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Occupational exposure to organic particles and combustion products during pregnancy and birth outcome in a nationwide cohort study in Sweden

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ABSTRACT

Objective To study if children of women exposed to organic particles and combustion products at work during pregnancy, have an increased risk of low birth weight, preterm birth or small for gestational age.

Methods A nationwide cohort of all occupationally active mothers and their children from single births during 1994 to the end of 2012 (1 182 138 observations) was formed. Information on birth outcome was obtained from the medical birth register. Information on absence from work, education, occupation, age, nationality and smoking habits was obtained from national registers. A job exposure matrix (FINJEM) was used to assess the exposure.

Results Pregnant women with low absence from work and high (>50th percentile) exposure to organic particles had an increased risk of giving birth to children with low birth weight (OR=1.19; 95% CI: 1.07 to 1.32), small for gestational age (OR=1.22; 95% CI: 1.07 to 1.38) or preterm birth (OR=1.17; 95% CI: 1.08 to 1.27). Subgroup analyses showed an increased risk of small for gestational age in association with exposure to oil mist. Exposure to oil mist and cooking fumes was associated with low birth weight. Paper and other organic dust was associated with preterm birth. Exposure to combustion products showed an increased risk of small for gestational age (OR=1.40; 95% CI: 1.15 to 1.71).

Conclusions The results indicate that occupational exposure to organic particles or combustion products during pregnancy is associated with restriction of fetal growth and preterm birth. More studies are needed to confirm a casual association.

Key messages

What is already known about this subject?
- Ambient air pollution in residential settings has been associated with adverse birth effects.
- Research on organic particle exposures in the occupational setting and adverse birth outcomes is scarce, even though the exposures are rather common.

What are the new findings?
- This study showed that exposure to organic particles (such as oil mist, cooking fumes paper dust and other organic particles) and combustion products (such as polycyclic aromatic hydrocarbons) was associated with an increased risk of adverse birth outcomes.

How might this impact on policy or clinical practice in the foreseeable future?
- This study will improve the knowledge and contribute to future preventative work regarding pregnant women in exposed occupations.

INTRODUCTION

Many Swedish women are exposed to particles from various sources in the work environment. About 16% of female employees reported exposure to inorganic dust, organic dust or chemicals for at least one-quarter of the working day in a national survey.[1] The employment rate among Swedish women is high, and most women continue to work during pregnancy, giving a high number of particle-exposed pregnancies.

Ambient air pollution in residential settings has been associated with adverse effects on birth weight.[2] Tobacco smoke is strongly associated with adverse birth outcome.[3] Additionally, polycyclic aromatic hydrocarbon (PAH) has been detected in the placenta and in breast milk and has been linked to complications in pregnancy.[4]

Thus, there are indications for a negative effect on birth outcome from exposure to ambient air pollution, tobacco smoke and combustion products, but very few studies have explored the relationship between occupational exposure to these substances.[5 6] Two American case-control studies on occupational exposures to particles and small for gestational age showed mixed results.[7 8] One French cohort study on exposure to occupationally generated combustion nanoparticles showed an increased risk of small for gestational age.[8 9] But, these previous studies are small, of retrospective design and/or have several methodological problems and rough exposure assessments, therefore more studies are needed.

Potentially, exposure to particles may generate oxidative stress that can lead to systemic inflammation and cause vascular dysfunction in the placenta, causing adverse birth outcomes such as low birth weight (LBW), small for gestational age and preterm birth.[10] Adverse birth outcomes are known predictors for negative health later in life and associated

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with respiratory diseases,[11] cognitive deficiencies[12] and cardiovascular diseases.[13]

We have earlier investigated occupational exposure to inorganic particles and pregnancy outcome.[14] This study is focused on the effects of exposure to organic particles of various origin, generated mechanically or during combustion. This study aims to investigate whether maternal occupational exposure to organic particles (dust from wood, animals, paper, textile, flour, oil mist, cooking fumes and other dust of organic origin) or combustion (PAH, diesel) products is associated with LBW, preterm birth or small for gestational age.

METHODS

Data sources

The study population consists of mother-child pairs of working mothers with singleton births. The cohort was based on the Swedish medical birth register from the National Board of Health and Welfare and merged with the register of sick leave and parental leave (MIDAS) from Swedish Social Insurance Agency and the Longitudinal integration database for health insurance and labour market studies (LISA) from Statistics Sweden. The medical birth register provided data on occupation, potential confounders and outcome variables that was collected both at the registration interview at the prenatal care facilities in the first trimester and throughout the pregnancy for all mothers in Sweden and their children. About 99% of all births in Sweden are included in the medical birth register.[15]

Swedish Social Insurance Agency register of sick leave and parental leave covers long-term sick leave (>14 days), parental leave and special sick leave related to the pregnancy from day 1. The information on absence was used to increase the validity of the exposures by assessing the number of days at work during pregnancy.

From the longitudinal integration database for health insurance and labour market studies at Statistics Sweden (SCB), information about the highest level of the mother's education at each pregnancy was collected and used as an indicator of socioeconomic status.

Exposure

Particle exposure was assessed by a job-exposure matrix (JEM) adapted by the research group from FINJEM to Swedish conditions.[16] The JEM in this study contained exposure estimations of 10 different types of particles over two time periods (based on measurements at occupational sites for each occupation) for about 100 occupational groups. The occupations in the JEM were coded according to the Swedish version of ISCO-58 and then converted to the Swedish version of ISCO-88. The mother's occupations in free text was collected from the medical birth register and then classified according to the Swedish version of ISCO-88, also described in previously published paper.[17]

The occupational exposure to organic particles and combustion products was divided into subgroups. The organic particles consisted of eight subgroups: wood dust, textile dust, flour dust, pulp or paper dust, dust from living animals, cooking fumes, oil mist and other organic particles (dust from soil, leather, plastic and soot). The combustion products were estimated by using PAH (particulate or volatile compounds) exposure and diesel engine exhaust (expressed as nitrogen dioxide per cubic metre (NO_2/m^3)) as indicator variables. Common occupations with PAH exposure were machine operators, welders, machine and engine mechanics, construction machinery operators and smiths and occupations with diesel engine exhaust exposure included policemen, taxi drivers, truck drivers, bus drivers and automotive mechanics.

Exposure to organic particles overall and subgroups was dichotomised into exposed and unexposed. Due to a larger number of subjects with higher exposure, the overall group was further subdivided into no exposure, low exposure and high exposure using the median (50th percentile, 0.08 mg/m^3) among the exposed as the cut-off between low and high.

The mother's presence at the work place during pregnancy was also stratified into three categories: *working full-time with low absence from work* including mothers that reported full-time work and had <50 days (median) of absence from work during pregnancy, *working full-time or part-time with moderate absence from work* including mothers reporting part-time work or with 50 (median) or more days but fewer than 112 (75th percentile) days of absence during pregnancy and *high absence from work* including mothers that reported full-time or part-time work at the interview and with 112 (75th percentile) or more days of absence during pregnancy.

Outcome

LBW is defined as a birth weight <2500 g[18] regardless of gestational age. Small for gestational age describes if the baby's birth weight is below a certain centile for the gestational length and indicates risk of fetal growth restriction. The outcome is estimated by a calculated growth curve of weight and gestational age (defined as birth weight below 2 SD of the mean).[19]

It is common to use 280 days or 40 weeks from the first day of the last menstrual period to estimate the date of birth for a full-term pregnancy. Estimated date of confinement (EDC) was primarily based on ultrasound evaluation in the second trimester. Preterm birth is defined by a gestational length of <37 completed weeks.[20]

Confounders

Through a review of previous studies on adverse pregnancy outcomes and particle exposure, potential confounders were identified.[6 21 22] Confounders included in the final model were those which resulted in a deviation of >5% in the point estimate between the model with and without the confounder (with the exposure groups divided into organic particles, PAH and diesel exhaust and the outcome of small for gestational age, preterm birth and LBW).

The variables initially assessed were the children's birth year (quartiles), gender, parity (first child, second child or third child or more) and the mother's nationality (Swedish, EU15/Nordic countries except Sweden or outside EU15), family structure (married/living together with the father, and others), current smoking habits (non-smokers, smokers 1–9 cigarettes per day, smokers 10 cigarettes per day or more), body mass index (normal range, underweight, overweight, obese according to WHO in kg/m^2), age (five categories in intervals of 5 years), occupational exposure to noise (<75 dB or equal, or more), physical work (±) and job strain (±) and work at the beginning of pregnancy (full-time, part-time or not at all) and the highest completed educational level (high school 2 years or less, university <3 years, university 3 years or more or graduate). The variables that were included in the final model are presented in table 1.

Table 1 Baseline characteristics* of the study participants (995 843) in per cent (%) and number (n) of participants with exposure to organic particles and combustion products (PAH+diesel exhaust)

Number (n) and column per cent (%) of participants	Organic particles	Combustion products		All births
		PAH	Diesel exhaust (NO_2)	
	Exposure n (%)	Exposure n (%)	Exposure n (%)	n (%)†
Mother's age (years)				
<25	17 995 (19.2)	1511 (16.5)	1063 (10.5)	111 051 (11.2)
≥25, <30	33 143 (35.4)	3610 (39.5)	3407 (33.5)	328 776 (33.0)
≥30, <35	27 477 (29.3)	2709 (29.6)	3697 (36.3)	362 597 (36.4)
≥35	15 042 (16.1)	1316 (14.4)	2010 (19.8)	193 419 (19.4)
Smoking				
Non-smokers	78 000 (84.5)	7502 (83.3)	8961 (89.3)	900 154 (90.4)
Smokers, ≥1, ≤9 cigarettes per day	9782 (10.6)	1008 (11.2)	675 (6.7)	59 874 (6.0)
Smokers, ≥10 cigarettes per day	4562 (4.9)	497 (5.5)	397 (4,0)	21 945 (2.2)
Highest completed educational level				
High school ≤2 years (1)	46 539 (50.4)	4700 (51.6)	2953 (29.1)	267 775 (26.9)
University <3 years (2)	35 157 (38.0)	4149 (45.6)	6456 (63.5)	414 529 (41.6)
University ≥3 years or graduate (3)	10 738 (11.6)	256 (2.8)	753 (7.4)	309 072 (31.0)
Nationality				
Swedish	74 195 (79.2)	7974 (87.2)	9626 (94.6)	887 847 (89.2)
EU15 and Nordic countries (except Sweden)	2865 (3.1)	284 (3.1)	190 (1.9)	27 029 (2.7)
Outside Europe	16 571 (17.7)	888 (9.7)	359 (3.5)	80 711 (8.1)
Parity				
First child	41 051 (43.8)	4013 (43.9)	5288 (52.0)	461 203 (46.3)
Second child	32 413 (34.6)	3248 (35.5)	3347 (32.9)	360 660 (36.2)
Third child or more	20 193 (21.6)	1885 (20.6)	1542 (15.2)	173 980 (17.5)
Working at the beginning of pregnancy				
Full-time	59 740 (63.8)	7844 (85.8)	8525 (83.8)	648 050 (65.1)
Part-time	33 917 (36.2)	1302 (14.2)	1652 (16.2)	347 793 (34.9)
Absence from work (days)				
<50	38 439 (41.0)	3163 (34.6)	4588 (45.1)	518 275 (52.0)
≥50 and <120	32 222 (34.4)	3472 (38.0)	2929 (28.8)	276 789 (27.8)
≥120	22 996 (24.6)	2511 (27.5)	2660 (26.1)	200 779 (20.2)
Occupational noise				
Unexposed	21 476 (22.9)	5452 (59.6)	5110 (50.2)	826 422 (83.0)
Exposed	72 181 (77.1)	3694 (40.4)	5067 (49.8)	169 421 (17.0)

*All the confounders have been tested with X^2, and show distribution ($p<0.05$) in relation to the exposure to organic particles and combustion products (PAH+diesel exhaust).
†There were no missing values, except for smoking (1.4%) and highest completed educational level (0.4%).
PAH, polycyclic aromatic hydrocarbon.

Data analysis

ORs and 95% CIs were estimated by multivariable logistic regression using STATA SE V.13.1 (StataCorp, College Station, Texas, USA). Variables in table 1 were tested with X^2 ($p<0.05$).

RESULTS

The database included 1 182 138 observations of mothers with singleton births that reported full-time or part-time work at the registration interview in gestational week 10 of pregnancy. After additional restriction to mother-child pairs with information on job-code as well as leave of absence, the study base consisted of 995 843 observations (84.2%).

The baseline characteristics of the study participants in relation to exposure are presented in table 1. Level of exposure to both organic and PAH declined when age or educational attainment increased. The proportion between full-time and part-time workers that were exposed to organic particles was consistent with all births, while workers exposed to PAH and diesel engine exhaust were more often in full-time employment. Workers with a higher number of days absent more often were exposed to both organic particles and combustion derived products (PAH and diesel exhaust) and smokers were over-represented among the exposed. The results indicate an increased level of exposure to occupational noise among those exposed to organic particles or combustion derived products. In addition, mothers born outside Sweden, and especially outside Europe, constitute a higher proportion of those exposed to organic particles. A smaller fraction of mothers with their first child were exposed to organic particles and PAH than mothers with a second or third child.

The adjusted analysis on the dichotomous exposure to organic particles (table 2) shows a significantly increased risk for all outcomes: small for gestational age (OR=1.14; 95% CI: 1.04 to 1.25), LBW (OR=1.15; 95% CI: 1.07 to 1.23) and preterm birth (OR=1.16; 95% CI: 1.10 to 1.23) in the group of mothers that

Table 2 Maternal occupational exposure* to organic particles and small for gestational age (SGA)†, low birth weight (LBW), dichotomised as <2500 g and ≥2500 g, and preterm birth (PTB), dichotomised as <37 weeks and ≥37 weeks subdivided by work participation during pregnancy

	Working full-time with low absence from work‡				Working full-time or part-time with moderate absence from work§				Working full-time or part-time with high absence from work¶			
	Crude	(n=376 831)	Adjusted**	(n=370 126)	Crude	(n=418 233)	Adjusted**	(n=410 370)	Crude	(n=200 779)	Adjusted**	(n=196 878)
	OR (95% CI)	No. of cases	OR (95% CI)	No. of cases	OR (95% CI)	No. of cases	OR (95% CI)	No. of cases	OR (95% CI)	No. of cases	OR (95% CI)	No. of cases
SGA												
Unexposed	1	8353	1	8187	1	7144	1	6998	1	2631	1	2572
Exposed (y/n)	1.29 (1.20 to 1.40)	746	1.14 (1.04 to 1.25)	721	1.28 (1.20 to 1.37)	1130	1.11 (1.02 to 1.20)	1088	1.30 (1.18 to 1.44)	441	0.97 (0.85 to 1.11)	425
Low exposure	1.19 (1.08 to 1.32)	430	1.10 (0.98 to 1.22)	422	1.19 (1.10 to 1.30)	573	1.08 (0.98 to 1.20)	560	1.15 (1.00 to 1.33)	201	0.93 (0.79 to 1.10)	195
High exposure	1.46 (1.30 to 1.64)	316	1.22 (1.07 to 1.38)	299	1.39 (1.27 to 1.52)	557	1.14 (1.02 to 1.26)	528	1.46 (1.28 to 1.67)	240	1.01 (0.86 to 1.19)	230
P for trend			0.001				0.013				0.942	
LBW												
Unexposed	1	12 492	1	12 272	1	9049	1	8859	1	3748	1	3649
Exposed (y/n)	1.37 (1.29 to 1.46)	1175	1.15 (1.07 to 1.23)	1137	1.12 (1.05 to 1.19)	1253	1.03 (0.95 to 1.11)	1203	1.15 (1.05 to 1.26)	555	0.94 (0.84 to 1.05)	530
Low exposure	1.29 (1.19 to 1.40)	692	1.12 (1.03 to 1.22)	675	1.05 (0.96 to 1.13)	638	0.99 (0.91 to 1.09)	616	1.06 (0.93 to 1.20)	263	0.92 (0.79 to 1.06)	253
High exposure	1.50 (1.37 to 1.65)	483	1.19 (1.07 to 1.32)	462	1.21 (1.11 to 1.31)	615	1.07 (0.97 to 1.18)	587	1.25 (1.10 to 1.41)	292	0.96 (0.83 to 1.11)	277
P for trend			<0.001				0.264				0.445	
PTB												
Unexposed	1	19 995	1	19 654	1	14 476	1	14 179	1	6832	1	6658
Exposed (y/n)	1.39 (1.32 to 1.46)	1887	1.16 (1.10 to 1.23)	1833	1.06 (1.01 to 1.11)	1897	0.98 (0.92 to 1.05)	1831	1.09 (1.01 to 1.16)	957	1.00 (0.91 to 1.09)	929
Low exposure	1.34 (1.26 to 1.43)	1142	1.15 (1.08 to 1.24)	1118	0.98 (0.92 to 1.05)	960	0.93 (0.86 to 1.00)	932	1.01 (0.92 to 1.11)	458	0.95 (0.86 to 1.06)	450
High exposure	1.46 (1.35 to 1.57)	745	1.17 (1.08 to 1.27)	715	1.15 (1.08 to 1.23)	937	1.05 (0.97 to 1.14)	899	1.17 (1.07 to 1.28)	499	1.04 (0.94 to 1.17)	479
P for trend			<0.001				0.565				0.645	

*Exposure divided into dichotomous and unexposed (0), low exposure (>0–50th percentile) and high exposure (>50th percentile). The 50th percentile=0.08 mg/m^3.
†SGA, estimated by a calculated growth curve of weight and gestational age.
‡Full-time workers who stated that they were working full-time at the interview in week 10 and had fewer than 50 days of absence from work (<50th percentile) during pregnancy (excluding the first 14 days of sickness).
§Part-time workers who stated that they were working part-time at the interview in week 10 or had 50 or more days (≥50th percentile) but fewer than 112 days of absence from work (<75th percentile) during pregnancy (excluding the first 14 days of sickness).
¶All workers who responded to the question about work at the interview in week 10 and had 112 or more days of absence from work (≥75th percentile) during pregnancy, except those who stated that they were not working at all.
**OR adjusted for mother's age, education, smoking habits, nationality, occupational exposure to noise and parity.

were exposed and had the *lowest* absence from work compared with unexposed mothers with the *lowest* absence from work.

The categorical analysis of maternal exposure to organic particles subdivided by presence at the workplace (table 2) showed significantly increased adjusted risks of all adverse birth outcomes (small for gestational age (OR=1.22; 95% CI: 1.07 to 1.38), LBW (OR=1.19; 95% CI: 1.07 to 1.32) and preterm birth (OR=1.17; 95% CI: 1.08 to 1.27)) for mothers exposed to *higher* levels of organic particles with the *lowest* absence from work. The adjusted risk for mothers with a *low* level of exposure and the *lowest* absence from work also increased for the outcome small for gestational age (OR=1.09; 95% CI: 0.98 to 1.22) and significantly increased for LBW (OR=1.12; 95% CI: 1.03 to 1.22) and preterm birth (OR=1.15; 95% CI: 1.08 to 1.23).

In table 3, maternal occupational exposure to PAH was associated with a statistically significantly elevated risk of small for gestational age (OR=1.40; 95% CI 1.15 to 1.71) and LBW (OR=1.49; 95% CI: 1.27 to 1.75), in full-time working mothers with low absence from work. The risk of preterm birth was slightly and non-significantly increased in full-time working mothers with low absence from work (OR=1.13; 95% CI: 0.98–1.30). No association with exposure was seen in mothers with moderate or high absence from work.

This study also analysed the risks associated with exposure to combustion products in form of diesel engine exhaust (using NO_2 as indicator of exposure), and there was no increased risk compared with the reference in the group with low absence in the adjusted analysis of the outcomes; preterm birth (OR=1.00; 95% CI: 0.88 to 1.14), small for gestational age (OR=0.70; 95% CI: 0.56 to 0.88) and LBW (OR=0.78; 95% CI: 0.65 to 0.93).

In a subanalysis, without the inclusion of police officers (that might introduce a selection bias), the results showed no significantly decreased ORs between diesel engine exhaust and small for gestational age (data not shown).

In table 4, subgroup analyses on type of organic particles in relation to adverse birth outcomes were assessed. When adjusted for confounders, exposure to oil mist resulted in a significantly higher risk of small for gestational age (OR=1.39; 95% CI: 1.13 to 1.70) and LBW (OR=1.48; 95% CI: 1.26 to 1.74). Cooking fumes showed a statistically significantly elevated risk of LBW (OR=1.16; 95% CI: 1.02 to 1.31) and preterm birth (OR=1.13; 95% CI: 1.02 to 1.25). In addition, exposure to paper dust (OR=1.23; 95% CI: 1.08 to 1.39) and other organic particles (OR=1.13; 95% CI: 1.02 to 1.25) was associated with a statistically significantly increased risk of preterm birth.

DISCUSSION

Exposure to organic dust during pregnancy was associated with an increased risk of LBW, small for gestational age and preterm birth. The risk correlated with exposure intensity, and with absence from the workplace during pregnancy.

In order to investigate what was driving the association regarding the organic particle exposure, a subgroup analysis was performed. In this analysis, only a few agents were associated with the outcomes, mainly oil mist (for small for gestational age and LBW), cooking fumes (for preterm birth and LBW), other organic dust (preterm birth) and paper dust (preterm birth). With the exception of paper dust, the exposures that showed an increased risk in the subanalyses (table 4) include combustion products (such as PAH). Oil mist can contain low concentrations of PAH when mineral oil is heated. Cooking oil contains traces of PAH when heated[23] and thereby also cooking fumes, even other organic dust that contains soot, contains PAH. For paper dust the relation to combustion particles is less apparent, but when looking at the occupations in that sector, many of them are warehouse workers and they are thereby possibly exposed to exhaust from wheel loaders and forklift trucks. This indicates that combustion products might be the cause of the association even though the subgroups also contain other substances. No association was found for textile, animal or wood dust. This was in line with previous studies investigating the impact of occupational environment on adverse birth effects (preterm delivery and small for gestational age) in jobs where organic particles can be found, mainly with a focus on the textile industry.[7 24] These studies showed no increased risk of adverse birth effects for pregnant employees.

Maternal occupational exposure to combustion-derived products (in form of PAH) showed a significant increased risk of adverse outcome in the form of small for gestational age and LBW and slightly increased risk of preterm birth in the group with low absence from work. The PAH exposure measure contain other occupations than for the subgroups listed above for organic particles (oil mist, cooking fumes, other organic dust). The results are in line with previous studies on PAH exposure and adverse birth outcome.

In addition, mechanistical data support that PAH plays a role on disruption of normal placental function. PAH as well as other particulate matter have been associated with oxidative stress.[25 26] PAHs transfer through to the placenta and thereby induce a toxic effect in the fetus.[27 28] Rappolee *et al*[29] described in a review that benzopyrene (a specific PAH) causes compensatory differentiation in placental trophoblast stem cells, which give rise to placental hormones that are important for the development of the conceptus.[29] An inverse relationship between placental weight and benzopyrene in the placenta, indicates a possible association with adverse birth outcome like low head circumference, LBW and low gestational length.[4] Intrauterine inflammation might be associated with particle exposure and preterm birth,[30] but the area needs more research.

Earlier studies on diesel exhaust and NO_2 and adverse birth outcome have shown somewhat unclear results.[31–33] In this study, combustion-derived products in form of diesel exhaust exposure (NO_2) showed a significantly decreased risk for the outcome of small for gestational age. The results might be due to selection of healthier workers then the general working population.[34] Without the inclusion of police officers, who might be healthier than other workers, the results showed no significantly decreased ORs, implying that selection bias might influence the results. In addition, levels of exposure to diesel engine exhaust might be too low to show adverse birth effects in this study. This was shown in a study by Lewné *et al*, where they discovered that most occupations, except tunnel construction workers, had low levels of diesel engine exhaust exposure.[35] In this study, there were few tunnel construction workers.

There are other limitations in this kind of study. Non-differential misclassification can be introduced when using a JEM to assess the exposure,[36] even if the assessment is done objectively and blinded. A JEM can never be as accurate as personal measurements throughout the pregnancy, so some level of non-differential misclassification has probably been introduced (eg, when women change jobs during pregnancy or variability in the composition of dusts across jobs and industries). However, a non-differential misclassification in this case is likely to lead to attenuation of the effect and underestimation of risk.

Table 3 Maternal occupational exposure* to combustion products (indicator: PAH) and small for gestational age (SGA)†, low birth weight (LBW), dichotomised as <2500 g and ≥2500 g, and preterm birth (PTB), dichotomised as <37 weeks and ≥37 weeks subdivided by work participation during pregnancy

	Working full-time with low absence from work‡				Working full-time or part-time with moderate absence from work§				Working full-time or part-time with high absence from work¶			
	Crude	(n=376 831)	Adjusted**	(n=370 126)	Crude	(n=418 233)	Adjusted**	(n=410 370)	Crude	(n=200 779)	Adjusted**	(n=196 878)
	OR (95% CI)	No. of cases	OR (95% CI)	No. of cases	OR (95% CI)	No. of cases	OR (95% CI)	No. of cases	OR (95% CI)	No. of cases	OR (95% CI)	No. of cases
PAH												
SGA												
No exposure	1	8993	1	8805	1	8185	1	7999	1	3032	1	2957
Exposure	1.57 (1.29 to 1.91)	106	1.40 (1.15 to 1.71)	103	1.19 (0.96 to 1.47)	89	1.04 (0.84 to 1.29)	87	1.04 (0.76 to 1.43)	40	0.89 (0.65 to 1.22)	40
LBW												
No exposure	1	13 496	1	13 240	1	10 207	1	9968	1	4251	1	4129
Exposure	1.71 (1.47 to 2.00)	171	1.49 (1.27 to 1.75)	169	1.02 (0.83 to 1.25)	95	0.95 (0.77 to 1.16)	94	0.97 (0.73 to 1.27)	52	0.84 (0.63 to 1.12)	50
PTB												
No exposure	1	21 668	1	21 279	1	16 236	1	15 877	1	7689	1	7489
Exposure	1.32 (1.15 to 1.52)	214	1.13 (0.98 to 1.30)	208	0.92 (0.77 to 1.09)	137	0.86 (0.72 to 1.03)	133	1.03 (0.84 to 1.26)	100	0.95 (0.77 to 1.17)	98

*Exposure divided into unexposed and exposed.
†SGA, estimated by a calculated growth curve of weight and gestational age.
‡Full-time workers who stated that they were working full-time at the interview in week 10 and had fewer than 50 days of absence from work (<50th percentile) during pregnancy (excluding the first 14 days of sickness).
§Part-time workers who stated that they were working part-time at the interview in week 10 or had 50 or more days (≥50th percentile) but fewer than 112 days of absence from work (<75th percentile) during pregnancy (excluding the first 14 days of sickness).
¶All workers who responded to the question about work at the interview in week 10 and had 112 or more days of absence from work (≥75th percentile) during pregnancy, except those who stated that they were not working at all.
**OR adjusted for mother's age, education, smoking habits, nationality, occupational exposure to noise and parity.
PAH, polycyclic aromatic hydrocarbon.

Table 4 OR for maternal occupational particle exposure* to subgroups of organic particles, among full-time working mothers with low absence† from work during pregnancy in relation to the outcome small for gestational age (SGA)‡, low birth weight (LBW), dichotomised as <2500 g and ≥2500 g and preterm birth (PTB), dichotomised as <37 weeks and ≥37 weeks

	SGA		LBW		PTB	
	Adjusted§		Adjusted§		Adjusted§	
	(n=369 064)		(n=369 300)		(n=369 115)	
	OR (95% CI)	No. of cases	OR (95% CI)	No. of cases	OR (95% CI)	No. of cases
Wood						
No exposure	1	8803	1	13 257	1	21 233
Exposure	1.05 (0.87 to 1.28)	105	1.02 (0.86 to 1.20)	152	1.04 (0.92 to 1.19)	254
Animal						
No exposure	1	8884	1	13 365	1	21 403
Exposure	0.74 (0.49 to 1.11)	24	0.87 (0.64 to 1.18)	44	1.03 (0.83 to 1.30)	84
Paper						
No exposure	1	8804	1	13 234	1	21 188
Exposure	1.10 (0.89 to 1.35)	104	1.16 (0.99 to 1.36)	175	1.23 (1.08 to 1.39)	299
Textile						
No exposure	1	8782	1	13 228	1	21 185
Exposure	1.04 (0.87 to 1.25)	126	1.00 (0.86 to 1.16)	181	1.04 (0.92 to 1.16)	302
Flour						
No exposure	1	8895	1	13 389	1	21 454
Exposure	1.13 (0.64 to 1.97)	13	1.05 (0.66 to 1.64)	20	1.03 (0.72 to 1.48)	33
Oil mist						
No exposure	1	8809	1	13 246	1	21 287
Exposure	1.39 (1.13 to 1.70)	99	1.48 (1.26 to 1.74)	163	1.11 (0.96 to 1.29)	200
Cooking fumes						
No exposure	1	8731	1	13 122	1	21 038
Exposure	1.14 (0.97 to 1.34)	177	1.16 (1.02 to 1.32)	287	1.13 (1.02 to 1.25)	449
Other organic						
No exposure	1	8725	1	13 130	1	20 990
Exposure	1.01 (0.86 to 1.18)	183	0.96 (0.85 to 1.09)	279	1.13 (1.02 to 1.25)	497

*Exposure divided into unexposed and exposed.
†Full-time workers who stated that they were working full-time at the interview in week 10 and who had fewer than 50 days of absence from work (<50th percentile) during pregnancy (excluding the first 14 days of sickness).
‡SGA, estimated by a calculated growth curve of weight and gestational age.
§OR adjusted for the confounders of the mother's age, education, smoking habits, nationality, occupational exposure to noise and the children's parity.

In this study, information on absence as a daily value throughout each pregnancy was available. That made it possible to assess the occupational exposure more precisely, reducing some of the misclassification of exposure.

The absence from work was also used to control for residual confounding that could occur in the form of socioeconomic effects being related to the occupation rather than the exposure (table 2). Since the effect was mainly/only seen in women with low absence from work and not in women with the same occupations who had high absence from work, residual socioeconomic confounding seems unlikely.

Strengths in this register-based cohort study are the large number of study participants and the detailed information on outcomes, occupation and confounders with few missing values. Another strength is that the information was collected prior to the outcome and the exposure assessment was made objectively and blinded to the outcome.

CONCLUSION

Organic particle exposures in the occupational setting are rather common and this study found that exposure to organic particles (such as oil mist, cooking fumes paper dust and other organic particles) and combustion products (such as PAH) increase the risk of adverse birth outcomes. There are few earlier epidemiological studies in this area, but an association between PAH and reduced placental function is supported by mechanistical data, more studies are needed to confirm the findings.

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Competing interests None declared.

Patient consent for publication Not required.

Ethics approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. For this type of study formal consent is not required. The study was approved by the regional ethics committee in Stockholm on 14 August 2014 (case number: 2014/1108-31/5).

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Data sharing statement Data can be obtained through acquisition from Swedish registers. The data collection process is described in the method section of this paper.

Data code for analysis in STATA can be obtained from the corresponding author on request.

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