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Short communication

Assessment of the bioaccumulation of metals to chicken eggs from residential backyards

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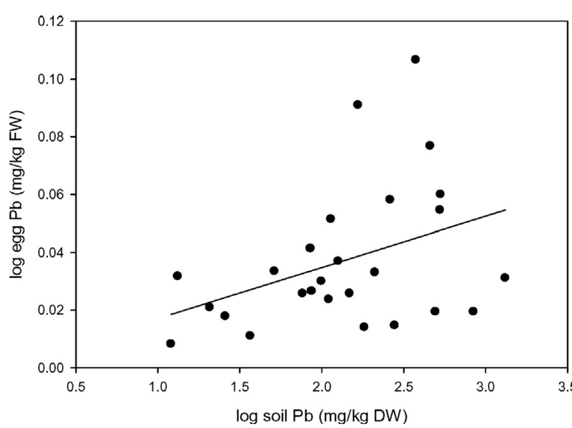
HIGHLIGHTS

- We measured metal contaminants in soil and eggs from 26 backyard chicken coops in NSW Australia.
- The levels of As, Cd, Cu and Zn were low, both in soil and in home-grown eggs
- The HIL for Pb in soil and the health standard for Pb in produce was exceeded in 7 of the 26 sites.
- The level of Pb in home-grown eggs was higher than in commercial eggs.
- As soil Pb increased, concentrations of Pb in eggs increased. No relationship was detected for Pb in feed.

GRAPHICAL ABSTRACT



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ABSTRACT

Soil in urban areas contains the residues of past land-uses and practices. Urban farming (keeping chickens, vegetable gardening) requires soil disturbance and can increase exposure of residents to these contaminants. We measured the level of lead, arsenic, cadmium, copper and zinc contaminants in soil and eggs from 26 backyard chicken coops across the Lower Hunter, NSW Australia. We compared the levels of metals in soil to Health Investigation Levels and metals in home-grown eggs to the levels in commercial eggs tested in this study or published by Food Standards Australia New Zealand. The levels of arsenic, cadmium, copper and zinc were low, both in soil and in home-grown eggs and were comparable to commercial eggs tested in this study. The Health Investigation Level for lead in soil (300 mg lead/kg soil) was exceeded at 7 of the 26 sites. The level of lead in home-grown eggs was generally higher than in commercial eggs. The reference health standard for meat (including chicken), fruit and vegetables of 0.1 mg lead/kg produce was exceeded in home-grown eggs from 7 of the 26 sites. There was a significant relationship between the lead level in eggs and the lead level in soil accessible to chickens. As soil lead increased, concentrations of lead in eggs tended to increase. No relationship was detected between the lead level in feed and in eggs. We recommend strategies to reduce ingestion of soil by chickens thereby reducing metal contamination in home-grown eggs.

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1. Introduction

In recent years, there has been a dramatic rise in the popularity of 'urban farming'. Pressure on consumers from rising food prices, the increased popularity of the local food movement and a desire for chemical-free produce have all contributed to an increase in the uptake of fruit, vegetable and egg production in residential backyards. 'Home-grown' is seen as a clean and green alternative. The small area required to house chickens and the ready-availability of eggs as a protein source make chickens well-suited to the urban farm. However, residential backyards are not necessarily the clean environments that might be envisaged. Backyard soils contain the residues of past land uses and practices, whilst redevelopment of contaminated land for residential purposes creates the potential for high levels of exposure to contaminants. It has been suggested that eggs produced on contaminated land have the potential to become a significant source of contaminant exposure for consumers (Cross and Taylor, 1996).

Studies using contaminated feed have demonstrated the potential for bioaccumulation of a range of contaminants in both the tissues and eggs of chickens. Trampel et al. (2003) reported elevated lead in the blood, tissues and eggs of lead-exposed hens, while Mazliah et al. (1989) found significantly higher blood lead levels in roosters than in hens fed the same lead dose, attributed to excretion of lead in the eggs of laying hens. Other contaminants demonstrated to accumulate in the edible portion of chicken eggs include arsenic, mercury and cadmium (Holcman and Stibilj, 1997, Leach et al., 1979, March et al., 1974). These observations predominantly arise from studies in which contaminants are administered orally or in feed. Further studies investigating contaminant uptake from soil are essential in order to define safe threshold values for urban farming. A recent Belgian study investigating contaminants in home-grown eggs detected lead levels more than six times higher in home-grown eggs than commercial free-range eggs (Van Overmeire et al., 2006). Following detailed analysis of egg, feed and soil contaminant levels, soil was found to be the major contributor of lead contamination to eggs in environmental settings (Waegeneers et al., 2009a).

We investigated metal contaminant levels in eggs from residential backyards in the Lower Hunter, NSW Australia. The contaminants examined in this study were arsenic, cadmium, copper, lead and zinc. Lead is of particular concern in the study area due to proximity to a former Lead/Zinc Smelter. We hypothesised that a major route of contaminant exposure to chickens in residential backyards is likely to be via ingestion of contaminated food or soil. Chickens typically scratch in the soil, foraging for invertebrates and seeds. Inadvertent ingestion of soil occurs while foraging, or via ingestion of soil particles adhering to food or dusty feathers during preening. As soil has been previously observed as the major source of metals in eggs (Waegeneers et al., 2009a), we predict that as soil contamination increases across residential sites, metal accumulation to eggs may increase. We also assessed potential relationships between metals in feed and metal accumulation to eggs.

To assess the degree of metal contamination in residential soils and eggs produced at these sites a number of standards were employed as benchmarks. There are no Australian guidelines for levels of metals in soil to safely keep poultry. The National Environment Protection (Assessment of site contamination) Measure, 1999 (NEPM, 2013) however, sets the *Health-based Investigation Level* (HIL) for soil metals on standard residential sites. This assumes that home-grown produce contributes <10% of fruit and vegetable intake and no poultry are kept. There are no guidelines for soil metals on residential properties with substantial vegetable gardens (contributing 10% or more of vegetable and fruit intake) with or without poultry providing either eggs or meat (Imray and Langley, 2001). Given these limitations, we compared metal levels in soils at residential sites to these HIL's to identify sites elevated in metals and at risk of contaminating produce.

The *Food Standards Code* sets *maximum levels* of metal contaminants which are permitted in foods considered to provide a significant contribution to the total dietary exposure (Food Standards Australia New Zealand [FSANZ], 2013). Eggs are considered to be a minor contributor to dietary intake; consequently, there are no maximum limits for these contaminants in eggs in Australia. Nevertheless, Food Standards Australia New Zealand (FSANZ) acknowledges the potential health hazard posed by eggs produced on highly contaminated land (FSANZ, 2009). Internationally, neither the European Union or the United States Food and Drug Administration have set standards that specifically apply to metal contaminant levels in eggs. Therefore, we compared contaminant levels detected in home-grown eggs to contaminant levels in commercial eggs purchased from a supermarket. We also compared our results to the FSANZ 23rd Australian Total Diet Study which reports contaminant levels in commercial foods across Australia (FSANZ, 2011).

In the case of lead we have also used the *maximum level* of lead permitted in meat (including chicken), fruit and vegetables of 0.1 mg lead/kg fresh weight as a reference for lead contamination of eggs (FSANZ, 2013). In 2010, the Joint Food and Agriculture Organisation/World Health Organisation Expert Committee on Food Additives (JECFA) concluded that the former *provisional tolerable weekly intake* of 25 μg lead/kg body weight could no longer be considered health protective and no further reference health standard has been determined (JECFA, 2010). FSANZ assesses lead exposure based on an exposure range of 0.3–0.6 μg lead/kg body weight/day for children aged 1–4 years, where the risk of an adverse effect is considered to be low (FSANZ, 2011, JECFA, 2010).

Given that chickens may bioaccumulate metals to eggs from the ingestion of contaminated food or soil, the aims of this study were to: (1) assess the level of metal contamination in soils of residential backyards where poultry were kept; (2) determine whether eggs produced in residential backyards are contaminated with arsenic, cadmium, copper, lead and zinc; (3) investigate the relationship between the level of contaminants in soil and the level of contaminants in the eggs of chickens housed there-on (for metals that were elevated); and (4) assess whether feed was a source of metals contributing to bioaccumulation in eggs (for metals that were elevated).

2. Methods and materials

2.1. Recruitment & sampling strategy

Private home-owners were recruited on a voluntary basis from across the Lower Hunter, NSW, Australia. In total, 26 home-owners participated in the study. The criteria used to select participants for inclusion in the study were as follows: laying hens must have been in their current location for at least 6 months prior to sampling and no rooster to be kept with hens (due to animal ethics considerations). Sites were sampled across Lake Macquarie and Newcastle local government areas; these were primarily urban, except for one remote rural site, and included locations within the Lead Abatement Strategy Contamination Survey Grid surrounding the former Pasminco–Cockle Creek Lead/Zinc Smelter.

An interview was conducted with home-owners providing information on known site history and husbandry (including breed, age, coop construction and feeding practices). At each site a composite soil sample was collected. This consisted of five subsamples to a depth of 10 cm from within the coop and run including areas where hens were free-ranging. A sample of commercial hen feed was taken for analysis from each household. A combined egg sample of at least 10 eggs was collected at each site.

In addition to home-grown eggs from residential households, eggs from eight different commercial producers were also tested. A single half dozen carton was purchased from the supermarket for each of the eight producers. All 6 eggs were combined to form a composite sample that was prepared and analysed as described below.