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Reducing the Human and Environmental Risks of Obsolete Pesticides

*A GIS-Based Tool
for Priority-Setting*



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CONTENTS

| | |
|--|-----------|
| SECTION 1 OVERVIEW | 7 |
| International Commitment to Minimize Risk | 8 |
| Role of the GEF and World Bank | 9 |
| Need for Prioritized Interventions | 12 |
| | |
| SECTION 2 RISK ASSESSMENT METHOD FOR PRIORITY-SETTING | 15 |
| Characterize Chemicals | 15 |
| Assign Hazard Indicators | 16 |
| Overlay Geo-Referenced Population or Environmental Data | 19 |
| Identify Hot Spots for Intervention | 22 |
| | |
| SECTION 3 SETTING CLEANUP PRIORITIES IN TUNISIA | 23 |
| Hot Spots — Hazards to Public Health | 24 |
| Hot Spots — Hazards to Ecoregions and Biodiversity | 26 |
| What Was Learned | 31 |

**SECTION 4 CLEANUP AND SAFEGUARDING HIGHLIGHTS
IN AFRICA 33**

| | |
|----------|----|
| Tunisia | 33 |
| Tanzania | 34 |
| Mali | 35 |
| Ethiopia | 36 |

SECTION 5 REDUCING THE RISK 37

ENDNOTES 39

BIBLIOGRAPHY 41

BOXES

| | | |
|---|---------------------------------------|----|
| 1 | The complexity of obsolete pesticides | 8 |
| 2 | Tackling POPs in Tajikistan | 11 |
| 3 | African Stockpiles Programme | 12 |
| 4 | Tunisia's environmental wealth | 27 |

FIGURES

| | | |
|---|--|----|
| 1 | World Bank current portfolio of projects to eliminate obsolete pesticides | 10 |
| 2 | Pesticide storage sites in Tunisia | 24 |
| 3 | Density of children and organophosphates and carbamates | 25 |
| 4 | Population density and distribution of human LD ₅₀ -weighted ingredients | 26 |
| 5 | Stockpiles of herbicides in the Critical/Endangered Mediterranean woodlands and forest | 27 |
| 6 | Potential threat to <i>Falco cherrug</i> | 28 |
| 7 | Ichkeul National Park and wildlife species at risk | 29 |
| 8 | Relative toxicity of chemicals stockpiled near Ichkeul National Park | 30 |
| 9 | The African continent has some 50,000 tons of obsolete pesticides | 34 |

TABLES

| | | |
|---|---|----|
| 1 | Sample stockpile volume of active ingredients | 17 |
| 2 | WHO ranking of sample stocks of active ingredients | 18 |
| 3 | Active ingredient volume by chemical class and end use | 18 |
| 4 | LD50-weighted volume by hazard range for humans | 20 |
| 5 | Active ingredient intensity for three sample districts by vulnerable population segment | 21 |



An old DDT storage facility in the Regional Hospital of Menzel Bourguiba, Tunisia.

SECTION 1 OVERVIEW

 obsolete pesticide stocks have accumulated in most of the world's developing countries and economies in transition in recent decades. International organizations estimate that some 500,000 tons are stockpiled worldwide, about half of which are located in countries of the former Soviet Union. Across the African continent, obsolete stocks total about 50,000 tons, while Latin America has at least 30,000 tons (box 1).

Training and resources to safely manage pesticide use, storage, and destruction are often lacking in such countries, particularly at remote storage sites. Many warehouses are dilapidated

and not secured. Over time, containers and packages deteriorate, and spills and leaks often find their way into surface waters from runoff or into groundwater from leaching through soil, resulting in environmental contamination and human exposure (World Bank 2002).

In many countries, storage sites once located far from residential areas are now surrounded by fast-growing urban communities. Where pesticides are stored in the open, families that live and work in the vicinity may suffer acute or chronic exposure. Long-term exposure has been linked to a range of adverse health effects, from problems of the nervous, immune, reproductive, and endocrine systems

BOX 1 The complexity of obsolete pesticides

The Food and Agriculture Organization of the United Nations (FAO) defines obsolete pesticides as all pesticide products not in current use because they have been banned, have deteriorated or are damaged, have passed their expiration date, cannot be used for any other reason, or are not wanted by the current owner.

Obsolete pesticides are chemically complex, given that some 1,000 active ingredients in many thousands of formulations are used to manufacture pesticides around the world. More than 20 percent of obsolete stocks consist of Persistent Organic Pollutants (POPs): Chlorinated hydrocarbons (organochlorines) that persist in the environment; bioaccumulate in humans, wildlife, and fish; and are highly toxic. In addition to POPs, obsolete stocks typically include organophosphates (less persistent yet more toxic than POPs), carbamates and synthetic pyrethroid insecticides, fungicides and herbicides, and even botanical and microbial groups.

The key reasons obsolete pesticides have accumulated in developing countries are:

- product bans,
- inadequate storage and poor stock management,
- unsuitable products or packaging,
- donation or purchase in excess of requirements,
- lack of coordination between donor agencies, and
- commercial interests of private sector and hidden factors.

Sources: FAO (1995a, 1995b, 1996); World Bank (2002).

and various types of birth defects to injury of specific organs of the body and cancer. Nearby such storage sites, one may find livestock grazing and edible crops growing on land irrigated with contaminated water also used for drinking (World Bank 2002).

International Commitment to Minimize Risk

The international community is committed to eliminating obsolete pesticide stocks in developing regions

around the world and protecting humans and the environment from further buildup. In 1998, a multilateral treaty known as the Rotterdam Convention was adopted to promote shared responsibilities in preventing unwanted importation of extremely hazardous pesticides and other chemicals into developing countries. The following year, the Basel Convention was opened for signature. This international treaty was designed to prevent the transfer of hazardous waste from developed to less developed countries and to

assist developing countries in devising environmentally sound management of hazardous waste to avoid shipment across borders.

In 2001, the Stockholm Convention on Persistent Organic Pollutants (POPs) was adopted to help eliminate or severely restrict the production of POPs chemicals. Under the Stockholm Convention, 12 POPs became the focus of international action, nine of which are pesticides.¹ Operational requirements for signatory parties include the development of National Implementation Plans (NIPs), which provide baseline information about POPs in a given country (e.g., stocks; emission sources; and institutional, policy, and regulatory capacity) (World Bank 2009).

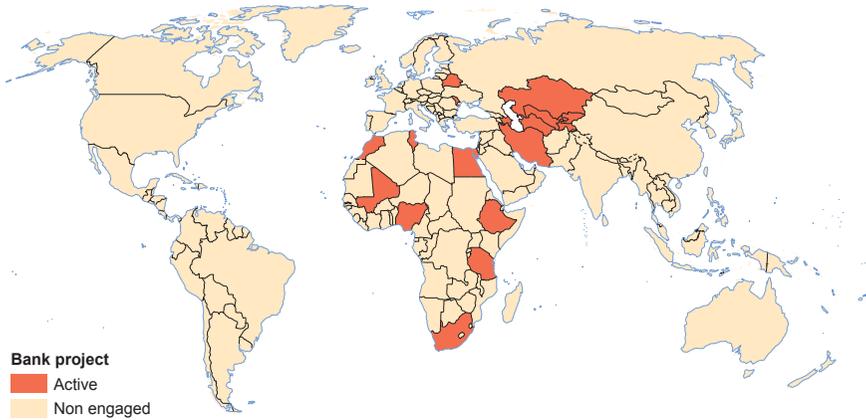
Role of the GEF and World Bank

Recognizing that developing countries and economies in transition would require capacity building to develop and address the priorities of their NIPs, the Stockholm Convention designated the World Bank's Global Environment Facility (GEF) as its interim financial mechanism. To date, the GEF has provided some 136 countries funding for developing NIPs that describe how they will meet their obligations under the Stockholm Convention.

The World Bank, a GEF-implementing agency, has decades of project experience across a variety of sectors and extensive technical knowledge involving the sound management of chemicals. The Bank is helping client countries throughout the world achieve GEF-supported objectives. An ongoing focus is the safe management, reduction, and elimination of POPs stockpiles. Analytical studies that include health monitoring have helped China, Mexico, and Vietnam design successful interventions to reduce the adverse effects of pesticides. Through its safeguarding policies, the Bank works to reduce the impact of pesticides and other chemicals in its country work programs.

The Bank's current portfolio of projects to eliminate obsolete pesticides focuses on Europe and Central Asia (ECA) and Africa (figure 1). In the ECA region, project lending and technical assistance center mainly on POPs pesticides. In Azerbaijan and the other Caspian states (Iran, Kazakhstan, Russia, and Turkmenistan), the Bank is providing technical assistance to address the high-priority POPs problem identified by the Caspian Environment Program. In Azerbaijan, the focus is on training and capacity building in inventory and options for safe collection and disposal. A five-year project in Moldova, with US\$12.6 in total funding, has focused on stockpiles management

FIGURE 1 World Bank current portfolio of projects to eliminate obsolete pesticides



Data source: Active projects, World Bank.

and destruction, development of a regulatory framework, and institutional strengthening. Consistent with completed GEF-funded NIPs, the Bank plans to finance the Belarus government's solid waste management agenda and has proposed a risk-reduction project in Tajikistan that includes strengthening of POPs legislation and regional information dissemination (box 2).

In Africa, the Bank is administering US\$60 million in funds to support the first phase of the Africa Stockpiles Programme (ASP). This continent-wide initiative aims to safely eliminate obsolete pesticide stocks from African countries and build capacity to prevent further buildup. The first phase of the ASP was approved by the World Bank Board, GEF, and FAO in 2005; \$25

million of funding is provided by the GEF (box 3).

ASP field operations comprise four steps:

- **Training.** Local personnel are trained to correctly identify, safely handle, repack, label, store, and secure obsolete pesticides.
- **Inventory.** Trained personnel conduct a detailed national inventory of public stocks and their locations; the collected information is stored in the Pesticide Stock Management System (PSMS), a web-based application developed by FAO used to record, monitor, and manage stocks of pesticides, including obsoletes. The data collected is used to inform environmental risk assessments and help plan cleanup operations.

BOX 2 Tackling POPs in Tajikistan

The Republic of Tajikistan developed a National Environmental Action Plan in 2007 that identified POPs as a threat to public health and the environment. In June 2009, the GEF approved a Project Information File for a POPs Elimination, Risk Mitigation, and Site Remediation Project with US\$4 million in grant funding. The proposed project aims to reduce the environmental and public-health risks from POPs pesticides by eliminating stockpiles and reducing farmer reliance on such pesticides.

A pre-feasibility study conducted by the TAUW Consortium in April 2010 did an initial inventory and risk assessment of the Vaksh burial site and sampled 17 former warehouses in the Khatlon region. The study recommended ways to reduce site risks, including various on-site technologies for pesticides destruction and options for containment of contaminated soils. Based on this study and stakeholder views, key conclusions were drawn for project preparation:

- Areas that pose the greatest risk are the Vaksh burial site and privately-owned, former pesticide warehouses and adjacent pits in the Khatlon region. The Vaksh burial site has about 4,000 tons of POPs that contain obsolete pesticides and an estimated 40,000 tons of contaminated soils. The obsolete pesticide stocks will be inventoried, repackaged, and stored in an interim storage facility (to be built on the same site) until destruction.
- On-site (*in-situ*) disposal technologies are likely to be less costly than shipment to an incineration facility in Europe. However, the tender will not be limited to any particular type of technology but will focus on the final outcome (disposal or destruction of obsolete pesticides and heavily contaminated wastes, taking into account performance standards, feasibility, regulatory requirements, and cost-effectiveness to elicit as large a number of bids as possible). The evaluation criteria for selecting disposal/destruction technology will be determined as part of the Environmental Impact Assessment.
- Available GEF funds will likely not allow for the destruction of all pesticides at the Vaksh burial site. Thus, priority will be given to the highest risk POPs pesticides: DDT (highly sought after by waste miners due to its market value), aldrin, dieldrin, and other highly toxic pesticides (e.g., arsenic-based compounds).
- If additional funds become available, private warehouses will be prioritized based on risk to public health and the environment. Obsolete stocks in these warehouses will be inventoried, repackaged, transported to the interim storage facility on the Vaksh burial site, and destroyed. Contaminated soils would be excavated and transferred to the Vaksh burial site, where they would be handled together with contaminated soils.

Source: Authors' data.

- **Safeguarding.** With support from the FAO-hosted Technical Support Unit and CropLife International, trained personnel conduct safeguarding activities of the identified stockpiles: collecting, repackaging, safe storing, and risk mapping.²

BOX 3 African Stockpiles Programme

The African Stockpiles Programme (ASP) is an unprecedented partnership between African countries, donor governments, civil society, and multilateral organizations to eliminate the serious public health and environment threat of obsolete pesticide stocks. Virtually every country in Africa has stockpiles of obsolete pesticides accumulated over the past several decades. The challenge of clearing them from the continent in an environmentally sound and safe manner is expected to take 12–15 years.

The first phase of the ASP, already under way, targets seven countries for full cleanup and disposal activities: Ethiopia, Mali, Morocco, Nigeria (special preparatory activities), South Africa, Tanzania, and Tunisia. Preparations for undertaking cleanup and disposal operations will be made in another eight high-priority countries, selected from among 16 (Benin, Botswana, Cameroon, Côte d'Ivoire, Egypt, Ghana, Lesotho, Liberia, Mozambique, Namibia, Niger, Rwanda, Senegal, Sierra Leone, Sudan, and Swaziland).

Current ASP partners include the African Development Bank, African Union, Belgium, Canada, CropLife International (CLI), Denmark, European Union, FAO, France, GEF, Japan, the Netherlands, New Partnership for Africa's Development (NEPAD), Norway, Pesticides Action Network-Africa (PAN-Africa), Secretariat of the Basel Convention, Swedish International Development Cooperation Agency (SIDA), Switzerland, United Nations Economic Commission for Africa (UNECA), United Nations Environment Programme (UNEP), United Nations Industrial Development Organization (UNIDO), World Bank, World Health Organization (WHO), and World Wide Fund for Nature/WWF.

Source: www.africastockpiles.net.

- **Disposal.** After safeguarding obsolete pesticides, participating countries must decide on how to dispose of the stocks, based on a set of available disposal-technology options and performance standards and costs. All disposal options are in keeping with international, regional, and national legislation, regulations, and standards.

Need for Prioritized Interventions

Public health and environmental authorities in the countries affected are eager to remove and decontaminate stockpile sites. But cleanup and safe disposal of obsolete pesticides can be costly. Conducting national inventories of public stocks and their locations requires training in safe and accurate product identification,

handling, and labeling. Repackaging, storage, shipment, and incineration all depend on an array of factors, including product type, degree of contamination, and the disposal method used. Cost factors include the total quantity to be disposed of, site locations, and distance to ports of exit.

Given the wide distribution of contaminated sites, the high cost of field operations, and scarcity of public resources, prioritizing stockpiles for cleanup is quickly becoming a

necessary first step for policy makers in developing countries and economies in transition. An effective priority-setting method must not only analyze the chemical and risk characteristics of the obsolete pesticide stocks. It must also integrate these with the distance from human communities and critical ecosystems and biodiversity, especially the most vulnerable groups. The next section outlines such a method developed by the World Bank's Development Research Group, Environment and Energy Team.



Obsolete pesticide scavenged from burial site is heading to the local market in Central Asia.

SECTION 2

RISK ASSESSMENT METHOD FOR PRIORITY-SETTING

Based on the completed inventory of obsolete pesticide stocks in Tunisia under the ASP, a framework for risk assessment, developed by the World Bank's Development Research Group, Environment and Energy Team, was applied to this pilot project.

This risk assessment method involves four steps:

1. Characterize chemicals by active ingredient at the storage site level.
2. Assign alternative hazard indicators.
3. Overlay population-distribution and environmental data with the toxicity-weighted pesticide

contents of stockpiles for ranking by geographical area.

4. Identify priority areas or hot spots for cleanup.

Characterize Chemicals

The first step is to characterize the active ingredient—the chemical in each pesticide formulation that kills the pest in question—for each pesticide at the respective storage site. Data on the properties of active ingredients can be collected from a variety of proprietary and public sources. Since no one database contains all active ingredients, it is useful to have several sources.³ The best method for referencing is the Chemical Abstract



Abdelaziz Lagnaoui

Pesticide market in Lagos, Nigeria.

Number (CAS) or the correct spelling of the active ingredient. Once the active ingredients of the respective stockpile have been determined, the next step is to measure the total volume of active ingredients contained in the stock. This is achieved by multiplying the quantity of pesticide in the stock (found in the inventory database) by the concentration of active ingredient (table 1).

Assign Hazard Indicators

To calculate the relative toxicity of each stockpile, the active ingredients are referenced and classified according to their (i) World Health Organization (WHO) recommended classification by

hazard, (ii) chemical class and intended use, and (iii) acute toxicity indicator and hazard range.

The active ingredients are referenced according to their WHO toxicity rankings (WHO 2005), which are listed in the database sources used in Step 1. The WHO uses five toxicity rankings: Extremely Hazardous (Ia), Highly Hazardous (Ib), Moderately Hazardous (II), Slightly Hazardous (III), and Unlikely To Pose Health Hazard (table 5). Highly hazardous and moderately hazardous active ingredients (Ia and Ib) represent 5.8 percent (38.50 kg) of all stockpiles by volume (table 2).

Active ingredients are also referenced according to their chemical class and end use. Organophosphates, carbamates, pyrethroids, and organochlorines—chemical classes associated with severe health effects—together comprise more than 55 percent of all stocks in the sample (Zahm, Ward, and Blair 1997; FAO 2001) (table 3).

In addition to volume-based hazard indicators, WHO acute toxicity indicators—the lethal dose (mg per kg of body weight) or lethal concentration (mg per liter of body weight) for 50 percent of a test group (LD₅₀ and LC₅₀, respectively)—are used to rank active ingredients. Toxicity values vary exponentially, highlighting the

TABLE 1 Sample stockpile volume of active ingredients

| Pesticide | | | Active ingredient | | | |
|--|----------|-----------------|-----------------------|---------------|--------------------|---------------|
| Commercial name ¹ | Quantity | Unit of measure | Name | Concentration | Unit of measure | Volume (kg) |
| Phosdrin | 50 | liter | Mevinphos | 100 | g/liter | 5.00 |
| Dimecron | 50 | liter | Phosphamidon | 500 | g/liter | 25.00 |
| Furadan | 70 | kg | Carbofuran | 5 | % W/W ² | 3.50 |
| Lannate | 20 | kg | Methomyl | 25 | % W/W ² | 5.00 |
| Decis | 200 | liter | Deltamethrin | 25 | % V/V ³ | 50.00 |
| — | 78 | kg | Metaldehyde | 50 | % W/W ² | 39.00 |
| Novathion | 150 | liter | Fenitrothion | 50 | % V/V ³ | 75.00 |
| — | 100 | kg | HCH (gamma-HCH) | 50 | % W/W ² | 50.00 |
| Anteor C3 | 200 | kg | Cymoxanil | 45 | % W/W ² | 90.00 |
| Fyfanon | 300 | liter | Malathion | 500 | g/liter | 150.00 |
| Cuprosan | 68 | kg | Copper oxychloride | 50 | % W/W ² | 34.00 |
| Dosanex | 50 | kg | Metoxuron | 80 | % W/W ² | 40.00 |
| Antracol | 112 | kg | Propineb | 70 | % W/W ² | 78.40 |
| — | 30 | liter | Trifluralin | 480 | g/liter | 14.40 |
| Total volume of active ingredients: | | | | | | 659.30 |

Notes: 1. Commercial names may not be unique, depending on producer and country.

2. W/W = weight per (mass) weight.

3. V/V = volume per volume.

limitation of using only volume-based hazard indicators for priority-setting.

Next, a toxicity-weighted measure of hazard is constructed for each active ingredient. This is calculated by inverting the LD₅₀ or LC₅₀ value to give more toxic chemicals greater weight.

Among the 14 active ingredients samples, there is great variation within sub-populations. For example, the toxicity-weighted volume of 100 kg of the active ingredient Mevinphos, with an LD₅₀ value for humans of 4 mg per kg, is calculated as $100 \times 1/4 = 25$. That of 100 kg of Trifluralin,

TABLE 2 WHO ranking of sample stocks of active ingredients

| <i>Active ingredient</i> | <i>Volume (kg)</i> | <i>WHO toxicity ranking</i> | <i>Percent of volume</i> |
|--------------------------|--------------------|-----------------------------|--------------------------|
| Mevinphos | 5.00 | Ia | 0.76 |
| Phosphamidon | 25.00 | Ia | 3.79 |
| Carbofuran | 3.50 | Ib | 0.53 |
| Methomyl | 5.00 | Ib | 0.76 |
| Deltamethrin | 50.00 | II | 7.58 |
| Metaldehyde | 39.00 | II | 5.92 |
| Fenitrothion | 75.00 | II | 11.38 |
| HCH (gamma-HCH) | 50.00 | II | 7.58 |
| Cymoxanil | 90.00 | III | 13.65 |
| Malathion | 150.00 | III | 22.75 |
| Copper oxychloride | 34.00 | III | 5.16 |
| Metoxuron | 40.00 | Table 5 | 6.07 |
| Propineb | 78.40 | Table 5 | 11.89 |
| Trifluralin | 14.40 | Table 5 | 2.18 |
| Total | 659.30 | | 100.00 |

TABLE 3 Active ingredient volume by chemical class and end use

| <i>Active ingredient</i> | <i>Volume (kg)</i> | <i>Chemical class</i> | <i>End-use type</i> | <i>Percent of volume</i> |
|--------------------------|--------------------|-----------------------|------------------------|--------------------------|
| Mevinphos | 5.00 | Organophosphate | Insecticide | 0.76 |
| Phosphamidon | 25.00 | Organophosphate | Insecticide/acaracide | 3.79 |
| Carbofuran | 3.50 | Carbamate | Insecticide/nematicide | 0.53 |
| Methomyl | 5.00 | Carbamate | Insecticide | 0.76 |
| Deltamethrin | 50.00 | Pyrethroid | Insecticide | 7.58 |
| Metaldehyde | 39.00 | Molluscicide | Molluscicide | 5.92 |
| Fenitrothion | 75.00 | Organophosphate | Insecticide | 11.38 |
| HCH (gamma-HCH) | 50.00 | Organochlorine | Insecticide | 7.58 |
| Cymoxanil | 90.00 | Aliphatic nitrogen | Fungicide | 13.65 |
| Malathion | 150.00 | Organophosphate | Insecticide/acaracide | 22.75 |

(continued on page 19)

TABLE 3 Active ingredient volume by chemical class and end use (*continued from page 18*)

| Active ingredient | Volume (kg) | Chemical class | End-use type | Percent of volume |
|--------------------|---------------|--------------------|--------------|-------------------|
| Copper oxychloride | 34.00 | Inorganic | Fungicide | 5.16 |
| Metoxuron | 40.00 | Urea | Herbicide | 6.07 |
| Propineb | 78.40 | Dithiocarbamate | Fungicide | 11.89 |
| Trifluralin | 14.40 | 2,6-Dinitroaniline | Herbicide | 2.18 |
| Total | 659.30 | | | 100.00 |

which has an LD₅₀ value for humans of 1,930 kg per mg, is calculated as $100 \times 1/1,930 = 0.052$. There is also great variation across sub-populations. For example, Deltamethrin is ranked fifth in terms of LD₅₀-weighted volume for humans, but it is first for fish, and by an extremely wide margin. This demonstrates the importance of the perspective one uses to gauge priorities.

Finally, these weighted volumes are summarized according to the hazard range of the respective active ingredient: High Hazard (LD₅₀ < 50 mg per kg), Medium Hazard (LD₅₀ = 50–500 mg per kg), and Low Hazard (LD₅₀ > 500 mg per kg). When calculated for humans, it is found that more than 78 percent of the toxicity-weighted volume of stockpiles is highly hazardous (table 4).

Similar calculations can be performed for mammals, birds, and fish, using the appropriate ranges of LD₅₀ and LC₅₀.

Overlay Geo-Referenced Population or Environmental Data

To assess whether stockpiles are spatially correlated with vulnerable segments of the population and environment, relevant socio-demographic and biodiversity data can be overlaid onto pesticide information for ranking by geographical area.

To assess the potential threat to public health, population data is collected from the most recent census. It is advantageous to have this information at a more refined geographical unit of analysis to increase confidence in associating proximate stockpiles of obsolete pesticides with health effects. The next step is to determine the distribution of the total population and vulnerable segments by this geographical unit (in this case, district level). Women of child-bearing age and young children (under five years) are used since these groups are

TABLE 4 LD50-weighted volume by hazard range for humans

| <i>Active ingredient</i> | <i>Volume (kg)</i> | <i>LD50 for humans (mg/kg)</i> | <i>LD50 weighted volume (kg)</i> | <i>Percent of total volume</i> | <i>Hazard range</i> |
|--------------------------|--------------------|--------------------------------|----------------------------------|--------------------------------|---------------------|
| Mevinphos | 5.00 | 4.0 | 1.25 | 24.9 | High |
| Phosphamidon | 25.00 | 17.9 | 1.40 | 27.8 | High |
| Carbofuran | 3.50 | 8.0 | 0.44 | 8.7 | High |
| Methomyl | 5.00 | 17.0 | 0.29 | 5.9 | High |
| Deltamethrin | 50.00 | 135.0 | 0.37 | 7.4 | Medium |
| Metaldehyde | 39.00 | 283.0 | 0.14 | 2.7 | Medium |
| Fenitrothion | 75.00 | 250.0 | 0.30 | 6.0 | Medium |
| HCH (gamma-HCH) | 50.00 | 88.0 | 0.57 | 11.3 | High |
| Cymoxanil | 90.00 | 1,196.0 | 0.08 | 1.5 | Low |
| Malathion | 150.00 | 1,375.0 | 0.11 | 2.2 | Low |
| Copper oxychloride | 34.00 | 700.0 | 0.05 | 1.0 | Low |
| Metoxuron | 40.00 | 3,200.0 | 0.01 | 0.2 | Low |
| Propineb | 78.40 | 5,000.0 | 0.02 | 0.3 | Low |
| Trifluralin | 14.40 | 1,930.0 | 0.01 | 0.1 | Low |
| Total | 659.30 | 14,203.9 | 5.02 | 100.00 | |

especially susceptible to the effects of highly toxic active ingredients. The active ingredients are also geo-referenced to the district-level unit.

By combining this data, it is possible to determine the intensity of each active ingredient at the district level for each of the indicators used. The information can be summarized by the total population and per capita, and the analysis can be repeated for the more vulnerable segments of the population (table 5). Results demonstrate that

setting priorities based only on volume or total population could be misleading.

Instead of summarizing the information by district, one could also explore the interface between obsolete pesticide stockpiles and ecoregions, national parks, and biodiversity, including animal or fish species susceptible to particular active ingredients or classes of active ingredients.

TABLE 5 Active ingredient intensity for three sample districts by vulnerable population segment

| Indicator | Women of childbearing age | | | Children (under 5 years of age) | | |
|---|---------------------------|------------|------------|---------------------------------|------------|------------|
| | District 1 | District 2 | District 3 | District 1 | District 2 | District 3 |
| Population | 9,751 | 9,480 | 8,834 | 1,775 | 2,312 | 2,409 |
| | <i>kg/1,000</i> | | | <i>kg/1,000</i> | | |
| Volume | 32.14 | 18.29 | 19.53 | 176.56 | 75.00 | 71.61 |
| <i>WHO hazard rank</i> | | | | | | |
| Ia | 0.51 | 2.64 | 0.00 | 2.82 | 10.81 | 0.00 |
| Ib | 0.51 | 0.00 | 0.40 | 2.82 | 0.00 | 1.45 |
| II | 7.69 | 10.55 | 4.41 | 42.25 | 43.25 | 16.19 |
| III | 15.38 | 3.59 | 10.19 | 84.51 | 14.71 | 37.36 |
| Table 5 | 8.04 | 1.52 | 4.53 | 44.17 | 6.23 | 16.60 |
| <i>Chemical class</i> | | | | | | |
| Organophosphate | 23.59 | 2.64 | 0.00 | 129.58 | 10.81 | 0.00 |
| Organochlorine | 0.00 | 5.27 | 0.00 | 0.00 | 21.63 | 0.00 |
| Carbamate | 0.51 | 0.00 | 0.40 | 2.82 | 0.00 | 1.45 |
| Pyrethroid | 0.00 | 5.27 | 0.00 | 0.00 | 21.63 | 0.00 |
| Other | 8.04 | 5.11 | 19.13 | 44.17 | 20.93 | 70.15 |
| <i>End-use type</i> | | | | | | |
| Insecticide | 24.10 | 13.19 | 0.40 | 132.39 | 54.07 | 1.45 |
| Herbicide | 0.00 | 1.52 | 4.53 | 0.00 | 6.23 | 16.60 |
| Fungicide | 8.04 | 3.59 | 10.19 | 44.17 | 14.71 | 37.36 |
| Other | 0.00 | 0.00 | 4.41 | 0.00 | 0.00 | 16.19 |
| <i>Acute toxicity (weighted volume)</i> | | | | | | |
| LD50 (humans) | 26.50 | 33.11 | 9.85 | 145.59 | 135.75 | 36.13 |
| LD50 (mammals) | 31.04 | 28.90 | 9.36 | 170.50 | 118.49 | 34.33 |
| LD50 (birds) | 18.12 | 29.63 | 22.84 | 99.52 | 121.48 | 83.76 |
| LC50 (fish) | 2.33 | 67.14 | 0.01 | 12.80 | 275.31 | 0.03 |
| <i>Hazard range (humans)</i> | | | | | | |
| High | 20.78 | 27.20 | 6.50 | 114.18 | 111.54 | 23.84 |
| Medium | 4.04 | 5.13 | 2.05 | 22.18 | 21.03 | 7.51 |
| Low | 1.68 | 0.78 | 1.30 | 9.23 | 3.18 | 4.78 |

Identify Hot Spots for Intervention

This simplified risk assessment exercise focuses on 14 active ingredients and three districts, yet developing countries typically have several hundred chemicals and districts. While calculations can be sorted and ranked using spreadsheets, a Geographic Information System (GIS) offers a more powerful tool for facilitating the

prioritization of cleanup. Using GIS, researchers can analyze the spatial distribution of the obsolete stockpiles in relation to population density and areas rich in biodiversity. These spatial patterns, in turn, allow policy makers to visualize the threat to human health and biodiversity and decide on needed measures to reduce exposure. The next section summarizes the results of applying this risk assessment method using a GIS decision tool in Tunisia.

SECTION 3 SETTING CLEANUP PRIORITIES IN TUNISIA

Like other low- and middle-income countries, Tunisia has sites of obsolete pesticide stockpiles that pose serious health and environmental risks. Under the ASP, the waste management agency of Tunisia's Ministry of Environment and Sustainable Development, known as ANGED (*Agence Nationale de Gestion des Déchets*), has finalized and verified a detailed inventory of all publicly-held pesticide stockpiles in the country. The inventory notes the geo-location of the storage sites, their characteristics, the identity and quantity of contaminants, and the general condition of the stockpiles.

Overall, Tunisia has about 1,984 metric tons of obsolete pesticide formulations (759 tons of active ingredients) in 197 storage sites. A total of 563 metric tons (74 percent of the total) of active ingredients were identifiable from the database, while 196 tons (26 percent) were not. A preliminary investigation revealed that only 11 percent of the stockpiles were contained in undamaged packages; 47 percent of packages were either broken or showed surface damage, 8 percent indicated leakage, and 34 percent were considered to be contaminating the soil and equipment (figure 2).

FIGURE 2 Pesticide storage site in Tunisia



Hot Spots — Hazards to Public Health

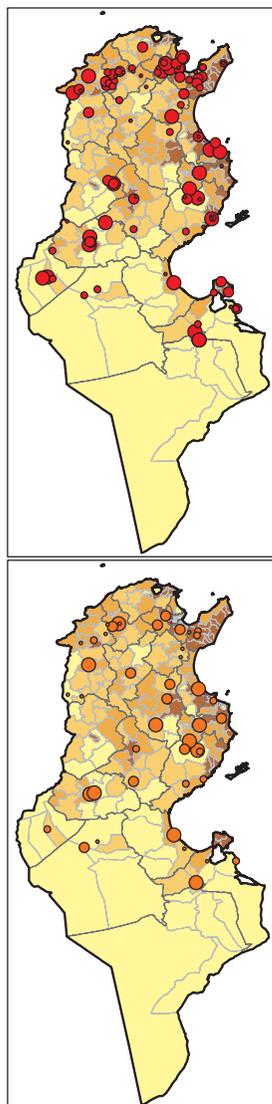
The risk assessment method outlined in Section 2 was applied to Tunisia's 197 sites to rank priority sites for cleanup and safeguarding. For each pesticide, exposure damage potential was determined by three factors: the pesticide's risk, number of exposed people (by weighted vulnerability class), and degree of exposure.⁴ It was found that the pesticide classes of greatest risk (WHO Ia and Ib) were stockpiled in only a quarter of

the country's delegations,⁵ and large volumes appeared only in delegations above the 90th percentile. The robustness of the method was tested by assigning wide-ranging variables to key model parameters, including weighted and unweighted populations and pesticide volumes and several distance risk-decay values. Results were heavily dominated by five sites, which achieved a high priority index value for some combination of hazard, population vulnerability, and risk-decay parameters (Dasgupta, Meisner, and Wheeler 2009).

The analysis drew upon population and biodiversity information in a GIS. Demographic characteristics, derived from the census at the delegation administrative level, included age and gender categories, which were matched to corresponding boundaries in the GIS. Biodiversity data was at species, ecoregion, and protected-area scales. To identify the country's most important endangered species, range maps provided by Conservation International were matched with International Union for Conservation of Nature (IUCN) Red List categories. Critical/endangered ecoregions were identified by Olsen et al. (2001), while the United Nations Environment Programme–World Conservation Monitoring Centre and IUCN (2007) provided spatial data on the location of parks, with selected areas delineated with boundaries.

Using the GIS decision tool, district-level population density was mapped onto the coordinates (latitude and longitude) of obsolete pesticide stockpiles. Mapping results showed a high concentration of stockpiles co-located with highly populated areas, particularly in northern Tunisia. When population density maps of vulnerable populations (children under age five and women of childbearing age) were overlaid onto distribution maps of stockpiles with organophosphates and carbamates—two chemical classes associated with severe health effects—it was found that organophosphates were more prevalent in northern districts, while carbamates predominated in eastern districts (figure 3). When population density

FIGURE 3 Density of children (<5 years) and organophosphates (top) and carbamates (bottom) (darker areas represent higher population per square area)



Data sources: 2004 Demographic Census of Tunisia, Institut National de la Statistique (INS); Stockpile locations: Agence Nationale de Gestion des Déchets (ANGed).

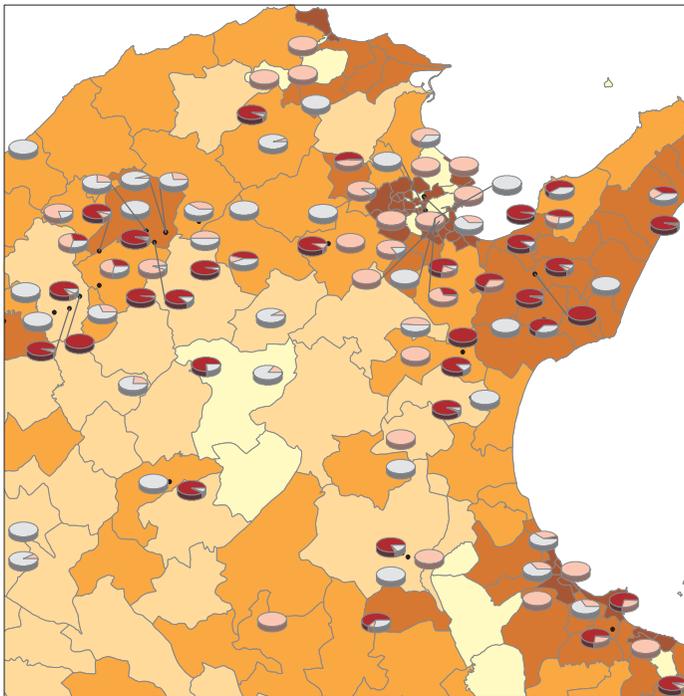
in northern Tunisia was mapped onto stockpiles toxicity-weighted for humans, results revealed several districts where the share of highly hazardous material is close to 100 percent (figure 4). Thus, depending on relative stockpile volume and storage conditions, these districts could be flagged as a top priority for cleanup and safeguarding (Dasgupta and Meisner 2008).

Hot Spots — Hazards to Ecoregions and Biodiversity

To ascertain whether obsolete pesticide stockpiles pose hazards to any of Tunisia’s critical ecosystems and biodiversity (box 4), the risk assessment method outlined in Section 2 was applied, using geographic overlays of species range maps, critical/endangered ecoregions, and national parks of global significance in terms of biodiversity.⁶

FIGURE 4 Population density and distribution of human LD₅₀-weighted ingredients

Colored pies represent the share of high (dark red), medium (pink), and low (grey) hazard active ingredients; darker areas represent higher population per square area.



Data sources: 2004 Demographic Census of Tunisia, INS; Stockpile locations: ANGED.

BOX 4 Tunisia's environmental wealth

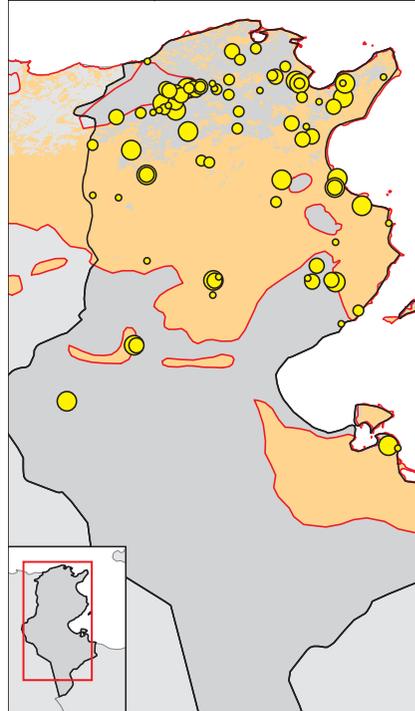
Tunisia is diverse in climate and elevation, ranging from the dry Sahara in the south to the semi-arid and more mountainous Mediterranean region in the north. As a result, the country is remarkably rich in ecosystems and biodiversity. According to the World Wildlife Fund (WWF) classification system, Tunisia comprises five ecoregions. The northern part of the country encompasses two critical/endangered ecoregions of global significance: Mediterranean Conifer and Mixed Forest and Mediterranean Woodlands and Forest. Conservation International considers this area a global hot spot of biodiversity. Two other ecoregions—Northern Sahara Steppe and Woodlands and Mediterranean Dry Woodlands and Steppe—are classified as vulnerable by the WWF.

According to the Third National Report on Biodiversity in Tunisia, the country has 2,924 species of vascular plants, of which 239 are endangered and 101 seriously threatened. The number of fauna species totals 2,210 (78 mammals, 362 birds, 336 fish, and 1,434 invertebrates), of which 57 species are seriously threatened, particularly birds, fish, and reptiles.

Sources: Olsen et al. 2001; www.biodiversityhotspots.org; <http://smap.ew.eea.europa.eu>

GIS mapping results showed that a large volume of stockpiled herbicides are located within the critical/endangered ecoregion of the Mediterranean Woodlands and Forest (figure 5).

FIGURE 5 Stockpiles of herbicides in the Critical/Endangered Mediterranean woodlands and forest



Data sources: Modified WWF Ecoregions (Olsen et al., 2001); Stockpile locations: ANGED.

Tunisia, along with Algeria and Morocco, provides winter habitat for many species that breed in Eurasia and winter throughout the Mediterranean region. Among the 130 species known to use Tunisia as a stopover on their way to and from the Afro-tropical region, *Falco cherrug* has been identified as endangered by the International Union for the Conservation of Nature. To determine

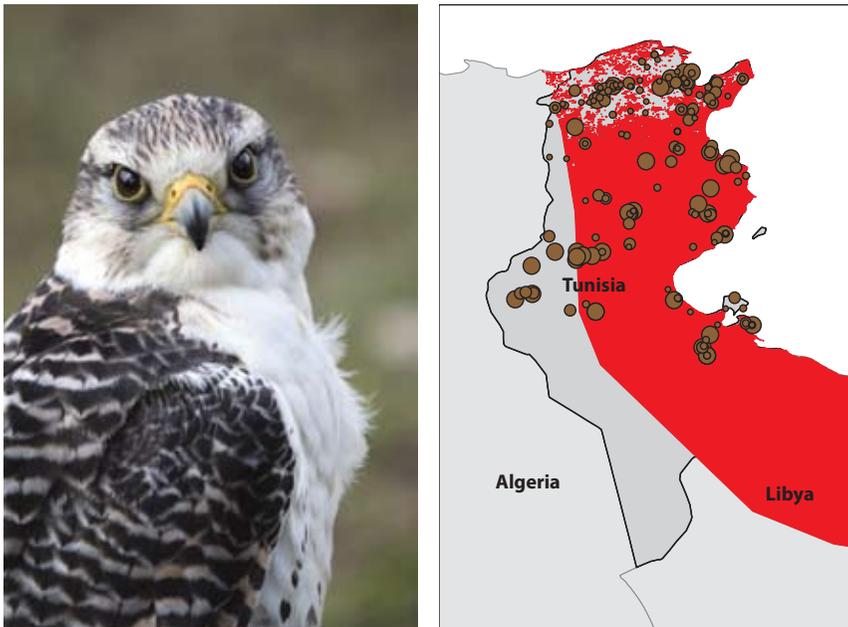
whether obsolete pesticide stockpiles pose a risk to *Falco cherrug*, the bird's known range map, based on global data,⁷ was charted. Using the GIS software tool, distribution of stockpiles with LD₅₀-weighted active ingredients was overlaid onto the species range map (figure 6). Determining whether *Falco cherrug* feeding or nesting grounds coincide with the stockpiles is an area of concern that warrants further investigation.

Ichkeul National Park, located in northern Tunisia about 25 km south of Bizerte near the shores of the Mediterranean Sea, has global

significance in biodiversity, with more than 600 species of flora and many fauna, including 225 species of avifauna. According to the IUCN, wildlife at risk in Ichkeul National Park include an endangered mammal (*Gazella cuvieri*),⁸ two endangered birds (*Oxyura leucocephala* and *Falco cherrug*), and a near-threatened fish (*Heptranchias perlo*) (figure 7).

The geo-location of stockpiles indicated that four are located in close proximity to Ichkeul National Park. Most of the stored pesticides are insecticides, and three sites (in Menzel Bourguiba) also include organochlorine compounds.

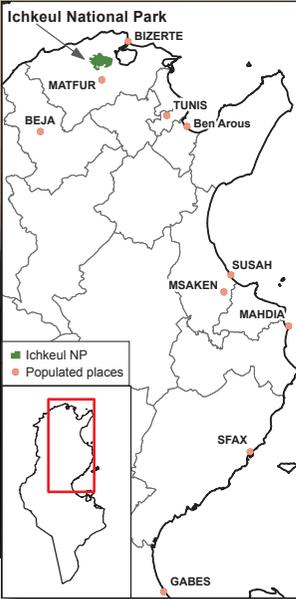
FIGURE 6 Potential threat to *Falco cherrug*



Data sources: Modified WWF Ecoregions (Olsen et al., 2001); Stockpile locations: ANGED.

FIGURE 7 Ichkeul National Park and wildlife species at risk

Data sources: Protected areas: UNEP-WCMC and IUCN, 2007; Stockpile locations: ANGED.



Dhifaouzi/Wikimedia Commons



ImageShack

Given the persistent nature of this chemical class, risks to the environment are particularly severe, especially at one site where the entire stock indicates surface damage in packaging.

To assess the overall environmental impact of the pesticides, the Environment Impact Quotient (EIQ) associated with the active ingredients was used.⁹ Researchers at Cornell University constructed the EIQ by combining information on dermal toxicity, chronic toxicity, systemicity, fish toxicity, leaching potential, surface-loss potential, bird toxicity, soil half-life, bee toxicity, beneficial arthropod toxicity, and plant surface

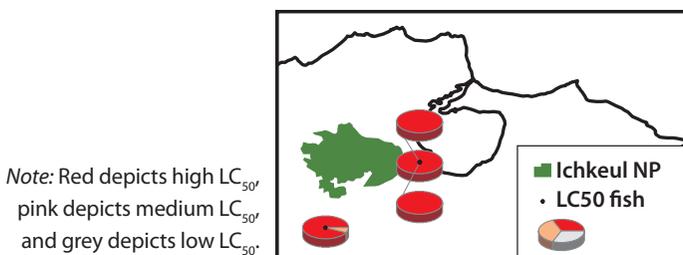
half-life for individual pesticides. Estimates revealed that chemicals stored at stockpiles at one site (in Mateur) are associated with potentially significant effects on fish, birds, bees, and beneficial arthropods. In addition, this stockpile has 806.5 kg of highly toxic Parathion-methyl.¹⁰ This finding is particularly alarming as 19 percent of the containers in Mateur already indicate signs of leakage (figure 8).

This exercise provided a reasonable first approximation for cleanup action since it highlighted sites that achieve a high priority value for certain combinations of hazard, exposure, environmental vulnerability, and relative proximity to the toxic load.

FIGURE 8 Relative toxicity of chemicals stockpiled near Ichkeul National Park

| Stockpile | EIQ | LC ₅₀ -weighted active |
|-----------------------|--------|-----------------------------------|
| Mateur * | 250.33 | 1,214.68 |
| Menzel Bourguiba, 1** | - | 65,625 |
| Menzel Bourguiba, 2 | - | 450,000 |
| Menzel Bourguiba, 3 | - | 175,000 |

* 19% of stock indicates leakage.
 ** 100% indicates surface damage.



Data sources: Protected areas: UNEP-WCMC and IUCN, 2007; Stockpile locations: ANGED.

What Was Learned

This method proved effective in assessing the relative toxicity risk of stockpile sites to people and biodiversity in Tunisia as it integrated data on at-risk populations and ecosystems, their proximity to stockpiles, and the toxic hazards of the stockpile chemicals. Because this risk-assessment method was integrated

with a GIS-based tool for hotspot analysis, it was possible to visualize the intersection of vulnerable segments of the population and environment with highly toxic stockpiles. Finally, test results demonstrated a clear ranking and sequence strategy for operations, suggesting that policy makers using this method would be able to focus disposal efforts and public resources on the highest priority areas.



SECTION 4 CLEANUP AND SAFEGUARDING HIGHLIGHTS IN AFRICA

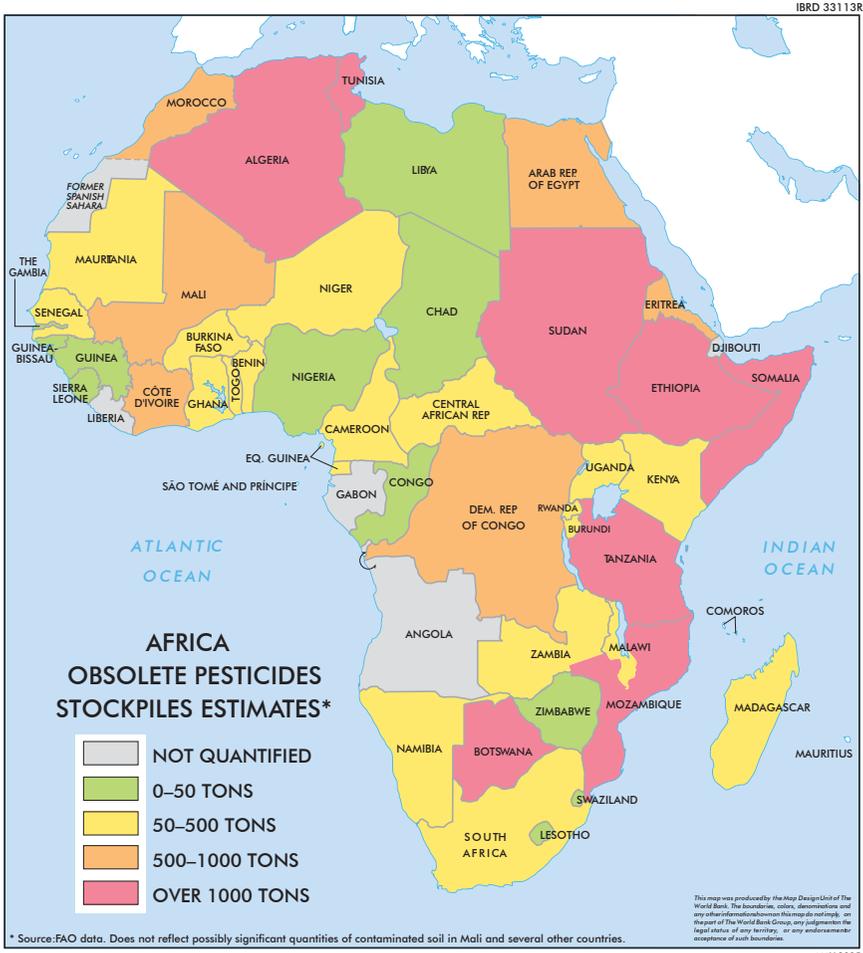
Inventories of obsolete pesticides have been completed in several high-priority African countries under the ASP and preparation for disposal is under way (figure 9). As more national inventories become available, policy makers may wish to consider the geo-referenced risk assessment method presented in Section 2 as an option for prioritizing cleanup. Highlighted below are selected ASP projects and their various stages of cleanup and safeguarding.

Tunisia

The Tunisia pilot project is funded by the GEF (US\$4 million), French

Global Environment Facility (\$1 million), and Tunisian government (\$0.5 million), with additional support from the World Bank's Development Grant Facility. ASP-Tunisia has completed its national inventory of more than 1,900 metric tons of obsolete pesticide formulations, and preparation for collection and disposal is under way. The data collected in site surveys has been used in FAO-developed software to generate a risk assessment of each store, making it possible to easily identify and prioritize high-risk sites for urgent action (Section 3). One such site was identified on the grounds of the Menzel Bourguiba hospital, where it was found that 40 tons of DDT—much

FIGURE 9 The African continent has some 50,000 tons of obsolete pesticides



of it leaking—had been stored for 50 years. The DDT was safely repackaged and stored until removal and final destruction.

Tanzania

Over the past 40 years, Tanzania has accumulated more than 1,300 tons of

obsolete pesticide stocks. Under the ASP-Tanzania project, launched in 2007, 650 tons of obsolete stocks had been inventoried by mid-2009. The inventory process has been closely linked with a national communication strategy, which includes training of NGOs to implement community-based awareness raising. The project has successfully tested a monitoring

and evaluation toolkit provided by the World Bank and FAO. Total project financing is US\$7.48 million, with funds provided by a GEF grant (\$6.87 million), the Ethiopian government (\$0.39 million), and the Netherlands via FAO (\$0.22 million).

To address the likely budget gap for disposal and prevention activities, the project is considering alternatives to costly shipments to Europe for high-temperature combustion in dedicated incinerators. One promising option is the high-temperature cement kiln. Earlier disposal operations using cement kilns—including a 1996 study by the German Agency for Technical Cooperation (GTZ) of dinitro-o-cresol (DNOC) in Tanzania—were unable to verify destruction efficiency. But lessons from these studies were later used in a test burn of two obsolete insecticides in a cement kiln in Vietnam (Karstensen et al. 2006). The hazardous chemicals were destroyed in an irreversible and environmentally sound manner in full compliance with the Stockholm Convention.

Mali

The US\$8.33 million ASP-Mali project, with \$3.98 million from the Multi-donor Trust Fund and \$2.55 million in GEF grant funding, has inventoried some 1,100 tons of obsolete pesticides, plus a large volume of contaminated



soils and buried pesticides. Civil society and nongovernmental organization (NGO) participation in prevention and awareness-raising activities is high. Adequate safeguarding of widely scattered obsolete stocks (particularly high-risk sites) prior to pesticide disposal has been a major project challenge. On-the-ground operations to reduce public health and environmental risks are progressing.

At the **Molodo** site, ASP-Mali launched operations to remove, safeguard, and transport obsolete toxic stocks left over from past regional locust and bird control programs. The project removed 600 barrels of dieldrin and parathion from a cemented pit located within 50 yards of Molodo's plant protection facility to a safer storage facility in Noumoubougou, about 30 km from Bamako. Some 400 liters of obsolete liquid pesticides found in the plant protection facility were transferred to newer containers. Decontamination by land farming, a technique that works the soil and promotes natural degradation

of pesticides by soil bacteria, was successfully tested at the storage site and vicinity with support from FAO and Wageningen University of the Netherlands.

The project applied this land-farming technique at the **Niogomera** site, where large stocks of obsolete pesticides and empty containers had contaminated the soil for more than 20 years. Built in 1965 by the former Locust and Bird Control Organization of West Africa, the Niogomera storage center, known as the Pesticide Graveyard, was secured and fenced in 2002, and a retention system was built to reduce water contamination in a nearby village. Failure of the system in the early 2000s posed a serious public health and environmental risk. In response, the project constructed a dyke to retain site rainwater and prevent contamination during field operations. In addition, 500 rusted and damaged metal containers, stored as nine large waste piles, were crushed and transported to the Noumoubougou site for final disposal.

Ethiopia

Before 2000, Ethiopia was found to have stockpiled more than 2,500 tons of obsolete pesticides. The key reasons included unregulated imports, selling, and donations over a 50-year period. Most of these obsolete stocks are of poor quality and are improperly packed and labeled. The

country was also found to have 1,000 tons of contaminated soils at more than 900 sites. A national inventory conducted by FAO in 1999 found more than 1,500 tons of obsolete stocks at 256 sites. A major disposal project conducted from 2000–2003 under the leadership of FAO, in collaboration with Ethiopia’s Ministry of Agriculture, collected and moved these obsolete stocks to ten in-country storage sites before transporting them to Finland for high-temperature incineration. A total of US\$4.4 million was required, with funds from the Netherlands (\$2.2 million), Sweden (\$1.2 million), and the United States (\$1 million) (Haylamicheal and Dalvie 2009).

A second project phase, initiated in 2006, is to dispose of the country’s remaining obsolete stocks at incineration facilities in the UK and Germany. This phase also focuses on container management, regulatory and policy reform, promotion of Integrated Pest Management (IPM) and Integrated Vector Management (IVM), and pesticide awareness-raising activities. The total cost of disposal and post-disposal activities is about \$US8.13 million, with funds provided by Belgium (\$3.89 million), Finland (\$1.11 million), Japan (\$1.14 million), the ASP (\$1.30 million), CLI (\$0.40 million), and Ethiopia (\$0.29 million). A US\$2.62 million GEF grant signed in 2007 supports disposal and prevention activities.

SECTION 5 REDUCING THE RISK

Many participating ASP countries underestimated the quantities of stockpiled obsolete pesticides during initial project preparation. The subsequent discovery of additional stocks during field operations, combined with the rising unit cost of disposal consistent with international and regional conventions, leaves many countries facing a financing gap.

But this challenge is not unique to ASP countries. Most developing countries and economies in transition with accumulated obsolete stocks lack sufficient financial resources to manage inventory and disposal operations safely and reliably. In light of the

large quantities of stocks, the growing expense of cleanup operations, and limited public resources, priority-setting is quickly becoming a necessary first step for policy makers.

Any project involving obsolete pesticides cleanup is a complex and dangerous undertaking for several major reasons. First, the chemicals are extremely toxic. In most cases, obsolete pesticides are improperly stored or discarded in abandoned sites, posing serious risks to human health and the environment. They are particularly harmful to those directly in contact with the chemicals, such as agricultural workers and communities living near storage sites. Through soil, water,

and the food chain, the pollutants accumulate in the fatty tissue of both humans and animals, and residues find their way into the blood stream. Some of these chemicals are proven to cause cancers, birth defects, and neurological problems. Moreover, many of the negative impacts are borne disproportionately by the poor (Goldman and Tran 2002).

Second, the cleanup process is not without risk. It involves a series of complex operations of chain of custody, from taking inventory to handling and transport and final disposal. In many instances, the chain of operations entails environmental, health, and socioeconomic impacts.

Finally, the costs associated with cleanup operations tend to be high, but poor countries often have more urgent priorities. For these reasons, it is critical to assess the situation at the national, regional, and local levels and prioritize sites to appropriately manage the cleanup process. This study provides a tool to systematically assess and prioritize the potential effects of obsolete stocks to inform plans, programs, and policies to manage them.

From a donor perspective, there is a significant reputational risk

associated with obsolete-pesticide cleanup operations. As a result, a full environmental and social assessment is often required prior to project appraisal. The environmental impacts are related mainly to handling, transport, and disposal operations. The major institutional risk is that such projects involve dangerously toxic and hazardous waste materials. The first step in preparing the Environmental Assessment is collecting baseline data, used as indicators for comparing sites. For this purpose, overlaying population-distribution and environmental data with the toxicity-weighted pesticide contents of stockpiles is a practical tool to visualize the potential impacts on human health and the environment, and to devise sound mitigation measures.

The development of methods and tools that incorporate alternative hazard criteria, coupled with the spatial dimensions of potential exposure, highlight trade-offs inherent in decision making. Future cleanup investments that adopt such pre-appraisal approaches as the GIS-based method applied in Tunisia can minimize the hazards to public health and the environment, and maximize the efficiency of public resources.

ENDNOTES

1. The POPS pesticides are aldrin, chlordane, endrin, dieldrin, heptachlor, DDT, toxaphene, mirex, and hexachlorobenzene (HCB).
2. The Technical Support Unit has developed a series of technical guidelines to assist country teams in this activity. (FAO 1995a, 1995b, 1996).
3. For Tunisia, six main sources were used to reference active ingredients: the pesticide manual of the British Crop Protection Council (www.pesticidemanual.com/index.htm), U.S. National Medical Library of Medicine (<http://chem.sis.nlm.nih.gov/chemidplus/chemidlite.jsp>), pesticide database of the Pesticide Action Network (PAN) (www.pesticideinfo.org), Extension Toxicology Network (EXTOXNET) (<http://extoxnet.orst.edu/ghindex.html>), International Programme on Chemical Safety (www.inchem.org), and Pesticide Management Education Program (<http://pmep.cce.cornell.edu>).
4. Population data was downloaded from the 2004 Demographic Census of Tunisia (National Statistics Institute), and two vulnerable population classes were constructed (children under age five and women of childbearing age); land area was computed at the delegation level from the GIS databases of the ANGED (Dasgupta, Meisner, and Wheeler 2009).

5. In Tunisia, delegations are second-level administrative divisions between the governorates and sectors.
6. This section is excerpted from Blankespoor et al. (2009).
7. The delineated habitat range coincides with 18 site observations recorded in Isenmann et al. (2005).
8. Thanks to reintroduction efforts in Tunisia, another mammal of particular interest in the *Bovidae* family is *Oryx dammah* (Direction de la Conservation de la Nature, Direction Générale des Forêts Ministère de l'Agriculture 2001) and Royal Belgian Institute of Natural Sciences (2006).
9. $EQI\ total = \{C[(DT*5) + (DT*P)] + [(C*((S=P)/2)*SY) + (L)] + [(F*R) + (D*((S+P)/2)*3) + (Z*P*3) + (B*P*5)]\}/3,$

where DT = dermal toxicity, C = chronic toxicity, SY = systemicity, F = fish toxicity, L = leaching potential, R = surface loss potential, D = bird toxicity, S = soil half-life, Z = bee toxicity, B = beneficial arthropod toxicity, and P = plant surface half-life.

10. Parathion is an organophosphate compound. It is a potent insecticide and acaricide and is highly toxic to non-target organisms, including humans. Parathion-methyl is a cholinesterase inhibitor. It has been classified as a POP by the UNEP and as Extremely Hazardous (toxicity class Ia) by the WHO. It is very toxic to bees, fish, birds, and other forms of wildlife. More details are available at <http://en.wikipedia.org/wiki/Parathion>.

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