Chemosphere 139 (2015) 340–348

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

Nitrogen Dioxide pollution and hazardous household environment: What impacts more congenital malformations

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HIGHLIGHTS

- We show that only the minor malformations are associated with exposure to NO_2.
- Major malformations are associated with hazardous exposures in a household.
- Exposure to close hazardous environment has a more profound impact on health.

ARTICLE INFO

Article history:
Received 17 April 2015
Received in revised form 11 June 2015
Accepted 26 June 2015
Available online 11 July 2015

Keywords:
Nitrogen Dioxide
Congenital malformations
Household environment
Socio-economic status

ABSTRACT

Nitrogen Dioxide (NO_2) is a product of fuel combustion originating mainly from industry and transportation. Studies suggest an association between NO_2 and congenital malformations (CM). We investigated an independent effect of NO_2 on CM by adjusting to individual factors and household environment in 1024 Bedouin-Arab pregnant women in southern Israel. This population is characterised by high rates of CMs, frequent consanguineous marriages, paternal smoking, temporary housing and usage of open fire for heat cooking.

Information on household risk factors was collected during an interview. Ambient measurements of 24-h average NO_2 and meteorological conditions were obtained from 13 local monitors.

Median value of daily NO_2 measured in the area was 6.78 ppb. CM was diagnosed in 8.0% (82) of offspring. Maternal NO_2 exposure during the 1st trimester >8.6 ppb was significantly associated with minor CM (RR = 2.68, $p = 0.029$). Major CM were independently associated with maternal juvenile diabetes (RR = 9.97, p-value = 0.002) and heating by open fire (RR = 2.00, p-value = 0.049), but not NO_2 exposure.

We found that NO_2 emissions had an independent impact only on minor malformations, whereas major malformations depended mostly on the household environment. Antepartum deaths were associated by maternal morbidity.

Abbreviations: APD, ante-partum death; ATD, Admission–Transfer–Discharge; CM, congenital malformations; GIS, geographic information system; ICD, International Classification of Diseases; IP, industrial park; IQR, interquartile range; NO_2, Nitrogen Dioxide; NOx, gases including mix of nitrogen dioxide and nitric oxide; O_3, Ozone; OED, Obstetric Emergency Department; OR, Odds Ratio; $PM_{2.5}$, Particulate Matter $\leqslant 2.5$ μm; PM_{10}, Particulate Matter $\leqslant 10$ μm; PPD, Peri-Partum Death; PS, permanent settlements; SES, socio-economic status; SO_2, Sulfur Dioxide; SUMC, Soroka University Medical Center; TTS, traditional tribal settlements.

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http://dx.doi.org/10.1016/j.chemosphere.2015.06.091
0045-6535/

1. Background

1.1. Congenital malformations

Congenital malformations (CM) present a major risk of fetal and neonatal morbidity and mortality. According to the WHO estimations, this condition occurs in 1 out of 33 infants, worldwide (WHO, 2014).

The most sensitive period for inducing development of birth malformations is assigned to 3–8 weeks of gestation (Mattison, 2010; Vrijheid et al., 2011). In approximately half of the cases the etiology is believed to be a product of an independent influence or a combination of genetic factors, maternal medications and infections, behavioral exposures and maternal low socioeconomic status, older age, consanguinity, malnutrition (Kalter, 2003; Wigle et al., 2008) and environmental factors, e.g. proximity to industrial facilities, hazardous waste sites and agricultural areas (WHO, 2014).

1.2. An impact of ambient pollution on congenital malformations

Over the last decade there is a growing evidence of an adverse impact of exposure to ambient air pollution on fetal development. Infant mortality, birth weight, prematurity and immune system disorders have all been reported as associated with higher ambient levels of Particulate Matter $\leqslant 10\ \mu m$ (PM_{10}), Nitrogen Dioxide (NO_2), Sulfur Dioxide (SO_2) and other pollutants. (Srám et al., 2005; Glinianaia et al., 2004; Proietti et al., 2013; Stieb et al., 2012; Curtis et al., 2006)

A significant amount of research links ambient air-pollutants with CMs. (Vrijheid et al., 2011; Mattison, 2010; Wang and Pinkerton, 2007; Chen et al., 2014; Proietti et al., 2013; Agay-Shay et al., 2013) The meta-analysis conducted by Vrieheid et al. of 10 epidemiologic studies reported an adverse impact of NO_2 and SO_2 on development of coarctation of the aorta and tetralogy of Fallot, and PM_{10} was found related to an increased risk of atrial septal defects (Vrijheid et al., 2011). The meta-analysis conducted by Chen et al. (2014) reported a significant association found between NO_2 concentrations and coarctation of the aorta. The recent report from a research in Barcelona indicated an association between interquartile range (IQR) increase in NO_2 (12.2 μg/m3) and coarctation of the aorta (Odds Ratio (OR) = 1.15; 95% CI: 1.01, 1.31) and digestive system defects (OR = 1.11; 95% CI: 1.00, 1.23). (Schembari et al., 2014). Israeli researchers found a similar adverse impact of exposure to NOx on specific malformations in the circulatory system and genital organs. (Farhi et al., 2014)

Thus, researchers repeatedly find CM related to NO_2 exposure, whereas its ambient levels remain relatively stable over time, as opposed to the levels of SO_2 and PM_{10} – both constantly decreasing as shown in multiple studies worldwide (Chen et al., 2011; Querol et al., 2014; Karanasiou et al., 2014; Turalioğlu, 2005).

Furthermore, despite an extensive research of an impact of ambient air pollution on neonates, adjustment to individual confounding factors has been problematic in many of the studies focusing on this type of exposure, as pointed out by Chen et al. (2014). While estimating the risk of exposure at a population level, very few confounders can be taken into account in the analysis and is usually limited to parental smoking, occupation, maternal age and season of conception.

A study by Bentov et al. (2006) indicated an increased rate of major CMs among Arab-Bedouin newborns in the Negev region (Israel), whose mothers live within 20 km from the Negev industrial park (IP) (5.6%), compared to mothers residing in remote localities (4.8%). Variation in major CM by distance from IP was unlikely to be explained by a difference in utilization of health care services or varying distribution of consanguineous marriages.

The study by Bentov et al., however, as well as the rest of the published reports on the association on NO_2 with CMs, usually do not account for the exposures measured in immediate subjects proximity and individual risk factors. In the presented study, we aimed to estimate an independent effect of an ambient exposure to NO_2 emissions on congenital malformations and fetal mortality in the Bedouin population. Our estimates were adjusted to individually recorded risk factors related to household environment and parental background, as well as other pollutants and meteorological conditions.

Assuming an increasing severity of an outcome on a scale from healthy subjects to children with minor anomalies, then – to children with major anomalies and finally, ante-partum death (APD) cases – we hypothesized that mothers to neonates with highest degree of morbidity are more likely to be exposed to maternal risk factors and environmental hazardous surroundings compared to others.

1.3. Arab-Bedouin population

Bedouins in the Negev dwell in either recently established permanent settlements (PS) or traditional tribal settlements (TTS). In the area, the Bedouin population shows an increased tendency to cease practicing a nomadic life style and move from TTS to PS. Residents of PS have an access to modern municipal infrastructure (running water, electricity, telephone service, garbage disposal, sewage treatment, paved roads) and live in modern houses. Residents of TTS live in temporary pre-fabricated housing, shacks, or tents without access to municipal infrastructure. Cooking and heating, in both types of residence, is often provided by open fires, causing exposure to pollution from bonfires. The Negev Bedouin population is of low socio-economic level with a high rate of unemployment (up to 20%) and low educational level (Statistical Yearbook of the Negev, 2010). According to Abu-Saad (2002) smoking is very common among Bedouin men (55–74%). Consanguineous marriages are very frequent within Bedouin population-60%, where 36% of the marriages are between first cousins (Zlotogora et al., 2003).

The Bedouin-Arab population is potentially exposed to the emissions of the local industrial park, which consists of 24 chemical and pharmaceutical facilities, has an incinerator and serves as the national industrial waste disposal site. The list of emissions from the IP chemical plants and evaporation pools includes a variety of aliphatic, aromatic and polycyclic hydrocarbons and a few dozen nonorganic agents and may be a significant source of NO_2 in the area. Traffic, on the other hand, usually attributed to high levels of NO_2 (Grundström and Pleijel, 2014) is negligibly scarce in the study area (Fig. 1).

2. Methods

2.1. Study procedures

We enrolled women of Arab-Bedouin origin at the time they were admitted for a delivery at Obstetric Emergency Department (OED) of the Soroka University Medical Center (SUMC). Upon their arrival women were provided with explanations about the study and were invited to consent to participate in the study. After the delivery the enrolled women were approached by Arab-speaking interviewers with an extensive questionnaire on the personal risk factors and the exact address during the pregnancy. The diagnoses of the neonates and the women were collected from the medical charts filled out at the hospitalization. The data on ambient exposure was further verified based on the residence locations confirmed during the interview.