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Early-life residential exposure to soil components in rural areas and childhood respiratory health and allergy

Graham Devereux [a,*], Nara Tagiyeva [a], Stephen W. Turner [a], Jon G. Ayres [b], Anthony Seaton [a], Gordon Hudson [c], Rupert L. Hough [c], Colin D. Campbell [c,d], Charles A. Shand [c]

[a] Division of Applied Health Sciences, School of Medicine and Dentistry, University of Aberdeen, Foresterhill, Aberdeen, AB25 2ZD, UK
[b] Institute of Occupational and Environmental Medicine, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK
[c] The James Hutton Institute, Craigiebuckler, Aberdeen, AB15 8QH, UK
[d] Department of Soil and Environment, Swedish University of Agricultural Sciences, Uppsala, Sweden

HIGHLIGHTS

- We have linked a birth cohort with the Scottish Soils Database.
- We have looked for associations between asthma, allergy and soil content.
- No associations found for soil content at residence at age 5 years.
- Silt content at birth residence adversely linked with respiratory health up to age 5.
- Early life exposure to soil silt may adversely influence childhood respiratory health.

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ABSTRACT

The increase in asthma and allergies has been attributed to declining exposure to environmental microorganisms. The main source of these is soil, the composition of which varies geographically and which is a major component (40–45%) of household dust. Our hypothesis-generating study aimed to investigate associations between soil components, respiratory health and allergy in a Scottish birth cohort. The cohort was recruited in utero in 1997/8, and followed up at one, two and five years for the development of wheezing, asthma and eczema. Lung function, exhaled nitric oxide and allergic sensitization were measured at age five in a subset. The Scottish Soils Database held at The James Hutton Institute was linked to the birth cohort data by the residential postcode at birth and five years. The soil database contained information on size separates, organic matter concentration, pH and a range of inorganic elements. Soil and clinical outcome data were available for 869, 790 and 727 children at one, two and five years. Three hundred and fifty nine (35%) of children had the same address at birth and five years. No associations were found between childhood outcomes and soil content in the residential area at age five. The soil silt content (2–20 μm particle size) of the residential area at birth was associated with childhood wheeze (adjusted OR 1.20, 95% CI [1.05; 1.37]), wheeze without a cold (1.41 [1.18; 1.69]), doctor-diagnosed asthma (1.54 [1.04; 2.28]), lung function (FEV_1: beta −0.025 [−0.047; −0.001]) and airway inflammation (FE_{NO}: beta 0.15 [0.03; 0.27]) at age five, but not with allergic status or eczema. Whilst residual confounding is the most likely explanation for the associations reported, the results of this study lead us to hypothesise that early life exposure to residential soil silt may adversely influence childhood respiratory health, possibly because of the organic components of silt.

Abbreviations: CI, confidence interval; FE_{NO}, fractional exhaled nitric oxide; FEV_1, forced expiratory volume in 1 s; FVC, forced vital capacity; GEEs, General Estimating Equations; IQR, interquartile range; NO, nitric oxide; OR, odds ratio; PEF, peak expiratory flow; PM, particulate matter; SIMD, Scottish Index of Multiple Deprivation; SSD, Scottish Soils Database; TIN, triangulated irregular network.

* Corresponding author at: Child Health, Royal Aberdeen Children's Hospital, Aberdeen AB25 2ZG, UK. Tel.: +44 1224 558196; fax: +44 1224 551919.
E-mail addresses: g.devereux@abdn.ac.uk (G. Devereux), n.tagiyeva-milne@abdn.ac.uk (N. Tagiyeva), s.w.turner@abdn.ac.uk (S.W. Turner), j.g.ayres@bham.ac.uk (J.G. Ayres), a.seaton@abdn.ac.uk (A. Seaton), Gordon.Hudson@hutton.ac.uk (G. Hudson), Rupert.Hough@hutton.ac.uk (R.L. Hough), Colin.Campbell@hutton.ac.uk (C.D. Campbell), charles.shand@hutton.ac.uk (C.A. Shand).

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1. Introduction

Soil is a prime source of the essential elements and potentially toxic substances, which can enter the human body indirectly through the consumption of food products. Soil can also enter the human body directly through inhalation, inadvertent ingestion, deliberate eating and skin lesions. There are several well known examples of the influences of deficiencies or excesses of essential or toxic elements in soil, and the effects of inhaling soil containing fibrous minerals on human health (Abrahams, 2002; Hough, 2007; Oliver, 1997).

The hygiene hypothesis (Strachan, 1989) has been proposed as an explanation for the increase in asthma and allergic disease in westernised countries in the latter decades of the 20th century. Humans have evolved in a pathogen rich environment and the hygiene hypothesis posits that a modern westernised, non-traditional lifestyle no longer exposes people to the diverse microbe-rich environment, in response to which the human immune system has evolved and most probably requires for 'normal' maturation. This concept is supported by the observation that children brought up on farms and exposed to a heavy burden and wide variety of micro-organisms are less likely to develop asthma and allergic disease (Braun-Fahrlander et al., 1999; Ege et al., 2006, 2011; Riedler et al., 2001). Early life exposure to a diverse, micro-organism-rich environment appears to be especially important in reducing the risk of asthma and allergic disease.

A major exposure source of micro-organisms is the soil and this has led to the concept that 'dirt' may be good in preventing asthma and allergic disease. Indeed it has been formally hypothesised that the disconnection of man and the soil might be one of the major contributors to the increase in asthma and allergic disease (von Hertzen and Haahtela, 2006). Soil is a complex, diverse mixture of mineral matter, organic matter, water, and air (Brady and Weil, 2008) whose composition varies widely geographically. The diversity of microbes in soil is vast and new molecular methods applied to landscape scale studies are starting to show that microbial community composition varies with soil type and land use (Singh et al., 2009). Whilst exposure to soil is conventionally considered to be an outdoor phenomenon, indoor exposure occurs as soil is transported indoors on shoes, clothes and in the air, comprising about 40–45% of household dust (Layton and Beamer, 2009; Trowbridge and Burmaster, 1997).

To investigate whether exposure to soil is protective against asthma and allergic disease, we conducted an exploratory study of possible associations between soil composition and early childhood asthma and allergic disease. We linked data from a local birth cohort study with data from the Scottish Soils Database (SSD). The soil database contained information on size separates (sand, silt, clay), organic matter concentration, pH values and a range of inorganic element concentrations. It was envisaged that the results of this investigation would generate novel hypotheses for further investigation. Outside occupational settings, few studies have investigated the influence of soil components on human health, although the specific effects of some soil minerals are well documented (Sing and Sing, 2010; Smith and Lee, 2003). To our knowledge there have been no studies on children's respiratory health in association with environmental exposure to soil components.

2. Methods

2.1. Data description

Two data sources were used: (1) a longitudinal birth cohort investigating associations between maternal diet and childhood asthma/allergic disease, and (2) the SSD held at The James Hutton Institute. The details of the birth cohort have been described elsewhere (Martindale et al., 2005). In brief, 2000 healthy pregnant women attending an antenatal clinic (Aberdeen Maternity Hospital, AMH), at median 12 weeks gestation, were recruited in 1997/8. The AMH provides the antenatal care for the entire Grampian region (population ~ 550,000). There was no selection for asthma or allergic disease (Martindale et al., 2005). The ensuing cohort of 1924 live singleton births was followed up at one, two, and five years with response rates of 79% (n = 1511), 71% (n = 1373) and 65% (n = 1253), respectively. At each follow-up a postal questionnaire was used to ascertain the presence of respiratory and allergic symptoms in the cohort children. The questions were those used in the International Study of Asthma and Allergies in Childhood (ISAAC) (International Study of Asthma and Allergies in Childhood Steering Committee, 1998): specifically 'wheeze ever', 'wheeze in the last 12 months', 'wheeze in the absence of colds', 'asthma ever' and doctor diagnoses of asthma, eczema and hay fever. A derived outcome of 'active asthma' was defined by positive responses to both 'doctor diagnosed asthma' and 'wheeze in the last 12 months'. At the five-year follow-up children were also invited to attend for a more detailed assessment. 755 children attended for measurement of lung function by spirometry (peak expiratory flow PEF, forced expiratory volume in 1 s FEV_1, forced vital capacity FVC), exhaled nitric oxide (FE_{NO}), and allergic status (≥1 positive skin prick test to cat, timothy grass, egg, and house dust mite allergens, 3-mm cut off (ALK Abello, UK)). Other factors that could potentially confound any association with childhood outcomes were collected during pregnancy, at delivery and follow-up. The study was approved by the Grampian Research Ethics Committee and informed written consent was obtained from the mothers and assent from the children where possible. Data from the cohort study were selected for this study if the participants lived in a rural location. This selection was made because (1) the relationship of people with the soil is likely to be closer in rural settings, and (2) soil samples from built areas do not form part of the soil database. The cohort study data were linked to SSD soil composition data using the postcode of the child's mother's home at the date of birth and at five years.

The SSD has several components (Brown et al., 1987). We had the available soil profile descriptions of horizons (distinct soil layers approximately parallel to surface) and analytical data from approximately 13,000 sites throughout Scotland. The study area of soils was restricted to North East Scotland and included only cultivated top soils from the postcode areas of the cohort children. The soil used for the chemical analysis was taken from the central part of the cultivated surface horizon. From the available data (1439 out of 1587 samples) the average position of the soil sample was between 5 and 15 cm below the soil surface. The soils had been analysed according to the following protocols. The soils were air-dried and sieved through a screen with 2-mm openings. Particle size analysis according to the international classification (clay < 2, silt 2–20 and sand > 20–2000 μm) was determined using a hydrometer method after dispersion of the soil in 1 M sodium hydroxide (Bouyoucos, 1936). Exchangeable cations (Ca, Mg, Na, K) were measured by displacement with 1 M ammonium acetate (Chapman, 1965). The metals (Ba, Co, Cr, Cu, Ga, Mn, Mo, Ni, Pb, Sr, Ti, V) were measured by aqua regia extraction (Berrow and Stein, 1983). Total C and N were measured with an elemental analyser. Total P was measured by a fusion technique (Smith and Bain, 1982).

2.2. Data linkage

The postcode was used as the geographical link between the soil and health data. Postcode structure in the UK is hierarchical and consists of a series of alphanumeric characters (maximum of 7 characters). The full 7-character code defines a limited number of addresses or a single large mail-delivery point. For this study we used the 5-character postcode sector code. These spatial units for the cohort children data are arbitrary in terms of the soil pattern and may cross boundaries between soils having different properties.