DUNEDIN STUDY CONCEPT PAPER FORM

Provisional Paper Title: A legacy of lead: the significance of house age on soil and childhood blood lead concentrations
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Please describe your proposal in 2-3 pages with sufficient detail for helpful review.

Objective of the study:
After being granted access to the previously requested Dunedin Study data (residential addresses and blood lead concentrations at age 11), we have been able to determine the age and makeup (i.e. brick, weatherboard) of residential dwellings for Dunedin Study participants, which has enabled us to compare the relationship between the built age of the property versus childhood blood-Pb levels. In combination with our own soil Pb data, our results and interpretations have led us towards the hypothesis that the age of residential properties in Dunedin has an impact on soil lead and childhood blood lead concentrations (see Fig. 1).

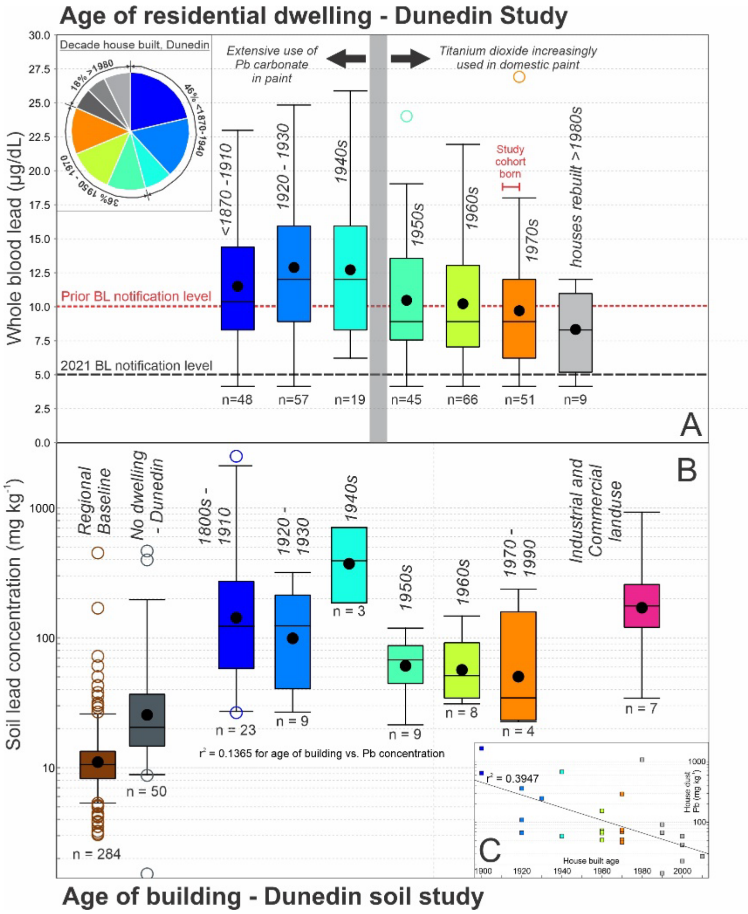

Figure 1. *A Whole blood-Pb concentrations (age 11) vs. built household age of Dunedin Study participants. Participants who lived at the same address from age 3 - 11 only were considered. Pie chart represents the age of properties for Dunedin City. B. Soil lead concentrations vs. built age of the building (residential, schools), as well as regional baseline data representing expected natural background lead concentrations. C. Lead concentrations in household dust vs. built age of the property.*

Figure 1A shows that the blood-Pb values at age 11 of Dunedin Study participants is distinctly higher for children who grew up in households that were built prior to 1950 (mean blood-Pb of 12.3 μg/dL n = 124) when compared to blood-Pb values for children in houses built after 1950 (mean blood-Pb of 10.1 μg/dL n = 161). Recent research shows detectable adverse health and cognitive effects of lead exposure in both adults and children at levels as low as 1 μg/dL (Budtz- Jørgensen et al. 2013; Lanphear et al. 2018), with each increase in blood-Pb of 1 μg/dL leading to a loss of one IQ point (Budtz- Jørgensen et al. 2013). Our soil lead concentrations (Figure 1B; Turnbull et al. 2019) show a similar trend, with Dunedin soils collected from properties (houses and schools) that were built prior to 1950 having mean soil-Pb concentrations of 141 mg/kg^{-1} compared to mean soil-Pb concentrations of 57 mg/kg^{-1} from post-1950 properties. In both instances, soils from sites with buildings have significantly higher lead concentrations than that expected for natural background Pb concentrations as established in the regional baseline (mean Pb = 11 mg/kg^{-1}; Martin et al. 2017)

While blood-Pb concentrations for New Zealand children and adults have significantly decreased with the banning of leaded gasoline in the mid-1990s (Fawcett et al. 1996; Mannetje et al. 2020), we hypothesize that there is still a considerable legacy of lead in the home environment, specifically in older pre-1950s buildings. There is no known safe level for lead exposure, especially in early childhood where the effects of lead on the developing brain may have long-lasting and irreversible negative outcomes in later life (Bellinger 2008). With the elimination of leaded gasoline, the assumption is that lead in the urban environment no longer poses a significant health risk as it once did. However, recent studies in London highlight the persisting legacy of lead contamination and the issue of old lead paint derived surfaces deteriorating and remobilizing in soils and airborne particles (Resongles et al. 2021).

Our link between increased exposure to lead from old pre-1950s buildings is important. Dunedin, as well as many major urban centres in New Zealand (and globally), has a large proportion of houses built prior to 1950 (46% of Dunedin houses were built prior to 1950). Leaded paint prior to 1950 contained as much as 50% by volume lead and has a distinct isotopic signature that we have recognized within out soil Pb-isotope dataset. Our working hypothesis is that lead paint in older houses in New Zealand continues to contribute to elevated lead loadings within the home environment, particularly in houses built prior to 1950.

In addition to the previous objectives of our study, we would like to test whether previously published negative lead-related cognitive and socio-economic outcomes in later life (specifically at age 45) (Reuben et al., 2017; Reuben, Elliott et al., 2020) can be directly linked to the age of the residential property that Dunedin Study participants grew up in. Using an instrumental variable approach, this would enable us to show causation and not just correlation regarding elevated blood-Pb levels, age of residential dwelling and negative cognitive and socio-economic outcomes in later life. Specifically, if age of housing during childhood, which is associated with childhood blood-Pb levels, is unrelated to IQ and social class during childhood but does predict IQ and social class or IQ / social class decline by midlife, it would strongly indicate that blood-Pb levels in childhood exerted a causal influence on brain integrity and social class.

This extension to our previous study builds on the hypotheses that lead continues to be a considerable pollution issue, with historical leaded paint now the main contributor to elevated lead loadings within households and their surrounding soils. Elevated lead within the home environment is of particular concern given the amount of time people spend indoors, and the numerous potential indoor exposure pathways for lead (and other toxic metal) uptake, especially by infants for which the effects of lead exposure are particularly deleterious. Results will therefore be of importance in assessing whether houses (and also educational facilities, specifically early childhood education centres) built prior to 1950 need to be assessed in greater detail to determine their risk for Pb contamination, and therefore to enable steps to be taken to mitigate the effects of such.

Data analysis methods:

In addition to the Dunedin Study data we have already received (Dunedin Study participant childhood addresses as well as blood-Pb levels at age 11) the extra variables that we now request access to will be used to directly compare previously published negative lead-related cognitive and socio-economic outcomes in later life (Reuben et al., 2017; Reuben, Schaefer et al., 2019, Reuben, Elliott et al., 2020) to the residential age of the property study participants grew up in during childhood. This will enable us to assess past and current risk factors for lead contamination in urban environments (i.e. residential soils, household dust), enabling us to make assessments on past, present and future risks for Pb contamination of households in Dunedin, and nationally.

Our analytic plan will follow those utilized in Reuben et al., 2017, 2019 and 2020 with one exception: following an instrumental variable approach we will substitute housing age for childhood blood-Pb level as a predictor of the lead-associated outcomes previously published in those studies. Previously used covariates will be retained for this study.

We also request data on blood-Pb levels at age 21 and SM reports of potential lead hazard exposure at age 21 to potentially rule-out other sources of lead exposure if this data is easily accessible (e.g. digitized). If it is not we may plan to fund-raise to digitize this archival data for future study.

Variables needed at which ages:

Additional variables desired to supplement those currently provided:

- Age 45 outcomes and covariates– we request age 45 versions of the variables utilized in the analyses published by Reuben et al., 2017, Reuben, Schaefer, et al., 2019, and Reuben, Elliott, et al., 2020 and identified as significant outcomes of lead or necessary covariates:
    - Outcomes
        - Total cortical surface area
        - Bilateral hippocampal grey matter volume (bihippocampus)
        - Fractional anisotropy
        - BrainAGE
        - WAIS-IV full-scale IQ (fsiq45astd)
        - Informant reported cognitive problems (infComplaints45)
        - Socioeconomic status
        - The P-factor
    - Covariates
        - Maternal verbal IQ (momiq3_
        - WISC-R childhood IQ (IQ79std)
        - Childhood family socioeconomic status (SESchildhd)
        - Family history of mental illness

Additional variables desired if easily available:

- Blood-Pb concentrations measured at age 21.
- Lead-hazard exposure questionnaire data from age 21 (assessment phase 21 book question ID numbers A1146-A1151)

Significance of the Study (for theory, research methods or clinical practice):

If we can demonstrate that negative cognitive and socio-economic outcomes in adult life can be correlated not only to elevated blood-Pb concentrations (as already established by Reuben et al. 2017, 2019, 2020), but also the age of the residential property study participants grew up in during childhood, we have a strong case for causation, rather than just correlation – using housing age as an instrumental variable. Our hypothesis that houses built prior to 1950 contain elevated indoor lead loadings, as well as elevated soil lead concentrations, is important as most of these properties will still contain surfaces covered by leaded paint. Unless these painted surfaces are completely removed (which causes a hazard in itself) or maintained by the regular application of non-leaded paint, these old lead-painted surfaces will continue to deteriorate over time and contribute to lead accumulation both in household dust and in residential soils. Several opportunities to mitigate this ongoing risk to household lead exposure can then be realised to further reduce the background exposure to lead, with education targeted towards mitigation strategies to reduce household lead exposure (e.g. washing homegrown vegetables, frequent vacuuming, regular maintenance of painted surfaces).

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