EXPOSURE ASSESSMENT TO HAZARDOUS PESTICIDES – STRATEGIES TO REDUCE HUMAN AND ENVIRONMENTAL RISKS

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Abstract. In a generic way, obsolete pesticides can be defined as those that can no longer be used for their intended purpose or any other purpose and thus need to be disposed. Almost every developing country and economy in transition has stocks of obsolete pesticides. Due to many factors, obsolete pesticides have been stored under conditions that do not meet safe and responsible requirements, posing a significant risk of leaking. The assessment of the storage and containment conditions for obsolete pesticides implies a site-by-site evaluation in order to detect these eventual leakages. Leaked pesticides will be dispersed in the environment by wind, evaporation, spillage into water, surface runoff or leaching through the soil. The exposure effects to humans and animals will be similar to non-obsolete pesticides, although the chemical composition is different from the original product. Strategies to reduce human and environmental exposure require more that an isolated exposure assessment and it is not possible to standardize “how to eliminate pesticides obsolete stockpiles”, as a site by site approach is needed. Regardless of the local legislation, environmental condition and diversity in the techniques that may be applicable for particular sites at different countries, there are four basic steps that should work as a start to the obsolete pesticides safe containment and removal process. An inventory is required as first, followed by a risk characterization, site stabilization and finally the disposal. This work will focus in particular on the methodology for the inventory and for the risk characterization such as the site stabilization and disposal steps for all obsolete pesticides stockpiles rely on these two key activities.

Keywords: Obsolete pesticides, storage and leakages, exposure, human and environmental risks.

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1. Introduction

Obsolete pesticides can be defined as those that can no longer be used for their intended purpose or any other purpose and thus need to be disposed. The definition includes pesticides that have past their expiry date, banned pesticides, unidentified pesticides products, damaged and degraded products, buried pesticides and containers.

Over the years, a significant amount of obsolete pesticides have been stockpiled all over the world. Due to many factors, obsolete pesticides have been stored under unsafe conditions and substandard requirements posing a significant risk of leaking, leading to human and environmental exposure. Pesticide stockpiles in these conditions require urgent action.

In general, the problem does not concern the use of pesticides but the pesticides that have not been used and became obsolete and the associated risks resulting from their inadequate management and storage. The problem dates back to the 1950s and 1960s when the use of pesticides was increased in order to raise agricultural production. Pesticides were distributed free of charge to farmers, leading not only to overuse but also to unsound management of residuals and packaging materials (Vijgen and Engenhofer, 2009). And if the storage sites were once located away from residential areas they are now surrounded by urban communities where people living and working nearby are exposed to these obsolete pesticides and suffer consequent health problems.

The exposure effects to humans and animals will be similar to the one originated by non-obsolete pesticides, although the chemical composition is different from the original product.

The assessment of the storage and containment conditions for obsolete pesticides implies a site-by-site evaluation. Regardless of the local legislation, environmental condition and diversity in the techniques that may be applicable for particular sites at different countries, there are four basic steps that should work as a start to the obsolete pesticides safe containment and removal process.

An inventory is required as first followed by a risk characterization, site stabilisation and finally disposal. The inventory will allow determine which products should be categorized as obsolete pesticides and which are usable. The risk derived by obsolete pesticide stockpiles is a combination of toxicity or hazard of the product and an exposure assessment. The site stabilisation has as purpose to decrease the environmental contamination, reducing both risks and accidents. The disposal represents the solution for those products that can no longer be used for their intended purpose and cannot be reformulated to become viable again.

This work focuses in particular on the inventory and on the prioritization of the stores and regions based on environmental risks characterization as the site stabilization. Disposal steps for all obsolete pesticides rely on these two key activities: inventory and environmental assessment. A step by step methodology for a risk assessment, specific for obsolete pesticides stockpiles, is outlined here. Data on the store (location, structure, management and organization) are combined with information on obsolete pesticides (quantity, toxicity and packaging conditions) and ranked according to the risk calculated both to the store and to a region in a comparative criterion (FAO, 2011).

2. The Legacy Problem

Stocks of obsolete pesticides occur in most of the developing countries and economies in transition. It is estimated that about 500 000 tons are stockpiled worldwide (Dasgupta et al., 2010), half of which are located in countries of the former Soviet Union. In the African continent, the total obsolete stocks is about 50 000 tons, while Latin America has at least 30 000 tons (FAO 1995a, 1995b, 1996; WB, 2002).

The exact quantity of obsolete pesticides is unknown as many of these products are very old and documentation is often lacking. Many times the problem is only known when an inspection is conducted and the real situation is brought up; in October of 2011, a mission to Mongolia from several international pesticides organizations discovered obsolete pesticides stocks stored under substandard conditions in different locations in the country. The scale of the problem, however, is difficult to determine without a further research (Milieukontakt, 2012).

Obsolete pesticides are placed mostly at 10 000 locations of the former Soviet Union, the Southern Balkans and new EU member states (Vijgen and Engenhofer, 2009). According to FAO (2012), in Central Europe, the highest amounts of obsolete pesticides are placed in the Russian Federation (100 000 tones); Macedonia (38 000 tones); Ukraine (25 000 tones); Uzbekistan (12 000 tones); Belarus (11 000 tons); Kazasthan (10 000 tons). Outside Central Europe, about 27 400 tons are placed in Africa; 6 500 tons are placed in Asia; 241 000 tons in Eastern Europe and 11 300 tons in Latin America and the Caribbean area.

2.1. OBSOLETE PESTICIDES OCCURENCE AND EXPOSURE

There are many factors that may have led to the accumulation of obsolete pesticides in developing countries : i) product bans; ii) inadequate storage and poor stock management; iii) unsuitable products or packaging donation or purchase in excess of requirements; iii) lack of coordination between donor agencies and commercial interests of private sector and hidden factors (FAO, 2011; WB, 2002).

Obsolete pesticides result from the degradation of non-obsolete pesticides and the resulting by-products are usually more toxic than the original product. Obsolete pesticides are chemically complex as about 1 000 of active ingredients compose many thousands of pesticides formulations.

Persistent Organic Pollutants (POPs) represent more than 20% of the obsolete pesticides stocks worldwide. In particular, chlorinated hydrocarbons (organochlorides) persist in the environment are highly toxic and bioaccumulate in humans, wildlife and fish. Besides to POPs, obsolete stocks also include organophosphates (less persistent but more toxic than POPs), carbamates and synthetic pyrethroid insecticides, fungicides and herbicides, and even botanical and microbial groups (Lagnaoui et al., 2010).

Over time obsolete pesticides often leak from corroded or otherwise damagged containers into the surrounding environment which is the main pathway for contamination. The resulting environmental hazards will be caused by the dispersion in soil, leaching into the groundwater through the contaminated soil, surface water contamination by surface runoff and wind dispersion of pesticides dusts or pesticide contaminated soil particles and widepread through natural disasters like hurricanes and floods (ASP, 2009).

While the stockpiles remain where they are and continue to leak, any damage caused will increase. The unsafe storage also leads to vandalism: these products are repackaged, provided with a new label and sold at regular markets; the theft of products otfen occurs as well as illegal digging and burning at large burial sites and these sites are easily accessed by children to play in obsolete pesticides sites (Dasgupta and Meisner, 2008).

People living and working nearby may be exposed to these pesticides suffering acute or chronic exposure. Long-term exposure have been associated with a range of adverse health effects from problems of the nervous, immune, reproductive and endocrine systems causing birth defects, injury of a specific organ body and cancer. The short-term acute effects are usually associated with nauseas, headaches, sore eyes, skin rashes and dizziness.

2.2. PROGRESS ON OBSOLETE PESTICIDES SITES CLEAN-UP

2.2.1. *European Union Member States*

The common practice in European member countries is to “return to sender” the unused or outdated products whereby the ownership of any obsolete stocks is clearly defined. The EU law obliges the producers to manage the obsolete pesticides, including their collection and destruction. This extends to new member states under the enlargement process (Vijgen and Engenhofer, 2009).

The principal international agreements that regulate obsolete pesticides are the Stockholm Convention on Persistent Organic Pesticides 2001 (POPs), the Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and their Disposal (1989), the UNECE Convention on Long-Range Trans-Boundary Air Pollution (1979 and the 1998 Protocol on POPs) and the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals (1998).

In particular, the Rotterdam Convention is a global treaty upon pesticides and industrial chemicals that are banned or severely restricted in participating countries. Besides the exchange of information on those chemicals between the countries it gives them the right to refuse imports of certain chemicals which they cannot manage safely. The EU legislation covers all countries whether they are part of the convention or not and includes a broader range of chemicals (EU, 2009).

The Stockholm Convention only bans the use of a selected number of POPs and barely addresses obsolete pesticides. In the EU, obsolete pesticides are regulated by Regulation (EC) Nº 850/2004 of 29 April 2004 which complements earlier Community legislation on POPs. To a certain extent, this regulation goes further than the international agreements emphasizing the aim to eliminate the production and use of the internationally recognized POPs. The Regulation contains provisions regarding production, placing on the market and use of chemicals, management of stockpiles and wastes, and measures to reduce unintentional releases of POPs (EU, 2009).

2.2.2. *Non-European Union Member Countries*

For non-EU member states the problem has been and continues to be an issue. In these countries, national legislation is less developed, ownership of land is not always defined, producers have disappeared or cannot be held accountable and infrastructure for effective remedial treatment is non-existent (Vijgen and Engenhofer, 2009).

However, a few actions have been taken: in the framework of the Arctic Council Action Plan to Eliminate Pollution of the Arctic (ACAP), around 2 000 tones of obsolete pesticides have been repackaged in North-Western Russia (ACAP, 2008); in 2002 Albania received financial support from the EU PHARE programme to eliminate all obsolete pesticides; the World Bank has initiated the cleanup of around 2 200 tones of POPs, PCBs and soil-contaminated with PCBs, in the Republic of Moldova which was concluded by the end of 2007; the Dutch Ministry of Foreign Affairs has financed a project to eliminate acute risks of obsolete pesticides in Moldova, Kyrgyzstan and

Georgia from 2005 to 2008; in 2011 a consortium of the International HCH and Pesticides Association (IHPA), Milieukontakt International and the independent legal expert Helle Husum was established to conduct a pilot remediation of obsolete pesticides sites in Vietnam (Milieukontakt, 2012). Still, the main problem arises from the fact that activities remain partial as there is no systematic approach across all countries concerned and not all potential sources are targeted.

3. Measures to Reduce or to Mitigate Exposure to Obsolete Pesticides

Strategies to reduce human and environmental exposure require more that an isolated exposure assessment; it is not possible to standardize "how to eliminate pesticides obsolete stockpiles" as a site by site approach is needed.

Regardless of the local legislation, environmental condition and diversity in the techniques that may be applicable for particular sites at different countries, there are four basic steps that should work as a start to the obsolete pesticides safe containment and removal process.

As first an inventory is required, followed by a risk characterization, site stabilisation and finally disposal. The inventory will allow determine which products should be categorized as obsolete pesticides and which are usable. The risk derived by obsolete pesticide stockpiles is a combination of toxicity or hazard of the product and an exposure assessment. The site stabilisation has as purpose to decrease the environmental contamination, reducing both risks and accidents. The disposal represents the solution for those products that can no longer be used for their intended purpose and cannot be reformulated to become viable again. The following sections will focus on issues related to the inventory and the prioritization of stores based on environmental risk.

3.1. INVENTORY

The inventory is an accurate record of the pesticides in stocks, enabling to determine which products should be categorized as obsolete pesticides and which are usable. A comprehensive inventory of obsolete pesticides stocks is important in order to understand the scope and nature of the problem. Cleanup and safe disposal of obsolete pesticides have high costs therefore the interventions must be prioritized on the basis of a detailed inventory of pesticide stockpiles and contaminated sites. An inventory should be reliable as it is the solid basis for planning, budgeting and executing removal activities determining the identity of the contaminant, its proximity to people and to the environment. It should be based on actual field data gathered at every site where stocks exist. The collected information should then be inserted in the

Pesticide Stock Management System (PSMS), a web-based application developed by FAO used to record, monitor and manage stock of pesticides, including obsoletes.

3.2. RISK CHARACTERIZATION METHODOLOGY

Risk assessment of pesticide stockpiles impact on human health is not an easy and accurate process due to the differences in the exposure period and frequency, type of pesticides (toxicity) mixtures or cocktails, geographic and meteorological characteristics of the sites where stockpiles are located. Such differences affect mainly the population that lives near the stockpiles storage facilities with obsolete pesticides leakage (Damalas and Elefthrorinos, 2011).

The difficulties in assessing risks of obsolete pesticides on human health and the complexity make the usual approach for risk assessment a very hard task to apply to obsolete pesticides stockpiles. In particular, the magnitude of the exposure to obsolete pesticides depends on the chemical properties of pesticides, their toxicity and storage conditions in addition to the exposure characteristics. As these factors vary from site to site and from year to year, the results from any field study, on the fate and behaviour of the pesticide are specific for any particular location and season. Moreover, when dealing with obsolete pesticides in such a huge scale of the stockpiles it is absolutely necessary to consider the risks resulting not only from the pesticides' chemical toxicity but also from the storage conditions (Damalas and Elefthrorinos, 2011).

In this context, the Food and Agricultural Organization (FAO) has developed a tool specific for obsolete pesticides stockpiles prioritizing sites and regions which should receive prior attention. The tool provides a set of practical methodologies to develop a risk based management of obsolete pesticides based on a very objective chemical and environment criteria that can be used to develop an effective environmental management plan for obsolete pesticides. It is a system for prioritizing affected storage locations based on the comparative risk posed by each of the locations where obsolete pesticides are currently stored (FAO, 2011).

This tool was based on real situations experienced in locations where obsolete pesticides are currently found and validated by FAO with extensive field tests in several countries. The methodology considers three major components for the risk characterization. The first one collects and analyses additional information in order to appraise the environmental and public health risks associated with each stock of pesticides (risk assessment). The second one identifies the most dangerous stores by ranking them according to environmental and public health priorities based on risk assessment (prioritization of the stores). The last one provides a methodology for identifying, classifying and selecting the regions where stocks of obsolete pesticides are accumulated, which should receive prior attention (regional prioritization) (FAO, 2011).

3.2.1. *Risk Assessment*

The main goals of the risk assessment are to collect information and calculate two risk factors to characterize each site.

The first step is to gather information on the store: its location (region, district, map coordinates and altitude); the structures of the store (roof, walls, floor and ventilation); management and organization of the store (security, safety and management procedures).

Following, it is necessary to collect information on pesticides located at or inside the store including quantity, the toxicity class according to the World Health Organization (WHO) and the packaging conditions of each pesticide. A list of all pesticides contained in a store should be elaborated.

The collected information will be used to calculate a risk factor (F_P) which represents the risk related to the conditions associated with pesticides (conditions prevailing in the store). This risk factor has a linear progression (the higher the F_P the higher the associated risk) and it is used to rank the stores according to the level of risk related with the pesticides contained in each store, toxicity and packaging conditions. The basic principle relies on the more pesticides contained in a store the more toxic those pesticides are and/or the worst the condition of the packaging in terms of leaking, the higher the associated risk (FAO, 2011).

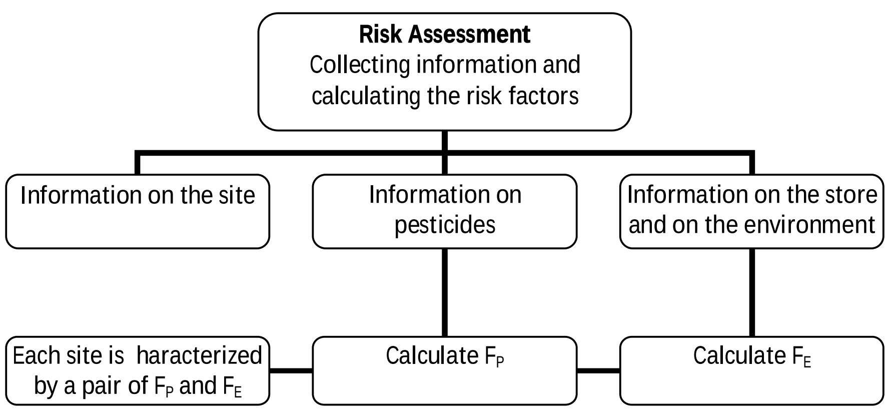

Figure 1. Risk assessment methodology (adapted from FAO, 2011).

The last step is to collect information on the store and on the environment around the store, including proximity to human settlements, water sources, agricultural and livestock activities, wildlife and biodiversity. This information is used to calculate a risk factor F_E based on the assessment carried out for each store. This second risk factor F_E is associated with the pesticides contained in each store considering that the worse structure and the greater store's relationship with or proximity to critical areas, the higher the risk or potential risk to public health and to the environment, in case of an accident at the store.

In general, for each pesticide identified in a store it is necessary to (FAO, 2011):

- Assess their quantity (Q);
- Classify them according to their toxic hazard (WHO, 2005): Ia, extremely hazardous; Ib, highly hazardous; II, moderately hazardous; III, slightly hazardous; U, unlikely to present acute hazard pesticides;
- Score the pesticide toxicity according to the following criteria (S_T): 1 for class U; 2 for class III; 4 for class II; 8 for class Ib and 16 for class Ia;
- Assess the conditions of the containers and give them a score (S_C) according to the following criteria: 1 if none of the containers are damaged; 8 if less than 50 % damaged; and 16 if more than 50 % damaged;
- Calculate the pesticide "*i*" score, S_{Pi} (Eq. 1);
- Calculate F_P as the sum of all the S_{Pi} scores (Eq. 2) obtained for the individual pesticides in the store.

$$S_{Pi} = (3 \cdot S_T + S_C) \cdot Q \qquad \text{Eq.1}$$

$$F_P = \sum S_{Pi} \qquad \text{Eq.2}$$

In equation 1, the toxicity score (S_T) is multiplied by a factor of 3 as toxicity class is considered three times as important as the condition of the containers (FAO, 2011).

In the Table 1 the calculation of the risk coefficient is presented for all possible situations according to the toxicity and containers conditions scores.

The risk factor F_E is calculated according to nine criteria weighted by a factor to include the relative contribution in the risk assessment calculation (FAO, 2011):

- Management procedures (max. 4);
- Safety conditions (max. 5);
- Hazards affecting the store (max. 15);

- Human settlements (max. 20);
- Water sources and soil (max. 20);
- Agriculture, livestock activities, wildlife and biodiversity (7);
- Store conditions (max. 20);
- Content conditions (max. 6);
- Security conditions (max. 3).

TABLE 1. Storage containers conditions and toxicity score values.

Toxicity score, S_T			Storage containers conditions score, S_C		
WHO	S_T	$3.S_T$	No Damage $S_C = 1$	Minor or moderate damage $S_C = 8$	Serious damage $S_C = 16$
Ia	16	48	$S_P = 49$	$S_P = 56$	$S_P = 64$
Ib	8	24	$S_P = 25$	$S_P = 32$	$S_P = 40$
II	4	12	$S_P = 13$	$S_P = 20$	$S_P = 28$
III	2	6	$S_P = 7$	$S_P = 14$	$S_P = 22$
U	1	3	$S_P = 4$	$S_P = 11$	$S_P = 19$

The most severe weighting factors are applied to store conditions, human settlements, water sources, and environmental hazards affecting the stores. The risk factor F_E is obtained by the sum of these weighting scores and this factor can reach a maximum of 100 which is the worst situation (FAO, 2011).

3.2.2. *Prioritization of the Stores*

The main purpose of this section is to clearly identify the stores that pose a comparatively high level of risk to the general public and to the environment. The methodology allows recognizing the most critical stores based on the calculated risk.

After each store being characterized with the two risk factors F_P and F_E it is possible to identify the most dangerous stores. All available data must be analyzed and used to identify the group of stores that should be considered critical and pose the greatest immediate threat to the public health and to the environment.

The prioritization process is based on a comparative analysis of all the stores studied; however, we must be aware that the analysis does not provide an absolute scale for the risk factor associated with the pesticides. Instead the analysis allows dividing the stores in the following categories (FAO, 2011):

- **Critical stores**: high scores for both F_P and F_E. In general these stores contain products classified with the most WHO hazardous class, stored in large quantities, badly packaged or in packages that are leaking (high score for F_P).The containment offered by the stores is critical and the dispersion of chemicals would result in a severe impact for the environment or for the general public (high score for F_E).
- **Problematic stores**: high scores for F_E or F_P. A detailed analysis should be done to determine what make them a relatively high risk for either F_E or F_P because the risk of an immediate accident at one of these stores may make the store a high priority.
- **Lower priority stores:** low scores for F_E and F_P. The impact on public health and/or the environment is low. Usually, in this situation, stores contain smaller quantities of less hazardous pesticides that are generally well packed and/or are located in more favorable environments in what concerns to natural accidents or hazards to happen.

A first analysis may be applied to F_E values in order to identify the stores with the worst environmental conditions irrespective of the pesticides they contain. The same analysis may be applied to a modified risk factor F_P^* in order to identify the most problematic stores according to the chemicals they contain. The modified risk factor is calculated by the following expression for each store (FAO, 2011):

$$F_P^* = \frac{F_P}{\max F_P} \cdot 100 \qquad \text{Eq.3}$$

The risk factors values should then be ranked individually and plotted in a histogram in decreasing order (Figure 2).

In the histogram representation, stores with F_P^* higher than 50% are classified as problematic due to the pesticides that are present: high toxicity, damaged containers and/or large quantities of pesticides. Stores with F_E higher than 50% are classified as problematic due to conditions of the store, packaging and/or environment. All stores with F_P^* and F_E higher than 50% should be classified as critical (FAO, 2011). This representation has the advantage that immediately identifies the stores presenting both a very high F_E score and a very high F_P^* score.

The next step is to determine the critical, problematic and lower-priority stores. The classification for each store may be easily achieved by plotting F_E and F_P^* in a graph. The new risk factor F_P^*will be the *y* coordinate and the risk factor F_E will be the *x* coordinate. The location of the stores in the graph will classify the stores according to the quadrant of the graph. The stores located in the top right-hand corner of the graph present the highest risk and consequently the highest priority. The stores located at the bottom left-hand of the graph will be classified as lower-priority. The stores located in the two other quadrants will be classified as lower-priority (Figure 3).

When many stores are present at the same location it is necessary to plot the gathered and collected information for each store.

3.2.3. *Regional Prioritization*

This section concerns to the prioritization of the geographic regions by selecting stores where environmental and health risks are at the highest level.

Based on the risk factors calculated before, regional risk factors RF_P and RF_E should be calculated for each region in a national level. The regional risk factors, RF_P and RF_E, are calculated by adding the risk factors F_P of all stores and by adding the risk factors F_E of all stores in one region, respectively. These new risk factors will give the cumulative environmental and public health risks associated with all stores existent in a certain region. The regional risk factors should be normalized so that a maximum value of 100 corresponds to the worst scenario (FAO, 2011):

$$RF_P^* = \frac{RF_P}{max.RF_P} \cdot 100 \qquad \text{Eq.4}$$

$$RF_E^* = \frac{RF_E}{max.RF_E} \cdot 100 \qquad \text{Eq.5}$$

The two factors RF_P^* and RF_E^* can also be represented in an X-Y graphic to identify the region presenting the worst cumulative and public health risk according to the previous classification: critical, problematic and lower-priority (Figure 3) where the higher the environmental and public health risks, the higher the regional factors RF_P^* and RF_E.

4. Risk Characterization Methodology Applied to a Hypothetical Case Study

This section applies the above described methodology on a group of stores, assuming that the first stage of inventory, with the information on the location and types of pesticides that are known to exist, has already been done. A sample of pesticides was used from a real obsolete pesticides stockpile (Dasgupta and Meisner, 2008) and extended to several hypothetical sites. Five stores have been inventoried (A, B, C, D, E) and the risk factor F_P was calculated using FAO (2011) methodology.

TABLE 2. Pesticides inventory in five stores and risk factor F_P (Dasgupta and Meisner, 2008).

				Toxicity		Container		Pesticide
	N.º	Pesticide	Q (tons)	WHO	Score S_T	Condition	Score S_C	Score S_P
A	1	Dimecron	15	Ia	18	Minor	8	930
	2	Lannate	12	Ib	8	Serious	16	480
	3	DDT	10	II	4	Minor	8	200
	4	Anteor C3	5	III	2	Serious	16	110
	5	HCB	25	U	1	No	1	100
	F_P							1820
B	1	Dimecron	3,5	Ia	18	Minor	8	217
	2	Lannate	15	Ib	8	Serious	16	600
	3	DDT	20	II	4	Minor	8	400
	4	Anteor C3	5	III	2	Serious	16	110
	5	HCB	12	U	1	No	1	48
	F_P							1375
C	1	Decis	50	II	4	Minor	8	1000
	2	Cuprosan	50	III	2	Serious	16	1100
	F_P							2100
D	1	Dimecron	10	Ia	18	Minor	8	620
	2	Lannate	12	Ib	8	Serious	16	480
	3	DDT	15	II	4	Minor	8	300
	4	Anteor C3	5	III	2	Serious	16	110
	5	HCB	15	U	1	No	1	60
	F_P							1570
E	1	Phosdrin	15	Ia	18	Minor	8	930
	2	Furadan	30	Ib	8	Serious	16	1200
	3	Novathion	25	II	4	Minor	8	500
	4	Fyfanon	10	III	2	Serious	16	220
	F_P							2850

For site A the risk factor F_P is 1820, for site B is 1375, for site C is 2100, for site D is 1570 and for site E is 2850.

The risk factor F_E was calculated assuming the following scores for each one of the nine criteria.

TABLE 3: Risk factor F_E for each one of the five stores according to FAO (2011) criteria.

Criteria	Stores				
(1 – 9)	A	B	C	D	E
1. Management procedures (max. 4)	4	2	1	3	2
2. Safety conditions (max. 5)	5	3	2	3	3
3. Hazards affecting the store (max. 15)	15	7	5	10	15
4. Human settlements (max. 20)	20	10	8	15	15
5. Water sources and soil (max. 20)	20	10	8	15	9
6. Agriculture, livestock, wildlife, biodiversity (max. 7)	7	5	4	6	6
7. Store conditions (max. 20)	4	2	1	5	3
8. Content conditions (max. 6)	5	5	8	6	3
9. Security conditions (max. 3)	15	7	10	7	15
F_E	95	51	47	70	71

The next step is calculate the modified risk factor (Eq. 3), ranking the sites according to the calculated values for both risk factors ($F_P^*$and F_E) and represent them in a histogram (Figure 2).

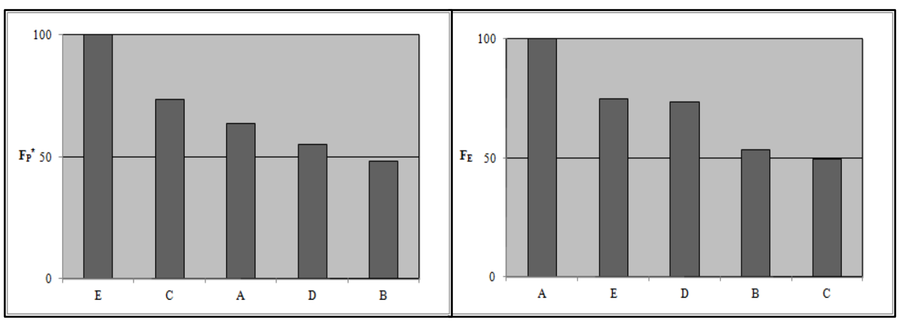

Figure 2. Ranking of the sites according to the F_P^* and F_E risk values.

The ranking of F_E values indicates that sites A, E, D, and B are problematic (F_E is higher than 50%).

For the regional prioritization of the stores it was considered that stores A, B, and C are located in region 1, stores C and D are located in region 2 and store D is located in region 3. The regional modified risk factors RF_P* and RF_E* are calculated in the Table 4.

TABLE 4. Regional modified risk factors, RF_P* and RF_E*.

Sites	F_E	F_P	F_E^*	F_P^*	Region	RF_E	RF_P	$RF_E^* = x$	$RF_P^* = y$
A	95	1820	65	57	1	146	3195	100	87
B	51	1375	35	43					
C	47	2100	40	57	2	117	3670	80	100
D	70	1570	60	43					
E	71	2850	100	100	3	71	2850	49	78

Both risk factors (R_E and F_P^*) may be plotted in an X:Y graph representing F_E the *x* coordinate and F_P^* the *y* coordinate, for each site (Figure 3). The same representation may be adopted for both regional risk factors (RF_E^* and RF_P^*) where RF_E^* is the *x* coordinate and RF_P^* is the *y* coordinate for each site.

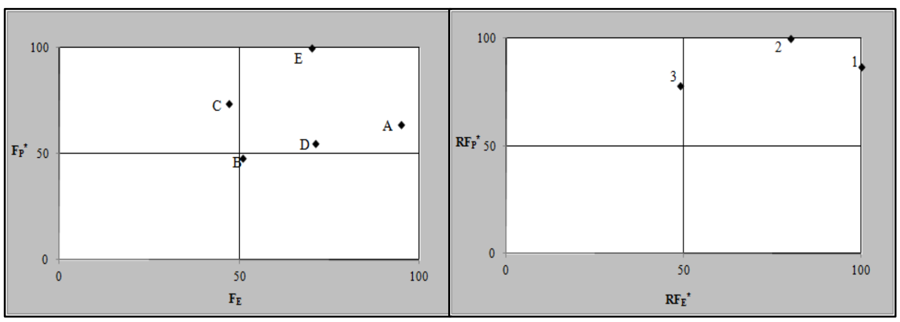

Figure 3. Site and regional characterization according to their priority.

According to this representation sites A, D and E are classified as critical (both F_E and F_P higher than 50%) and sites C and B are classified as problematic (F_P^* higher than 50% and F_E higher than 50%, respectively).

Regions 1 and 2 are classified as critical and these should be the first regions to have an intervention, region 3 is classified as problematic and should be the next one to be remediated.

5. Conclusions

In many countries the problem of obsolete pesticides stockpiles remains unsolved. The scale of the problem is still a big issue in a relevant number of European, Eastern European, Caucasus and Central Asian countries. In some locations the situation is described as devastating due to the huge amount of pesticides stockpiled and improperly stored. In 2008 it was estimated that about

260 000 tones of obsolete pesticides required urgent intervention with an associated clean-up cost of over 700 million euro (Vijgen, 2009).

The decision of stores priority in a remediation strategy, when the funding does not reach all the situations in a country, must be based in simple and feasible criteria. However, the most common approach has been based on the assessment of an international expert or consultant, resulting in a relative risk posed by each particular situation but not following a standardize criteria in the prioritization process (FAO, 2011). This usual risk assessment approach tries to define the magnitude of a particular risk that will be acceptable and while it is focused on known quantities hazards often misses the huge uncertainties regarding both individual sensitive synergies and interactions of multiple exposures. In addition, while there are many studies and regulations on pesticide uses and its effects on human health and on the environment few approaches have been expressly directed to obsolete pesticide stockpiles. In this context, the methodology developed by FAO (2011) allows calculating the risk resulting from obsolete pesticides stockpiles in a very realistic way.

This methodology showed to be effective in assessing the relative toxicity risk of stockpiles sites to population and to the environment as an integrated data on “at-risk” population, their proximity to stockpiles and the toxic hazards of the stockpile chemicals. The hot spots analysis shows the priority stores and regions with highly toxic stockpiles and, in this way, the disposal efforts and public resources can be focused on the highest priority areas.

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