as a function of the work stations.
Over the entire campaign, one aberrant measurement was found on one roller driver. Although this measurement does not corroborate all of the measurements made on this work station, it was kept.

Postes	N	Moyenne géométrique	Médiane	Minimum	Maximum
Conducteur de finisseur	19	1 111	1 082	165	5 369
Régleur finisseur	21	993	1 050	268	5 347
Opérateur au râteau	22	935	780	219	4 139
Conducteur de compacteur*	5	1 732	1 265	775	10 243
Total prélèvements individuels	67	1 048	1 047	165	10 243
Blancs	21	68	68	8	847

–Figure 1–
Gaseous PAH exposure as a function of the work stations.



–Table 4–
Sum of the particle PAHs (ng/m3) as a function of the work stations.
Over the entire campaign, one aberrant measurement was found on one roller driver. Although this measurement does not corroborate all of the measurements made on this work station, it was kept.

Postes	N	Moyenne géométrique	Médiane	Minimum	Maximum
Conducteur de finisseur	19	10	8,9	1,6	133,7
Régleur finisseur	21	13	15,3	2,7	144,3
Opérateur au râteau	22	10,5	12,3	1,5	56,1
Conducteur de compacteur*	5	39,0	17,6	14,3	1 205,1
Total prélèvements individuels	67	12,2	11,9	1,5	1 205,1
Blancs	21	2,2	2,1	0,9	9,4

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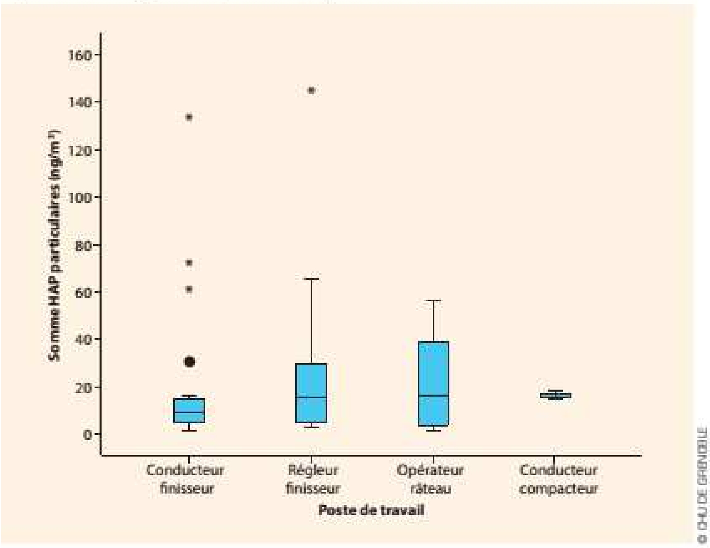
If we compare with the sole OELV value of naphthalene available (50 000 000 ng/m3), the median represents 0.003% of the OELV, the maximum 0.02% of the OELV.
The particular PAH values (fluoranthene, pyrene, benzo[a]anthracene, chrysene, benzo[b] fluoranthene, benzo[k]fluoranthene, benzo[j]- fluoranthene, benzo[a]pyrene, benzo[e]pyrene, dibenzo[a,h]anthracene, benzo[ghi]perylene, indeno[123-cd]pyrene), which correspond to the sum of each of the PAHs, are given by work station in table 4 and figure 2.
The highest geometric value and the highest maximum value are for the roller driver station.
The sum of the particle PAH concentrations is between 1.5 ng/m3 and 1 205,1 ng/m3 for all of the work stations. The majority PAHs are generally fluoranthene and pyrene and occasionally, chrysene and benzo[e]pyrene.

–Figure 2–
Gaseous PAH exposure as a function of the work stations.



The BaP concentrations for the work stations studied are all well below the value recommended by the CNAMTS of 150 ng/m3: they are all below 8% of this recommended value, with the exception of a sample from a roller driver for which the exposure represents 68% of this value. The exposure levels measured in this study are slightly lower than those reported in the scientific literature. Most of the studies mention BaP concentrations that do not exceed one tenth of the value recommended by the CNAMTS.

The benzo[a]pyrene toxic equivalent concentrations (BaPeqT), calculated from carcinogenic PAHs and their toxic equivalent factors, are between 0.2 and 113.1 ng/m3 for all of the work stations, or levels about 30% higher than those of the BaP alone. The BaPeqT levels represent at most 7.4% of the value recommended by the CNAMTS.

Cutaneous exposure

The goal was to study, using various bio-markers, the profiles of exposure to PAHs during the application of asphalt mixes for the purpose of evaluation of health risks. To illustrate this approach, the example is given for 1-hydroxypyrene (1-OHP) and 3-hydrobenzo[a] pyrene (3-OHBaP), metabolites of particle PAHs. 3-OHBaP is the metabolite of benzo[a] pyrene, which is eliminated in the urine. It is particularly valuable because it is the best indicator of exposure to carcinogenic PAHs. 1-OHP and 3-OHBaP were analyzed on the samples at the beginning and the end of work shifts, the metabolites of the gaseous PAHs only at the end of the shift (table 5).

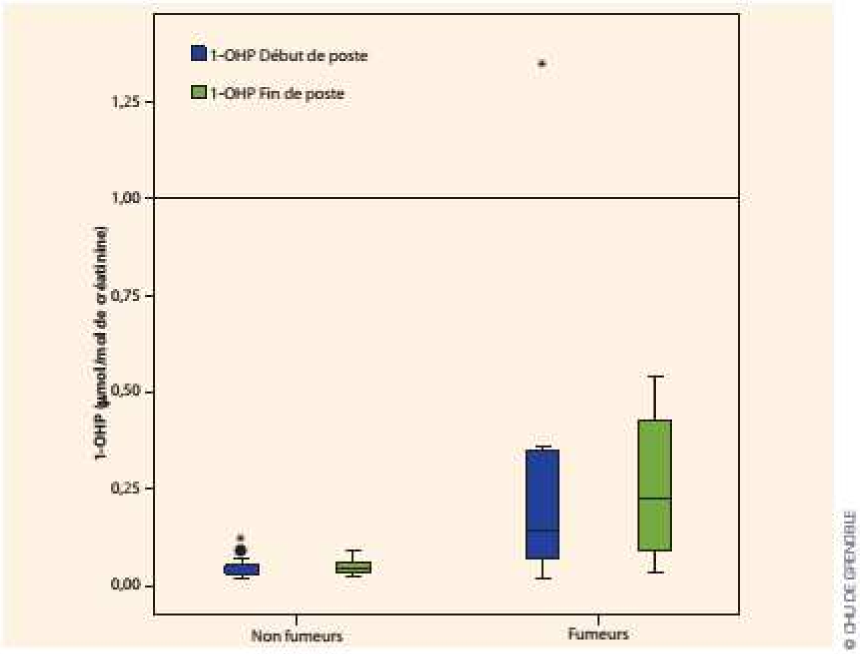
–Table 5–
Statistical analysis of the 1-OHP and 3-OHBaP measurements as a function of the tobacco use of the employees.
The results are expressed with respect to creatinine, which is a metabolic waste product from creatine, mainly eliminated by the kidneys and excreted in the urine. Its level reflects the functional state of the kidneys.

Métabolite	Données statistiques	Début de poste (nmol/mol créatinine)	Fin de poste (nmol/mol créatinine)
1-OHP	**Non fumeurs N**	20	20
	Moyenne géométrique	***0,046***	***0,043***
	Médiane	0,05	0,045
	Minimum	0,02	0,02
	Maximum	0,12	0,09
	Fumeurs N	10	10
	Moyenne géométrique	***0,15***	***0,18***
	Médiane	0,14	0,23
	Minimum	0,02	0,03
	Maximum	1,35	0,54
3-OHBaP	**Non fumeurs N**	20	20
	Moyenne géométrique	***0,026***	***0,024***
	Médiane	0,019	0,024
	Minimum	0,01	0,01
	Maximum	0,19	0,14
	Fumeurs N	10	10
	Moyenne géométrique	***0,042***	***0,045***
	Médiane	0,055	0,050
	Minimum	0,01	0,01
	Maximum	0,12	0,11

We did not observe any significant difference in 1-OHP concentrations between the beginning and the end of the work shift, whether for smokers ($p = 0.767$) or non-smokers ($p = 0.145$).
We observed significantly higher levels of 1-OHP in smokers compared with non-smokers, both at the beginning ($p = 0.001$) and at the end of the shift ($p < 0.001$). Tobacco smoke thus exercises a major interference on the 1-OHP concentrations in this study (figure 3).

These levels are very substantially below the value of 1µmol/mol of creatinine for which we observe the absence of a genotoxic effect in the general population.
The 3-OHBaP concentrations at the beginning and the end of the shift are all very substantially below the recommended value of 0.4 nmol/mol of creatinine. We do not observe a significant difference in 3-OHBaP concentrations between the beginning and the end of the work shift, neither for smokers (p = 0.95) nor non-smokers (p = 0.44). We do not observe a significant difference in 3-OHBaP concentrations as a function of the tobacco use of the subjects, whether at the beginning or the end of the work shift.
Similar conclusions were produced for the other biomarkers, metabolites of gaseous PAHs.
Lastly, the new version of the Cimarout database, recently developed by Usirf, includes all of the occupational exposure data obtained during this national campaign in conjunction with the field observations made during the work.

–Figure 3–
Statistical processing of the data concerning 1-OHP at the beginning and the end of the shift as a function of the tobacco use of employees.



This database constitutes a tool including both technical and preventive data that is useful for the entire road construction profession.

Factors that influence the individual concentrations
In order to determine the factors which influence the individual atmospheric concentrations of the various PAHs, multivariable linear regression models were created. On this 2015 campaign, they reveal the following variables:
• variables which significantly influence the concentrations of gaseous PAHs: number of work site trucks, maintaining of the traffic, tonnage applied, temperature of the asphalt mixes;
• variables which significantly influence the concentrations of particle PAHs: temperature of the asphalt mixes, percentage of asphalt binder, tonnage applied;

• variables which significantly influence the BaP toxic equivalent concentrations: percentage of asphalt binder, number of work site trucks, percentage of recycled materials;
• variables which significantly influence the total pyrene concentrations: temperature of the asphalt mixes.
These results plead in favor of the recommendation to use warm asphalt mixes which limit fume emissions and to include the lowest possible concentration of asphalt binder. With regard to the two campaigns overall, the percentage use of recycled materials in the asphalt mixes does not seem to have an influence on the results obtained.

Conclusion

These occupational exposure studies showed that, according to the project configurations, the atmospheric exposures to PAHs were low to very low. It is important to point out that the cutaneous exposure was taken into account thanks to biological analyses (urinary metabolites of pyrene, BaP and gaseous PAHs), which allowed for the integration of the various routes of absorption of PAHs among employees and the efficacy of individual means of protection.
Cutaneous exposure, carried out based on any anonymous statistical study, concluded that the risk was low. It is important to point out that the tobacco use status of the employees has a substantial influence on the concentrations of almost all of the PAH metabolites. These biological analyses, carried out at the request of companies and occupational health physicians, were given individually to the occupational health physicians and collectively to the prevention managers.
Fume capture systems, of limited number or with systems that were sometimes clogged, do not stand out in the PAH statistical study, but this does not bring into question their value, which was demonstrated in other studies4. It is consequently recommended that work site equipment be equipped with fume capture systems, for which the efficacy must periodically be verified (absence of clogging). Is the comprehensive approach the one best suited for evaluating the efficacy of this type of system at a work site? The initial results seem to suggest this.
These studies allowed for validation of the factors that influence individual concentrations, such as the temperature of the asphalt mixes, the percentage of asphalt binder, the number of trucks, the maintaining of traffic and the tonnage applied.
To limit the emissivity, it is primordial to control the temperature throughout the asphalt mix production line, to decrease the application temperatures, to install capture systems and windshields on finishers, to decrease the percentage of asphalt binder, to use vegetable fluxes and to wear covering clothes. Because of the potential cutaneous absorption, the wearing of clothes with sleeves and long legs is recommended in order to limit the skin surfaces that could be exposed to PAHs and also to sun radiation.

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Other socio-economic impacts

- List of the key parameters to follow-up is established (e.g. number of jobs created, financial savings, etc.) (few weeks after the start of the action):
  - number of jobs created: 1 person at USIRF and new positions in environmental department,
  - personnel trained: 300 persons/year (technicians on SustainEuroRoad construction sites)
  - revenue generated: 0€

- Calculations on quantitative aspects of the socio-economic benefits achieved (at the end of the action):
  - number of jobs created: new positions in environmental departments estimated at about 150 people,
  - personnel trained: 3000 persons/country, i.e. 10 000 persons (technicians on SustainEuroRoad construction sites)
  - revenue generated: two options for exploitation:
    - subscription: 500 €/year → used for maintenance and hosting of the software
    - possible exploitation at national level by SustainEuroRoad partners → potential new economic model (not yet decided at end of October 2018)
