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Asthma, respiratory symptoms and lung function in children living near a petrochemical site[☆]

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ABSTRACT

Residential proximity to environmental hazards has been related to adverse health outcomes. Respiratory health and allergies in children living near petrochemical sites have not been extensively studied. We evaluated the association between residential proximity to the petrochemical site of Tarragona (Catalonia, Spain) and the prevalence of asthma, respiratory symptoms and lung function in children. Children aged 6–7 ($n=2672$) and adolescents aged 13–14 ($n=2524$) residing near two large petrochemical sites and those living in a city with medium vehicular traffic were cross-sectionally compared with children from an area with low vehicular traffic and without industry. The prevalence of symptoms was measured using the International Study of Asthma and Allergies in Childhood written and video questionnaires. Lung function measurements were done in a subsample of 959 adolescents in the four areas. Multivariable analyses were done to estimate the effects of the residential area on symptoms and lung function adjusted for potential confounders. Crude prevalence of symptoms was similar across the studied areas. After adjustment, children and adolescents living near a petrochemical site had a statistically significant higher prevalence of respiratory hospitalizations in the previous year (Prevalence Ratio (PR)=1.49; 95%CI, 1.06–2.09) and of nocturnal cough (PR=1.29; 95%CI 1.05–1.57), respectively. Reduced lung function values among adolescents residing near the petrochemical areas were not observed. Although a higher prevalence of asthma in children and adolescents living near the petrochemical sites could not be demonstrated, as described in other studies, respiratory hospitalizations and nocturnal cough could be related to short-term exposures to pollutants. Other clinical and sub-clinical respiratory health effects in the petrochemical industry areas should be investigated.

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Abbreviations: SO₂, Sulfur dioxide; NO₂, Nitrogen dioxide; PM₁₀, Particulate matter with an aerodynamic diameter less than 10 μm; PM_{2.5}, Particulate matter with an aerodynamic diameter less than 2.5 μm; PAH, Polycyclic aromatic hydrocarbons; FAS, Family Affluence Scale; FVC, Forced vital capacity; FEV₁, Forced expiratory volume within 1 second; PEF, Peak expiratory flow; ISAAC, International Study of Asthma and Allergies in Childhood

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1. Introduction

Asthma, allergic rhinitis and eczema in childhood are important public health concerns, not only in terms of health care costs but also in terms of school absenteeism and quality of life (Braman, 2006). The available data suggest that in high-income countries, asthma prevalence is continuing to increase or has reached a plateau (Anandan et al., 2010). Children's lungs are more susceptible to airborne environmental exposures and there is strong support for air pollution effects on the development of lung function in children and adolescents (Gotschi et al., 2008; Miller and Marty, 2010; Duijts, 2012). It is well known that ambient air pollution is a possible cause of variations in asthma prevalence

through effects on incidence, severity, prognosis and duration (Bateson and Schwartz, 2008; Holguin, 2008; Tzivian, 2011).

Oil refineries and petrochemical plants release a wide range of volatile agents and particulate matter into the atmosphere. Residential proximity to these industrial sites has been linked with cancer, adverse pregnancy outcomes and respiratory disorders (Yang et al., 2004; Whitworth et al., 2008; Brender et al., 2011). The association between asthma symptoms in children and proximity to petrochemical sites has been demonstrated in several studies (Ware et al., 1993; Yang et al., 1998; Loyo-Berriós et al., 2007; Smargiassi et al., 2009; White et al., 2009; Wichmann et al., 2009; Moraes et al., 2010; Rusconi et al., 2011).

The largest chemical site in southern Europe and the Mediterranean region is located in Tarragona county (Catalonia, north-eastern Spain). In local communities there is growing concern about the possible link between living close to the site and respiratory disorders, particularly asthma. Since the petrochemical activity started in the 1960s, the impact of air pollution on respiratory health of children has not been studied. Evaluating the impact of industry may contribute to policies aiming at a decrease of health effects in children.

The aims of this study were to estimate the prevalence and severity of asthma as well as respiratory and allergic symptoms and to evaluate lung function of children living near the petrochemical sites of Tarragona and children living in areas with urban pollution compared with children living in relatively unpolluted areas of the county. We hypothesized that exposure to petrochemical pollutants would lead to consequences on the respiratory health of children living near the industrial areas.

2. Material and methods

2.1. Study area

Tarragona city (140,184 inhabitants, 2010) is the main town of the county (249,718 inhabitants, 2010). Furthermore, an important seasonal increase of population related to tourism takes place in summer. The chemical site of Tarragona is divided into two main areas: First, the North Industrial Complex (4.7 km²) is located 10 km north of the main city and includes an oil refinery and other chemical industries. Second, the South Industrial Complex (7.2 km²), is located parallel to the coast and contains several chemical and petrochemical plants. Many residential neighborhoods are located close to the industrial facilities (Fig. 1).

Among the products manufactured by companies established in the North Industrial Complex are benzene, ethylene, fuel oil, gasoline, kerosene, propylene, propylene oxide, polypropylene and styrene. Companies established in the South Industrial Complex produce diverse compounds such as acrylonitrile–butadiene–styrene (ABS), butane, chlorine, ethylene oxide, polyethylene, kerosene, halogenated organic compounds, polyols, polypropylene, polystyrene, polyethylene, polyvinyl chloride, propane and vinyl acetate. The total production of the two complexes is about 19 million tons per year (14 million tons in the North Industrial Complex and 5 million tons in the South Industrial Complex (AEQT, 2010)).

Atmospheric emissions of sulfur oxides, nitrogen oxides and non-methane organic volatile compounds have been estimated at 14,209, 8982 and 3064 t per year, respectively (PRTR-España, 2010).

Other industrial point sources of air pollution in this area include a municipal solid waste incinerator and a hazardous waste incinerator (168,000 and 45,000 t processed per year, respectively) and two power plants using natural gas (production capacity of about 800 MW). Mobile sources include motor vehicle emissions from a motorway (32,000 vehicles per day) and two highways (one parallel to the coast, 20,000 vehicles per day, 6% heavy duty; other to Tarragona from the North, 16,000 vehicles per day, 6% heavy duty (Ministerio de Fomento, 2010)). 54% of the county vehicles are registered in Tarragona city (private car, 62,558 and lorry and van, 11,608 (Institut d'Estadística de Catalunya, 2010)). In addition, a harbor in the zone handles crude oil and chemical products as well as coal, other minerals and cereals. The amount of soybean hulls unloaded in the harbor is significantly lower than in the past (Rovira et al., 2010).

The area has a Mediterranean climate characterized by warm summers, moderate winters and irregular and scarce rainfall: (average temperature, 14.9 °C (7.5–24.9); precipitation accumulated, 414 mm; relative humidity, 68% (63–71); maximum solar radiation, 15.7 MJ/m², in a meteorological station closest to the refinery). Predominant winds are from the south in summer and from the north

during the rest of the year. Inversion conditions are uncommon (Generalitat de Catalunya. Servei Meteorològic de Catalunya, 2010).

According to the local air quality monitoring network, the ranges of SO₂, NO₂, PM₁₀, PM_{2.5}, benzene and benzo(a)pyrene annual average for 2010, were 2–6 µg/m³, 15–29 µg/m³, 17–30 µg/m³, 10–11 µg/m³, 0.9–3.7 µg/m³ and 0.11 ng/m³, respectively (Generalitat de Catalunya. Departament de Territori i Sostenibilitat, 2010). Ozone episodes (hourly averages of more than 180 µg/m³) are not rare in summer.

Levels of polycyclic aromatic hydrocarbons (PAH) in soils and vegetation of Tarragona County are periodically monitored and are similar to those registered in other urban and industrial zones of Europe (Nadal et al., 2011). The total average PAH levels in the air near the petrochemical site are comparable with those measured in industrial sites and in suburban areas in Europe (Ramírez et al., 2011). Considering environmental and dietary intake, the concentrations of PAH in Tarragona County do not involve a significant additional non-carcinogenic and carcinogenic risk (Linares et al., 2010). Risk assessment related to atmospheric volatile organic compounds evaluated in previous studies have shown average concentrations below their chronic reference concentrations for non-carcinogenic effects (Ramírez et al., 2012).

We divided the municipalities into four areas according to their proximity to industry (Fig. 1): North Industrial Complex (NC), South Industrial Complex (SC), Tarragona city center (TC), the urban area with medium vehicular traffic and the rest of the county (RC) with low vehicular traffic and no industry.

2.2. Study participants

Schools were used as sampling units. The target age ranges were 6–7 and 13–14. First grade primary and second grade secondary school students were selected for the study. The entire list of the schools from the four areas was selected: 67 primary schools (2672 children aged 6–7 years) and 32 secondary schools (2524 adolescents aged 13–14 years). Children placed in special instructional units were excluded. The study population consisted of school children who both lived and attended schools in one of the four study areas.

The governing bodies of all schools in the area gave their consent and cooperation for the study, as the educational authorities. Parents of potential participants were sent a letter explaining the nature of the study and asking written informed consent for their children to participate in the study. The study protocol was approved by the Ethics Committee of Tarragona University Hospital Joan XXIII.

2.3. Questionnaires

Health information was obtained using the core questionnaire on asthma, rhinitis and eczema from the International Study on Asthma and Allergies in Children (ISAAC) (Asher et al., 2006; Lai et al., 2009). Questionnaires were available in two local languages, Catalan and Spanish that had been translated following the ISAAC protocol.

School teachers distributed the questionnaires to the children and they also collected them after they had been completed by the parents at home. A self-administered questionnaire was completed in the school setting by adolescents. The ISAAC international video asthma questionnaire with verbal instructions in Spanish was shown to the adolescents after they had completed the written questionnaire. Data were collected between March and June 2010.

In addition to the ISAAC questionnaire, demographic and environmental data were collected. Demographic information included date of birth, gender, place of birth, parental nationality (foreign nationality was defined as both parents born abroad), length of residence in the town and parental educational level (highest of mother and father). Socioeconomic family level was measured using the Family Affluence Scale test (FAS) (Currie et al., 2008), a validated indicator that includes information about family car ownership, bedroom occupancy, family holidays in the past year and computer ownership. The summed scores produce an ordinal scale in three affluence levels: low, intermediate and high. Additional questionnaire items included family history of asthma (at least one parent with history of asthma), length of breastfeeding, respiratory hospitalizations in the last year (only for children), potential indoor exposures as type of cooking, presence of pets in the house and exposure to environmental tobacco smoke at home (at least one person currently smoking in the house). Adolescent smoking habits were also recorded; those who smoked regularly, even “less frequently than once a week”, were defined as smokers.

The definition of respiratory health outcomes were those of the ISAAC questionnaire (Lai et al., 2009). Asthma prevalence was determined by past and current (preceding 12 months) wheezing episodes, persistent cough unrelated to colds and influenza and ever having had a lifetime history of asthma. The severity of current wheezing was defined as an affirmative response to at least one of the following questions: frequency of wheezing attacks (four or more), episodes that disturbed sleep (one or more nights per week) and episodes that limited speech (at least one). Questions related to the prevalence of allergic rhinitis were past or current rhinitis (preceding 12 months) and itchy/watery eyes in the previous year unrelated to colds or influenza. Atopic eczema prevalence was determined by past or current (preceding 12 months) chronic itchy rash. The definition of wheeze by

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