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EDITORIAL

The need for an integrated approach to the global challenge of POPs management

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Over the last six decades, the unsustainable management of chemicals through their life cycles has resulted in widespread and massive contamination of the environment, biota and humans with persistent organic pollutants (POPs) and other persistent toxic substances. The recent integration of the secretariats to the Stockholm, Basel and Rotterdam Conventions, along with the associated synergy of efforts, represents the best international opportunity to holistically address and improve the management of these chemicals and their related wastes.

During the last decade, the 178 parties to the Stockholm Convention have been addressing the 12 POPs initially listed in the convention. Recently, ten new POPs were added, including three hexachlorocyclohexane (HCH) isomers (α-, β- and γ-HCH (lindane)) and, for the first time, fluorinated POPs (perfluorooctane sulfonate (PFOS), its salts, perfluorooctanesulfonyl fluoride (PFOSF) and other PFOS precursors) and brominated POPs (certain polybrominated diphenyl ether (PBDE) homologues and hexabromobiphenyl).

The effectiveness evaluation of the convention is undertaken by assessing trends of POPs concentrations in air and human milk. However, as many of the POPs have generally not been produced for a decade or more, their levels are already falling in most cases. Even PFOS and DDT, for which exemptions allow some continued use, are manufactured in much lower volumes than in the past. Simple time trends of the listed POPs can therefore give a misleading picture of the success of global chemical management.

Reviewing the first 10 years of the Stockholm Convention implementation by the alternative approach of assessing reductions of global POPs inventories and progress with the management of POPs stockpiles better demonstrates the practical challenges of POPs legacies. There has only been very slow progress with the destruction of POPs pesticides and polychlorinated biphenyl (PCB) stockpiles especially in developing countries and countries with economies in transition. These countries often have few—or no—adequate destruction facilities. They face huge challenges with the end-of-life management of PCB and pesticide stockpiles and increasing e-waste containing PBDEs. Their problems are often magnified by exports of POPs in waste and products from industrial countries (Breivik et al. 2011).

Export of POP-contaminated materials back to the original producers, normally industrial countries, for destruction is very expensive at about US$2,000 to US$5,000/tonne.[1] The management costs for the worldwide total of approximately 3 million tonnes of PCB-containing equipment alone have thus been estimated at between US$6 billion and US $15 billion (Stockholm Convention 2010).[2] This can be

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[1] The final cost for the destruction of highly chlorinated wastes in, e.g. BAT incinerators may be less than US$1,000/tonne, but the packing and shipping often charge much more than the destruction itself.

[2] The inventories of 88 countries indicate more than 6 million tonnes of contaminated PCB equipment and oils. The Secretariat of the Stockholm Convention estimates that a more realistic value could be 3 million tonnes (Stockholm Convention 2010).

compared with the total budget of the Stockholm Convention of US$0.55 billion for all POPs activities (total allocated Global Environment Fund (GEF) funding from 2003 to 2010), which shows the discrepancy between the task and the allocation of funding to international agencies.

The situation is similar for pesticide stockpiles. There has been hardly any progress over the past decade[3] in Africa, where 50,000 tonnes of stockpiles has an estimated management cost of US$250 million. First steps are made in Eastern Europe, Caucasus and Central Asia (EECCA) countries, where the stockpile is estimated to be 240,000 tonnes with an estimated management cost of US$1 billion (Vijgen et al. 2012).

The article introducing the International HCH and Pesticide Association (IHPA; www.ihpa.info) and its activities (Vijgen et al. 2012) shows how the IHPA has been working for 20 years to bring stakeholders together in order to address the challenges of the management and remediation of pesticide stockpiles—particularly in the EECCA countries (Vijgen et al. 2012). An important part of this work is the International HCH and Pesticide Forums, which provide a platform for bringing stakeholders together (Vijgen et al. 2012). This special issue of *Environmental Science Pollution Research* (ESPR) includes selected papers from the 11th HCH and Pesticide Forum held in Gabala, Azerbaijan, along with related papers with an emphasis on lindane/hexachlorocyclohexane production sites. Six decades of lindane/HCH production has generated the world's largest stockpile of POPs estimated to be 4.8 to 7.2 million tonnes of HCH waste isomers arising from approximately 600,000 tonnes of lindane production,[4] but detailed information on the size and location of the deposits is often missing (Vijgen et al. 2011). The IHPA continues to work on the assessment and management of the HCH legacy in an attempt to plug these data gaps.

Article 6 of the Stockholm Convention requires parties to develop appropriate strategies for identifying HCH and other POPs stockpiles and wastes in their national implementation plans from August 2012 on. They must then manage stockpiles in a 'safe, efficient and environmentally sound manner.' Detailed information on assessment, management and remediation of such sites is therefore needed, especially by less developed countries. Several of the papers published in this issue address issues relevant to the obligations of countries in this context.

The review by Torres et al. (2012a, b) on lindane/HCH production and formulation sites in Brazil highlights that all these sites are contaminated. The first detailed exposure assessment of a major production site shows that acute health-based thresholds were exceeded by a factor of 2 for ΣHCH and by a factor of 600 for dioxins (Torres et al. 2012a, b). At one site, the use of an inappropriate 'remediation technology' had actually *increased* the pollution of the site by unintentional formation of POPs (including dioxins). Similarly, a recent assessment of the last operating lindane production facility in India (Jit et al. 2011) showed that until recently HCH waste isomers where stockpiled on 'white mountains' (see Fig. 1 in Vijgen et al. 2012) and partly dumped in the vicinity, thus contaminating the wider environment with associated risks to human health. These examples illustrate the challenges faced by developing/transition countries with the management of production wastes and contaminated sites. To reduce/stop human exposure faced by local residents and to minimise environmental damage, there is an urgent need for best-practice experiences from successful remediation operations to be shared.

An example of a best-practice approach for the assessment of ground water pollution at a former HCH production site is presented in this issue by Wycisk et al. (2012). The study introduces an integrated methodology for assessing HCH ground water contamination from the contaminated mega-site at Bitterfeld/Wolfen in Germany, where approximately 60,000 tonnes of HCH waste isomers was dumped. The modelling covers 45 km^2 and allows the future fate of HCH and other groundwater contaminants to be determined.[5] However, the work undertaken at this site so far mainly involves measures to reduce contamination by capping. A comprehensive remediation of the major landfill is estimated to cost between 700 and 2,000 million €. A second case presented in this issue reports 115,000 tonnes of HCH dumped in Spain with similar groundwater pollution problems. The annual release of HCHs to surface waters is estimated to be more than 130 kg (Fernández et al. 2012).

Another best-practice approach presented in this issue relates to the demolition of buildings heavily polluted with HCHs, 2,4,5-T and other pesticides at a closed factory within the city area of Hamburg in Germany (Weber and Varbelow 2012). A key finding of the comprehensive pollution assessment at this site revealed that the spills from over 50 years of daily operation has resulted in a total soil contamination inventory of approximately 830 tonnes of organohalogens—including 260 tonnes of HCH. A second paper on the same factory details the inventory of the historical deposited wastes and assesses the fate of the wastes deposited in a major landfill (Götz et al. 2012). The two papers present the most comprehensive inventory and

[3] At the current clean-up rate of the African stockpile, it would take 100 years to complete the task (World Bank 2002).

[4] The production of 1 tonne of lindane (γ-HCH) generates 8 to 12 tonnes of HCH waste isomers not as active as insecticide.

[5] At this site, groundwater pollutants have been ranked in order of priority, and although groundwater is heavily polluted with HCH, the congeners rank 8th (α-HCH), 9th (δ-HCH), 15th (γ-HCH) and 18th (β-HCH) in the priority list, emphasising that a comprehensive assessment of all relevant pollutants is necessary (Wycisk et al. 2012).

pollution assessment of a pesticide production site which has a dioxin inventory of 333 to 854 kg TEQ.[6] They can be used as another example of a best-practice approach. It is chastening to consider that the pollution legacy at this factory has been contained only after spending approximately 100 million € on each site, with an additional 1 million €/year for 'pump and treat' with monitoring. The 10-year guarantee on the cut-off wall at the production site recently ended, however, the question remains—as with other containment sites—who will carry the responsibility for the next 1,000 years or more during which the POPs can slowly leak into the environment?

Another Brazilian case study in this issue from Torres et al. (2012a, b) reports the fate of polychlorinated dibenzodioxins/polychlorinated dibenzofurans (PCDD/PCDF)-contaminated lime mined from an organochlorine (EDC/PVC) industry landfill site. The lime was then used for neutralisation of citrus pellets, which were subsequently exported to the European feed market. This caused widespread contamination of European milk and dairy products, and the example highlights how the poor regulatory control of PCDD/PCDF previously deposited in landfill sites can cause large-scale food contamination. Landfill mining is likely to increase in the future as natural resources such as metals become scarcer, and the case highlights the importance of identifying POP-containing deposits as required by Article 6 of the Stockholm Convention. Such sites should be included in a national database to ensure that activities such as landfill mining are not allowed.

This special issue of ESPR also introduces the first comprehensive review of pollution at a 3M PFOS/PFC production plant in Minnesota, USA (Oliaei et al. 2012). The fate of PFOS waste deposits around production sites is a key concern for the Stockholm Convention as it is estimated that the total historic production of 96,000 tonnes of PFOSF has generated about 26,500 tonnes of related wastes (Paul et al. 2009), for which the fate is unknown. The fate and management of these wastes are crucially important as they are highly persistent and probably water soluble, so their eventual escape from landfills is almost inevitable in the long term (Weber et al. 2011).

These case studies in this special issue together demonstrate the importance of thorough assessments of organohalogen production sites as part of the process of updating the national implementation plans for the Stockholm Convention.,[7,8] Guidance on inventories of PFOS and PBDEs that include dedicated chapters on contaminated sites has recently been developed to support this process (Stockholm Convention 2012a, b).

The case studies also illustrate the enormous scale of the challenge associated with POPs legacies. Firstly, they show that even in industrial countries most 'remediation' undertaken to date involves containment rather than the 'destruction or irreversible transformation' required by the Stockholm Convention for POPs wastes. This approach leaves pollutants for future generations to manage and is not consistent with sustainable development. Secondly, they show that the cost of securing and monitoring disposal sites is enormous, and an appropriate best available technique (BAT) for the destruction of the wastes at the time of their generation would have been a far cheaper solution. This is perhaps the most important message from this special issue. It is of particular relevance for stakeholders currently involved with the production of organohalogen (and other persistent and toxic) compounds in developing and transition countries. In cases where production wastes are either disposed of or dumped (Donath 2012), or treated by inadequate incineration technology leading to dioxin releases and related pollution (Takeda and Takaoka 2012; Weber et al. 2008), it is almost inevitable that much more difficult and expensive problems are being stored for the future.

Production capacity of organohalogen chemicals has shifted from industrial countries to developing countries over the past 30 years (UNEP 2012).[9] An important driving force has been the lower operating costs associated with lower environmental standards. According to an interview with Donath, the former Head of the Environmental Affairs for the Basel Chemical Company 'Ciba Spezialitäten', the savings on treatment of wastes, effluents and exhaust gases can be as high as 15 to 20 % of the product price (Donath 2012). The translocation of 'environmentally challenging' chemical production facilities from industrial countries to developing/transition countries is, however, often a 'lose–lose' situation. Not only does it increase pollution in developing/transition countries having inadequate regulatory and enforcement capacity for production, but also, the resulting lower product market price undermines production using appropriate but costly environmental BAT standards in industrial countries. Donath (2012) notes that CIBA had invested CHF 800 million in environmental BAT facilities by the 1980s to meet stringent Swiss/European environmental standards,

[6] This amount can be compared with the total dioxin releases of 58.5 kg toxic equivalent (TEQ)/year from 68 countries having established inventories for the Stockholm Convention (UNEP 2011).

[7] The pollution around production sites of the organobromine industry has not yet been documented.

[8] The unsustainable global end-of-life and recycling flow of PBDE-containing material have recently been documented (UNEP 2011).

[9] While production capacity was often shifted (e.g. by joint ventures), companies also have independently started productions. In the case of PFOS, even the voluntary phaseout in industrial countries have triggered the start/increased production in China with related pollution increase (Lim et al. 2011). These mechanisms are a challenge to more sustainable production, as highlighted for the organofluorine industry (Lindstrom et al. 2011).

but due to the translocation of production to China or India, the environmental infrastructure was underutilised and deteriorated over time.

The first decade of the Stockholm Convention implementation has demonstrated that developing countries and most countries with economies in transition do not have appropriate destruction technologies for PCBs and POPs pesticides. It follows that they also have inadequate capacity to destroy other organohalogens and related wastes. The availability of destruction technologies is a pre-requisite for the environmentally sound management of production wastes and thus for clean production of organohalogen compounds. Without clean production and guarantees for appropriate end-of-life management and treatment, the production of organohalogen compounds cannot be considered sustainable.[8] If the chemical industry wants to continue the current production of thousands of organohalogens and other persistent chemicals (Strempel et al. 2012)[10] in a sustainable manner, then they must urgently contribute to the establishment of appropriate treatment and destruction capacity. Governments will also need support to establish robust regulatory and legal frameworks for chemical and waste management—including extended producer responsibility—where these are not currently in place.

The Stockholm Convention made an important step forward in the international regulation of chemicals by promoting the substitution of critical chemicals. Also, the convention requires that priority consideration should be given to alternative processes that do not generate POPs. Green chemistry, using less persistent and less toxic chemicals, therefore presents an attractive and important alternative path which is arguably cheaper, reduces future liabilities and has the potential to be implemented more rapidly. The systematic review of alternatives of POPs by the POPs Review Committee of the Stockholm Convention might provide a global lead in this direction. Such structural changes and the sun-setting of unsustainable existing production will still take time. Pragmatically better waste management schemes and destruction capacity will still be needed in the interim to manage the thousands of persistent toxic substances currently produced (Strempel et al. 2012)[10] and used in articles which ultimately end up in the recycling and end-of-life schemes. Capacity is also needed to address the legacy of more than 60 years of unsustainable production now stored up, e.g. in pesticide stockpiles and in current material flows including brominated POPs in plastic housing electronics, in foams, textiles, construction insulation or, in the case of fluorinated PFOS, in synthetic carpets, textiles and even food contact paper.

The urgency of the need to change to a more sustainable production with lower long-term liabilities has been increased by the GEF, dramatically cutting its financial contribution to just 20 % of the total costs for implementing POPs projects. This presents an enormous dilemma for developing countries as they are now required to generate 80 % of co-funding. This seriously increases the risks of failure of efforts to properly manage POPs globally. A more integrated approach is therefore needed to bring all stakeholders to the table in order to develop a sustainable approach to mitigating the risk posed by these stockpiles[11] and wastes from current production and end-of-life. In particular, a larger contribution is urgently needed from the industry in line with the ‘polluter pays principle’. The former producers of PCBs have not yet, for example, contributed to the management of the PCB problem within the convention. In addition, there is only very limited support from the industry through CropLife International towards pesticide stockpile remediation in Africa, and the slow progress[3] highlights that more support is needed. Without such support, the original promise of the Stockholm Convention to eliminate POPs will not be delivered, and the global management of POPs (and other) chemicals will inevitably continue to fail.

The claims of organohalogen industries that they have now adopted ‘sustainable production’ will be meaningless without these fundamental changes and will simply continue the long-term practice of leaving the end-of-life problems to the public and to importing countries. The convention's framework with the synergy approach between waste (Basel) and chemicals (Stockholm, Rotterdam and the Stra-

[10] A recent screening for potential persistent, bioaccumulative and toxic chemicals using thresholds defined under the European Chemical legislation REACH concluded that 2,930 chemicals (3.1 %) of the 95,000 assessed chemicals may exceed the persistent, toxic and bioaccumulative (PBT) criteria of REACH (Strempel et al. 2012). Furthermore, the study revealed that from the more recently registered 2,781 chemicals of the EU's ELINCS list, a fraction of 5.2 % may exceed the PBT criteria, therefore a higher share compared to the total list including earlier registered (‘existing’) chemicals (Strempel et al. 2012). The proportion of potential PBT chemicals has therefore increased.

[11] Here, interesting cooperation in the form of public–private partnerships might be developed. In these initiatives, the IHPA has played and can play a catalysing role of bringing stakeholders together to move this process forward towards concrete solutions.

tegic Approach of International Chemical Management (SAICM)[12]) might offer a frame towards more sustainable productions and material cycles—but will need a more effectively integrated approach with major contributions from the chemical producers and associated manufacturing industries.

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[12] SAICM attempts to cover chemicals in a holistic way but does not have the status of a convention (Weinberg 2008).

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He received his PhD in 1996 from Tübingen University and worked from 1997-2002 as head of a Dioxin/POPs R&D laboratory for IHI Co Ltd. (Yokohama/Japan) with research links to Kyoto and Ritzumeikan Universities. He is an active member of the "global POPs research community" and has published more than 100 reviewed papers and a book chapter covering these issues. He has also been the author of several technical guidance papers for the Stockholm Convention. He is a member of the Editorial Board of ESPR and edits a series on POPs contaminated sites. Since 2010 Dr. Weber is a visiting Professor at the Tsinghua University POPs Research Centre in Beijing.

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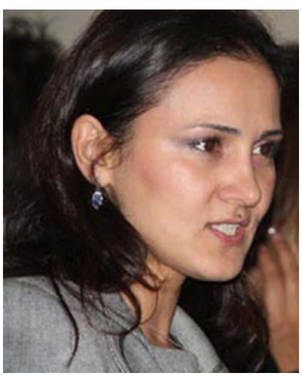

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Gulchohra has been implementing various regional projects related to the inventory of obsolete pesticide stocks and the monitoring of POPs in the environment of Azerbaijan. She was a Chair of the National Committee of the 11th International HCH and Pesticides Forum held in September 2011 in Gabala city of Azerbaijan. Presently, Gulchohra is involved in a number of projects, including activities related to raising public awareness to POPs, as well as development of laboratory and skills capacity to deal with these chemicals.

John Vijgen born in 1951 in Heerlen, The Netherlands, is educated as Civil Engineer at the Technical University of Aachen, Germany. Since 1998, he has been working as a consultant for Tauw in the Netherlands on the elimination of 200,000 tons with HCH and Lindane contaminated soils and wastes, decontamination of 200,000 tons. At present he is director of the International HCH & Pesticides Association (IHPA), which he founded in 1998 with the objective of eliminating obsolete pesticides in Central and Eastern Europe, the Caucasus and Central Asia Republics (EECCA). Over more than 20 years, he has been organizing the Int. HCH and Pesticides Forum, the last one in 2011 in Gabala in Azerbaijan. The Forum provides an international platform to solve obsolete pesticides problems, brings stakeholders together to exchange experiences, involves donors, public and private problem owners, scientists and civil society and dedicated politicians. In 2006, he published "The Legacy of Lindane HCH Isomer Production", a major contribution for the nomination of Lindane and HCH-isomers as POP in the framework of the Stockholm Convention. He was involved in a large number of pesticides clean-ups and worked many years on evaluation of POPs destruction technologies. Recently, with Green Cross and Milieukontakt Int.,he has been managing the GEF-FAO project on capacity building on obsolete and POPs pesticides in EECCA countries and is at present involved in the EU financed project on improving capacities for obsolete pesticides in the Former Soviet Union" with the same partners.