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13TH IHPA FORUM AND SELECTED STUDIES ON POPS

Assessment and review of organochlorine pesticide pollution in Kyrgyzstan

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Abstract The current study describes the preliminary assessment and securing activities of the largest and most hazardous POPs-contaminated sites in Kyrgyzstan. In 2010, cattle died and population were found with high pesticide levels in blood, human milk, and placenta. In the first phase of the study, a historic assessment of the pesticide dumping at the landfill/dump sites have been conducted. In the second phase, soil analysis for organochlorine pesticides in the areas of the pesticide disposal sites, the former pesticides storehouses, agro-air strips, and the cotton-growing fields were conducted. By this assessment, a first overview of the types and sources of pollution and of the scale of the problem is compiled including information gaps. From major pesticides used, DDT, DDE, and HCH were measured in the highest concentrations. With the limited analytical capacity present, a reasonable risk assessment could be performed. This paper also reports on practical risk reduction measures that have been carried out recently at the two major pesticide disposal sites with support of a Dutch environmental engineering company, an international NGO (Green Cross Switzerland) and local authorities from the Suzak region within an UN project. Local population living near the sites of the former pesticide storehouses and agro-airstrips are advised not to cultivate vegetables and melons or to raise cattle on these areas. Instead, it is recommended to grow technical crops or plant trees. Further recommendations on monitoring and assessment is given including the suggestion to consider the findings in the National Implementation Plan of Kyrgyzstan.

Keywords Organochlorine pesticides · POPs · Soil contamination · Pesticide storehouses · Pesticide burial sites · Chemical landfills · Agro-airstrips · Poisoning incidents · Protection of vulnerable groups · Remediation

Introduction

Since the start of the Stockholm Convention in 2001, much attention is paid globally to the threat and management challenges of persistent organic pollutants (POPs). The management and destruction of POPs stockpiles and waste in developing countries and in countries in transition are a major challenge for the respective countries and for the overall implementation of the Stockholm Convention (Dollimore and Schimpf 2013; Vijgen et al. 2013, 2015; Weber et al. 2013). However, even industrial countries still face considerable problems in destroying POPs stockpiles and managing POPs contaminated sites in an environmentally sound manner today (Oliaei et al. 2013; Weber et al. 2015a; Vijgen et al. 2011).

The management of organohalogen pesticides (OCPs) and wastes/stockpiles are a particular challenge in the Stockholm Convention implementation (Dollimore and Schimpf 2013; Vijgen et al. 2013). In industrial countries today, the major issues are the management of POPs pollution at and around former

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production sites (Götz et al. 2013; Oliaei et al. 2013; Weber and Varbelow 2013; Weber et al. 2008; Wimmerová et al. 2015; Wycisk et al. 2013). The Eastern Europe and the Caucasus and Central Asian (EECCA) region including the Russian Federation has, in addition to POPs contamination at former organochlorine production sites (Amirova and Weber 2015; Lysychenko et al. 2015; Revich and Shelepchikov 2008), particular management and control challenges with the large stockpiles of unused POPs pesticides amounting to approximately 240,000 t (Vijgen et al. 2013). For the stockpile areas and other sites polluted with OCPs pesticide, the wide range of toxicological effects for flora and fauna and especially for humans have to be considered (Toichuev 2011a; Toichuev et al. 2017) including the effects of OCP on development of tumors (Beyond Pesticides 2016; Mrema et al. 2013; Toichuev and Paizova 2011); the gene structures (Toichuev and Payzyldaev 2014); congenital malformations in children (Toichuev and Tostokov 2006); immunodeficiency (Corsini et al. 2013; Mrema et al. 2013; Toichuev et al. 2004); dysbiosis (Toichuev 2005) and hepatitis (Toichuev et al. 2012); neurotoxicity (Mrema et al. 2013); and development of placental pathologies of pregnant women, fetus, and newborns (Toichuev et al. 2017). These heath risks of the population at and around the POPs contaminated sites is very urgent and of particular concern (Toichuev et al. 2017; WHO 2013).

Kyrgyzstan ratified the Stockholm Convention in 2006. Within the development of the National Implementation Plan for the Stockholm Convention, it was highlighted that OCPs are a priority for POPs management in Kyrgyzstan (Kyrgyz Republic 2006). Similar to other former Soviet Union countries, POPs OCPs in particular DDT, HCH, Aldrin, and others were used in large amounts in Kyrgyzstan (Kyrgyz Republic 2006). OCPs were even found in the mountain glaciers of Kyrgyzstan (Lunev 2004; Kyrgyz Republic 2006).

The largest pollution and the contemporary acute problem is however in southern Kyrgyzstan, since large amounts of pesticides, including POPs pesticides banned due to listing in the Stockholm Convention were used in the 1970s and 1980s for the pests control in cotton and tobacco production which were strategically important raw materials for the former Soviet Union. In 1970s/80s, organochlorine pesticides accounted for ca. 66% of the total pesticides used (Kyrgyz Republic 2006).

In Kyrgyzstan, the disposal of waste pesticides started in 1973. Different areas were designated for the disposal of pesticide stocks. The first of pesticide disposal sites was located ca. 12 km from the village Kochkorka, Kochkor district of Naryn Province and the second one was in Suzak district of Jalal-Abad Province near the village Kyzyl-Bayrak and Ak-Chabyr area (Lunev 2004; Kyrgyz Republic 2006).[1]

Moreover, there are some former pesticide storehouses and agro-airstrips which were transferred to the private sector (Toichuev et al. 2007). Some pesticide stocks have been removed from pesticide stores following a repackaging training by TAUW bv within a UN project.

In 2010, it was discovered that livestock and other animals around the pesticide landfills died (Fig. 1). The meat of these animals were partly consumed and some consumers were hospitalized. In reaction to this series of poisoning incidents of animals and humans, a group of Kyrgyz and International NGOs, a Dutch environmental engineering company, and local authorities from the Suzak region decided in 2012 that short-term risk reduction measures were needed. The activities were supported by the Global Enabling Facility (GEF) of the Worldbank.

In the current paper, a preliminary assessment of soil contamination and mitigation measures and the current status of the sites are described. Since there are many similar sites in the region (Pieterse et al. 2015; Vijgen et al. 2013) but also in other countries in Africa and South America (Dollimore and Schimpf 2013; Torres et al. 2013), the assessments done with the simple analytical equipment and tools available and the limited resources aim to give also for developing countries with such sites and situation a case study on urgent assessment and mitigation measures with the technology and resources available. In a second paper of this special issue, the human exposure and related effects on humans from this contaminated megasite is described (Toichuev et al. 2017).

Materials and methods

Historical investigation

The first step for the assessment of contaminated sites is the historical investigation of contaminated sites (European Environmental Agency 2005). Knowledge on the history of pesticide use IMP-SBNAS-KG has studied and compiled the pesticide data from archives from the 1970th including the location of pesticide storehouses and the agro-airstrips in settlements of southern Kyrgyzstan for the provinces, districts, and the collective and state farms and forestry enterprises. Also, the list of pesticides used and quantities in particular of the disposed pesticide stocks were assessed. The major aim of the compilation was for the development of measures to control and prevent diseases from pesticides on human health and biodiversity.

Pesticide monitoring

The Institute has launched its own pesticide research in 1995 and has worked on five projects: “Medical and biological aspects of public health in cotton and tobacco-growing areas of southern Kyrgyzstan” (1995–1999, GR #0000466 as of 20.06.1995) and five international projects: World Bank

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[1] In international literature the site near Kyzyl-Bayrak is usually referred to as Suzak B and the site near Ak-Chabyr as Suzak A.

Fig. 1 Dead sheep at poisoning incident (2010) at Suzak pesticide landfill leading to human exposure

(WB) Project #100020592 "Technical studies of obsolete pesticides in the Kyrgyz Republic, the Republic of Tajikistan and the Republic of Uzbekistan" (2004), Project "Promotion of the Kyrgyz Republic in preparation of the National Implementation Plan (CWP) of the Stockholm Convention on Persistent Organic Pollutants (POPs)" (UNEP / GEF # GEL-2328-2971-4714; 2004). While the major focus of the studies in the institute was/is on the assessment of the impact of the pesticides on human health (Toichuev et al. 2017), also preliminary assessment of contaminated soils has been conducted.

In this survey, 11 soil samples were taken from the surface of pesticide disposal sites, agro-airstrips, and pesticide storehouses. Furthermore, six soil samples were collected from the former vegetable fields (six samples) and cotton fields (six samples). One sample was taken 70 km from the storage sites as a background sample.

Soil samples were collected at the different locations by a square shovel to a depth of 20 cm. For each individual samples, five sampling spots in a square of the respective sites site each 200 g of soil from the center of the square and the eastern, western, northern, and southern corner of the square were taken and combined to generate 1 kg soil sample for each site. The collected soil samples were ground to result in a homogeneous soil sample. For soil analysis, all samples were averaged by quartering. For the analysis, 10 g of soil was extracted.

Also some water samples were screened for OCPs to assess run off from sites and impact to the water phase.

Two water samples were collected from the Kugart River in 2013 and 2014 which partly receive water from runoff from the areas of the pesticide landfills.

Water samples were also taken from warm spring, Bazar-Korgon reservoir, and an underground well (3, 4, and 5 on schematic map in Fig. 2).

Water samples were also collected from the well (V on the schematic map in Fig. 2) located on the territory of Suzak district at a distance of 22 km from south-eastern part of the Tash-Baka pesticide burial site.

Water samples were collected in sterile glass bottles (200 ml). Then, 1000 ml of water samples were subjected to OCPs analysis in accordance with the guidelines MU 2142-80 and MU 4220-86.

One wheat sample was taken for a very preliminary assessment if this might be a possible exposure pathway in the area. Milk, meat, and human milk have been measured in another study (Toichuev 2011b).

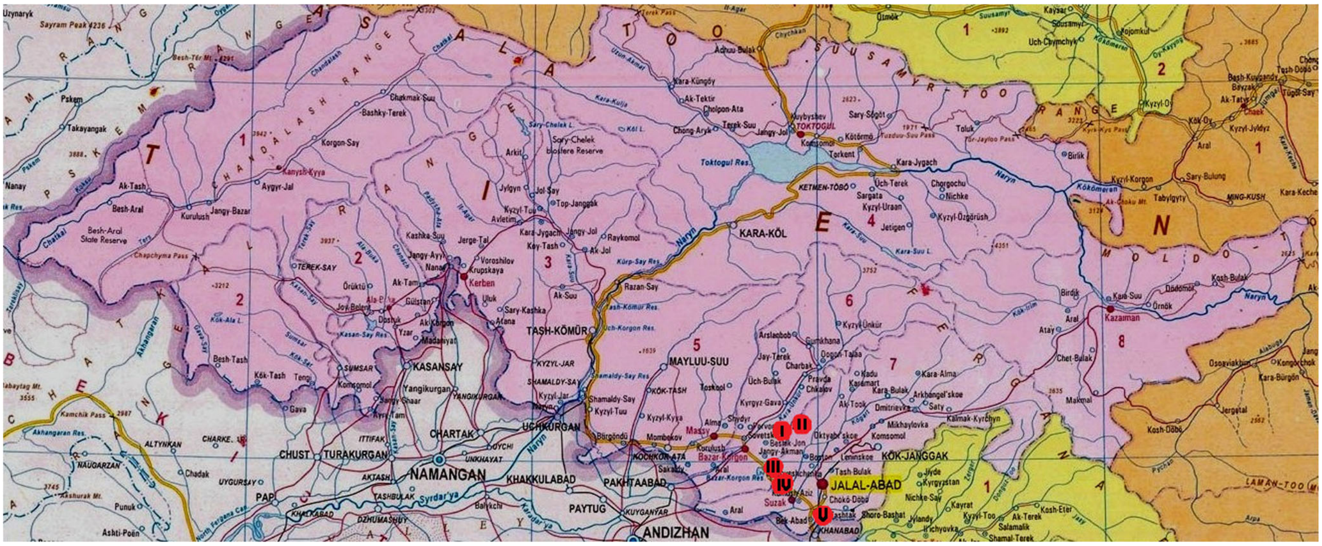

Fig. 2 Location of pesticide burial sites. Bazar-Korgon district (6) and Suzak district (7). Water from Tash-Baka pesticide burial site (II) flows into the river Kogart. Water from Ak-Chabyr pesticide burial site (I) flows into the river Kara-Unkur. Both rivers flow into the river Kara-Darya, left tributary of the river Syr-Darya

For the analysis, grains of wheat (5 kg) grown in 10–15 m from the Tash-Baka pesticide disposal site were collected, cleaned by hand, sifted through a sieve, and grinded.

Twenty grams of grinded wheat grains (flour) was transferred into flasks with sealing plugs in accordance with standard guidelines No. 1350-75, 22.09.1975 (Determination of OCPs in grains and flour). The method prescribes the extraction of pesticides from the test sample by using organic solvents. For extraction of OCPs, 100 g of flour was shaken in 300 ml chloroform and then settled for 15 min and then filtered. Chloroform was distilled off in a rotary evaporator at low temperatures (35–50 °C) until all chloroform were removed resulting in a dry residue. The residue was dissolved in 30 ml of hexane. To purify the sample from fats and proteins, the sample was transferred on a clean-up column containing 10 g activated silica gel. The column was rinsed with 100 ml of benzene and hexane mixture (50/50) extracting the OCPs from the column while fats and proteins remained in the column. The solvents were distilled again in a rotary evaporator. The extract were injected in hexane in gaschromatograph (see below) and the OCP identified and quantified by external calibration.

The soil samples were stored at the institute in darkness at 10 °C in the laboratory until they were analyzed.

Purification of soil samples was carried out by a combination of oxidative destruction with sulfuric acid and column clean up. For the sulfuric acid treatment, the extracts (in hexane) were shaken with sulfuric acid until newly added sulfuric acid stayed colorless. The column purification were performed with aluminum oxide and silica gel.

OCPs (HCH and its isomers, DDT, DDD, DDE, aldrin, and dieldrin) were extracted from soil samples by using (a) acetone (with additional moistening the soil with distilled water), and (b) a mixture of hexane and acetone (moistening the soil with ammonium chloride). Cold extraction by shaking on a shaking machine for 1.5 h was performed.

After a clean-up, the samples were analyzed on a gas-liquid chromatograph “Svet-100” in the laboratory of toxicology, radiology, morphology, and ecology of the Institute of Medical Problems and in the laboratory of toxicology of the Osh Regional. An analytical method for the major used pesticides were developed which covered major OCPs (DDT, DDD, DDE, HCH isomers, Aldrin, and Dieldrin) in soil.

For the instrumental analysis, a gas chromatograph Model - 3700 (MOZ Moscow) was used. The chromatograph is equipped with a detector DPR (DES), evaporator, column heating oven, and detector oven.

A metal column (sized 1 m × 22 mm × 4 mm) on Chromatone N-AW-DMCS (0.16–0.2 mm) with a liquid phase (5% OV-17) was used for separation. Nitrogen was used as a carrier gas with a flow of 30 ml/min. The temperature of column heating oven was 190 °C, the temperature of evaporator was 230 °C, and the temperature of detector oven was 240 °C.

The retention time for the individual pesticides was measured from the time at which the sample is injected to the point at which the display shows a maximum peak height for the respective compound.

Table 1 presents data on sensitivity and retention time (RT) of the most common organochlorine pesticides measured, the number of theoretical plates (N).

Quality assurance/quality control

Laboratory blank tests were performed. The levels of the OCPs in laboratory were all below detection demonstrating that no cross contamination occurred in the laboratory.

Selected samples were analyzed twice demonstrating good reproducibility of results within ±30% variability.

The retention times and sensitivity were checked daily before analyzing the samples.

Mitigation action for securing the site

Short-term mitigation action was made possible early 2013 by financial support from the GEF/UNDP Small Grants Programme in Kyrgyzstan and co-funding from Green Cross Switzerland, OSCE Centre in Bishkek, and the Milieukontakt Private Donations Fund. The taken action was based on the historical investigations and the outcome of the health study.

Results and discussion

Outcome of the historical investigation

The management of contaminated sites in a country starts with a basic desk study or historical investigation, which may lead to more detailed investigations, remediation, or land redevelopment (European Environmental Agency 2005).

According to official archival data, there were 183 former pesticide disposal sites and agro-airstrips at the end of 1990 in southern Kyrgyzstan.

Table 1 Retention time, sensitivity, and number of chromatographic plates in the analysis

Pesticide type	Sensitivity μg/ml	RT	N
Aldrin	0.5	5.2	780
HCHs	0.5	2.3–27	250
Heptachlor	0.5	4.0	780
4′4’DDD	0.1	13.0	–
4′4’DDT	0.5	15.6	304
4′4’DDE	0.5	9.6	260
Methoxychlor	2.0	20.0	195

A total of 59 pesticide storehouses and 29 agro-airstrips were located in 5 of the 18 cotton-growing areas located in southern Kyrgyzstan. Also, 39 pesticide storehouses and 8 agro-airstrips were located in 4 tobacco-growing areas. The rest of pesticide storehouses and agro-airstrips were located in the other 9 districts. Twenty three storehouses and 4 asphalt-paved agro-airstrips are located in cotton-growing and tobacco-growing districts, respectively. The territory of each airport was about 5 ha. As of 2015, the location of 57 sites were identified. Studies and monitoring to identify further sites and detailed locations are under way.

The historic investigation on the OCP situation in the available documents revealed that in the territory of Kyrgyzstan, in total at least 1876 t of pesticides were buried including 1033 t of POPs pesticides. The documented information is considered reliable and probably cover most of disposed pesticides. The major amounts of pesticide are contained in two major disposal sites in the south of the Republic. The first pesticide disposal site is located in Ak-Chabyr area at a distance of 15 km from the village. The second pesticide disposal site is located in Tash-Baka area in Suzak district of Jalal-Abad Province at a distance of 3–4 km from the village Kochkorka. In 1973, a total of 272 t of pesticides have been buried at this site. From 1979 to 1990s, additionally 308.5 t of pesticides were buried on the territory of 5000 m^2 with the largest share from DDT accounting for 293 t.

The pesticide disposal sites in Suzak district contain in total 1296 t of disposed pesticides, including 655 t of DDT and 69.5 t of Aldrin and a range of unknown pesticides. The total pesticide disposal area at this site is 10,000 m^2.

Preliminary site investigation at the major pesticide deposits

Major monitoring activities on environment and humans were conducted for the two largest pesticide storage sites due to the high contamination potential of these sites including likely human exposure.

Preliminary assessment of soil contamination

Analysis of surface soil samples collected from the territory of Tash-Baka pesticide disposal site showed relatively low OCPs concentrations at sampling site A (composite sample): γ-HCH—0.09 mg/kg and DDE—0.86 mg/kg, total 0.95 mg/kg. A second composite sample from the site at a second sampling location had somewhat higher levels with γ-HCH—0.2 mg/kg, DDE—1.05 mg/kg, DDD—1.63 mg/kg, DDT—1.47 mg/kg and therefore in total 4.35 mg/kg were found in soil samples collected from another point of the site.

These data showed that the top surface soil was contaminated with POPs pesticides in the low ppm range above the Californian "Total Threshold Limit Concentration" (TTLC) for DDT (Henderson et al. 1998). However, this moderate level of pesticide contamination which were lower compared to the surrounding of the landfill (see below) indicate that the soil coverage of the site was not heavily impacted by the disposed pesticides but that care was taken when the burial site was capped with soil.

The pesticide concentration in soil samples collected at a distance of 1 km from Tash-Baka pesticide disposal site (Fig. 3a, b) were two to three orders of magnitude higher contaminated compared to the soil at the landfill site. Detected levels were γ-HCH—268 mg/kg, DDT—768 mg/kg, DDD—147 mg/kg, DDE—60.1 mg/kg, total 1243 mg/kg.

Furthermore, concentrations of pesticides measured in soil samples collected from the area located at a distance of 3 km from the site were also elevated with levels of 21.1, 17.1, 13.4, and 9.4 mg/kg, respectively.

These high levels indicate that at the time of disposal of the POPs pesticides at this site, the OCPs were partly scattered into the surrounding maybe during de-loading or scattered with the wind and contaminating a larger area around the

Fig. 3 **a** Pesticide burial sites in Suzak A before securing the site (2009). **b** Pesticide burial sites in Suzak district with trench (2013)

landfill. The relative low contaminated soil on the landfill seems to stem from capping of the landfill with clean soil.

The high levels of POPs pesticides in the soils surrounding the landfill might have been the source for the high contamination of livestock around the landfill.

Background soil samples without specific impact from agricultural use collected in 70 km distance from the site (west direction) contained γ-HCH at concentration of 0.1 mg/kg, DDE—0.16 mg/kg, DDT—0.27 mg/kg, total 0.52 mg/kg.

Concentrations of OCPs found in the village situated downstream the Tash-Baka site were γ-HCH—0.17 mg/kg, DDE—1.66 mg/kg, DDD—0.63 mg/kg, total 2.46 mg/kg.

These levels were ca. five times above the soil levels 70 km from the site ("background") and had 50% of the levels from the soil on the landfill (Table 2) and was also above Californian "Total Threshold Limit Concentration." Therefore, soil in the village is also impacted by POPs pesticides and might also contribute to the exposure of the population with POPs pesticides, e.g., via chicken/egg and cattle/milk at/around the village which transfer POPs from the soil to the food chain (Hoogenboom et al. 2016; Weber et al. 2015a, b).

Analysis of soil samples collected in 2013 from the surface of Ak-Chabyr pesticide disposal site had high DDE (148 mg/kg), DDD (56 mg/kg), and DDT (244 mg/kg), therefore total DDT and metabolites of 448 mg/kg. The HCH levels were low (0.42 mg/kg).

Preliminary assessment of water contamination

In addition to the impact on soils, pesticides from the two disposal sites have an impact on water. In spring, the climate of southern Kyrgyzstan causes snow melting and the formation of creeks and streams with associated flooding that partly wash away pesticides from impacted sites into the rivers.

A preliminary assessment of potentially impacted river water was conducted in 2008, 2013, and 2014 (Table 3).

The Ak-Chabyr pesticide burial site is located on a hill between Suzak and Bazar-Korgon districts. The location of pesticide burial sites is indicated on the country map (Fig. 2). Water from the surface of the site is flowing toward the Bazar-Korgon district and flows into the river Kara-Unkur and Bazar-Korgon Lake (III on the schematic map in Fig. 2) that is located at a distance of 15–16 km from the site. The water also comes from an underground warm well (IV on the schematic map of Fig. 2).

Water partly impacted from the second pesticide burial site—Tash-Baka (II on the country map in Fig. 2) that is located on the other side of the hill flows into the river Kugart. The river flow into the river Kara-Darya and then Syr-Darya that flows through the territory of Kyrgyzstan, Uzbekistan, Tajikistan, and Kazakhstan and finally end in the Aral Sea.

HCH and DDT were detected in the Kugart river. In 2013, levels were 0.007 mg/l for HCH and 0.0014 mg/l for DDT while the levels in 2014 were 0.002 mg/l for HCH and 0.0010 mg/l. With this initial dataset, it cannot be concluded that the lower levels in 2014 indicate a decreasing trend or if this was due to lower inflow due to seasonal variability. Here, more data are needed for any interpretation.

Groundwater around the landfills partly used for human consumption was found to contain HCHs and DDT. HCH and DDT levels in the Bazar-Korgon water reservoir, near the Ak-Chabyr pesticide disposal site, were 0.05 and 0.07 mg/l respectively (Table 3).

The elevated level in the water reservoir might result from a ground water plume moving toward the drinking water reservoir by pumping of the ground water. The groundwater situation at the landfill need further assessment and the drinking water from the well need cleaning with, e.g., carbon filtration.

An initial assessment of underground water samples from a warm healing spring located 10 km from the pesticide landfill site and 600 m from the road contained detectable γ-HCH (0.00012 mg/l) and DDD levels (0.0001 mg/l). It is however not clear if this is an impact from the landfill site or from OCP impacted agricultural area in the region (see below).

Table 2 Organohalogen pesticides (OCP) in soil samples collected from Tash-Baka pesticide disposal site (Suzak district) and of one grain sample in the vicinity

Sampling location of soils	OCPs, mg/kg				
	HCHs	DDE	DDD	DDT	Total
Tash-Baka pesticide disposal site A	0.09	0.86	0	0	0.95
Tash-Baka pesticide disposal site B	0.2	1.05	1.63	1.47	4.35
Soil samples collected at a 70 km distance from the site (west)	0.093	0.156	0	0.27	0.519
Soil samples collected at a distance of 1 km from Tash-Baka pesticide disposal site	268	60.1	147.1	768	1240
Soil samples collected at a distance of 3 km from Tash-Baka pesticide disposal site	21.1	9.4	13.4	17.1	60.9
Samples collected from the settlement located downstream the site	0.17	1.66	0.63	0	2.46
Grains of wheat sampled near the Tash-Baka pesticide disposal site (2008)	2.8	3.09	1.1	2.7	9.69

Table 3 Results of initial analysis of water samples collected near the Tash-Baka and Ak-Chabyr (Suzak region) pesticide disposal sites

Sampling year/sampling site	OCPs, mg/l			
	HCH	DDE	DDD	DDT
2014/water from the Kugart River, Kyzyl-Bayrak rural community, near the Tash-Baka pesticide disposal site	0.0002	0	0	0.0010
2013/water from the Kugart River, Kyzyl-Bayrak rural community, near the Tash-Baka pesticide disposal site	0.0007	0	0	0.0014
2008/underground water from water source#5, near the Tash-Baka pesticide disposal site, Yrys rural community	0.0034	0.0054	0	0
2008/underground water from water source #3, 10 km from Ak-Chabyr pesticide disposal site	0.0001	0	0.0001	0
2008/water from the Bazar-Korgon water reservoir, near the Ak-Chabyr pesticide disposal site	0.05	0	0	0.07

Initial assessment of human levels and human exposure around the disposal sites

Larger activities on human contamination were conducted in recent years. Sampling and analysis of 508 placenta samples has shown high OCP contamination of up to the 3.1 mg/kg (ppm) level of mainly DDT and related degradation products and HCHs (Toichuev et al. 2017).

Furthermore, samples of breast milk of six women examined in 2008 living in settlements near Tash-Baka pesticide disposal site had high OCPs levels including γ-HCH (0.003–0.08 mg/l or 0.075–2.0 mg/g milk fat), DDE (0.004–0.08 mg/l or 0.1–2.0 mg/g milk fat), DDT (traces 1.47 mg/l or 36.75 mg/g milk fat), and Aldrin (0.007–0.009 mg/l or 0.175–0.225 mg/g milk fat). Total OCPs concentration level was 1.65 mg/l (Toichuev 2011b).

In 2013, another six women (breast milk) were examined; all samples contained HCH (0.023–2.2 mg/l or 0.575–55 mg/g milk fat) and DDE at concentrations of 0.04 to 0.15 mg/l or 1.0–3.75 mg/g milk fat. Average concentrations of total HCH and DDT and its metabolites were 0.425 ± 0.21717 mg/l or 10.62 mg/g milk fat and 0.077 ± 0.01097 or 1.92 mg/g milk fat, respectively. The breast milk of a shepherd living near Ak-Chabyr pesticide disposal site contained high levels of DDE (0.04 mg/l) and DDT (0.06 mg/l) and lower levels of α-HCH (0.003 mg/l).

A range of exposure pathways need to be considered and assessed for human exposure of local people which has started with some assessments. The major exposure pathway of POPs is normally food in particular of animal origin. Up to now, only a few studies were conducted.

The most monitoring efforts were done for meat from the poisoning incident of the dead sheep in the 2010 incident were measured and found to contain elevated OCP levels: α-HCH—0.013 ± 0.001 mg/kg, γ-HCH—0.005 ± 0.001 mg/kg, β-HCH—< 0.001 mg/kg; DDT—0.018 ± 0.002 mg/kg; DDD—0.0036 ± 0.0003 mg/kg, DDE—0.022 ± 0.0002 mg/kg, total 0.063 mg/kg. Aldrin and Dieldrin were not detected in these samples (Toichuev 2011b). These OCP levels are not sufficient to explain the death of the sheep, since for sheep mild signs appear at ca. 22 mg/kg γ-HCH, and death occurs at 100 mg/kg γ-HCH. The acute oral LD_{50} dose for DDT in sheep and goats is > 1000 mg/kg (WHO 1996; PAN UK). Since also other pesticides were disposed at the site, the acute lethal effect in the sheep rather resulted from other pesticides possibly non-OCPs with high acute toxicity such as carbamates or organophosphorus pesticides which were, however, not monitored in this study due to analytical capacity limitations. The toxic effect might also result from the toxicological mixture of the range of pesticides and pesticide degradation products likely present. Further studies are needed with a better possibly involving screening tools for toxicity. Such a toxicity screening using CALUX bioassay tests has recently been conducted for leachates from a pesticide dumpsite in Tajikistan (Pieterse et al. 2015). In the assessment of 32 people contaminated by liver and meat of the poisoned sheep, OCP pesticides could be detected in 8 blood samples with the relative high detection limits due to the limited sampling volume. OCP levels detected in the blood samples included DDE in five patients (0.015 ± 0.005 mg/l), γ-HCH (0.018 ± 0.005) and 0.013 ± 0.005 mg/l in six patients. Total concentration level of OCPs ranged from 0.03 to 0.054 mg/l (Toichuev 2011b). Levels of OCPs at 0.05 mg/l might be enough for clinical manifestations of poisoning by OCPs (Toichuev 2011b). Furthermore, the pesticides or pesticide degradation products which were responsible for the death of the sheep (which were not POPs pesticides) likely had heath impacts on the patients ingesting the meat. For such an assessment, non-target screening would be needed which is not available in the country.

Milk sample collected from sheep grazing in 3 km from the site contained high levels of α-HCH (0.003 mg/l or 0.075 mg/

g milk fat), DDE (0.04 mg/l or 1.0 mg/g milk fat), and DDT (0.06 mg/l or 1.5 mg/g milk fat). These levels are high and comparable and partly even higher than DDT levels found in other countries/regions in the 1970s at the time of high volume DDT application (Jaga and Dharmani 2003; Smith 1999).

Milk from cows grazing near the pesticide disposal site were sampled and analyzed. The concentrations of HCH and DDE in milk of cows ranged from 0.03 to 0.07 mg/l or 0.75 to 1.75 mg/g milk fat (Toichuev 2011b).

In addition, grain of wheat was sampled in 2008, growing near the Tash-Baka pesticide disposal site. The grain contained high levels of POPs OCP including HCH—2.8 mg/kg, DDT—2.7 mg/kg, DDD—1.1 mg/kg, and DDE—3.1 mg/kg.

This demonstrates the exposure from food and feed around the disposal sand that there are different exposure pathways for human OCP exposure via food.

Furthermore, high levels of OCPs was detected in a dead beetle at the site (sampled 2011) with total OCPs concentration of 44.25 mg/kg including α-HCH (1.84 mg/kg), γ-HCH (22.9 mg/kg), DDE (7.11 mg/kg), DDD (3.5 mg/kg), and DDT (8.95 mg/kg) (Toichuev 2011b). This indicates that lower trophic levels in animals contribute to contamination of the food chain.

Since ground water and surface water in the area are also to some extent contaminated with pesticide, also this pathway contributes to overall exposure.

Initial monitoring at other potential POPs pesticide hot spots

Preliminary assessments of some other pesticide hotspots have been conducted. Here, soil from the former pesticide storehouses and agro-airstrips was measured. Expired pesticide stocks have been removed from several of these pesticide storehouses facilitated by a repackaging training by TAUW in 2008 (Fig. 4). The soils in and around these sites are however still contaminated (Fig. 5). Together with the pesticide landfills, these are the major potential POPs pesticide contaminated sites in Kyrgyzstan.

Soil samples collected from the pesticide storehouse in the Saray village contained high DDT and metabolites with a total concentration of 252 mg/kg (see Table 4). The soil of another pesticide storehouse in Joosh was measured with total DDT and metabolite levels of 975 mg/kg (Table 4).

The levels of DDT and metabolites in soils collected from the agro-airstrip of Saray village were 32.6 mg/kg (Table 4). Slightly higher levels of DDT and metabolites were detected in soils at the agro strips of the rural community Ak-Tash with 65.7 mg/kg and the agro strip of Joosh with 51.6 mg/kg (Table 4).

No traces of HCH, Aldrin, and Dieldrin were found in these areas.

This initial monitoring of two former pesticide storage sites indicate that soils at such sites in Kyrgyzstan can be highly contaminated with POPs pesticides (in particular DDT) and that all storage sites should be assessed and for the time being uses should be restricted and controlled.

Also, the levels at all three monitored agro-airstrips were 30 to 66 times above the Californian Total Threshold Limit Concentration (Henson et al. 1998). The agro-airstrip areas should be further assessed and the land probably prohibited for raising of cattle to avoid associated contamination of milk and meet.

Former cotton fields, which are now used for growing vegetables, were also studied in 1998–1999, 2004, and 2014. OCPs (DDT, DDE, DDD, α-HCH) were detected in six samples collected from the sites where cotton was cultivated in 1998–1999 (Table 5). Concentration levels of OCPs were different in samples collected from the upper and lower parts of the fields. No traces of Aldrin and Dieldrin were found. In 2004, the same OCPs were detected, but their concentrations were lower in the upper part of the fields than in the lower part (Table 5). All samples collected in 2014 showed no traces of OCPs in the upper part of the fields and small concentrations in the lower part of the field. But the concentration level was

Fig. 4 Pesticide storage sites before removal of pesticide stocks in 2008/2009

Fig. 5 Abandoned and destroyed former pesticide storage site

much lower than that recorded in 2004, indicating a wash out and partly degradation of the OCPs.

DDE and DDT were detected in six and three samples, respectively, collected from the fields, used for vegetable cultivation. No trace of HCH, DDD, Aldrin, and Dieldrin were revealed. This is explained by the fact that OCPs are washed away from the upper parts of fields during the irrigation and deposited in the lower part of the fields. Some of them are adsorbed by plants (e.g., cotton). This is evidenced by the detection of OCPs in cotton seeds. Concentrations of OCPs were much higher than those in soil samples.

Water samples were taken from the area where pesticides have been applied in history. Four water samples were collected during spring time (two samples at the upper part of the agricultural area (inflow) and two samples at the lower part of the agricultural area where water run of from the field (outflow)). The pesticide levels in the melt water flowing into the agricultural area where below detection limits. In the outflowing water from the agricultural areas, OCPs were detected with HCHs at 0.0007 and 0.0002 mg/l, DDE at 0.0013 and 0.0014 mg/l, and DDT at 0.0014 and 0.0011 mg/l. This demonstrates that OCPs were/are partly washed out of the soil into the water.

Implementation of risk reduction measures.

After the international community recognized the treats due to the poisoning incident, international funding and support were acknowledged by GEF/UNDP.

With the GEF/UNDP Small Grants and international co-funding available early 2013, the consortium of NGOs, the Dutch engineering company, and local authorities agreed in a Memorandum of Understanding to join forces and bring the dump site under control (Molenkamp et al. 2013). The memorandum confirmed the will to actively cooperate in order to lower the negative impacts of Ak-Chabyr (Suzak A.) on the local population and the environment by:

- Awareness raising and training
- Press campaigns
- Implementation of technical works (remediation for short-term risk reduction)
- Involvement and engagement of the local population

Table 4 The results of tests carried out on soil samples collected from the former pesticide storehouses, agro-airstrips located in Kara-Suu district

Soil sample collection site in Kara-Suu district	OCPs, mg/kg				
	HCH	DDE	DDD	DDT	Total
Pesticide storehouse in rural community Saray	0	44.7	171	36.5	252
Pesticide agro-airstrip in rural community Saray	0	7.8	14.7	10.1	32.6
Pesticide storehouse in rural community Joosh	0	60.1	147.1	767.7	975
Pesticide agro-airstrip in rural community Joosh	0	13.4	17.1	21.1	51.6
Pesticide agro-airstrip in rural community Ak-Tash	0	9.4	26.3	30	65.7

Table 5 The results of OCPs tests carried out on soil samples collected from cotton fields

Soil sample collection site from cotton field	2004		2014	
	Upper part of the field	Lower part of the field	Upper part of the field	Lower part of the field
Rural community Saray, c/f Kuvat	–	0.003	0	0.001
Rural community Saray, c/f Kuvat	–	0.06	0	0.007
Rural community Saray, c/f Abaz-Ata	0.006	0.16	0	0.04
Rural community Saray, c/f Abaz-Ata	0.005	0.34	0	0.045
Collective farm Aboz-Ata	0.006	0.07	0	0.056
Collective farm Aboz-Ata	0.005	0.097	0	0.055

Within the awareness raising and press campaigns, the local population living near the sites of the former pesticides storehouses and agro-air strips is advised not to cultivate vegetables and melons to meet their dietary needs and not to let cattle graze on these areas. Instead, it is recommended to plant trees or grow technical crops.

The different parties (governmental institution, research community, civil society organizations) agreed to do their utmost to fully implement the memorandum as agreed and inform each other on important developments. The parties agreed as well to cooperate in the frame of this memorandum as a project working group and assigned different tasks to the different members of the working group.

In addition to awareness raising activities and press campaigns, the technical working group hired a local engineer and architect to prepare all needed local documents to get all necessary permits for implementation of the technical works fully in line with local and national legislation and international best practices.

With the limited overall project budget of USD 112,000 available, the following measures were implemented to mitigate the acute risks and contain the dump site on at least the short to medium term:

1. Digging of a trench around the perimeter of the site to prevent migration of contaminants by run-off rain water (see Fig. 3b)
2. Installation of a HDPE (plastic) top cover over the hotspots to prevent migration of contaminants by wind and infiltrating rainwater
3. Installation of a fence around the perimeter of the site to keep out Waste Miners (and prevent cattle from falling down the trench)
4. Building of a guard house and assigning a guard to look after the site

Although a final disposal (i.e., destruction) of the disposed/stored POPs pesticides is the best option to finally solve the problem of such POP landfills.

To date, safe disposal facilities are not available in the region. The transport route to Western Europe is blocked by hazardous waste transport restrictions of the Eurasia Customs Union. Currently, only demonstration projects of proven non-combustion technologies for disposal of the POPs waste might currently be feasible. In any case, the development of destruction projects will take time considering the challenges including finance. In the current context in which only limited funds are available, taking further risk mitigation steps is the most appropriate cost-effective short and medium alternative that greatly reduces the risks posed by these sites and has been effective at similar sites (Bouwknegt et al. 2017; Fokke et al. 2017). It is therefore strongly advised to further facilitate risk mitigation activities, given that the process of securing funds for final disposal is lengthy, and as the poisoning incidents show, risks are present that could have been prevented even with a limited budget. The importance of accepting a phased approach in reaching the goal of securing and remediating the stockpile sites is illustrated in various project management approaches (Kips et al. 2017).

Conclusions/outlook

In the current paper, preliminary assessment were conducted with limited analytical capacity present in the country.

At the two largest pesticide contaminated sites in Kyrgyzstan and of pesticide storages and agro-airstrips and agricultural fields where OCPs have been applied. With the exception of agricultural areas, all assessed sites had POPs pesticide contamination at levels which posed risk to humans and grazing animals. The highest risks where around the two major landfills and the pesticide stores with proven high levels of exposure of humans and cattle. But also, at the agro-airstrip areas, land use needs to be restricted and this restriction needs to be enforced.

The preliminary assessment of some of these sites highlight that all agro-airstrips and pesticide storages need to be monitored to clarify the contamination levels and related risks for exposure to humans and biota including cattle and game. Until such monitoring is conducted, these sites should be restricted for use in particular for cattle and accumulating vegetables.

The case of the contaminated sheep and the relatively high contamination levels at 1 and 3 km from the landfill sites highlighted that the monitoring also needs to be extended to a wider area around the landfill sites where pesticides were stored.

Preliminary securing measures have been implemented for the highest risk sites (the pesticide landfills) with the limited budget available. Further, more comprehensive securing measures and remediation measures should be initiated and conducted in the future. In particular, it will need to be assured that no grazing of cattle takes place for a zone of at least 3 km around the site until a gridded monitoring has been performed.

For areas where farmers want to raise cattle, the soil needs to be assessed for contamination which however is currently only possible for the major used OCPs measured in this study. Since these OCPs were major pesticides, they are a good overall indicator of pesticide contamination around the site. The monitoring of only the current POP OCPs around the site is however not sufficient for an appropriate risk management, as can be seen by the death of the sheep which could not be explained by the OCP contamination but was (partly) caused by other pesticides currently not monitored. Therefore, for a follow-up study, the monitoring capacity needs to be improved or cooperation with experienced laboratories or universities needs to be established best with non-target screening and assessment of toxicity of mixtures present from pesticide mixtures and degradation products.

In such an improved monitoring, the exposure and contamination of people needs to be further assessed to understand the contamination level around these sites and the exposure pathways.

Efforts to clean up the dump sites in Southern Kyrgyzstan would have important health and environmental benefits and contributes to sustainable development of the country. To comprehensively solve the problem, large projects financed by international donors are needed for collection, repackaging, and disposal of the stockpiles. Furthermore, the problems with export restrictions of POPs waste need to be solved. For the time being with the limited budgets available in particular, measures to secure and limit access to the highest contaminated areas can be implemented. Such risk mitigation measures, however, should be accompanied by well-targeted education and awareness raising activities for the potentially affected population.

These activities should be formulated and included in the National Implementation Plan of the Stockholm Convention which is currently being updated by the State Agency for Protection the Environment and Forestry under the Government of the Kyrgyz Republic in cooperation with UNEP.

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References

Amirova Z, Weber R (2015) Massive PCDD/F contamination at the Khimprom organochlorine plant in Ufa—a review and recommendations for future management. Environ Sci Pollut Res Int 22: 14416–14430

Beyond Pesticides (2016) Pesticide Induced Disease Database. http://www.beyondpesticides.org/resources/pesticide-induced-diseases-database/cancer

Bouwknegt MA, Fokke BFH, Kips PHA (2017) Sustainable management of POP pesticide contaminated landfills in Armenia and Georgia. Proceedings of the 13th IHPA Forum, November 03–06, 2015, Zaragoza, Spain

Corsini E, Sokooti M, Galli CL, Moretto A, Colosio C (2013) Pesticide induced immunotoxicity in humans: a comprehensive review of the existing evidence. Toxicology 307:123–135

Dollimore L, Schimpf W (2013) Obsolete pesticide stocks—the past 25 years, lessons learned and observations for the future. Outlooks on Pest Management 24(6):251–256

European Environmental Agency (2005) Progress in management of contaminated sites. Published 16. Mar 2005. https://www.eea.europa.eu/data-and-maps/indicators/progress-in-management-of-contaminated-sites. Accessed 25 Aug 2017

Fokke B.F.H., Kips Ph.A., Bouwknegt M.A (2017) Sustainable management of POP Pesticides contaminated sites in Viet Nam. Proceedings of the 13th IHPA Forum, November 03–06, 2015, Zaragoza, Spain

Götz R, Sokollek V, Weber R (2013) The Dioxin/POPs legacy of pesticide production in Hamburg: part 2: waste deposits and remediation of Georgswerder landfill. Env Sci Pollut Res Int 20:1925–1936

Henderson R, Bell MW, Borzelleca JF, Clark EH, Crouch EAC, Giesy JP, Ryan PB, Seiber JN, Travis CC (1998) Risk-Based Waste Classification in California

Hoogenboom RL, Ten Dam G, van Bruggen M, Jeurissen SM, van Leeuwen SP, Theelen RM, Zeilmaker MJ (2016) Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/fs) and biphenyls (PCBs) in home-produced eggs. Chemosphere 150:311–319

Jaga K, Dharmani C (2003) Global surveillance of DDT and DDE levels in human tissues. Int J Occup Med Environ Health 16(1):7–20

Kips PhA, Fokke BFH, Bouwknegt M.A (2017) Modern project management in land rehabilitation – Application of PRINCE2 methodology. Proceedings of the 13th IHPA Forum, November 03–06, 2015, Zaragoza, Spain

Kyrgyz Republic (2004) preparation of a national plan for the Stockholm Convention on POPs." Bishkek, 26–28 January, 2004, PP.115–122

Kyrgyz Republic (2006) National plan for the stockholm convention on persistent organic pollutants. Approved government resolution № 371 of the Kyrgyz Republic. Bishkek 3rd July 2006

Lunev MI (2004) Inventory and ecological and toxicological aspects in solving the problem of obsolete pesticides. Proceeding of the national workshop on “the problems of persistent organic pollutants in the Kyrgyz Republic” Bishkek, Kyrgyz Republic

Lysychenko G, Weber R, Gertsiuk M, Kovach V, Krasnova I (2015) Hexachlorobenzene waste deposits at Kalush city (Ukraine)—threat to western Ukraine and transboundary water bodies and remediation efforts. Environ Sci Pollut Res Int 22:14391–14404

Molenkamp S, Pronk W, Zhakipova I (2013) Groups at risk from obsolete pesticides in Kyrgyzstan. Proceedings of the 12th HCH and Pesticides Forum, 6–8 November 2013, Kiev, Ukraine

Mrema EJ, Rubino FM, Brambilla G, Moretto A, Tsatsakis AM, Colosio C (2013) Persistent organochlorinated pesticides and mechanisms of their toxicity. Toxicology 307:74–88

Oliaei F, Kriens D, Weber R, Watson A (2013) PFOS and PFC releases and associated pollution from a PFC production plant in Minnesota (USA). Environ Sci Pollut Res Int 20:1977–1992

Pieterse B, Rijk IJC, Simon E, van Vugt-Lussenburg BMA, Fokke BFH, van der Wijk M, Besselink H, Weber R, van der Burg B (2015) Effect-based assessment of persistent organic pollutant- and pesticide dumpsite using mammalian CALUX reporter cell lines. Environ Sci Pollut Res Int 22:14442–14454

Revich B, Shelepchikov A (2008) Persistent organic pollutants (POPs) hot spots in Russia. The fate of persistent organic pollutants in the environment, NATO science for peace and security series, vol 2008, pp 113–126

Smith D (1999) Worldwide trends in DDT levels in human breast milk. Int J Epidemiol 28(2):179–188

Toichuev R.M. (2005) Bifidoflora of gastrointestinal tract in neonates, depending on the concentration of organochlorine pesticides in breast milk of nursing mothers. Journal Current Pediatrics. Vol. 4. Ann. 1. X Congress of pediatricians of Russia "Ways to improve the efficiency of medical aid to children", Moscow, 8–10 February 2005, PP. 530–531

Toichuev RM (2011a) The effects of pesticide disposal sites Ak-Chabyr and task-Baka of bazar-Korgon and Suzak districts on the state of health of the population, flora and fauna of the areas. Bulletin of Southern Branch of the National Academy of Sciences of the Kyrgyz Republic, Osh, pp 116–119

Toichuev R.M. (2011b) Adverse effects of pesticide deposit sites Ak-Chabyr and Tash-Baka located in Bazar-Korgon and Suzak districts of Zhalal-Abad region (Kyrgyz Republic) on the population health and biota. Proceedings of the 11th HCH and Pesticides International Forum, 7–9 September 2011, Azerbaijan

Toichuev R, Paizova Z (2011) The effect of pesticide pollution load on the prevalence of breast cancer in Osh region (Kyrgyz Republic). ISEE, Barcelona-Spain **No. 594**

Toichuev RM, Payzyldaev TR (2014) The problems of pesticides in southern Kyrgyzstan. CSCM - World Congress on CBRNe Science & Consequence Management, Tbilisi, Georgia, 1–5 June 2014

Toichuev R.M., Tostokov E.T. (2006) The effect of organochlorine pesticides (OCPs) on the formation of congenital malformations (CM) in children. Proceedings of the V Russian Congress "Modern technologies in pediatrics and pediatric surgery." M.: "Overlay", 2006, P.308

Toichuev RM, Shaynazarov TS, Nematov MA, Abduraimova ChD, Paizova ZM (2004) Changes in concentration of immunoglobulins in breast milk of nursing mothers, depending on the concentration of organochlorine pesticides in breast milk. Proceedings of the 3rd Russian Congress "Modern technologies in pediatrics and pediatric surgery." - M .: Medpraktika, 2004: PP. 396–397

Toichuev RM, Paizova ZM, Toichueva GR (2007) Pesticide pollution in the environment of southern Kyrgyzstan. International scientific-practical conference "Adyshev's reading. Modern problems of ozone depletion and climate change » Bulletin OshTU 2007 №1. PP. 37–45

Toichuev R, Tostokov E, Joldoshov S, Argynbaeva A (2012) The effect of organochlorine pesticides (OCPs) on the prevalence of hepatitis in children. ISEE, Columbia (USA)

Toichuev RM, Zhilova LV, Paizildaev TR, Khametova MS, Rakhmatillaev A, Sakibaev KS, Madykova ZA, Toichueva AU, Schlumpf M, Lichtensteiger W, Weber R (2017) The effect of organochlorine pesticides in placenta on pregnancy, childbirth and newborn health in Kyrgyzstan. Env Sci Pollut Res Int (in press)

Torres JPM, Fróes-Asmus CIR, Weber R, Vijgen JMH (2013) Status of HCH contamination from former pesticide production and formulation in Brazil – a task for Stockholm Convention implementation. Environ Sci Pollut Res Int 20:1951–1957

Vijgen J, Abhilash PC, Li Y-F, Lal R, Forter M, Torres J, Singh N, Yunus M, Tian C, Schäffer A, Weber R (2011) HCH as new Stockholm convention POPs—a global perspective on the management of Lindane and its waste isomers. Env Sci Pollut Res Int 18:152–162

Vijgen J, Aliyeva G, Weber R (2013) The forum of the international HCH and pesticides association—a platform for international cooperation. Env Sci Pollut Res Int 20:2081–2086

Weber R, Varbelow G (2013) The dioxin/POPs legacy of pesticide production in Hamburg: part 1 securing of the production area. Env Sci Pollut Res Int 20:1918–1924

Weber R, Gaus C, Tysklind M, Johnston P, Forter M, Hollert H, Heinisch H, Holoubek I, Lloyd-Smith M, Masunaga S, Moccarelli P, Santillo D, Seike N, Symons R, Torres JPM, Verta M, Varbelow G, Vijgen J, Watson A, Costner P, Wölz J, Wycisk P, Zennegg M (2008) Dioxin- and POP-contaminated sites—contemporary and future relevance and challenges. Env Sci Pollut Res Int 15:363–393

Weber R, Aliyeva G, Vijgen J (2013) The need for an integrated approach to the global challenge of POPs management. Environ Sci Pollut Res Int 20:1901–1906 http://link.springer.com/content/pdf/10.1007%2Fs11356-012-1247-8.pdf

Weber R, Schlumpf M, Nakano T, Vijgen J (2015a) The need for better management and control of POPs stockpiles. Environ Sci Pollut Res Int 22:14385–14390 http://link.springer.com/article/10.1007/s11356-015-5162-7/fulltext.html

Weber R, Watson A, Petrlik J, Winski A, Schwedler O, Baitinger C, Behnisch P (2015b) High levels of PCDD/F, PBDD/F and PCB in eggs around pollution sources demonstrates the need to review soil standards. Organohalogen Compd 77:615–618

WHO World Heath Organisation (2013) Contaminated sites and health. Report of two WHO workshops: Syracuse, Italy, 18 November 2011; Catania, Italy, 21–22 June 2012

Wimmerová S, Watson A, Drobná B, Šovčíková E, Weber R, Lancz K, Patayová H, Jurečková D, Jusko TA, Murínová L, Hertz-Picciotto I, Trnovec T (2015) The spatial distribution of human exposure to PCBs around a former production site in Slovakia. Environ Sci Pollut Res Int 22:14405–14415

Wycisk P, Stollberg R, Neumann C, Gossel W, Weiss H, Weber R (2013) Integrated methodology for assessing the HCH groundwater pollution at the multi-source contaminated mega-site Bitterfeld/Wolfen. Env Sci Pollut Res Int 20:1907–1917