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Children living near chipboard and wood industries are at an increased risk of hospitalization for respiratory diseases: A prospective study

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ABSTRACT

Pollutants emitted from wood processing factories may be harmful to the health of the population.

The aim of this prospective cohort study was to evaluate whether proximity to wood factories was associated with the risk of hospital admissions in children living in the Viadana district (Italy), where two big chipboard industries and other smaller wood factories (sawmills, multi-strata layer manufacturing) are located.

In 2006, children (3–14 years) living in the Viadana district were surveyed through a parental questionnaire ($n = 3854$), their home/school addresses were geocoded and the distances to the wood industries were calculated. Hospital discharge records for the years 2007–2009 were obtained. Cox proportional hazard regression models were used to estimate the association between hospitalization rates and distance to the factories, adjusting for sex, age, nationality, parents' education, exposure to passive smoking and reported traffic near home.

During the 3-year follow-up, the risk of hospitalization for all diagnoses (Hospitalization Hazard Ratio, HHR = 1.55; 95% CI: 1.24–1.95) and for respiratory diseases (HHR = 1.80; 95% CI: 1.14–2.86) was greater in the children living close (<2 km) to the chipboard industries, with respect to the children who lived at ≥2 km from any wood factory. The children living close to the smaller wood factories were also at increased risk of hospitalization for respiratory diseases (HHR = 1.74; 95% CI: 1.06–2.85).

This study highlights a health problem for the children living close to chipboard and wood factories in the Viadana district. Further research should develop accurate exposure models based on objective measurements of air pollution in order to confirm these findings.

Background

The wood industry may be a source of several air pollutants. In the primary wood processing stage, wood dust is generated by mechanical woodworking. In the chipboard production process, wood particles and laminates are glued together to produce wood boards. Urea formaldehyde resins are the most commonly used bonding agent in this stage, which is therefore characterized by the emission of formaldehyde in the atmosphere. Wood and chipboard manufacturing activities are often coupled with the production of energy by burning waste wood or fossil fuels, which can emit combustion byproducts like nitrogen dioxide, carbon monoxide (CO) and other chemical products (Samaras et al., 2001; Hedman et al., 2006). Air pollution in industrial areas is also increased by the heavy traffic that is induced by the presence of factories. The pollutants emitted into the atmosphere can fall to the ground by gravity, or be blown in another direction by the wind. The distance of dust dispersion depends on the composition, shape and particle size, while gas dispersion depends on its reactivity. Nitrogen dioxide, a relatively stable compound, can travel long distances, whereas formaldehyde is very reactive, has a short half-life in the atmosphere and a limited dispersion radius (Weinhold, 2008).

Epidemiological studies on workers exposed to formaldehyde and wood dust, like anatomists, pathologists, industrial workers of plastic laminates and woodworkers, suggest a strong impact of these pollutants on human health, particularly on the onset of respiratory diseases like asthma (Pérez-Ríos et al., 2010), as well as on lung and nasopharyngeal cancers (Armstrong et al., 2000; Vaughan et al., 2000; Hauptmann et al., 2004; Barcenas et al., 2005), Hodgkin's disease and lymphohaematopoietic disorders (Freeman

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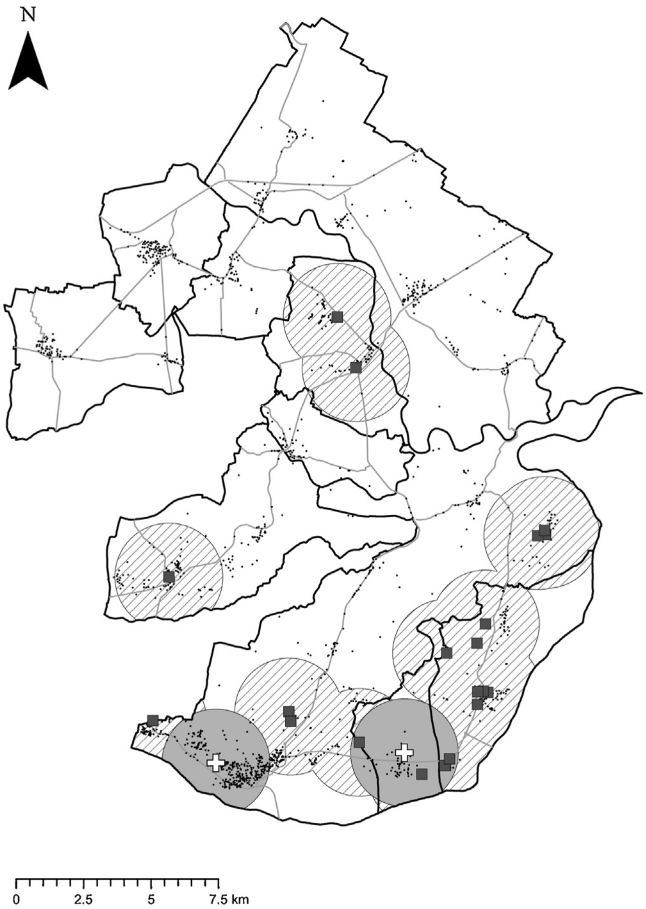

Fig. 1. Map of the Viadana district. Municipality borders are marked in black. Children's houses are represented by small black dots. Chipboard industries and other small wood factories are represented by white plus symbols and dark gray squares, respectively. Shaded and hatched areas represent areas within 2 km from chipboard industries and from the other small factories, respectively. Gray lines represent main roads.

et al., 2009). Occupational exposure to formaldehyde and wood dust may range between 0.06 and 3.01 mg/m^3, and between 0.11 and 59 mg/m^3, respectively (Takigawa et al., 2005; Fan et al., 2006; Ohmichi et al., 2006; Saejiw et al., 2009; Yamanaka et al., 2009; Vimercati et al., 2010; Bono et al., 2012).

Outdoor concentrations of air pollutants are definitely lower than occupational exposures. For instance, according to the IARC, outdoor formaldehyde levels are generally below 0.001 mg/m^3 in rural areas and below 0.02 mg/m^3 in urban areas (IARC, 2006). Very few studies have investigated the effects of outdoor exposure on populations who live near chipboard and wood factories.

The Viadana district is the largest chipboard industrial park in Northern Italy. It includes 24 factories (see Fig. 1). Two of them are large chipboard industries which mainly emit dust, formaldehyde, nitrogen oxides, volatile organic compounds, carbon monoxide, hydrochloric acid, hydrogen fluoride, copper and lead (de Marco et al., 2010). The remaining plants are 22 small wood manufacturing factories like sawmills, pallets or plywood factories. Recent research in the Viadana district showed that children living close to chipboard industries had a greater prevalence of respiratory and irritation symptoms of the upper airways, as well as neurovegetative symptoms, than children who lived far from them (de Marco et al., 2010; Girardi et al., 2012). These reports were based on a cross-sectional questionnaire survey that was carried out in 2006. In a retrospective study Rava et al. (2011) traced the same cohort of children four years before the 2006 study using the data from 2002 to 2005. An increased risk of hospitalization for respiratory diseases was found in children living at <2 km from the chipboard factories compared to children living farther away.

In our study, the same cohort of children was followed-up for three years after the questionnaire survey, in order to evaluate whether proximity to chipboard and wood factories was associated with the risk of hospitalization for respiratory conditions and for diseases of the nervous and sensory system by using a prospective longitudinal design.

Methods

Study design

This is a prospective cohort study focused on the children living in the Viadana district (Mantua, Northern Italy). In December 2006, the families of all the children were asked to fill in a detailed questionnaire including information on their address, the children's respiratory health, the known risk factors for respiratory diseases, their lifestyles and other potential confounders. Most of the questions were taken from internationally validated questionnaires, as previously described (de Marco et al., 2010). Overall 3907 questionnaires were delivered with a response rate of 98.6% ($n = 3854$). The cohort followed-up in the present study consists of all the 3773 children (3–14 years) who participated in the survey and who reported both their school and home addresses on the questionnaire.

The study was approved by the local ethics committee.

Hospitalization data

Hospital discharge records of the participants for the period from 1/01/2007 to 31/12/2009 were obtained from the Local Health Unit of Mantua and linked to the questionnaire survey data. The events of hospitalization were coded according to the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM).

In line with previous findings (de Marco et al., 2010), the discharge diagnosis classes considered were: all diagnoses excluding injury and poisoning, nervous and sensory system diseases, and respiratory diseases (Table 1). If a subject had had multiple hospitalizations for a given discharge diagnosis class, only the first admission was considered to compute the hospitalization rates (HR) for that class. If a subject had had multiple hospitalizations for

Table 1
Number of children hospitalized for each discharge diagnosis class.

Discharge diagnosis	ICD	Number of children hospitalized
All diagnoses	0–999	509
All diagnoses excluding injuries and poisoning	0–799	452
Diseases of the nervous system and sense organs[a]	320–389	30
Epilepsy	345	7
Disorders of the eye and adnexa	360–379	10
Diseases of the ear and mastoid process	380–389	5
Diseases of the respiratory system	460–519	124
Acute respiratory infections	460–466	38
Other diseases of the upper respiratory tract	470–478	58
Pneumonia and influenza	480–487	27

ICD: international classification of diseases.
[a] Only sub-categories with 5 or more children hospitalized are shown.

different discharge diagnosis classes, the first admission for each class was considered.

Exposure indicator

Since data on the environmental levels of air pollutants were not available when the data were analyzed, we defined exposure as a function of the distance of the children's homes and schools from the chipboard and wood manufacturing factories (de Marco et al., 2010).

The location of the children's homes and schools and of the factories were identified by the Gauss-Boaga coordinates: latitude (x) and longitude (y). The coordinates of 5 of the factories, including the 2 chipboard industries, were collected by the local environmental agency, using the Global Positioning System (GPS) technology in correspondence of the main chimney. The coordinates of the remaining factories and of the children's homes and schools were obtained by geocoding their postal addresses. The distances of the children's homes and schools from the closest factory (minimum distances) were computed.

A three-level proxy indicator of exposure was defined as follows:

i. no wood factories <2 km from home and school (reference group);
ii. at least 1 small wood factory (but no chipboard industries) <2 km from home or school (hatched areas in Fig. 1);
iii. at least 1 chipboard industry <2 km from home or school (shaded areas).

The "weighted minimum distance" either to any factory or to the chipboard industries was also defined as follows: (16/24 × home-factory minimum distance) + (8/24 × school-factory minimum distance), where 16 and 8 represent the hours usually spent by children at home and at school per day, respectively (de Marco et al., 2010).

Statistical analysis

The data were summarized with percentages for categorical variables or median with interquartile range (IQR) for continuous variables. In order to compare the three groups of exposures we used the Pearson's chi-squared test for categorical variables and the Kruskal–Wallis test for continuous variables.

The hospitalization rates (HR) for overall and specific cause hospitalizations were obtained by dividing the number of the children with at least one hospitalization for each discharge diagnosis class by the total number of person-years at risk. Only the primary discharge diagnoses were considered.

For each child, the person-years at risk were computed as the time from 1/1/2007 to the first event that occurred among hospitalization, the end of the study (31/12/2009), or the time of moving if a subject had moved outside the local health unit. The associations between hospitalization rates and the three-level distance indicator were estimated by Hospitalization Hazard Ratios (HHR), obtained by using Cox proportional hazard regression models. The potential confounders included in the models were obtained from the baseline questionnaire: gender, age, being foreign (having both non-Italian parents), maximum education level among parents (as a proxy for socio-economic status), exposure to second-hand tobacco smoke (a child was exposed if at least one parent smoked or somebody was reported to smoke inside the dwelling), exposure to traffic-related air pollution (high if cars or trucks passed constantly or frequently near home; low otherwise). The proportional-hazard assumption was tested for each covariate included in the model.

Statistical analyses were performed by using STATA 12 (Stata Corp, College Station, TX, USA), and a 5% significance level was adopted.

Sensitivity analyses

The main analyses were repeated:

- defining the hospitalization rates on the basis of both the primary and secondary discharge diagnoses.
- excluding both the subjects who had moved during the follow-up (as assessed by comparing the addresses recorded in the regional registry office database at baseline and at the end of the follow-up period) and the subjects who had not lived in the same dwelling for at least two years at the time of baseline survey (as assessed by the questionnaire information) to reduce the risk of exposure misclassification due to home address changes. Overall 2594 children were included.
- using the weighted minimum distance to any factory and to the two chipboard industries as exposure indicator.
- excluding 231 children who were reported to have lifetime asthma at baseline.

Results

Characteristics of the subjects

The children living at <2 km from the chipboard industries (38.4%) were slightly older, more exposed to vehicular traffic and to second-hand tobacco smoke than the children who lived at ≥2 km from the chipboard industries. Moreover, they were less likely to be foreigners (Table 2).

Lost to follow-up

Overall, 56 (1.5%) children moved outside the local health unit and were therefore lost to follow-up. The children lost to follow up were similar to the children who were followed-up for sex, age and nationality. However, when compared to the children who were followed-up, they had less educated parents (professional school or lower education: 65% vs. 35%, respectively) and they were more exposed to second-hand tobacco smoke (65% vs. 45%) and vehicular traffic (80% vs. 58%) (all $p < 0.01$).

Risk of hospitalization and distance to the factories

Overall 452 children (11.7% of total) were hospitalized for all diagnoses excluding injuries and poisoning (Table 1) during the 3 years of the follow-up (crude HR = 43.1/1000/year). Out of them, 112 (25%) had multiple admissions. Considering the three main diagnosis classes (diseases of the respiratory system, nervous system, and other non-traumatic causes) 87 children (78%) were further hospitalized for the same diagnosis class and 25 (22%) for different classes.

For all the discharge diagnoses considered, the crude HR were higher for the children who lived close to the wood or chipboard factories than for the children who lived farther away (Table 3).

When adjusted for potential confounders (Fig. 2), the children living close to chipboard industries had a greater risk of being admitted to hospital, during the follow-up, for any diagnosis excluding injury and poisoning (HHR = 1.55; 95% CI: 1.24–1.95) and for respiratory diseases (HHR = 1.80; 95% CI: 1.14–2.86) than the children who lived at ≥2 km from any wood industry. A statistical significant increased risk of hospitalization for respiratory diseases was also found in the children living at <2 km from the

Table 2
Characteristics of the children ($n = 3854$) according to the distance to the factories.

Covariates	Distance to the factories			p
	≥2 km from any wood industry	<2 km from small wood industries[a]	<2 km from a chipboard industry	
n (%)	1355 (35.9)	970 (25.7)	1448 (38.4)	
Age[b]	8.2 (5.4–11.0)	8.3 (5.6–11.3)	9.1 (6.4–11.6)	<0.001
Sex (% female)	46.1	46.9	46.1	0.93
Foreign nationality (%)	13.3	16.8	11.8	0.002
Parents' educational level (%)				
Primary/secondary/professional school or lower	37.1	33.3	35.6	0.104
High school	48.7	51.1	51.8	
Degree or superior	14.2	15.7	12.5	
Exposure to second-hand tobacco smoke	45.0	42.5	48.4	0.02
High traffic level near home (%)	57.2	55.5	62.1	0.002
Weighted minimum distance to any wood factory (km)[b,c]	5.12 (3.67–7.27)	0.61 (0.44–1.22)	1.04 (0.78–1.32)	
Weighted minimum distance to a chipboard industry (km)[b,c]	17.27 (15.35–19.08)	7.16 (3.84–9.95)	1.29 (0.99–1.82)	

[a] But ≥2 km from chipboard industries.
[b] Median (IQR).
[c] Weighted minimum distance = (16/24 × home-wood industry minimum distance) + (8/24 × school-wood industry minimum distance), where 16 and 8 represent the hours usually spent at home and at school per day, respectively.

Table 3
Number of children hospitalized, crude hospitalization rates and 95% confidence intervals (CI) for specific discharge diagnoses according to the distance to the factories.

Discharge diagnosis	≥2 km from any wood industry	<2 km from small wood industries[b]	<2 km from a chipboard industry
All diagnoses excluding injury and poisoning (ICD 0-799)			
n	133	106	212
Hospitalization rates[a] (95% CI)	34.7 (29.3–41.1)	38.9 (32.2–47.1)	54.1 (47.3–61.9)
Diseases of the nervous system and sense organs (ICD 320-389)			
n	8	8	14
Hospitalization rates[a] (95% CI)	2.0 (1.0–4.0)	2.8 (1.4–5.5)	3.3 (2.0–5.6)
Diseases of the respiratory system (ICD 460-519)			
n	33	37	53
Hospitalization rates[a] (95% CI)	8.3 (5.9–11.6)	13.1 (9.5–18.0)	12.7 (9.7–16.6)
Acute respiratory infections (ICD 460-466)			
n	10	15	12
Hospitalization rates[a] (95% CI)	2.5 (1.3–5.0)	5.2 (3.2–8.7)	2.9 (1.6–5.0)
Other diseases of the upper respiratory tract (ICD 470-478)			
n	18	17	23
Hospitalization rates[a] (95% CI)	4.5 (2.8–7.1)	5.9 (3.7–9.5)	5.3 (3.6–8.0)
Pneumonia and influenza (ICD 480-487)			
n	7	7	13
Hospitalization rates[a] (95% CI)	1.7 (0.8–3.6)	2.4 (1.2–5.1)	3.1 (1.8–5.3)

[a] Crude annual hospitalization rates per 1000 subjects.
[b] But ≥2 km from chipboard industries.

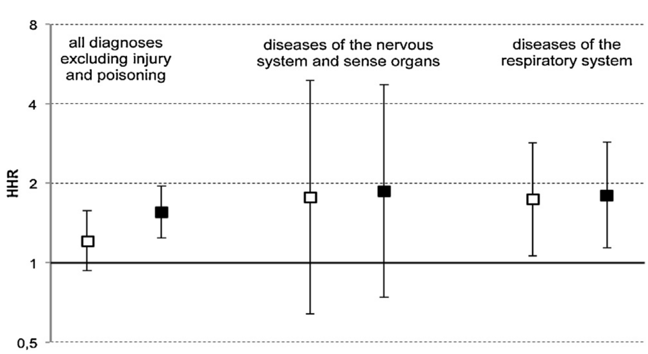

Fig. 2. Hospitalization Hazard Ratios (HHR) (adjusted for gender, age, being foreign, maximum education level among parents, exposure to second-hand tobacco smoke, exposure to traffic-related air pollution) and 95% confidence intervals represented on log 2 scale for the association between hospitalization rates and the three-levels distance indicator (living ≥2 km from any wood industry as reference category; white squares, <2 km from small wood factories (but ≥2 km from chipboard industries); black squares, <2 km from chipboard industries).

small wood factories (HHR = 1.74; 95% CI: 1.06–2.85). When restricting the analysis to the children who were not reported to have had lifetime asthma by their parents in the baseline questionnaire ($n = 3547$), the HHR were 1.66 (95% CI: 1.04–2.66) and 1.59 (95% CI: 0.96–2.64) for children living close to chipboard industries and the small factories respectively. Among respiratory discharge diagnoses, hospitalizations for acute respiratory tract infections were more frequent for the children who lived close to small wood factories (HHR = 2.72; 95% CI: 1.14–6.52) while the excess risk was not significant for children who lived close to the chipboard industries (HHR = 1.58; 95% CI: 0.63–3.97). There was also an indication of an excess risk of hospitalizations for pneumonia and influenza and for other diseases of the upper respiratory system for the children who lived close to chipboard industries (HHR = 2.07; 95% CI: 0.82–5.23 and HHR = 1.35; 95% CI: 0.71–2.56 respectively) and for the children who lived close to small wood factories (HHR = 1.28; 95% CI: 0.43–3.82 and HHR = 1.44; 95% CI: 0.73–2.85 respectively). The excess of risk of hospitalization for diseases of the nervous and sensory system was not statistically significant.

Table 4
Hospitalization Hazard Ratios (HHR)[a] and 95% confidence interval (95% CI) for the association between the weighted minimum distance to any factory or to the chipboard industries and the risk of hospitalization.[c]

	ICD	Number of children hospitalized	Weighted minimum distance to any factory (3.11 km increase[b]) HHR[a] (95% CI)	Weighted minimum distance to the chipboard industries (14.95 km increase[b]) HHR[a] (95% CI)
All diagnoses excluding injury and poisoning	0–799	452	**0.80 (0.70–0.91)**	**0.65 (0.53–0.80)**
Diseases of the nervous system and sense organs	320–389	30	0.89 (0.55–1.44)	0.61 (0.27–1.37)
Diseases of the respiratory system	460–519	124	**0.77 (0.59–0.99)**	**0.58 (0.38–0.88)**

[a] Adjusted for gender, age, being foreign, maximum education level among parents, exposure to second-hand tobacco smoke, exposure to traffic-related air pollution.
[b] Corresponding to the interquartile range (IQR).
[c] Estimates that are statistically significant at the 5% level are reported in bold-face.

Sensitivity analyses

The results were confirmed when both the primary and secondary diagnoses were considered in order to calculate hospitalization rates (Fig. 3, panel A). Moreover, a greater risk of hospitalization for diseases of the nervous system and sense organs emerged for the children who lived close to wood or chipboard factories as compared to the reference category.

When the analyses were restricted to the children who lived at the same address for 2 or more years before baseline and for the whole follow-up ($n = 2594$), the results on hospitalizations for all diagnoses and for respiratory diseases were confirmed (Fig. 3, panel B). Moreover, the children who lived close to the wood or chipboard factories had a 6-fold increased risk of being hospitalized for diseases of the nervous system and sense organs when compared to the children living at >2 km from any wood industry. The main results were also confirmed when using the weighted minimum distance either to any factory or to the chipboard industries as an alternative exposure indicator, suggesting a "dose–response" relationship between proximity to the chipboard industries and risk of hospitalization (Table 4).

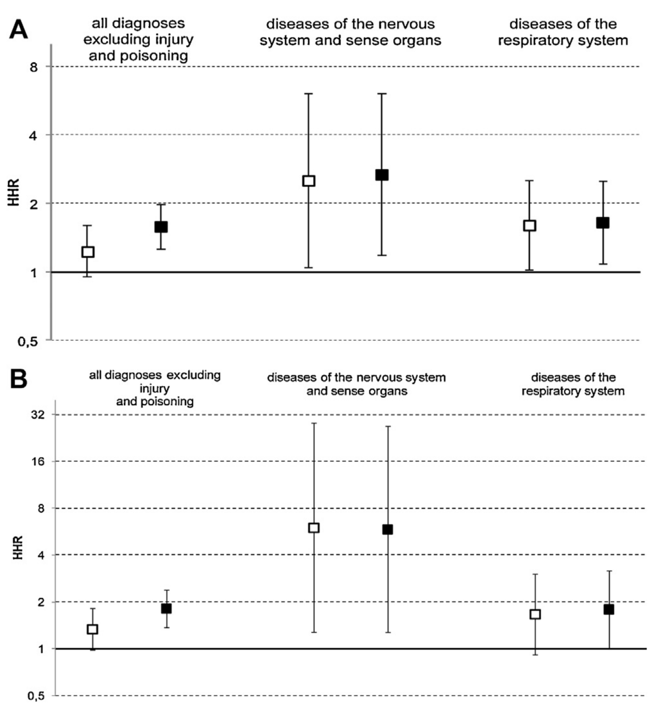

Fig. 3. Hospitalization Hazard Ratios (HHR) (adjusted for gender, age, being foreign, maximum education level among parents, exposure to second-hand tobacco smoke, exposure to traffic-related air pollution) and 95% confidence intervals represented on log 2 scale for the association between hospitalization rates and the three-levels distance indicator (living ≥2 km from any wood industry as reference category; white squares, <2 km from small wood factories (but ≥2 km from chipboard industries); black squares, <2 km from chipboard industries): sensitivity analyses defining the hospitalization rates on the basis of both the primary and secondary discharge diagnoses (A), and excluding both subjects that moved during the follow-up and subjects who had not lived in the same dwelling for at least two years at the time of baseline survey (B).

Discussion

To our knowledge this is the first longitudinal study on the health effects of living close to chipboard and wood factories in the general pediatric population. This study has the advantage that it made it possible to assess incidence rates and to calculate risk ratios prospectively using an appropriate study design where "exposure" precedes the outcome.

Hospitalization for respiratory diseases

Our analyses showed that living within 2 km from chipboard industries was associated with a significantly increased risk of hospitalization for all diagnoses and for respiratory diseases. These findings were confirmed when we tested whether residential history could have affected our analyses, by excluding the children who had changed their dwelling either in the 2 years before the baseline survey or during the following 3 years. Similarly, the results were confirmed when both the primary and secondary discharge diagnoses were considered to define the hospitalization events and when the weighted minimum distance was used as an alternative indicator of exposure. These three sensitivity analyses showed that alternative definitions of the exposure or the outcome did not substantially change our results. When restricting the analysis to the children who were not reported to have had lifetime asthma, the results were completely consistent, suggesting that the increased risk of hospitalization for respiratory diseases in children living close to chipboard industries is not limited to triggering asthma.

Among the sub-groups of respiratory diagnoses investigated, the risk of hospitalization was the greatest for pneumonia and influenza (HHR = 2.07, 95% CI: 0.82–5.23) in the group of children living close to the chipboard industries, and for acute respiratory tract infections (HHR = 2.72, 95% CI: 1.14–6.52) in the group living close to the small factories. These analyses, however, had a low statistical power because the number of events was small.

The analyses were adjusted for several factors that are known to be associated with respiratory diseases in children, including gender, age, nationality (Marcon et al., 2011), parents' education (as a proxy of socio-economic status (Biering-Sørensen et al., 2012)), as well as for concomitant exposures like passive smoking and vehicular traffic (Etzel, 2007; McConnell et al., 2010; Patel et al., 2010). It is therefore unlikely that these factors could have confounded the associations we found.

The excess risk of hospitalization for respiratory diseases that we observed suggests that the children who live closer to factories in the Viadana district are more exposed to emissions of air pollutants from industrial plants. In fact, air pollution can lead to a respiratory illness that is severe enough to require hospital admissions (Farhat et al., 2005; Giovannini et al., 2010), it can exacerbate asthma and pneumonia (Pope, 1989; Lin et al., 2003). Furthermore, air pollutants are known to affect a child's immune system and to increase susceptibility to respiratory infections (Akaike and Maeda, 2000; Tramuto et al., 2011; Ghosh et al., 2012;). The effects of environmental pollution on the respiratory health of children may be caused by acute exposures to high pollutant concentrations or by prolonged exposures to low levels of pollutants. In this study, both acute and chronic effects of air pollution may have contributed to our results.

Hospitalization for diseases of the nervous and sensory systems

We also investigated the association between the distance to the wood and chipboard factories and hospital admissions for diseases of the nervous and sensory systems. Significant associations with neurovegetative symptoms had previously been found both in the same cohort of children in the Viadana district (de Marco et al., 2010), and in a different pediatric population exposed to pollutants from wood processing (Dahlgren et al., 2003). Although this association was not statistically significant in the main analysis, when we considered both the primary and secondary discharge diagnoses, we found that the children living close to the factories had a more than doubled risk of hospitalization with respect to the children who lived farther away. One possible explanation for the apparent discrepancy between the main and the sensitivity analyses is that neurological disorders do not necessarily lead to hospitalizations, but they could coexist with other conditions that require hospitalization. However, it is also possible that the latter analysis was statistically more powerful because of the larger number of events.

When the analyses were restricted to the children who lived at the same residential address for at least 5 years, the risk estimates were even greater: the children living close to the wood and chipboard factories had a 6-fold greater risk of admission than the children who lived farther away. This finding may suggest that, in the case of neurological disorders, long-term exposure to air pollution is important. A lot of evidence highlighted a link between urban traffic and formaldehyde exposure with disorders of the nervous and sensory system. It has been reported that prolonged exposure to air pollutants such nitrogen dioxide, PM_{10} and hydrocarbons can decrease neurocognitive functions in children (Wang et al., 2009; Calderón-Garcidueñas et al., 2011). It seems plausible that insoluble particles of small size can penetrate, spread and accumulate in the respiratory tract and then be transported into the brain causing inflammation and neuropathologies (Morawska et al., 2008; Calderón-Garcidueñas et al., 2008). Formaldehyde has been documented to induce neurotoxic effects in cultured cortical neurons by inducing overproduction of intercellular oxygen species (Song et al., 2010; Tang et al., 2011; Kovacic and Somanathan, 2010), as well as in experimental studies on rats, where exposure to formaldehyde was shown to cause morphological changes to the brain (Aslan et al., 2006).

However our findings should be interpreted cautiously because of the small number of hospitalizations for diseases of the nervous and sensory systems that occurred during the follow-up.

Strengths and limitations of the study

The strengths of this prospective study were that an objective "hard" health outcome, namely hospitalization, was analyzed for the entire cohort (response rate 98.6%), which consisted of the whole population living in the District investigated, and that individual adjustment for potential confounding factors was obtained by internationally validated questionnaires.

The Viadana district is characterized by a mild continental climate, it is relatively wind-free (average wind speed in the last 13 years = 2.3 m/s, with prevailing wind directions: west and east-north-east (http://ita.arpalombardia.it/ITA/qaria/pdf/RQA-2009/RQA_MN_2009.pdf)) and it is not affected by sudden changes in climatic conditions. Nonetheless, the assumption of isotropic distribution of pollutants, which is implied by the use of the distance as a proxy of exposure to industrial pollutants, is the main limitation of this study. To overcome this limitation, accurate exposure models based on objective air pollution measurements will be needed.

Conclusion

This is the first prospective study evaluating the potential effect of outdoor exposure to emissions from wood and chipboard industries on health. This study adds to previous evidence that exposure to air pollutants may have a harmful effect on the pediatric population residing in the Viadana district, especially on respiratory health. This study highlights the need to monitor both the health status of the inhabitants living in proximity of wood and chipboard plants, and the level of pollutants. The implementation of preventive measures, with the aim of reducing these emissions, is also recommended. Accurate air pollutant exposure models should be further developed to confirm these findings.

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