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An African approach for Risk Reduction of Soil Contaminated by Obsolete Pesticides

Joop Harmsen (joop.harmsen@wur.nl) (Alterra/Aquatic Ecology and Water Management, Wageningen University and Research Centre, Wageningen, The Netherlands)
Mohamed Ammati, Mark Davis (FAO, Rome, Italy)
Cheikh Hamallah SYLLA (African Stockpiles Programme -Mali, Bamako,Mali)
Toumani SIDIBE (Centre Nationale de Lutte contre le Criquet Pèlerin, Bamako, Mali)
TRAORE Halimatou Koné (Laboratoire Central Vétérinaire, Bamako, Mali)
Amadou DIALLO and Amadou SY Demba (Centre National de Lutte Antiacridienne, Nouakchott, Mauritania)

ABSTRACT: Large amounts of pesticides have been shipped to Africa for locust control from the fifties of last century, but did not arrive on the proper place or proper moment thereby be coming obsolete. Stockpiles of these pesticides have created a serious problem and The Africa Stockpiles Programme (ASP), launched by FAO, is designed to rid Africa of stockpiles and to dispose them in an environmentally sound manner (ASP, 2009).

In July – August 2007, an investigation mission was organized by FAO pesticide management programme, in collaboration with Wageningen University and Research Centre and the relevant national counterpart institutions of the Ministries of Agriculture and the Ministries of Environment in Mali and Mauritania. In the project, three sites in Mali and three sites in Mauretania have been visited in the summer of 2007 and investigated

High concentrations of pesticides were found in soils on the stockpiles. From a risk-based point of view, contaminations are only a risk if they are or may become available. Based on the results obtained and results of analysis of the samples taken, risk reduction proposals have been made. All proposals are based on stimulation of the possibilities of biological degradation of the pesticides in combination with isolation and preventing rain water to transport the pesticides both vertical as horizontal. The results have been discussed in May 2008 and the first implementation has been started in Molodo (Mali) in July 2008.

INTRODUCTION

A number of remote sites in Mali and Mauretania have been contaminated by pesticides that were spilled during the course of desert locust control operations. The risk at each site differs according to a variety of factors, and in certain cases remedial action will be needed in order to protect both human health and the environment.

The Africa Stockpiles Programme (ASP), launched in September 2005, is designed to rid Africa of stockpiles of obsolete pesticides and to ensure new stockpiles do not accumulate. A key objective of ASP is to ensure that stockpiles are disposed of in an environmentally sound manner. Suitable technologies for disposal operations were evaluated in the first part of the project in the Disposal Technology Options study managed by World Wildlife Fund (Dyke, 2008). Because of logistic reasons, on-site treatment of waste and removal of the pesticides from contaminated soil was found to be a difficult task. Solutions have been found for repacking, removal and off-site treatment of the pesticides residues, but difficulties are still encountered in treatment of high amounts of soil contaminated by leaking vessels. Physically transport of cleaning equipment and applying this equipment and transport of high amounts of contaminated soils was found to be not feasible.

The work carried out and described in this paper provides an assessment of the current nature and extent of the contamination, the risk posed to health and environment and gives potential local solutions that may be applied to eliminate or substantially reduce the risks. High concentrations of pesticides can be found in soils where pesticides have been stockpiled. Regulations are mostly focused on these concentrations, but from a risk-based point of view, contaminations are only a risk if they are or may come available. A risk-based approach can be more useful than a concentration standards-based approach. This widens the range of options and therefore can facilitate more tailor-made solutions for individual sites that address the problem and are more viable. In a risk based approach stimulation of biodegradation of the pesticides and/or immobilization and isolation of the contaminant may play a role.

A site-specific assessment is necessary to provide a sensible solution. Some clean up approaches are also highly sensitive to the site and the conditions so there is no simple prescription to fix all problems. The following steps are necessary:

1. Investigation of the site, including historical use, the spread in the soil system, possibilities of transport, hydrology, climatologically conditions, etc.
2. Defining of the site specific risks.
3. Gathering of missing information

Based on all the information a remediation plan can be made to reduce risks, which has to be locally discussed

4. Possibilities for site specific and sustainable remediation by risk reduction.

After reaching agreement on the measures to be taken, realizing the local possibilities the last step follows

5. Implementation of the risk reduction measures.

MATERIALS AND METHODS

Three sites in Mali (Molodo, Sévaré and Niogoméra) and three sites in Mauretania (Nouakchott, Kiffa and Letfatar) have been investigated according the first 4 steps in the summer of 2007. It has already been established in earlier investigations that the sites were heavily contaminated. Therefore, the investigations in this project were not focussed on the extend of the contamination, but on the possibilities of transport of the pesticides and establishing by specific sampling and analysis if this transport really did occur. In the approach used within the African Stockpile Program, reduction of risks for people living in the surroundings of a contaminated site is considered as a primary goal to achieve. Risks are associated with the possibilities of transport of contaminants to target organisms. In the project we concentrate on humans as primary target organisms and cattle as secondary. Cattle are important because they are of economic interest and supply food (meat and milk) for the local population. Contact with pesticides is possible by (see figure 1):

- Direct, physical contact on the site
- Inhalation of volatilized pesticides
- Contact with pesticides that are transported from the site by 1) run-off in water phase facilitated by rain 2) Transport of pesticides adsorbed to soil by wind erosion
- Consumption of groundwater, polluted by the pesticides as a result of leaching
- Consumption of forage/crops cultivated in the site that take up contaminants.

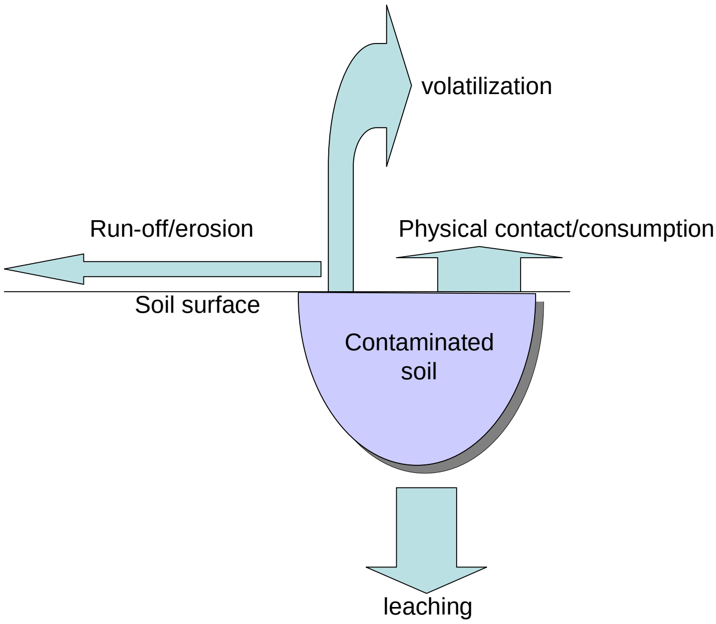

FIGURE 1 Risks to be considered on a contaminated site

There were very large differences between sites: small airports, an irrigated agricultural area, urban area, and sites at the boarder of the desert. All sites needed a specific approach. As an example the approach in Molodo is given. Molodo is situated in the Inner Delta of the Niger in an agricultural area. There was an old storage for pesticides and a large soil contamination was present at the corner of the storage. The yearly rain fall is between 250 and 600 mm. Most important identified risks were surface run-off by rain and leaching to the groundwater. So two gradients were distinguished, one in the direction of the groundwater (depth) and a horizontal one following the run-off water. Soil samples have been taken by augering (figure 2). The samples have been analysed on different pesticides. Further a concrete construction was present in which old vessels were dumped. (figure 2).

Based on the result of the mission in the summer of 2007 proposals have been made to reduce the risks of the pesticides. These proposals were basis for discussion (in May, 2008) with the local stake holders for consideration and for further implementation of the measures to reduce the risks of the obsolete pesticides (Harmsen, 2008). The actions necessary have been worked out in detail by SYLLA (2008). Plans have been further developed for the locations in Molodo (Mali) and Letfatar (Mauretania). The start of the first implementation took place at Molodo in the period July 14-17, 2008.

FIGURE 2 Sampling at the corner of the storage and removed vessels in one of three concrete construction, both in Molodo

RESULTS AND DISCUSSION

Monitoring. From all six sites, the following general conclusions could be drawn:

- On all locations vegetated and biological active zones were present, in which biodegradation could occur.
- The amount of precipitation is limited, From 20-200 mm/year in Nouakshott to 250-600 mm/year in Molodo. Most rainfall falls in the period June-September. The evaporation is higher and if it is possible to use vegetation, all precipitation can be evaporated, thereby preventing leaching to the groundwater system.
- In Mali transport of contaminants by surface run-off caused by heavy rains may occur.
- In Mauretania polluted soils can be transported by wind.
- In Mauretania formation of sand dunes can be used to cover the pollution and prevent. Vegetation can be used for stabilization of these dunes and to evaporate the small amount of rain.

Specific for Molodo, it was observed that the clay acts as an isolation to the groundwater. This layer was very compact and dry, also on a depth were groundwater could be expected (depths of surrounding wells. This was confirmed by the experience of the local population. By digging a well it was necessary to pass this clay layer. In the center of the pollution, pesticides could be observed also on higher depths (table 1). In the area influenced by run off (7 and 21 meter from the center) only the surface soil was contaminated.

TABLE 1 Measured concentration of pesticides in soil samples from Molodo (all concentration in mg/kg)

	Center							Distance 7 meter	Distance 21 m
Depth in cm	10	50	100	150	200	220	240	10	10
smell	HS	HS	HS	HS	HS	HS	HS	NS	NS
cyanophos					0.2				
dieldrin	26	12.5	651	25	1300	76	171	3.5	24
cyhalothrin				0.2	1.3				1.3
malathion					0.8				60
pyridaphenthion					0.06		0.03		
fenitrothion	33				6.7	0.4	0.1		
parathion ethyl	76,000	3,900	2,300	266	5,900	375	920		
parathion methyl					5.1	0.5	1.2		
phenthoate					5	0.4	0.1		
fenvalerate	19						0.1		
chlorpyrifos ethyl								0.08	
tetrachlorovinphos							0.03		
phosalone							0.3		

No Value means below detection limit *HS= high smell NS= no smell*

The non degradable Dieldrin was also detected on distance of the center, showing that transport by run-off has occurred. Parathion ethyl was present in high concentration in the center, but not on distance. Parathion is biodegradable and could be degraded in the vegetated and biological active soil.

Proposals for risk reduction. For remediation, the following strategy has been followed.

1. If possible, removal of the contamination in the source and spreaded contamination by biological treatment using landfarming. Landfarming is a simple and cheap technology, applicable all over the world.
2. Isolation of the contaminant, by evaporation of the precipitation using vegetation
3. Isolation of the contamination by using natural covers (e.g. sand dunes in Mauretania).
4. Increasing adsorption capacity of soal by adding local available black carbon (Charcoal). Organic contaminants are strongly adsorbed by black carbon (Koelmans et al., 2006).

In Molodo this general approach has been worked out as follows:

The soil in Molodo is mainly contaminated with Dieldrin and parathion ethyl, which are respectively non-degradable and degradable. The surface soil besides the contaminated center is biological active and can be used as the start of a landfarm. It can be expected that parathion ethyl, in soil from the center mixed with the surface soil, will be degraded. As part of the activities in Molodo the vessels from the 3 concrete construction (figure 2) were removed and these constructions were large enough as final destination of the landfarmed soil. A final safe destination is necessary, because dieldrin is not degradable. To prevent leaching from the concrete construction, the adsorption capacity of the soil on the bottom has to be increased by adding grinded charcoal. In the final situation the origin of the pollution (center), the area used for landfarming and the final destination have to be vegetated using deep-rooting vegetation that can survive under local dry conditions and are not eaten by cattle (BOUMEDIANA, 2001). *Vetiveria* (Mafei, 2002) and *Jatropha* have been selected.

Implementation. The first implementation has been started in Molodo in June 2008, followed by Sévaré in September 2008. The first results of Molodo are described below (see also figure 3).
For logistical reasons, it was necessary to start with the excavation of the center. One of the concrete construction has been used for temporary storage. Care was taken not to break the clay layer to prevent direct contact with the groundwater. The soil on the bottom has been enriched before with charcoal to increase the adsorption capacity. For refilling of the hole, bioactive surface soil has been used. Doing this, biological activity was introduced at the contact layer of center soil left and the soil used for refilling. It is expected that this activity will slowly decrease the residual concentration. After filling the soil has been enriched with local available compost and vegetated with *vetiveria* and *jatropha*.
A small landfarm has been constructed, just besides the center. This landfarm has been enriched with compost for further biological activation. A first charge of the contaminated soil has been spread on the landfarm. The results of this first charge are given in table 2.

TABLE 2 Pesticides concentration in soil on the landfarm

	July 16, 2008			*November 11, 2008*		
	Parathion-ethyl g/kg d.m.	Dieldrin g/kg d.m.	Ratio	Parathion-ethyl g/kg d.m.	Dieldrin g/kg d.m.	Ratio
1	0.527	0.786	0.67	0.0095	0.442	0.021
2	1.497	0.518	2.89	0.021	0.745	0.028
3	1.615	0.869	1.86	0.011	2.775	0.004
4	3.085	1.081	2.85	0.01	0.775	0.013
5	0.868	0.459	1.89	< 0.003	0.118	<0.025
Average	**1.52**	**0.74**	**2.03**	**0.011**	**0.97**	**0.018**

As expected the dieldrin concentration on the landfarm keeps constant. This also shows that the sampling on both days were comparable and the same depths has been sampled. The parathion-ethyl concentration has decreased significantly. More than 99% has been degraded. Use of the ratio also shows that more than 99% has been degraded. This degradation has been considered as successful. In the following step part of the soil will be transported to the final destination in the concrete construction and replaced by a new charge. After the last charge, all the soil in the landfarm will be transferred to the concrete construction and replaced by clean soil. The concrete construction will be covered with clean soil and a permanent vegetation will be planted based on the experience with the vegetation planted in 2008. The same permanent vegetation will planted in the landfarm area.

FIGURE 3 Implementation of risk reduction in Molodo. 1) Filling of the excavated center with biological active soil. 2) Making elevations around the landfarm. 3) Mixing the first charge on the landfarm. 4) Sampling on the landfarm. 5) Vegetation on the center area and around the landfarm. 6) Enrichment of soil in the concrete construction with charcoal.

CONCLUSIONS

A lot of sites in Africa are polluted with obsolete pesticides, send to Africa for locust control. In pilots in Mali and Mauretania, remediation strategies are developed that reduce risks and can be used under difficult African conditions. The remediation strategies are based on application of bioremediation using landfarming and isolation of the center of contamination. Implementation has been started in 2008 and was successful.

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