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Blood dioxin biomonitoring to assess local residents' exposure from a large urban remediation project ☆

Michael Staff [a,*], Vicky Sheppeard [a], Samanthi Abeywardana [a], Bradley Forssman [a], Alison Rutherford [a], Jochen F. Mueller [b], Olaf Paepke [c]

[a] New South Wales Health Department, Locked Bag 761, North Sydney 2060, Australia
[b] University of Queensland, National Research Centre for Environmental Toxicology, Australia
[c] Eurofins GfA, GmbH Laboratory, Hamburg, Germany

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ABSTRACT

Background: A total of 265 000 m^3 of dioxin contaminated soil and sediments from past industrial activity was treated on site in an urban setting in Sydney, Australia. To respond to local community concerns about potential dioxin exposure from fugitive emissions a human biomonitoring study was undertaken.
Objective: To determine whether local residents were exposed to significant amounts of dioxin from the remediation process.
Methods: Blood samples were collected from local residents around the site and a representative metropolitan control group. They were pooled within age and sex strata and the change in dioxin concentrations over the remediation period and a summary of the mid point and post remediation dioxin concentrations were compared between groups. Information on dietary intake was collected to look for possible confounding.
Results: The mean dioxin Toxic Equivalent concentrations (TeQ) decreased among both the local resident and control groups over the remediation period by 1.9 and 2.1 pg gm^{-1} lipid respectively. Modelled blood concentrations adjusting for age and sex did not detect a significant difference between groups for changes in either TeQ or 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8 TCDD). The summary measure approach did however demonstrate that the 2,3,7,8 TCDD concentrations among the local resident group was approximately 0.7 pg g^{-1} lipid higher compared to the control group post remediation. There were no significant changes in dietary intake sources of dioxin.
Conclusion: Biomonitoring demonstrated that local residents were not exposed to significant quantities of dioxin. Large scale remediation of dioxin contaminated land can be safely undertaken in an urban setting.

1. Introduction

Polychlorinated dibenzodioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and polychlorinated biphenyls (PCBs), collectively referred to as dioxins in this report, are persistent organic pollutants (POPs) that are ubiquitous in soils, sediments, air, and animal tissues (Alcock and Jones, 1996). Although the major route of human exposure is via bioaccumulation through the food chain (FSANZ, 2004), humans can be exposed to dioxins that have been created as unintentional by-products of the manufacturing process through their contact with contaminated urban environments caused by past industrial activity (USEPA, 2006; Weber et al., 2008). The adverse health effects of exposure to dioxins have been extensively studied in animal models, occupational settings and human epidemiological studies (ATSDR, 1998).

The company Union Carbide previously operated a chemical plant in the suburb of Rhodes on ten hectares of land adjacent to Homebush Bay, 15 km west of the centre of Sydney, Australia. The plant manufactured a range of chlorine-based chemicals including dichlorodiphenyltrichloroethane (DDT) and herbicides (2,4-dichlorophenoxyacetic acid and 2,4,5-trichlorophenoxyacetic acid) between 1928 and 1986 (Earth Tech, 2002; PB, 2002; Mannes et al., 2005). Waste containing dioxins as unintentional by-products was used as fill on the site, as fill on an adjacent industrial site and to reclaim land from Homebush Bay. Widespread contamination of Sydney Harbour with dioxins has been linked to the site (Birch et al., 2007) and a fishing ban has been imposed within the harbour. Elevated blood PCDD, PCDF and PCB concentrations have been detected among commercial fishers and their families who previously operated in the area and ate some of their catch (Rudge

☆ Institution where work performed, NSW Health Department, Locked bag 761, North Sydney 2060, Australia.

* Corresponding author. Address: Public Health Unit, Hornsby Hospital, Hornsby 2077, Australia. Tel.: +61 1 2 9477 9400; fax: +61 1 2 9482 1650.
E-mail address: mstaff@nsccahs.health.nsw.gov.au (M. Staff).

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et al., 2008). The site has been included among a group of international case studies to look at the contemporary and future relevance and challenges of dioxin and POP contaminated sites (Weber et al., 2008).

Extensive remediation of the peninsula occurred between 2004 and 2010 with the objective of making the area suitable for residential, open space and mixed land use. Dioxin contamination was identified as a major issue with concentrations of 2,3,7,8 TCDD up to 0.3 mg kg^{-1} measured in contaminated soil. A total of 265 000 m^3 of dioxin contaminated soil and sediments was treated on site by Directly-heated Thermal Desorption (DTD) to achieve concentrations suitable for medium density residential occupation or recreational use.

Thermal treatment of contaminated soils and sediments has potential health concerns, especially when plants are located within close proximity to local residents as is the case with this site (Cormier et al., 2006). With some residents living within a few hundred metres strict environmental controls and monitoring conditions were imposed upon the remediation process to protect the health of local residents from fugitive dust and treatment plant emissions (NSW EPA, 2004).

Blood dioxin testing has been extensively used as a biomarker to measure human exposure both for routine community surveys (Harden et al., 2004) and as a method to detect human exposure from known point sources such as manufacturing plants (Chen et al., 2004; Agramunt et al., 2005; Pless-Mulloli et al., 2005; Reis et al., 2007; Hedgeman et al., 2009). Longitudinal studies involving repeated blood measurements have also been conducted around point sources such as waste destruction plants (Evans et al., 2000; Gonzalez et al., 2000; Sampaio et al., 2004; Fowles et al., 2005).

The aims of the current study were to detect any increased human exposure from offsite movement of dioxin contaminants during remediation of the site, to interpret the significance of any detected exposure and to communicate to local residents any implications for their health.

2. Methods

2.1. Study population and recruitment

Areas on the Rhodes peninsula most exposed to dust during remediation were identified through air-dispersion modelling performed for the environmental assessments (Thiess, 2002). Air-dispersion modelling predicted that there was unlikely to be any impact of site emissions beyond 1.5 km from the site.

Local residents were eligible to be included in the study if they were over 30 years of age (male) or over 46 years of age (female), lived in the census collector district that included the site (total resident population 380 people) and envisaged remaining at their current address for the next 5 years. Females less than 46 years of age were excluded due to the possibility of fluctuating dioxin body burdens with breast feeding and pregnancy. Individuals who had previous or current employment at the Union Carbide site or another industrial facility on Rhodes Peninsula, or had current or previous employment in the pesticide manufacture or application industry were excluded. Controls were regular donors to the Australian Red Cross Blood Bank in the Sydney central business district with the same age/sex and current/past employment restrictions. Donors who lived or had lived within 1.5 km of the suburb of Rhodes were ineligible.

All households in the local collector district were invited by letter to participate in the study. Volunteers were asked to attend the local pathology service to provide a blood sample and return the baseline questionnaire. Controls were recruited by direct approach from a member of the study team when attending for their regular blood donation between November 2004 and February 2005.

2.2. Questionnaire

A standardised questionnaire based upon instruments used by others (Pless-Mulloli et al., 2005; Hedgeman et al., 2009) to collect demographic characteristics (age, sex, occupation, employment level and length of time at current residence) as well as measures of background exposure to dioxin through dietary sources, smoking and other activities was administered to all participants. This was done at baseline and again in 2010 to assess any changes in behaviour that might have caused a change in dioxin concentrations over the study period.

Participants were weighed at each blood donation visit and were asked to state their height on the questionnaire.

2.3. Exposure data collection and analysis

2.3.1. Collection of blood samples

To measure dioxin changes over the study period local residents provided 50 mL of blood in October 2004 (prior to commencement of remediation works), between March and June 2007 (mid works) and in May 2010 (immediately post works). Participants were recruited in the following five age/sex groups to ensure a representative community sample; males less than 46 years, males 46–60 years, males 60 years and older, females 46–60 years and females 60 years and older. Control group samples were collected between November 2004 to February 2005, July to October 2007 and during April 2010. Controls were recruited by stratified sampling over the same five age/sex groups as local residents with each individual supplying 5 mL of whole blood. All samples were collected in plain glass tubes and stored at −20 °C.

2.3.2. Blood sample pooling

After the final samples were collected pools for analysis were created from individuals who provided blood samples at all three time points. Blood samples were thawed, centrifuged and serum decanted. A group of three linked pools containing serum from the same group of individuals (one pool for each collection time) were created within individual age/sex cohorts. As participants aged over the study period they were allocated to a cohort based upon their age in 2004. Two groups of linked pools were created for each control cohort and three for each local resident cohort (except males less than 46 years where two pools were created) giving a total of 24 pools. An additional five groups of linked pools (one for each cohort) were created for controls who donated blood collected in 2004/5 and 2010 only.

2.3.3. Chemical analysis

All (pooled) samples were analysed by a World Health Organisation accepted laboratory for the determination of dioxin-like chemicals in human blood using isotope dilution method high resolution gas chromatography/high resolution mass spectrometry (Eurofins, 2011). Samples were analysed on a GC (DB-dioxin, 60 m, 0.25 mm i.d., 0.1 μm film thickness) interfaced to a VG Autospec MS operating at a resolution of approximately 10 000. A level of detection for 2,3,7,8 TCDD of 1 pg g^{-1} lipid was achieved for all samples except one where it was 3 pg g^{-1} lipid.

For the purpose of this study the main aim was to assess changes in the overall dioxin body burden, hence results were expressed as Toxic Equivalence (TeQ) representing the sum of the products of the concentration of each compound multiplied by it's Toxicity Equivalency Factor (TEF) as published by the World Health Organisation Organization in 2005 (Van den Berg et al., 2006). The TeQ are reported as upper-bound concentration (using