Levels and Implications of Persistent Organic Pollutants and other contaminants in South Africa. Results from the "LIPOPSA" project

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Introduction

Persistent organic pollutants (POPs) are persistent chemical compounds that have the potential for long-range transport, they bio-accumulate and bio-magnify in food webs, and they are toxic. Exposure to POPs can result in adverse effects including cancer, birth defects, endocrine disruption, and impaired neurological development in humans and animals. Several POPs are listed in the Stockholm Convention (SC) (http://chm.pops.int/). In general, there is need for updated information on the pollution levels of POPs in developing countries, but also industrialized developed countries in the southern hemisphere. Earlier studies of POPs in eggs of South-African wild birds showed elevated levels of DDTs, PCBs and PBDEs of which some were comparable to European bird eggs. These findings warranted further research. The main aims of the present study were: To investigate the presence and levels of POPs in sediments, soil and bird eggs from a highly industrialized area; to determine the influence of trophic level, habitat usage, and species specific differences on the congener profiles of selected POPs in bird eggs, and to assess human exposure and risk to POPs through the consumption of backyard chicken eggs.

Materials and methods

The main study area was in the heavily industrialised area of the Vaal Triangle, South Africa (SA) (Figure 1). The industries in the area include iron and steel works, petrochemical industries, chemical and agrochemical manufacturing plants, electricity generation from coal, manufacturing of consumer goods including plastics and synthetic rubber, as well as historic production of organochlorine pesticides such as lindane and DDT.



Figure 1. Map of the investigated area in South Africa (SA)

Soil and sediments:

Soil and sediment samples were collected in the industrialized Vaal triangle area, including Vaal River and its tributaries (Figure 2a). The soil and sediment samples were analysed for organochlorine pesticides (OCPs), polychlorinated biphenyls (PCBs), dioxin-like PCBs polychlorinated dibenzo-*p*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and polyaromatic hydrocarbons (PAHs). The samples were also

analysed using the H4IIE bio-assay reporter gene assay to screen for the occurrence of dioxin-like chemicals (DLC).

Bird eggs:

The wild bird eggs sampled were from: African Sacred Ibis (*Threskiornis aethiopicus*), African Darter (*Anhinga rufa*), White-breasted Cormorant (*Phalacrocorax carbo*), Black-crowned Night-heron (*Nycticorax nycticorax*), Black-headed Heron (*Ardea melanocephala*), Grey Heron (*Ardea cinerea*), Cattle Egret (*Bulbulcus ibis*), Crowned Lapwing (*Vanellus coronatus*), Red-knobbed Coot (*Fulica cristata*), Cape Sparrow (*Passer melanurus*), Southern Masked Weaver (*Ploceus velatus*), and Cape Turtle Dove (*Streptopelia capicola*). The bird species represented several trophic levels (scavengers, piscivores, insectivores/omnivores, and granivores) and different habitats (aquatic, terrestrial and combined aquatic/terrestrial). The Bird egg samples were analysed for OCPs, PCBs, and brominated flame retardants (BFRs) such as Polybrominated diphenyl ethers (PBDEs) and hexabromocyclododecane (HBCD).

Results and discussion

Pilot study: sediment

All organohalogens analysed were present in the South African environment with concentrations ranging between 39 000 ng g⁻¹ for Σ PAHs and 0.01 ng g⁻¹ for dicofol. Principal component analysis (PCA) indicated different sources in industrial and agricultural areas. Concentrations of WHO2005-TEQ in soils were generally higher than those in sediments. Soils from the industrial area of Vanderbijlpark and the residential area of Klerksdorp contained the highest concentrations. Based on the congener-specific HRGC/HRMS analyses, concentrations of WHO2005-TEQ ranged from 0.12 to 32 ng WHO2005-TEQ kg⁻¹, dw in sediments, and between 0.34 and 20 ng WHO2005-TEQ kg⁻¹, dw in soils.

The spatial distribution of metals and dioxin-like chemicals

Levels of summed heavy metals in soils ranged between 0.001-2500 mg/kg dm. The distributions of the heavy metals was associated with human activity, specifically in the urban and industrial centres of Vanderbijlpark and Sasolburg (Figure 2b). The H4IIE bio-assay results indicated that levels of DLC vary between the LOD and 120 ng TCDD-TEQ kg⁻¹ dm. The distribution of DLCs corresponded also to the level of human activity (Figure 2c).





POPs in wild bird eggs

DDTs were the POPs found in highest levels in all species, except Crowned Lapwing (Figure 3). The levels of sum DDT were relatively high compared to global levels reported in literature. DDT is still used for Indoor Residual Spraying (IRS) in malaria infected areas of SA. The use of Dicofol, might contribute as DDT source. HCB, HCHs, and chlordanes contributed 1-22% to sum organochlorine pesticides (OCPs) in all eggs except for crowned lapwing (Figure 3). DDTs and HCHs were most prevalent in piscivorus, while HCB was the most prevalent OCP in insectivores.



Figure 3. Relative contribution of HCB, HCHs, chlordanes, DDTs and mirex to \sum OCPs in wild bird eggs from South Africa.

Sum PCB levels ranged between 1-840 ng/g wm. The highest PCB levels were found in piscivorus species. The PCB pattern was dominated by PCB-138, -153 and -180. Sum PBDEs ranged between 0.4-220 ng/g wm, and BDE-153 was the most prevalent BDE congener. HBCD was found in low levels in all bird species and ranged from 0.2-10 ng/g wm. Levels of sum PBDEs were highest in the scavenging African Sacred Ibis. The lower brominated BDEs were related to granivorus and piscivorus species, whereas higher brominated BDEs were more prevalent in scavengers and insectivores (Figure 4). Diet, trophic level, and habitat associations with humans are the most important determinants of POP levels in birds' eggs.



Figure 4. Relative contribution of the individual PBDE congeners to sum PBDEs in eggs of wild bird species from South Africa, ranged according to trophic level

POPs in chicken eggs

Concentrations of WHO2005-TEQs were significantly highest in backyard chicken eggs from Vanderbijlpark (mean: 3.174 pgTEQ/g lipid weight), and lowest in commercial battery eggs (mean: 0.511 pgTEQ/g lw). Backyard chicken eggs from Sasolburg showed lower levels of WHO2005-TEQs than eggs from Vanderbijlpark. This indicated a higher level of exposure in the area around Vanderbijlpark, a site which is dominated by steel

and chemical industries. The levels of OCPs, PCBs and BFRs were significantly higher in Vanderbijlpark than in Sasolburg and in commercial chicken eggs, indicating that association with the chemical and steel industries is a much stronger factor for exposure to POPs than association with free ranging behaviour in general. The study reveals that humans consuming backyard eggs from the Vanderbijlpark vicinity are exposed for much higher levels of dioxins, OCPs, PCBs and BFRs than in the other studied rural area of Sasolburg, thus warranting further research.

The findings in the study, but in particularly the presence of HBCD in eggs from South African wild and domestic birds, are of high importance for conservation, human health, and the Stockholm Convention (SC) on POPs.

Eggshell thinning

Concentrations of BFRs, OCPs, and PCBs in the wild bird eggs were below the no observable effect limit (NOEL). However, levels of DDE measured in the bird eggs were at levels approaching toxicological threshold levels. This can indicate that the reproductive integrity of, specifically piscivore birds within the study area might be under additional stress by DDE and PCB. Even if toxicological thresholds are not reached, the additional physiological stress placed on individuals in combination with habitat destruction, food shortages, and a changing climate could seriously impact wild bird populations in South Africa.

Conclusions

Measurable levels of all the compounds analysed in abiotic and biotic matrices indicate an environment impacted by anthropogenic activity that could negatively affect the environment and human health. The ongoing monitoring of bird eggs is advisable as it provides essential information on time-trends and changing exposure profiles to POPs. The levels of POPs in backyard chicken eggs need to be assessed further, since this might indicate a significant route of exposure in humans living in low-income residential areas. Measurable levels of POPs and metals in soil from industrial areas need further investigation. These levels indicate that human populations in these areas are exposed to a wide range of toxicants.

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