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Respiratory symptoms, asthma and levels of fractional exhaled nitric oxide in schoolchildren in the industrial areas of Estonia

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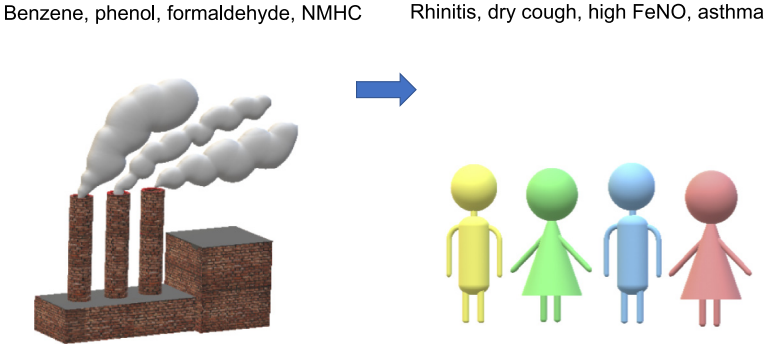
HIGHLIGHTS

- Industrial areas have increased levels of benzene, phenol, formaldehyde and NMHC.
- Children living in industrial area have higher prevalence of respiratory symptoms and asthma.
- Children living near shale oil industry and power plants have more often high FeNO levels.
- Children exposed to industrial pollutants have higher odds of respiratory diseases.

GRAPHICAL ABSTRACT



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ABSTRACT

Objectives: Exposure to air pollutants in the ambient environment has been associated with various respiratory symptoms, and with increased asthma diagnosis, in both children and adults. Most research to date has focussed on core pollutants, such as PM_{10}, $PM_{2.5}$, SO_2 and NO_2, and less attention has been given to the effects of industry-specific contamination. The current study aimed to examine the associations between respiratory symptoms, asthma, increased levels of fractional exhaled nitric oxide (FeNO) (as a marker of eosinophilic airway inflammation) and ambient levels of industrial pollutants (such as benzene, phenol, formaldehyde and non-methane hydrocarbons) for schoolchildren living near oil shale industries in Ida-Viru County, Estonia.
Methods: A total of 1326 schoolchildren from Ida-Viru, Lääne-Viru and Tartu Counties participated in a cross-sectional study, consisting of questionnaires on respiratory symptoms and asthma, as well as clinical examinations to measure FeNO. Dispersion modelling was used to characterize individual-level exposure to industrial air pollutants at each subject's home address. Associations between exposure and respiratory health were investigated using logistic regression analysis, and differences in results between regions were analysed using the Chi-squared test.
Results: The prevalence of respiratory symptoms ($p < 0.05$) in children living near (i.e. within 5 km) of an oil shale industry site in Ida-Viru County was 2–4 times higher than in children living in the reference area of Tartu County. Children exposed to 1 $\mu g/m^3$ higher levels of benzene and formaldehyde had a higher odds ratio (OR) of having rhinitis without a cold (OR 1.03, 95% confidence interval (CI) 1.01–1.06), of ever having had attacks of asthma

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(OR 1.05, 95% CI 1.01–1.10) and of having a dry cough a few days per year (OR 1.05, 95% CI 1.01–1.10). Children exposed to 1 μg/m^3 higher levels of benzene, formaldehyde, phenol and non-methane hydrocarbons had a higher odds ratio of having high FeNO levels (≥30 ppb): OR and 95% CI of 1.05, 1.01–1.09; 1.22, 1.06–1.41; 1.01, 1.00–1.01; and 1.75, 1.75–2.62, respectively.

1. Introduction

Industrial areas have often high concentrations of air pollutants, which may lead to increased morbidity and mortality; depending on the types of pollutants, and the concentration to which the population living in the region is exposed (Martuzzi et al., 2014). Children are particularly susceptible to air pollution exposure, as their pulmonary metabolic capacity has not yet fully developed (Kurt et al., 2016). Lifelong exposure to air pollution could therefore have adverse effects on the lung development of children (Rice et al., 2016).

There is evidence that children living near (i.e. within 5 km) of industrial sites, or exposed to industrial pollutants, have an increased risk of adverse health outcomes when compared with those living far away (i.e. >20 km), or those less exposed (Alwahaibi and Zeka, 2016; Bergstra et al., 2018; Lewin et al., 2013; Nirel et al., 2015; Smargiassi et al., 2014; Wichmann et al., 2009; Wilhelm et al., 2007; Wong et al., 2016; Yang et al., 1997). However, studies investigating associations between industry-related air pollution and health among younger populations are rare, as was highlighted by Pascal et al. in a recent review (Pascal et al., 2013).

Industrial activity in Ida-Viru County, in North-Eastern Estonia, consists mainly of oil shale extraction, power generation and shale oil production (OECD/ECLAC, 2016). Several previous studies have indicated that the activities of the oil shale sector may affect the respiratory health of children (Etlin, 1989; Tefanova et al., 1993; Vasar et al., 2011). According to surveys conducted between 1971 and 1981, children living in the Ida-Viru area had 1.1 times smaller lung capacity, and higher morbidity, than children living in the reference areas (also in Estonia). The studies of Etlin (1989) showed that the overall number of doctor's appointments was 1.3 times higher in Ida-Viru County than in other regions of Estonia, and the frequency of abnormal birth weight was also 60% higher (Etlin, 1989). During the 1990s, several complex surveys were conducted on preschool children living in two cities in North–Eastern Estonia (Kohtla-Järve and Jõhvi), examining the clinical-immunological parameters of their health condition, and the impact of air pollution on the level and structure of their morbidity. The results indicated that children aged between 3 and 6 years and living in Kohtla-Järve had a higher overall risk of morbidity, and a higher morbidity risk for respiratory diseases (Tefanova et al., 1993). Children living in Narva (a city in North-Eastern Estonia) have also been found to have more respiratory and asthma-like symptoms than those living in Tallinn, Pärnu, or Elva (Bjorksten et al., 1998; Vasar et al., 2006). According to Vasar et al. (2011), in the early 2000s there was more diagnosed asthma, and more respiratory symptoms indicative of asthma in the Ida-Viru region than in other parts of Estonia.

During the past decade, the pattern of oil shale usage has transformed, resulting in significant changes in the amounts and locations of air pollution emissions. Shale oil factory Enefit 280 commenced operation near Narva in 2012; and two Petroter factories at Kohtla-Järve (2014/2015) and the 300 MW Auvere Power Plant (2015) were opened with lower stacks, which change the dynamics of air pollution dispersion. However, despite the measures taken to reduce the emission of air pollutants, the health status of residents in oil shale industry region is still worse in many aspects than elsewhere in Estonia (Orru et al., 2018).

The aim of the current study was to detect whether the levels of respiratory problems among children living in oil shale industry areas remain higher than elsewhere, even though air pollution emissions have decreased and the oil shale usage pattern has changed. The primary focus was on the possible health effects of industry-specific pollutants, such as benzene, phenol, formaldehyde and non-methane hydrocarbons.

2. Materials and methods

The study population consisted of participants in two different studies: SINPHONIE (Schools Indoor Pollution and Health: Observatory Network in Europe) (Csobod et al., 2014) and SOHOS (Study of the Health Impact of Oil-Shale Sector) (Orru et al., 2016). SINPHONIE was a multidisciplinary research project covering the areas of health, environment, transport and climate change, aimed at improving air quality in schools and kindergartens. Twenty-four countries across Europe participated in the SINPHONIE project, and the data collection in Tartu County took place during January–February 2012. The SOHOS study focused on the possible health effects of the oil shale sector; data was collected from children in Ida–Viru and Lääne–Viru Counties between November 2014 and January 2015. This data also formed part of the material for the Estonian National Development Plan for the Use of Oil Shale 2016–2030. In total, the study population consisted of 1326 randomly selected schoolchildren from twenty-five schools, aged between 8 and 12 years and living in North–Eastern Estonia (in Ida-Viru and Lääne-Viru Counties) or South-Eastern Estonia (Tartu County) (Fig. 1, Table 1). Tartu and Lääne–Viru Counties are non-industrially-polluted regions and were included as reference areas. Schools were selected randomly, according to socioeconomic status and levels of industrial pollution. All clinical examinations were approved by the Research Ethics Committee of the University of Tartu.

2.1. Questionnaire study and clinical examinations

Questionnaires on health and socio-demographics were distributed to subjects by teachers, and were completed by parent and child together. The questionnaire concentrated on respiratory health, and included questions on physician-diagnosed asthma; the frequency of attacks of asthma; and allergies. The following questions were included in the study:

1. "Has your child ever had wheezing or whistling in the chest at any time in the past?" Yes/No
2. "Has your child ever had a problem with sneezing, or a runny nose, or blocked nose when he/she did not have a cold or flu?" Yes/No
3. "Has your child ever had asthma diagnosed by physician?" Yes/No
4. "Has your child ever had attacks of asthma?" Yes/No
5. "Has your child had wheezing or whistling in the chest without cold in the past 12 months?" Yes/No
6. "In the past 12 months, has your child had a dry cough at night, apart from a cough associated with a cold or chest infection?" Yes/No
7. "Does your child have dry cough without cold on some days during a year?"
8. "Does your child have phlegm without cold on some days during a year?"

Survey respondents were then invited to a clinical examination, during which the content of fractional exhaled nitric oxide (FeNO) was