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An African approach for Risk Reduction of Soil Contaminated by Pesticides

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An African approach for Risk Reduction of Soil Contaminated by Pesticides

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LoA. FAO No 37386, African Stockpile Project

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ABSTRACT

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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.

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 Ministry of agriculture and ministry 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 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, followed by Sévaré (Mali) and Ledfatar (Mauretania)

Keywords: Obsolete pesticides, remediation, risk reduction, Africa, African stockpiles

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Preface

In the first mission I was accompanied by Mohamed Ammati for the full period and Clemencia LiconaManzur during the first week. In the second mission I travelled with Mark Davies and in the third again with Mohamed Ammati. All three belong to FAOs headquarters in Rome. I thank them for their company, help and advices in these countries I did visit for the first time. I also thank the local staff of FAO, the responsible ministries and organizations in Mali and Mauretania for there support.

A special thank to both teams in Mali and Mauretania that joined me during visiting the locations in the first mission; Tourmani SIDIBE, Mrs. TRAORE Halimatou Koné and Cheikh Hamallah Sylla (Mali) and Diallo Amadou and SY Amadou Demba (Mauretania). We worked hard and efficient and their specific knowledge was important to make this mission successful. The contents of the daily mission reports (SY, 2007; SYLLA, 2007) Are also used for this report.

I also want to thank the following people for their input during the discussion of concept of this report in May 2008. These were Toumani SIDIBE, Sada SOW; Modibo Idrissa COULIBALY, TRAORE Halimatou KONE, Lassana TRAORE, Soualika BOIRE, and Cheikh Hamallah SYLLA All from Mali and Diallo Amadou, SY Amadou Demba and Mohamed EL Hacen Ould Javar (all from Mauretania).

The last mission described in this report was on the implementation of the of the measures in Molodo. This implementation was leaded by Cheikh Hamallah SYLLA The following people helped to make the implementation a success, Sada SOW, Lassana TRAORE, Modibo COULIBALY, Boubacar Aladiogo MAIGA, Malamine Baba KEITA, Ngolo DIARRA, M. Barry, Ibrahima Tiocary, Diabé KALOGA, Sabaké DIARRA, Youssouf TOGOLA, Demba SIDIBE, Balla SISSOK, d'Ogobassa DJIMDE and others.

Last but not least I want to thank all the local specialists, technicians, workers, farmers and inhabitants, their knowledge on the specific situation has been essential in order to make the recommendations presented in this report.

Summary

The Africa Stockpiles Programme (ASP), launched by FAO, 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. Most of the 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.

Disposal of obsoletes stocks or heavy contaminated soil is not easy to perform in Africa and they should be transported outside the continent for incineration according to the international standards. This solution is very expensive and not feasible for most of the contaminated sites. To this end, FAO Pesticide Management Programme, established a pilot project in collaboration with Wageningen University and Research Centre, to better understand the behaviour of pesticides under African arid conditions and explore local remediation technology for each site following a risk-based approach, not only based on removal of high concentrations of pesticides.

In July – August 2007, a first investigation mission was organized by FAO pesticide management programme, in collaboration with Wageningen University/ Research Centre and the relevant national counterpart institutions of Ministry of agriculture and ministry of environment in Mali and Mauritania.

High concentrations of pesticides (e.g. dieldrin, parathion, malathion, chlorpyrofos) 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. A risk-based approach can be more useful than an approach only based on elevated concentration and removal of these concentrations. This widens the range of options and therefore can facilitate more tailor-made solutions for individual sites. In a risk based approach stimulation of biodegradation of the pesticides and /or immobilization and isolation of the contaminant may play a role. The following steps are necessary:

1. Investigation of the site (e.g. historical use, hydrology, climate, transport)
2. Defining of the site specific risks.
3. Gathering of missing information, including sampling
4. Possibilities for site specific and sustainable remediation by risk reduction.
5. Implementation of the risk reduction measures.

In the project, three sites in Mali and three sites in Mauretania have been visited in the summer of 2007 and investigated according steps 1-3. Most important risks identified were, inhalation of volatilized pesticides if the site was close to inhabited area, transport to groundwater and physical contact by human and cattle, specific for Mali run-off by rain and specific for Mauretania wind erosion. Based on the results obtained and results of analysis of the samples taken, risk reduction proposals have been made (Step 4). All 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. On most sites the isolation layer could also be used to stimulate biodegradation. In populated areas, a plan for future use was part of the solution to prevent that houses will be built on the isolated site. All plans have in common that they reduce the risks for the local population, are simple and cheap and can be implemented on a sustainable way, even under the difficult African conditions.

The concept of this report was the basis for discussion (in May, 2008) with the local stake holders and for further implementation of the measures to reduce the risks of the obsolete pesticides. The main results of the discussions are included in this report. The actions necessary have been worked out in detail by SYLLA (2008-1) and SY (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 (Mali) in the period July 14-17, 2008. The work and experience at this site is also described in this report (see also SYLLA 2008-2). The following implementations were in Sévaré (Mali) and in in Ledfatar (Mauretania). The lather two implementations are shortly summarized in this report (See also SYLLA (2008-3) and Sid'Ahmed Ould Mohamed (2009).

1 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 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 (DTO) managed by WWF (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 report 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
4. Possibilities for site specific and sustainable remediation by risk reduction.
5. Implementation of the risk reduction measures.

It has to be mentioned that step 1 in this project is not meant to establish if and to which extend the sites are polluted. This has been established in earlier investigations.

The investigation were concentrated on the possibilities of transport of the pesticides and establishing by specific sampling and analysis if this transport really did occur.

Three sites in Mali and three sites in Mauretania have been visited and investigated according step 1-4. Training of local experts was part of the visit. The soil samples for this type of investigation will be analyzed in future by a pesticide laboratory in Bamako. A visit to this laboratory to make the proper arrangements was part of the mission.

The main subject in this report are steps 1-4. The following step 5, implementation, is the responsibility of local governments. This report gives the possibilities of risk reduction, but these must be in accordance with local wishes and planning. They can be considered as tools for further decisions by the Governments of Mali and Mauretania, supporting organisations and donors regarding further action to be taken at the contaminated sites concerned. Fortunately, there is a strong will to clean up the sites and to remove obsolete, old containers and to reduce the risks of pesticides in the soil. Therefor the first implementation was already started in July,2008

The concept of this report was the basis for discussion (in May, 2008) with the local stake holders and for further implementation of the measures to reduce the risks of the obsolete pesticides. The main results of the discussions are included in this report. The actions necessary have been worked out in detail by SYLLA (2008-1) and SY (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. The work and experience, including first results at this site, are also described in this report. The following implementations were in Sévaré (Mali) from September 14 to September 19, 2008 and in Ledfatar (Mauretania). The lather two implementations are shortly summarized in this report and thoroughly described by respectively SYLLA (2008-3) and Sid'Ahmed Ould Mohamed (2009).

2 Remediation using risk reduction

2.1 Risk factors

Contaminations in soils and sediment are responsible for environmental risks. On highly polluted sites or spots, use of remediation technology that removes the contaminant is the most common way to reduce the risks. However, if large areas are involved, the costs of the remediation can be too high and it will even be doubtful, whether society is willing to pay the costs of complete remediation. As a consequence, nothing will occur and these sites remain unused and are often abandoned.

Within most regulations, risks are directly related to concentrations that can be measured in soil or water. These values can be related to soil use, like industrial use, but also more critical use like in agriculture or an urban environment. Examples from The Netherlands are given in table 1.

Table 1. Reference values used in The Netherlands for soil and water in relation to their use (VROM, 2007 and VROM, 2000).

	Soil (mg/kg d.m.)				***Ground water (µg/l)***	
	Background value	*Residential areas*	*Industrial areas*	*Interven-tion value**	*Background value*	*Interven-tion value**
Drins (sum)	0.015	0.04	0.14	4	< DL	0.1
Lindane	0.0030	0.04	0.30	2		
Azinfos-methyl	0.0075	0.0075	0.0075	2	< DL	2
atrazine	0.035	0.035	0.5	6	0.029	150

* Above this value measures (remediation, prevention of risks) are necessary
DL – Detection Limit

In the approach used within the African Stockpile Program (ASP), 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 also figure 1):

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

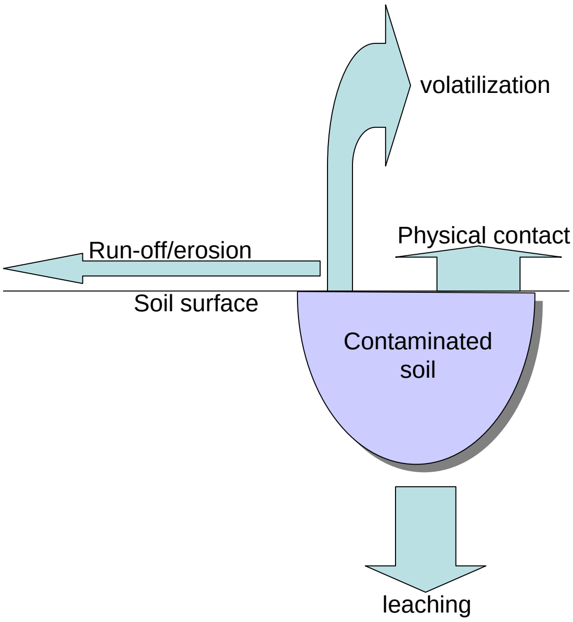

Figure 1 Risks to be considered on a contaminated site

If the contaminated area is situated close to surface water, it is also necessary to consider leaching and run-off to the surface water system, because surface water can also be used by human and cattle. Such a situation was not found on the sites described in this report.

Considering that it is not possible to remove all contaminants, remediation actions should first be concentrated on diminishing of the size of the arrows in figure 1. Secondly it should concentrate on in-situ possibilities of decreasing the concentration by use of biodegradation or decreasing of the availability of contaminants by increasing the sorption capacity of the soil.

2.2 Possible measures to reduce risks

2.2.1 Physical contact

To prevent physical contact the first effective step should be the building of a fence, combined with warning signs. This is good short term solution, but not very sustainable. The lifetime of a fence is limited and often an invitation for children to discover what is behind. Covering the contaminated soil with a living layer is more sustainable, but digging activities should be prevented to avoid return to the surface of the contaminant. So prevention of physical contact has to be combined with community decisions on the future use of the contaminated area.

2.2.2 Volatilization

The highest volatilization will occur from the surface of the contaminated soil. As soon as the surface pesticides are volatilized, pesticides from lower layers may diffuse to the surface and also become available for volatilization. However, the surface layer itself will become a resistance layer for diffusion, because temperature will decrease going downwards and diffusion is slow in the complex soil structure. Therefore, the amount of pesticides that will volatilize will decrease. If new surfaces are created (e.g. transfer of soil), volatilization will increase again. When it is not possible to remove the surface contamination, volatilization can be decreased by creating a resistance layer. This can be a living layer like in 2.2.1. This layer will be more effective, if the layer also has a potential for degradation and or adsorption (see further).

2.2.3 Leaching

Leaching to the groundwater is an invisible but very serious problem. If the groundwater is reached, wells downstream can become polluted and stay polluted for a very long time. If the groundwater is reached, active and expensive groundwater remediation will be necessary if the well is essential and cannot be closed or replaced. Because the groundwater table on most sites was very low, a groundwater remediation strategy is not found to be applicable on these contaminated sites. If the groundwater has not been reached, the possibility of leaching has to be minimized. The easiest way to do this is to prevent rainwater present on the site from percolating through the soil to the groundwater.

On the sites investigated this is not difficult to achieve. The precipitation is relatively low (300-600 mm). The potential evaporation is much higher and if it is possible to evaporate all the water brought by rainfall no leaching will occur. In this approach it is necessary that no extra water comes to the site by run-off from areas besides the site (see also 2.2.4). The 600 mm falls within the period June-September. If no evaporation will occur, this amount will give field capacity in a layer of 1 to 2 meter, so it will be essential to have evaporation during the rainy season. As for evaporation of pesticides, evaporation from the surface will give a resistance layer (crust) that will prevent further evaporation. The presence of vegetation will increase the evaporation. Deep rooting dry resistance vegetation will be most effective. If roots can reach the groundwater, this gives also a possibility to remediate the groundwater. The vegetation will act as a pump and remove the contaminated water. Organic residues of the vegetation (e.g. leaves) can be composted on the site (see also 2.2.5)

To increase the holding capacity of the topsoil, presence of some clay is desirable, but not too much, because this will cause cracking and water will be easily transported downwards through these cracks. Organic matter also increases the holding capacity of soil, but this is not sustainable in the hot climate of Mali and Mauretania. However increasing organic matter by composting activity in the first years may overcome the limited evaporation by the developing vegetation and will give vegetation the chance to develop well and create an intense root system.

2.2.4 Run-off and wind erosion

Rainfall is in a short period from June till the end of September. Showers are intensive and the soil is not able to absorb the amount of water in that short period. Flow of water can be seen everywhere on the soil surface. If water will flow from the contaminated site to other places, it may cause transport of soil contaminated with pesticides to lower situated areas. This kind of run-off should be omitted by keeping the water on the site.

Wind erosion was more observed on the sites in Mauretania. Wind erosion can be prevented by stabilizing structures as can be found north of the road Nouakchott – Boutilimit.

2.2.5 Consumption of crops

The uptake of pesticides by crops depends on their bioavailability for these crops. In general the uptake will be low for pesticides with a low solubility and higher for pesticides with a higher solubility. Important sources of contaminants in crops are soil and dust adhered on the surface of leaves and attached to roots (Delchen et al., 1999). Vegetation on a contaminated site should therefore be not consumable for human, and also not for cattle. Proper vegetation has to be selected.

2.3 Reduction of the availability of contaminants

2.3.1 Biodegradation

Some contaminants are biodegradable, providing conditions for degradation are present. Biodegradation of the degradable contaminants Polycyclic Aromatic Hydrocarbons (PAHs) and mineral oil occurs under aerobic conditions and will be stimulated by agricultural use or other beneficial use of the soil close to the surface. The same principals can be used for remediation of degradable pesticides. Bioavailable contaminants are easy degradable, but as shown by Harmsen et al. (2007) long periods are necessary to remediate residual concentrations in soils and sediments. Passive landfarming is a suitable bioremediation method to reach low residual values, because of the low input of energy and labour. Risks are reduced in a much shorter period (Harmsen, 2004). The slow biodegradation process can be combined with different types of land use and measures as described above in order to remove the contaminants and their impact on the longer term.

Vegetation e.g. growth of biomass on soil stimulates degradation. Most important are creation of aerobic conditions in the rooted zone and a good environment for micro-organisms in the rooted zone.

If the water table is high, it may have a negative effect on biodegradation, because the amount of air filled pores will become too small. This was not the case in Mali and Mauretania, were the water table was very low. Limited biodegradation by too dry conditions is earlier to be expected.

2.3.2 Immobilization

Risks are also reduced if contaminants are bounded stronger to the soil. Organic matter is a strong adsorbent. As mentioned, organic matter is not sustainable in hot conditions and a constant supply is necessary. This can be achieved in the upper layer by stimulation of vegetation. Short term increase of organic matter can be obtained by composting activities on the site.

Recent work shows that even more constituents in soil significantly contribute to strong adsorption. These constituents, referred to as carbonaceous carbon phases (i.e., black carbon, coal, kerogen or weathered oil), can be responsible for 90-99% of total sorption of organic compounds in sediment or soil (Cornelissen, et al., 2005; Koelmans et al., 2006, and references therein). This leads to 10-1000 times stronger sorption than on the basis of amorphous "soft" organic matter (normal organic matter in soil) only, and to similar reductions in actual risk.

Charcoal is an easy available source of black carbon in both countries. However, charcoal may increase the pH of soil and thereby reducing the capability of soil for biological life (growth of vegetation and biodegradation). This has been investigated and it was found that the there is an increase of the pH, but this will not affect biological life as long as the enrichment of the soil with charcoal is limited to 1-2% (see annex 1).

3 Field investigations Mali

3.1 Introduction

The field investigations in Mali have started on July 20 by going to Molodo. We have been accompanied by Sidibe Toumane and Sila Hammalah, both of FAO and Dr. Halimatou Traore of the Veterinary Laboratory. During the travel to Molodo the equipments passed customs and could be used during investigations. The Following sites nave been visited and investigated

- Molodo July 21 and 22
- Sévaré, July 23 and 24
- Niogoméra July 27 and 28

3.2 Site Molodo

16 families live in the village and 6 of them within 200 to 300 m. In the paste dieldrin and parathion have been used and empty vessels have been stored besides the depot in the period 1993- 2003. This has caused soil pollution at the north/east corner of the depot. In 2003 the vessels have been transferred to a concrete construction (waste in photo 1) close to the depot. Most important pesticides used were dieldrin (ULV 20% made by Shell) and parathion.

The village is situated between a principal irrigation channel, coming from the reservoir and a landing strip for airplanes (Figure 2).

Photo 1 sampling at the corner of the depot and removed vessels in concrete construction

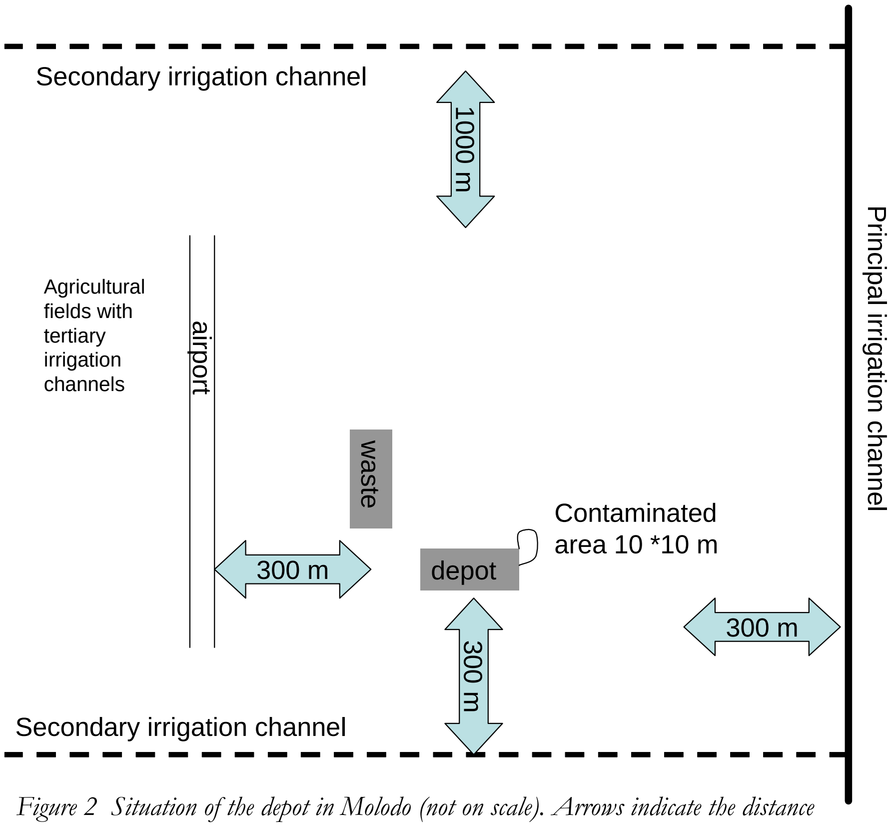

Figure 2 Situation of the depot in Molodo (not on scale). Arrows indicate the distance

3.2.1 Hydrological situation.

The Molodo area is an irrigation area and principal, secondary and tertiary irrigation channels are present. The river is situated 600 meter to the east and the reservoir for irrigation water 500 meter to the south. The yearly rain fall is between 250 and 600 mm.

The drinking water of the part of the village where the depot is situated is coming from a depth of 60 m. Further water is taken for washing and drinking water for cattle from wells that are taken the shallow groundwater. During the visit the water in these wells was on a depth of approx 1.5 m (see table 2). The level in the wells rises during the rainy season and the highest level is expected end of September, Beginning of October. During sampling, the groundwater was not reached on the level found in the wells but only reached on one sampling point at a depth of 3.2 meter on the contaminated site. That the soil keeps dry was confirmed during the excavation of the soil in 2008 (see chapter 6) It is assumed, confirmed by local people, that the soil containing clay will swell during raising of the water, thereby creating a less permeable layer, which prevents the groundwater to raise. Higher levels can be found on places were this layer has been broken, the existing wells.. Consequence for remediation is that during excavation, this layer should not be broken and excavation has to be limited to about 2 m and part of the deeper pollution will remain

It is not clear if two aquifers have to be considered, a deep one at 60m and a shallow one as a result of the irrigation system, or that they are connected with each others. The distance to the drinking water well is large (300m). For the risks, the shallow aquifer is the first one to be considered. If this water can have contact with the pesticides, the risk for drinking water has to be considered. It I therefore important that percolation of rainwater through the soil will be prevented to assure that the deeper contamination will be transported further in the groundwater system

The rain infiltrates in the soil and will wet the soil. If preferent channels in the soil are present it is possible that the rain water may quickly reach the groundwater. Based on soil drilling only the upper 60 to 100 cm of the soil was homogenous wet and below that the soil was very dry, which makes the presence of large preferential pores not likely. This has been established by making a small trial pit depth 50 cm. In the upper 20 cm roots were present which may act as preferential pores, but they were absent from 20-50 cm and the soil was very homogenous.

Table 2 Positions and depths of water wells

Point	***N***	***W***	***Water depth (m from soil surface)***
Well near house	14.23991	6.02818	- 2
Drinking water well	14.23948	6.02702	
Contaminated site	14.23656	6.02634	< -2.5
Well 1 near depot	14, 23641	6.02665	-1.46
Well 2 west of depot	14.23640	6.02782	-1.49
Waste site	14.23674	6.02716	

3.2.2 Sampling plan and results of sampling

The site in Molodo was the first site to investigate, so the learning process of using the equipment and the goals of sampling had to be combined. The goal of the sampling were establishing of vertical and horizontal distribution of the contaminants. This has been brought into practice by sampling in the hart of the contamination, at the expected boarder of the contamination (7 meter, distance) and in an expected clean part of the site (distance 21 meter). The sampling has been started in the clean part, to prevent doing mistakes with dirty samples.

The samples were taken in a gradient eastward from the north/east corner of the depot. Doing this it is possible to measure vertical and horizontal transport. Groundwater was not reached and it was assumed that the clay layer acts as an impermeable barrier for this water.

A non-smelling sample was not reached in the source of the contamination. It was decided, first to analyze the samples taken and if found necessary to return later if deeper sampling has been found necessary. The results of the laboratory measurements are presented in table 3.

Table 3. Measured concentration of pesticides in soil samples from Molodo (all concentrations in mg/kg

	Source							***Distance 7 meter***					***Distance21***		
Depth in cm	**10**	**50**	**100**	**150**	**200**	**220**	**240**	**10**	**50**	**120**	**250**	**320**	**10**	**92**	**252**
Smell	HS	HS	HS	HS	HS	HS	HS	NS	NS	NS	NS	NS	NS	NS	NS
Cyanophos					0.2										0.05
Dieldrin	26	12.5	651	25	1300	76	171	3.5			0.04	0.04	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		0.03						0.3
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			1.6	0.2			
tetrachlorovinphos							0.03								
Phosalone							0.3								

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

In the water sample 149, only fenvalerate in a concentration of 1 μg/l could be measured. Only a small amount was found in the source at surface level and not deeper. The mobility of fenvalerate is low and it is well degradable. Another use of fenvalerate may be responsible.

The results of analysis are mostly in agreement with the expectation. The source is very highly polluted. The high concentration of parathion ethyl especially at surface shows that this compound is present as pure product and can be transported as a liquid. This may explain the relatively low concentration of dieldrin at the surface. Dieldrin is transported by the parathion ethyl to a higher depth. Transport of Dieldrin is also caused by the use as a 20% formulation.

The presence of dieldrin in the surface samples at 7 and 21 meter shows that surface run-off has occurred. Parathion ethyl should also have shown run-off, but this compound has been degraded in the biological active surface soil. At higher depth, higher concentrations are sometimes found. It is assumed that concentrations at this level can also be introduced by carry-over (see also remark on dieldrin on the site Sévaré

3.2.3 Learning process

To prevent that contaminated soil from the top could contaminate lower parts during soil drilling, it was intended to use the casing. It was found, however, that the soil was strongly structured and it was not possible to lower the casing together with the soil drilling. Therefore, getting to desired depth was done without casing, 10 cm above the desired depth the casing was installed, followed by removing two auger volumes of soil. The following two auger volumes were used as sample. After sampling the casing was removed again to get to the desired depth. It was found that the Edelman augers were the best types in this soil. In the dry zone of the soil (about 60 cm to 240 cm) the soil had to be removed very carefully. In one of the holes the stone catcher has been used to remove a stone.

3.3 Site Sévaré

The site is situated on the airport of Sévaré. Pesticides were transferred into air planes and losses have occurred. If pesticides were not used during the flight they have incidentally being dropt by the aeroplane on the strip before the hangar Pure product and losses were streaming to the uncovered area and infiltrated in that area, a bank of 11 m. Rainfall from the covered area is also infiltrating in this area and flows over this area. Empty vessels have been stored in the same area. Different products have been used (Chlorpyrifos ethyl, deltamethrin, fenitrothion, fenvalerate and malathion). It is assumed that approximately 10.000 litre product have been spilled into the environment.

Photo 2 The polluted area besides the platform and construction of a transect

Risk defined are 1) the direct infiltration of pesticides in the edge besides the strip and possible contamination of the groundwater system. 2) Leaching is not only stimulated by the amount of rainwater directly on the soil (approx. 400 mm), but also by the rainwater from the strip. This amount exceeds the direct amount due to the larger surface of the strip; the strip is 38 meters broad. 3) Horizontal transport of pesticides by the rainwater during heavy rainfall from the polluted area to lower parts in the field.

Data on rainfall are given in table 4. This table illustrates that the total amount of rain is relatively low, but that the rain falls in short periods. During such a period run-off is observed.

Table 4. Rain fall on the airport of Sévaré in the period from 2004 to 2006

Year	*Amount (mm) and days with rain*	*May*	*June*	*July*	*August*	*Sep-tember*	*Total*
2004	Amount	0,9	51,1	143,0	207	37,9	440
	Days with rain	1	8	15	10	9	
2005	Amount	13	41,2	118,2	123,9	81,4	378
	Days with rain	4	10	14	15	9	
2006	Amount	7,9	17,2	152,3	189,9	88,8	456
	Days with rain	2	3	10	15	9	

Source : Amadou DIARRA, Délégué ASECNA Sévaré, July 2007.

3.3.1 Hydrological situation

There is no surface water present on the site. Run-off water of the total area infiltrates going downwards and may even go to a small channel on the east site of the airport. This surface water is used downstream in the village for washing.

The groundwater is on a depth of about 10 meters

The amount of rainfall in this area is about 425 mm (average of last three years) and most of the rain falls in July and August in heavy showers. The average number of days with rain was 45 in last three years.

3.3.2 Sampling plan and results of sampling

It is chosen to investigate the most heavily contaminated area (worst case situation). This was an area of 23*11 m. In the original plan soil drilling was planned on the contaminated strip and just besides the strip in the vegetation. Soil drilling, however, was not possible because the soil contained a lot of gravel and the plan had to be changed in the creation of trial pits. A depth of 50 cm could be reached, before the soil became so rocky that further digging by hand became impossible. Making the trial pits the flow of the groundwater has been followed and pits were made on distances of 11; 13.2; 16.5; 24.2; 37 and 48.5 m from the edge, following the groundwater flow. A combination of direct infiltration with large amount of pesticides and water supported infiltration is investigated in the vegetation at 11 and 13.2 meters. The pits further away gave an indication of surface run-off.
Samples have been taken on two depths, 5-10 and 50 cm. A surface samples has been taken besides the edge of the platform. It was possible to smell pesticides in the samples taken up to and including the distance of 16 m. All results are given in table 5.

Table 5. Measured concentration of pesticides in soil samples from Séfaré (all concentrations in mg/kg)

Distance from platform in m	***0.5***	***11***	***13***			***16***		***24***		***37***	***48***
Depth in cm	10	10	10	40	50	10	50	10	50	10	10
smell	HS	S	S	S	S	S	S	NS	NS	NS	NS
dieldrin		0.03									
fenvalerate	546	0.05	0.02			0.3				0.2	
fenthion	1000	2.1	0.3	0.05	0.07	0.2	0.02			0.03	
fenitrothion	13,000	0.2									
chlorpyrifos ethyl	514	0.2								0.03	
parathion ethyl	7.4	0.1									
tetrachlorvinvos		0.07	0.02								
phenthoate	22.5										
cyanophos				0.1		0.3	0.2				

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

High concentrations are measured just besides the platform. Pesticides are probably also present at higher depth, but it was not possible to obtain samples because of the rocky structure of the soil. The amount of pesticides present in the soil besides the strip was low, but could be smelled and decreasing with distance. It is assumed that run-off will occur, but this gives no accumulation of pesticides on further distances. Pesticides will be degraded in the soil. All pesticides applied are degradable, except dieldrin, but the amount measured was very low.

3.3.3 Learning process

The site has been visited shortly after arrival in Sévaré. Based on this visit the first sampling plan has been made, after identification of the risks. It was planned to use the augers. This has been thoroughly discussed with the team. Because there was already agreement on the strategy it was simple to turn on the sampling plan and to change to the use of trial pits. Involvement of administrators, managers and experts were found to be essential to obtain the proper information.

3.4 Site Niogoméra

The site was situated near the village Niogeméra, close to Yelimane. The village counts 2300 inhabitants. The depot was near a former landing strip east of the village. Closest houses were at a distance of 200 m and the closest well at 300 m. The main part of the village starts at 500 m from the site. Based on already available information, it was expected that the site has only been used to store empty vessels since 2002. However after interviewing (retired) people it was found out that the site has been in used since 1965 as one of the main distribution centres for Mali, Mauretania and Senegal. Main products stored and distributed were; Parathion, malathion and HCH and in less extend Dieldrin, Fenitrothion, lambdacyhalothrin and organic solvents to make the formulations. In a later stage also explosives (TNT have been stored). The site was situated almost on the top of the elevation. Surface run-off, if occurs will be in the direction of the village.

3.4.1 Hydrological situation.

The groundwater level on the site was estimated to be about 15 m. In a well at 300 and lower situated, a depth of 12 meter has been measured. Rainfall occurs in showers and run-off could be observed. The water is carried off following the lowest parts of the area.

3.4.2 Sampling plan and results of sampling

Run-off and infiltration to the groundwater are identified as risks. Further cattle frequently pass the site (photo 3) and sometimes even enter the site as shown by spurs close to the most heavily contaminated plots.

Photo 3. Grazing cattle at the fence (north) of the site of Niogoméra and spurs of cattle inside the fence

The sampling was focussed on the possibilities of run-off by measuring in a vertical gradient following the run-off water. At the first sampling place just outside the fence (west-side) grass was growing, indicating possible infiltration. On this place also a soil drilling has been made till 2 m. Other samples were taken from the surface at 27 and 60 meter distance from the fence, following the way of run-off water (table 6)

Table 6. Measured concentration of pesticides in soil samples from Niogoméra at different distances from the site (all concentrations in mg/kg)

Distance	***fence***				***27 m outside fence***	***60 m outside fence***
Depth in cm	10	72	135	188	5	5
Smell	NS	NS	NS	NS	NS	NS
Dieldrin	0.7	0.9	0.4	0.09		0.1
Fenvalerate		0.03		0.2		
chlorpyrifos ethyl		0.03	0.09	0.08		
Cyanophos			0.7	1.8		

The results show that no strong run-off has occurred. Near the fence, the values are slightly increase, but no heavy run-off has occurred on longer distance

Two drillings have been made inside the fence on sites where respectively parathion and dieldrin has been stored (table 7).

Table 7. Measured concentration of pesticides in soil samples from Niogoméra, highly polluted areas. (All concentrations in mg/kg)

	Parathion site				***Dieldrin site***			
Depth in cm	10	63	210	250	10	76	133	163
Smell	HS	HS	HS	HS	HS	HS	HS	HS
Dieldrin		0.01	21	0.1	0.3	0.3	0.3	1.6
Fenvalerate				0.1	0.2			
chlorpyrifos ethyl								
Cyanophos			0.2	0.1				
parathion ethyl	1.6	0.05	0.4		0.33			0.3
Cyhalothrine	35							
Malathion			0.04		0.04			

Concentrations found in these samples are low. Especially, because the smell inside the fence was very intensive.. Based on these analysis there is only a small problem. Based on the field observations , we consider these samples as polluted.

Small transects have been made beside vessels used for parathion. Vegetation was growing and active beetles were observed, indicating removal of original pesticides by biodegradation (table 8). No smell was observed

Table 8. Measured concentration of pesticides in soil samples from Niogoméra, biological active zones. (All concentrations in mg/kg)

	point 1		***point 2***	
Depth in cm	20	35	10	20
Smell	NS	NS	NS	NS
Dieldrin	1.2		0.9	0.05
parathion ethyl	0.05	0.2	1	

Water samples have been taken from the well at 300 m and the lake in the village. In both samples pesticides have been measured (Table 9). Amounts are close to the detection limits. We doubt however if the site is the source for the contamination. Probably there are also other sources If the concentration in the water of the lake is correct, the sediment of the lake should contain large amounts of pesticides. This sediment may act as a source for the water. This will be investigated further in a mission were no contaminated soil will be analyzed, to prevent carry-over. The water in the well will also be analyzed again

Table 9. Measured concentrations of pesticides in water samples from Niogoméra.(all concentrations in μg/l

	Well	***Water in lake***	***Detection limit***
Dieldrin	0.1	2	1
paration ethyl	5		
Malathion	3		2
fenitrothion	2		2
cyhalothrin		0.5	3
Chlorpyrifos ethyl		5	1

3.5 Laboratory measurement for the Mali-sites

The possibilities to analyse the soil and water samples on the laboratory of the National Veterinary Institute led by Halimatou Traore have been discussed on the laboratory on July 16, 17 and 30. During the discussion on 17 the whole staff was present and also Tahry Mostafa from Labomag in Morocco, who is going to work on the accreditation of this laboratory.

3.5.1 Sample treatment

After receiving the sample, store it on a cool place
- refrigerator (approx 4 'C) if the analysis can start in the same week
- freezer (approx -18 'C) if longer storage is necessary

Starting the analysis, carefully mix the sample. Do this on a place that does not affect residue analysis.

Take sub samples in selected samples for
- Soil characterization (organic matter, clay/texture and pH) and bring it to the soil laboratory
- Moisture (dry at 110 'C)
- Pesticides

For pesticides take care about the differences in concentration. There are large differences, from heavily polluted (g/kg) to clean (< 0.01 mg/kg), so concentration difference of 106 may occur. Start analyzing with the clean samples and continue with the more polluted. Use the information given with the samples, but remember these are expectations and reality can be different.

3.5.2 Pesticide analysis

The method to be used is based on ISO 10382, including some improvement of the project HORIZONTAL. These improvements are expected to be accepted by ISO and CEN. In short the method uses acetone and petroleumether to extract the soil sample. The acetone is removed by extraction with water and this extract can be analysed by gas chromatography. It is expected that further clean up is not necessary, but some methods are provided if this is necessary. The extract is first injected on the GC with the FID detector to get a rough estimate of the concentration of the pesticides and to establish the volume of the extract necessary for further analysis. These concentrated extracts will be injected on the GC with a specific detector (GC/NPD). The method uses internal standards to have a quality control for the whole procedure and injection standards to prevent variation of results due to the injection procedure. The method has been adapted by Tahry Mostafa in cooperation with the staff of the laboratory and described in his mission report. He has included a first screening by extracting 5 grams of soil with hexane under ultrasonic conditions to be injected in the GC equipped with FID to have an estimate on the concentrations present in the sample.

Based on the first results of Tahry Mostafa, the necessary solvents have been already ordered and shipped from The Netherlands to Mali during the period of the mission. Samples for soil characteristics have been selected on the July 30. On July 30 the equipment was well functioning as shown in photo 4.

Photo 4. Staff of the laboratory working together with Tahry Mostafa on the GC-equipment

4 Field investigations Mauretania

4.1 Introduction

The field investigation in Mauretania have been started on August 1 by going to the site in Nouakchott, The investigations on this site has been finished on August 6. In between we have visited site in Letfatar (August 3 and 4) and Kiffa. (August 4 and 5) We have been accompanied by Diallo Amadou (consultant for FAO) and SY Amadou Domba (CNLA). The amount of rainfall in Mauretania is limited and lower compared to the sites visited in Mali. The rainfall of three stations is presented in Table 10. Two of them were close to the investigated sites (Kiffa and Nouakchott), the third, was situated north of Letfatar and probably dryer than this site.

Table 10. Rainfall in three stations in Mauretania

STATION	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL	Year
Kiffa	**	**	**	**	0	1	68	136	83	2	0	0	290	2001
Nouakchott	**	**	**	**	0	0	0	30	74	0	0	0	104	
Tidjika	**	**	**	**	0	0	6	39	4	0	0	0	49	
Kiffa	12	0	**	**	8	5	0	118	43	20	0	**	205	2002
Nouakchott	**	0	**	**	0	0	0	21	22	0	0	**	43	
Tidjika	6	0	**	**	0	0	0	48	12	0	0	**	66	
Kiffa	**	**	**	**	0	39	67	141	55	66	**	**	368	2003
Nouakchott	**	**	**	0	0	0	3	12	8	14	**	**	37	
Tidjika	**	**	**	**	5	3	13	52	17	24	**	**	114	
Kiffa	**	**	**	**	5	4	85	202	23	0	**	**	319	2004
Nouakchott	**	**	**	**	0	0	3	9	1	0	**	**	13	
Tidjika	**	**	**	**	0	0	15	32	14	0	**	**	61	
Kiffa	0	10	0	0	3	23	77	75	274	19	**	**	479	2005
Nouakchott	0	29	0	0	0	17	0	100	45	0	**	**	191	
Tidjika	0	36	0	0	0	28	6	26	137	0	**	**	233	
Kiffa	**	**	**	**	84	13	61	68	107	0	**	**	333	2006
Nouakchott	**	**	**	**	0	0	14	20	14	0	**	**	48	
Tidjika	**	**	**	**	11	0	31	37	14	0	**	**	93	

4.2 Site Nouakchott

The site in Nouakchott is a depot in use for pesticides in the period 1975-2007. All kind of pesticides have been used, except dieldrin. In 2007 the residues in the depot have been removed leaving an empty depot that should be demolished, but removing of the depot will free the contaminated soil and residuals of the floor, which are heavily contaminated with pesticides. After the depot has been build settlement in the area has occurred and on the moment houses are just besides. Settlement is considered as a large risk on the site. After removal of the depot, the area will be used for housing. This housing is not official allowed, but the procedure is common practise and will be legalized after several years. Removal should therefore be combined with a clear plan for reuse of the site.

Photo 5. The depot in Nouakchott, outside and inside

4.2.1 Hydrological situation

Groundwater on the site was thought to be at -10 m, but during sampling the groundwater was reached at -3 m. The groundwater is not used because it is salt (influence of the sea). Rain fall on Nouakchott is 100 mm/year or less.

4.2.2 Sampling plan and results of sampling

The inside of the depot was heavily polluted. Entering the depot without protection is not to be considered because of risks for health Staying in the empty depot was considered as too dangerous for workers and it was decided not to sample here. Sampling in the depot should only give confirmation on a known fact, the soil inside is heavily polluted. Risks outside the depot were measured at the north site by taken surface samples on different distances from the depot (12, 7.5, 3.5 and 0 m) and beside the house at the east side. Deeper drills were placed just beside the depot and samples were taking till a depth of 3 meter.

It was possible to smell the pesticides outside of the depot, which means that people around the depot are constantly exposed to the pesticides.

Results of the surface samples are presented in Table 11, which table shows that the surface soil is slightly polluted, and that there is an inverse relation with the distance. This means that the store does not act as a source, but that presence pesticides is caused by other activities on the site

Table 11. Measured concentration of pesticides in soil samples from Nouakchott. (All concentrations in mg/kg)

Distance from store *m*	*depth* *cm*	***Chlorpyrifos content*** *mg/kg (ppm)* *A*	*B*	*Mean*	***Malathion content*** *mg/kg (ppm)* *A*	*B*	*Mean*
12 east	0-5	0.049	0.061	0.055	0.019	< 0.01	
7.5 east	0-5	0.025	0.020	0.023	< 0.01	< 0.01	< 0.01
3.5 east	0-5	< 0.01	0.016		< 0.01	< 0.01	< 0.01
0 east, middle of store	0-20	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
,,	66	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
,,	135	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
,,	220	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
0 north/east corner of store	224	< 0.01	0.084		< 0.01	< 0.01	< 0.01
NKC13	307	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

4.3 Site Letfatar

On the site of Letfatar, dieldrin has been stored. Vessels have leaked, but were also emptied by local population to be able to use the vessels for their own purposes. The site has been earlier investigated by Tauw in 2002 (Tauw, 2002). Based on their results they advised to close the site to prevent people and animals to have contact with the soil and to find a solution for the high concentration they have found in the drinking water.

The site is situated just east of the village and the last house has been build just besides the fence. This fence has been renewed beginning of 2007 to follow the conclusions of Tauw. Creation of sand dunes has made these fences not to function anymore, already in August 2007 (photo…). On our arrival goats were present in the polluted area. Compared to the photos in the Tauw report, higher and probably also more sand dunes were present. The visible number of places were vessels has been emptied were reduced to three, the other were covered with sand. Only on one place, the original soil containing a lot of rocks, was close to the surface. This was near the tree at the south site of the depot. Under this tree biological activity was present in the soil as shown by the presence of small heaps of soil created by *Coleoptere Pimelia Senegalensis-Tenebrioaidae.*

The groundwater is very deep. Groundwater in the well south of the site was -13 m and this well was situated at a lower level. The area is dry, with a yearly rainfall of approximately 100 mm.

Photo 6. Sand dunes have swamped the fence and made entrance easy

Photo 7. Tree at south site of the site and small heaps of soil under the tree produced by Coleoptere Pimelia Senegalensis-Tenebrioaidae

4.3.1 Sampling plan and results of sampling

Risks to be considered on this site are possibilities for direct contact and transfer to the groundwater. Direct contact was only possible on the few visible places left were vessels has been emptied. The sand brought to the site may act as a good isolator. To check the effectiveness we have taken samples on the slope of the dune above a place were according the photos of Tauw vessels has been emptied. On this site the thickness of the sand layer was 2 m before the rock containing layer has been reached. The second soil drilling was near the tree, were a depth of 50 cm could be reached. Samples were also taken of the small heaps of soil (surface of augering 2, in table. 11. The third soil drilling was on the place with the emptied vessels, a depth of 1 m could be reached (Table 12). Aldrin have been measured in all samples, but concentrations were below 0.01 mg/kg.

Regarding Dutch law concentrations above 4 mg/kg are considered as heavily polluted. On industrial site concentrations up to 0.14 mg/kg are allowed and this value is 0.04 mg/kg for living areas. US EPA PRG uses comparable limits for the same land use and these are respectively 0.15 and 0.03 mg/kg.

Table 12. Measured concentration of dieldrin in soil samples from Niogoméra (soil drillings). (All concentrations in mg/kg)

Sampling	***Depth cm***	***Dieldrin content mg/kg***		
Augering 1	10	0.37	0.24	0.31
	80	0.56	0.40	0.48
	160	0.06	0.03	0.04
	200	0.34	0.20	0.27
Augering 2	surface	0.03	0.04	0.03
	0-25	<0.01	<0.01	<0.01
	50	<0.01	<0.01	<0.01
Augering 3	0-5	0.01	0.02	0.02
	30	0.02	0.02	0.02
	70	<0.01	<0.01	<0.01
	115	<0.01	<0.01	<0.01

None of the samples presented in Table 12 has to be considered as heavily polluted. Highest concentrations were measured on the places were the sand has covered the contamination (augering 1). Probably the wind has brought clean sand together with contaminated particles from the polluted parts. Remarkable is that the augering between the pollution is relatively clean, which shows that dieldrin is not very mobile in the soil.

The places with emptied vessels are potential places were dieldrin could have leached to the groundwater. Two transect were made to a depth of 1 m just besides these places and samples have been taken from this transect, from the soil cemented by the pesticides and under this cemented soil. It was possible to smell the pesticides in the transect. By further investigation, it was found that two situations can be distinguished (figure 3)

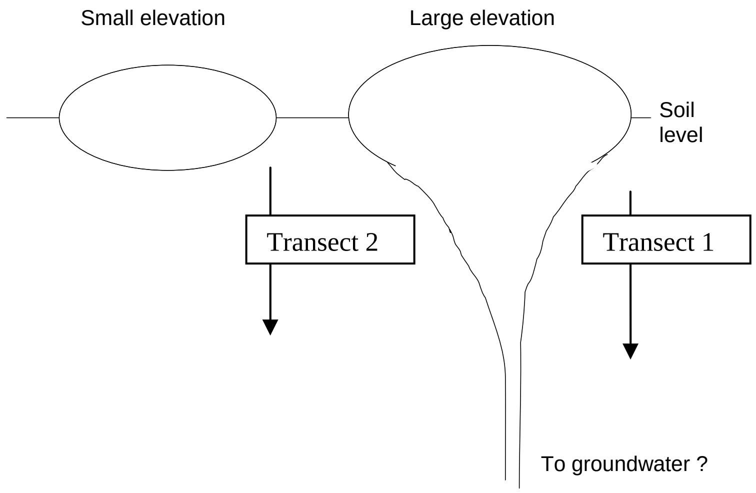

Figure 3. Shape of elevations with soil cemented by dieldrin

The shapes in figure 3 are in agreement with the theory of Hoeks and Rijtema (1982). The dieldrin can be considered as a solution not mixable with water. At first the soil is saturated with this solution, an equilibrium situation is achieved when the adsorption to the soil is strong enough to resist gravity. The situation were equilibrium is reached is called rest-saturation. As long as this is not achieved the solution will go downwards. With a small amount of dieldrin the shape as given in the left part of figure 3 is obtained. If more vessels have been emptied on the same place a more funnel like shape is obtained. The solution may even reach the groundwater and form a floating layer which can be as large as rest saturation allows. If this layer exists is not measured, to do this, it will be necessary to drill till a depth of approximately 15 m were the groundwater is present. Special equipment is necessary to do this.

Soil samples as been taken (photo 8) at two places near contaminated elevations as indicated in figure 3. The samples were taken at the edge of the concentrated pollution. Transect 1 was below a tunnel like large elevation and transect 2 below a small elevation (Table 13). In all samples aldrin was below 0.01 mg/kg, except the sample in transect 1 at 40 cm where a concentration of 0.8 mg/kg has been measured in both analyzed samples.

Photo 8. Sampling below a contaminated elevation

Table 13. Dieldrin in soil below the elevations

Sampling	**Depth below elevation cm**	**Dieldrin content mg/kg (ppb)**		
		1	*2*	*average*
Transect 1	0-5	27.2	25.9	26.6
	40 cm in middle of contamination	26.1	24.5	25.3
	40	17.2	18.6	17.9
	70	0.59	0.72	0.66
	125	0.19	0.35	0.27
Transect 2	25	0.61	0.41	0.51
	70	0.09	0.14	0.11
	100	0.13	0.18	0.16

As Table 13 shows, the soil just below the elevation in transect 1 is heavily polluted. The funnel shape was confirmed by the higher concentration when a sample was taken below the middle of the contamination. On a deeper level the concentration drops quickly to allow use of the soil in industrial areas, but much higher than allowed in living areas. The second transect also shows elevated concentration, but is relatively low for the layer 25 cm considering the pollution above. All measurements confirm the low mobility through the soil of dieldrin.

The possibility of wind transport has been checked by taking a soil sample near the road on 30 meter from the fence. This sample contained 0.06 mg/kg (individual measurements 0.08 and 0.04 mg/kg), which is close to the detection limit and regarding Dutch law this value equals the maximum concentration for places were people live. Although the concentration is not high, it shows the possibility of dieldrin to be transported by wind.

A water sample has been taken in a water well (photo 9) more than 300 meters south of the location. This water was clear and did not smell. The concentration Dieldrin measured was 0.04 µg/l. This is below the Dutch drinking water standard of 0.1 µg/l. The value is comparable with the WHO standard of 0.03 µg/l. The water sampled contained 0.07 µg/l aldrin, slightly above the standards. It should be realized that investigation of a heavily polluted site and sampling clean water is not a good combination. The water sample can be easily polluted by the sampler, even when he takes a lot of precautions (Cross contamination). In spite this, the dieldrin and aldrin concentration in the water, were low. It confirms the expectation (dieldrin is not mobile), that there has not been transport to the water well. The concentrations were much lower than measured in 2002 (TAUW, 2002) in probably the same well. They measured 0.55 µg/l.

Photo 9. The water well where a water sample has been taken

4.4 Site Kiffa

The site in Kiffa is besides a landing strip on an airport. The pollution situation was comparable with the one in Sévaré. An important difference however was that run-off was not identified as an important risk. All vessels stored on the site, including the most polluted soil have been removed beginning of 2007. This has decreased the smell inconvenience significant. However based on observations during the visit the soil is still heavily contaminated. The groundwater level is very low and no wells are in use in the direct environment of the airport.

4.4.1 Sampling plan and results of sampling

The soil in Kiffa contained a lot of stones and drilling was not possible. Therefore transects have been made till a depth of 50 cm. The first transect was just besides the bank of the strip, where the contamination was visible. The second was on a place where recovering of the soil with vegetation was visible and the third again on a visible contaminated place. Important on this site was the recognizing of recovery, which is a good point of departure for biodegradation. It was possible to smell pesticides in the samples from the first and third transect. It was not possible to smell them in the second transect.

The Kiffa–site has been sampled before. Results of the analysis are given in Table 14. Although the places of sampling are not known, there is a large differentiation in concentration as also has been observed during the visit.

Table 14. Results of soil analysis on the Kiffa-site

Code	***Result(mg/kg)***		
	Chlorpyrifos	***Fenitrothion***	***Malathion***
A 301	1.3	3.0	1.7
A 302	190	1384	7.8
A 303	2.5	6.3*	14.3
A 304	0.67	3.4	1.4
A 305	7.9	4.3	5.2
A 306	1.7	3.9	1.9
A 307	0.45*	18.1	0.23
A 308		11.3	327
A 309	2.7	8.85	410
A310 10-30cm	2.3	6.8	4.6
A310 10cm	0.44	6.2*	4.0
A310 30-40cm	1.43	8.2	212
A501 10-20cm	2133	2.8	1.35
A 311	3.5	9.8	8.3
DLK 1	6.1	55	811
DLK 2	202	299	0.59
DLK 3	29	5.9	5.1

- analysis not confirmed by GC/MS

5 Risk reduction

5.1 General

It was found that in the centre of the contamination, pesticides were penetrated to a larger depth. It is not to be expected that the soil will be removed and remediated elsewhere due to the high costs. If soil will not be removed, isolation or in-situ remediation are possibilities to reduce the risks. Proposals are given below and are based on the experiences during this mission. In chapter 5.2 and 5.3 they are worked out in proposals for all specific sites.

For extra background information, important physical properties and the possibility of biodegradation of the identified pesticides are presented in Table 15. K_{ow} (distribution coefficient octanol/water) is a measure for the adsorption to organic matter in soil. The higher the value, the stronger the adsorption. Solubility in water decreases with increasing K_{ow}. The solubility is an estimate of the risk for groundwater pollution. The Vapour pressure is an estimate of the possibility to volatilize from the soil surface, the higher this value the stringer the smell and possibility for transport. The possibility of biological degradation is also indicated with an estimate of the time necessary to reduce the concentration in soil to 50% of the original concentration. All pesticides except dieldrin are biodegradable. Dieldrin is considered to be non-degradable. On the long term, degradation can be possible. FAO 2000 gives a DT50 value for dieldrin of 7 years.

Table 15. Physical properties and possibilities for degradation of the pesticides identified and expected but not identified on the investigated sites (Data Tomlin, 2003)

Pesticide	*Log K_{ow}*	*Solubility in water (mg/l)*	*Vapour pressure (mPa)*	*Degra-dable*	*DT 50 Soil (d)*
IDENTIFIED					
chlorpyrifos ethyl	4.7	1.4	2.7	Y	10-120
cyanophos	2.65	46	105		
cyhalothrin	6.9	0.005	0.001	Y	28-84
dieldrin	6.2	0.186		N	
fenitrothion	3.43	30	18	Y	12-28
fenthion	4.84	4.2	0.74	Y	rapidly
fenvalerate	5.01	<0.001	0.02	Y	75-80-
malathion	2.75	145	5.3	Y	rapidly
parathion ethyl	3.83	11	0.89	Y	rapidly
parathion methyl	3.0	55	0.2	Y	rapidly
phenthoate	3.69	10	5.3	Y	rapidly
phosalone	4.01	3.05	<0.06	Y	1-4
pyridaphenthion	3.2	100	0.0015	Y	11-24
tetrachlorvinphos		11	0.0056	Y	2
NOT IDENTIFIED BUT EXPECTED					
deltamethrin	4.6	0.0002	0.00001	Y	21-25
lamdacyhalothine	7	0.005	0.0002	Y	6-40

5.1.1 Isolation

The two vertical possible risks are upward and down ward transport to atmosphere and groundwater respectively (figure 1). The horizontal transport occurs mainly due to run-off in Mali and probably transport by wind in Mauretania.

Vertical transport by wind can be prevented by covering the site. Leaching from the site can be prevented by taken measures that rain fall that falls on the site will be locally absorbed by the soil in combination with prevention that run-off water from outside the site enters the site, because this will increase the amount of water that may infiltrate further.

Covering of the site prevents the transport to the atmosphere by increasing the resistance for transport and by using a soil with a proper quality it will increase the possibility for biological activity (growth of vegetation and biodegradation). In Mauretania the development of sand dunes can be used as a natural process to cover a site. This is especially important if the pesticides have a high vapour pressure, like cyanophos.

Transport to the groundwater occurs only by transport by water. Transport as product has occurred already and the soil can be at residual concentration. If the transport medium (=water) can be eliminated, no further transport will occur to the groundwater. Covering with a non permeable material is a possibility, but this is considered not to be sustainable on most places. Covering with a non-permeable material will also prevent biodegradation. More sustainable will be to assure that all rainfall will be evaporated. Only evaporation by the soil surface is not enough to remove even the limited rainfall in both countries. For instance on the site in Letfatar the soil was wet till depths of 1 meter. A little help is necessary, which can be given by deep rooting vegetation. A precondition for this vegetation is that the vegetation will grow under the local conditions (drought resistant) is not consumable by human, but also not by cattle. Although uptake by plants is mostly limited this risk should be prevented by a proper choice of the vegetation. This choice should be locally made.

For Mali it is proposed to use Vetiver, which is a grass that produce essential oil in it roots. It is used to prevent soil erosion. The grass can be consumed by cattle, but they prefere other vegetation. It grows in zones with 400-2000 mm of rain and can survive dry periods (Maffei, 2002). Another choice for Mali can be *Jatropha*[1] or other local fence vegetations. The choice for Mauretania is more difficult, because of its drijer conditions.Dune vegetations may be suitable. Posible vegetations are given by BOUMEDIANA (2001). Most vegetations are however eaten by sheeps, so a selection is necessary.

[1]The growing of Jathropha is stimulated as a vegetation to provide biodiesel. Initiatives to grow jatropha have already been taken in Mali

To create such a vegetation several steps can be necessary,

- Covering the site with a clean soil
- Stabilizing this soil to prevent that will be removed by run-off or wind erosion
- Increase the fertility of the soil to promote the development of the vegetation
- Sow or plant the desired vegetation

5.1.2 Biodegradation

Most pesticides are well degradable if the concentrations do not exceed a level toxic for the micro-organisms involved. A few 'old' pesticides like dieldrin and aldrin are resistant to degradation, although more prove is published that even these pesticides are degradable if the time frame considered is long enough. Biodegradation asks for a biological active soil. It was found that even under high polluted conditions soils were recovering (photo 10)

	
Vegetation on infiltration area (Sévaré)	*Active beetle after removal of vegetation just besides parathion vessels (Niogoméra)*
	
Start of growing of vegetation on contaminated soil after removal of the vessels (Letvatar)	*Recolonization of ants (Letfatar)*

Photo 10. Biological activity on contaminated sites

A recovering soil is a challenge for bioremediation and gives the possibility to remove the contaminants on the long term. Remediation will start at the surface and will slowly extend to lower layers, providing that the conditions promote growth of the micro-organisms. If isolation is successful, larger depth will be dry and no degradation will occur. If locally infiltration will occur, the stimulated biodegradation may prevent leaching, because the pesticides will be degraded.

Table 16 gives the pesticides identified during this mission and the possibilities for degradation.

Table 16 Pesticides identified on the investigated sites in Mali and Mauretania

Pesticide	***Degradable***	***Identified on site***					
		Molodo	Sévaré	Niogo-méra	Nouak-chott	Letfatar	Kiffa
chlorpyrifos ethyl	Y	+	+	+/-	+/-		+
cyanophos	Y	+/-	+/-	+			
cyhalothrin	Y	+		+			
dieldrin	N	+	+/-	+		+	
fenitrothion	Y	+	+				+
fenthion	YY		+				
fenvalerate	Y	+/-	+	+/-			
malathion	Y	+/-		+/-	+/-		+
parathion ethyl	Y	+	+	+			
parathion methyl	Y	+					
phenthoate	Y	+	+				
phosalone	Y	+/-					
pyridaphenthion	Y	+/-					
tetrachlorovinphos	Y	+/-					

\+ identified and measured concentration >1 mg/kg
+/_ identified and measured concentration < 1 mg/kg

For stimulation of bioremediation it is advised to increase the biological activity by adding fertile soil, manure or to combine the bioremediation with composting. Organic matter will increase the growth of the necessary micro-organisms. Because the pesticides are already present for a long time, adaptation is not expected to be a problem and organisms able to degrade the pesticides will be present, It is only necessary to increase the population of these organisms by offering them the proper conditions for growth.

Because biodegradation is observed, the necessary micro-organisms are present on the sites. Soil were biodegradation has been observed can be used for inoculation of still polluted soil. Inoculation with external, commercial micro-organisms is not found to be necessary.

5.1.3 Protection of wells

As mentioned in previous chapters, there can be uncertainty on the pollution of the groundwater. To really identify these risks it is necessary to do several deep soil drillings, to the depth of the groundwater and to place filters to sample the groundwater and to measure the depth in order to be able to establish the direction of the groundwater. If pesticides are measured in the groundwater, it will be necessary to take action to prevent the local population to use this water. This will be a difficult action, because the pollution can be present there already for several decades. Removal is impossible, regarding the large depth of the groundwater. Remediation of the groundwater will be an action, necessary for several decades, which is also not a serious option on these sites. Therefore the solution of this problem has to go in the following direction.

- Decrease the amount that can leach from the sites (see 2.2.3)
- If wells are suspected based on hydrological considerations, replace them by a well that gets the water from a higher depth, followed by closure of the existing well. Doing this, money of deep soil drilling is not used to establish a risk and do nothing on the risk, but reduce immediately the potential risk.

For wells further away natural attenuation will occur, which is a combination of dilution, adsorption and biodegradation.

5.2 Mali

5.2.1 Molodo

The Molodo site is within the village and close to wells. Based on the field visit end of July 2007 and the visit in july 2008 there is no direct contact of the contamination with the groundwater.
There has been some transport via surface run-off. It is recommended to remove the upper 10 cm (Outside of the source) of the soil on the site and to replace this by clean soil. In the source, parathion ethyl is the most important pesticide present. This compound can be removed using biodegradation. The soil however also contains dieldrin which is not degradable. The following approach was recommended for the source area and discussed in May 2008. For the implementation see chapter 6.

- Remove the contaminated soil as far as possible. Store the soil in a temporary depot or in bags
- Construct a landfarm on which the soil can be remediated (10 x 20 meter).
- Fill this landfarm with biological active surface soil from the site (layer of 30 cm).
- Add 5 m^3 of soil from the source and mix.
- Follow the degradation
- As soon as the concentration is low and or stable, remove 5 m^3 from the landfarm and bring this to the final destination
- Replace by a new portion of contaminated soil.
- Remediate during the same time and repeat till all the soil is bioremediated

Construction of final destination of the soil

- Use for this destination the place where the empty vessels[2] have been stored.
- Add active carbon to the soil on the bottom
- Add the bioremediated soil
- Cover the remediated soil with surface soil from the site
- Plant vegetation on the depot to assure evaporation of the rain water. Use vegetation not consumed by human or cattle
- Plant trees around the site (see below)

Reconstruction of the source of contamination.

After removing of as much as possible contaminated soil, start to refill the place with biological active soil from the surface of the site. This soil will act as a primer for bioremediation and a source of active micro-organisms. The micro-organism will slowly penetrate the contaminated soil and biodegrade the degradable pesticides. Use clean soil for the upper meter. The water bearing capacity of this soil can be increased using organic matter from composting activities, or organic residuals (leaves etc.).

It will not be possible to remove all the contaminated soil besides the building. Therefore additional measures are necessary to prevent pollution of the groundwater. Most effective way is to prevent rainwater to pass the polluted layers. This can be done by using the capacity of vegetation to evaporate water. The amount of rainwater in Molodo is limited and vegetation can evaporate it all. The vegetation used should be not consumable for human and cattle.

There is an upwards seepage in the area. The water level in the wells around the site was higher than the water level reached by drilling. This means that the risk of pollution of water wells around the polluted area is low as long as the precipitation is evaporated. The risk can be further reduced by planting of trees around the polluted area. The extra evaporation will maintain the upward flow of the groundwater. For the same reason trees or other deep rooting vegetation should be planted around the final destination of the landfarmed soil.

5.2.2 Sévaré

The pesticides in Sévaré are concentrated besides the landing strip. The pesticides probably will be present till higher depths. It is therefore important to reduce the possibility of leaching. On the moment rainfall causes a run-off from the platform and the water passes the contaminated strip. This can be prevented by making an elevation at the edge of the platform and forcing the water to pass the edge on a clean part (corner platform and landing strip).

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[2] The vessels in the concrete construction are planned to be removed. If enough precautions are taken to prevent transport to the groundwater they may be stored and mixed with the soil and active carbon.

It is not necessary to treat the soil besides the polluted part (from 11 meter). Run-off did probably occur, but pesticides have been degraded in the biological active soil were also vegetation was present. This activity, in combination with the biodegradability of the applied pesticides gives an opportunity to reduce the amount of pesticides in the polluted part. The present high amount in this part prevents biological activity, and it is therefore necessary to dilute. The landfarm proposal for Molodo can be used and on this airport it can be applied on larger scale. Use the part from 11 to 16 meter to make the landfarm, because this soil will have the biological activity to initiate degradation.

Return the bioremediated soil to the same place, because this soil will act as a primer for active micro-organisms that will degrade residual pesticides.

Compared to Molodo, the soil in Sévaré is more permeable for water and no upwards seepage is present. Pesticides may leach to the groundwater. Transport can be prevented by planting trees with roots that can reach the groundwater, downwards the flow of the groundwater.

5.2.3 Niogoméra

Run-off is not found to be a real problem. It is however an issue to take care during activities. Making a small wall around the site is advised.

It is possible that pesticides are on there way to the groundwater. This may affect the quality of this water. In order to investigate the quality of the water the following steps are necessary:

1. Make at least 3 deep wells to monitor the depth of the groundwater to establish the direction of the groundwater.
2. Measure the groundwater level during a year a level the positions.
3. Make a deep well downstream of the polluted site with a filter in the upper part of the groundwater.
4. Take a sample and analyze

If the water contains pesticides, than it will be necessary to take precautions. It will not be possible to solve the problem and it will be necessary to take precautions. If the groundwater flow is in the direction of an existing well, it will be necessary to close this well and make a new one.

A more efficient way of spending money can be that it is assumed that the existing well can be reached by pesticides (see also 5.1.3). In that case, it is only necessary to make one deep hole to a level where the contaminations cannot be present. Place a filter and use this for drinking water. An advantage of this solution is that an existing open well is replaced by a closed well.

Risks on the site it selves can be reduced by applying bioremediation. The landfarm can have a position on the site.

5.3 Mauretania

5.3.1 Nouakchott

As follows from the analysis, the soil outside the depot is only slightly polluted. Pesticides identified are degradable. Only at larger depth close to the depot pesticides have been identified. Regarding the origin, bioremediation should be a possibility, but conditions are very dry and tiling of soil will give inconvenience for the people living around. Measure should reduce the exposure and isolation is the first step. The first ideas were as follows and risk reduction could be achieved by:

1. Finding a sustainable solution for the people living just beside the store. It will be risk full for them to stay in the house. Finding temporary solutions for neighbours during the activities described in 2.
2. Building a small wall (50 cm) around the depot, demolishing[3] the depot combined with removal of the most polluted soil. This soil can be send to Kiffa to be landfarmed (see also 5.3.3). It is not advised to make a landfarm in the urban area of Nouakchott.
3. Removal should be followed by refilling the site between the walls with soil. For this soil, the upper layer of the outside soil can be used. This will reduce the risk up there, because this soil is slightly polluted. Adding some manure and/or compost will increase the biological activity, and pesticides moving through the soil will be degraded. Mix the first layer of about 15 cm through the residual soil. Use also active carbon to immobilize the pesticides further.
4. Deep rooting vegetation will increase the capacity for degradation. And it is advised to plant this vegetation as soon as possible. Use vegetation that will not be consumed by human or cattle. Trees in combination with fence vegetation are recommended. Use vegetation that can survive under local climate conditions and the brackish groundwater. Trees will evaporate water, act as a water pump and clean the ground water.

In the discussion in May, it was brought up that the depot could also be used as a bioremediation hall. Important advantages were:

- Preventing of transport of contaminated soil over a large distance,
- Preventing inconvenience and risks for local residence because the depot is a closed system.
- For bioremediation water is necessary, evaporation will be less in a covered area
- Maximization of control in the covered landfarm

Before starting residuals of the concrete floor have to be removed and transported to a save place.

The concentration of pesticides in the depot is too high for active micro-organisms. Suitable conditions can be created by using part the outside surface soil in a layer of 15 cm in the depot in combination with organic matter (compost) to increase

[3] The author of this report has no experience in demolishing of stores and cleaning of the material.

biological activity. Water has to be added to this soil. Following step is mixing this layer with 5 cm of the original soil. It is expected that degradation of pesticides will start in this activated layer of total 20 cm. Degradation of the pesticides has to be followed by taking of samples and chemical analyses (see also the procedure used in Molodo (chapter 6). When most of the pesticides are degraded, the 20 cm of cleaned and active soil is mixed with the following layer of 8 cm (total layer 28 cm). After the same period as used for the first layer the layer of 28 cm is mixed with the following 10 cm (total 38 cm) and another time with the following 12 cm (total 50 cm).

During the bioremediation water has to be added to assure biological activity. This water can also be used to clean the inside of the depot.

After cleaning of 50 cm the cleaned depot has to be demolished. Because there will probably be some residual pesticides a small wall has to be build around the depot and filled up with soil from outside the depot (see also step 3 above). This soil is not further mixed, but used as a cover. Planting of deep rooting vegetation (step 4 above) will stimulate biological activity in deeper soil layers.

As mentioned, above measures are not enough, people will ignore the activities and build a house. This problem has been brought up by and was intensively discussed at the Centre National de Lutte Antiaeridiénne. A proposal suggested by one of the co-workers of the institute has perspective. He suggested building a small meteorological station for the institute at the site. This means that the institute keeps control on the site. Other use by the institute providing that the use allows isolation and vegetation is of coarse also possible.

5.3.2 Letfatar

The most important contamination in Letfatar is dieldrin, which is not degradable. Bioremediation as recommended on other sites is therefore not an option. Moreover the site is very dry and the sand can only contain small amounts of water. This makes biodegradation not a realistic option. Transport of Dieldrin by wind is found to be a risk and this may affect the soil quality in the village.

The site at Letfatar becomes more and more covered by sand dunes. This natural process can be used to cover the whole site and thereby isolating the site. Covering should be stimulating on the places were the sand layer is small and existing dunes shall be stabilized at the desired level. A sand layer of at least 2 m is recommended. The highest dunes during the visit were 5-6 m. Techniques as used north of the road from Nouakchott to Boutilimit, just east of Nouakchott are a good option. Fence vegetation is used there to make compartments. After obtaining of a stable structure, vegetation has to be planted that is able to evaporate the rainfall. Because the village is close and as observed, cattle is frequently passing the site (see also photo 7) vegetation should not be liked by the cattle although the roots of the vegetation probably will not reach the contaminated soil.

During 2007, contaminated soil was still visible on several places. Plastic foil should be used to cover this places first before creation of the dunes. This foil will act as an extra isolation, thereby giving an extra reduction for risks of transport to the groundwater.

5.3.3 Kiffa

On this site, the vessels have been removed and also the most polluted soil. The whole area can be considered to be polluted, but all pesticides involved are biodegradable. Recovering of the site has been observed, so biodegradation using landfarming is a good possibility. Doing this it should be realized that locally the pesticide concentration can still be high and toxic for micro-organisms. Landfarming should therefore be a step by step procedure. Landfarming should also not increase the other routes for risks (transport to atmosphere, contact with people and cattle, leaching, wind-erosion and leaching).
The following steps are proposed all to be carried out during the rainy season:

1. Place a fence around the site that prevents cattle to pass. As a result of increasing fertility vegetation will grow, which will be an invitation for cattle. The vegetation will probably not contain pesticides, but the soil eaten together with the vegetation will contain pesticides during the first years.
2. Adding soil and manure or compost and ploughing will increase the level of the area. Water at the south/west corner is now entering the area. This will be inverted and water from the area may run-off to the houses south of the area. To prevent this, a small dike has to be constructed at the west side.
3. During the dry season transport of still contaminated soil is possible by wind erosion. This can be prevented by using lines of fence vegetation (see also Letfatar). These lines have to be fertilized by adding soil, manure and or compost (**Year 1**).
4. In the wet season following on planting the fence vegetation, soil manure and or compost has to be added to the rest of the site and the first 10-15 cm has to be ploughed and harrowed. This shall not be a larger layer, because than the concentration of pesticides may be locally to high, preventing the desired biodegradation (**Year 2**). This can be followed by ploughing and harrowing the first 20 cm in September
5. In **Year 3** the first 30 cm can be ploughed and harrowed after the first rain followed by the first 40 cm in September.
6. Planting of vegetation not eaten by cattle on the whole site (**year 4**). The fence around the site will not be sustainable on the long term, but by applying this vegetation risks will be small, because the area will not be interesting for the cattle.

Because the entrance to the airport is limited, the landfarm on this site can also be used for bioremediation of soil from other sources, for instance the. removed heavily contaminated soil from the Kiffa-site, which is stored in a controlled depot outside this site.

5.3.4 Implementation and costs

Above activities can all be carried out and managed by local people and experts present in Mauretania. The degradation has to be followed by field observations and analysis of soil samples taken. This will be a cost factor if local capacity does not become available.

During the discussions in Mauretania in May 2008, an estimate of the costs of the plans has been made. These costs are summarized in table 17. More detailed information is described by SY (2008).

Table 17. Costs of soil remediation on the plots in Mauretania.

Site	***costs in US$***
Letfatar	46,000
Nouacchott	43,000
Kiffa	50,000
Supervision	69,000
Support from FAO and Wageningen University	80,000
Total	288,000

To compare, the costs for only removal of the contaminated soil in Ledfatar and cleaning elsewhere, are estimated by Tauw (2002) on at least 2,200,000 US$. This large difference shows that the African approach developed in this project gives good opportunties for a realistic remediation of the polluted sites investigated in this project, but also remediation elsewhere in Africa.

6 Impementation of risk reduction

6.1 Molodo (Mali)

6.1.1 General set up

It is important to know the starting situation. Two sites are important, The hot spot contamination at the magazine and the situation at the depot, which will be the final destination of the contaminated soil. The situation at the hot spot is given in figure 4. Heavily polluted soil was found at the corner of the magazine. The soil further away is considered to be biological active.

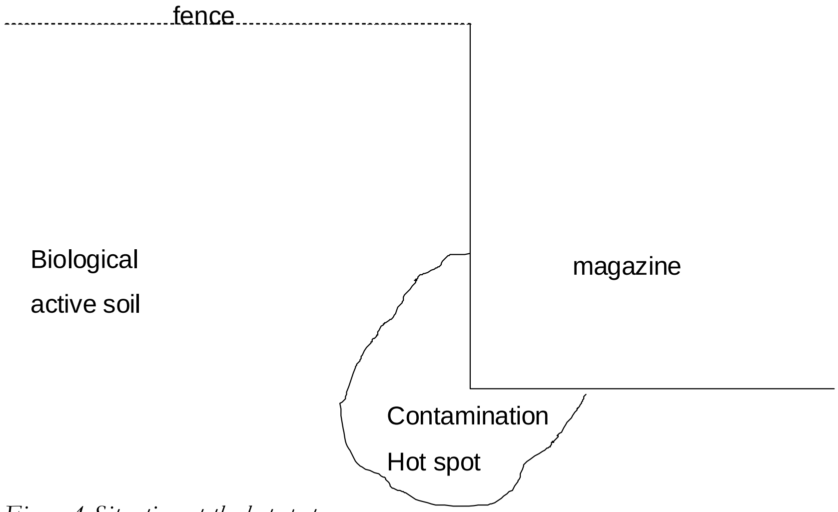

Figure 4 Situation at the hot spot

The depot is given in figure 5. Three different depots can be considered On July 13 the empty embalage has been removed from I and II. The soil left in these depots has to be considered as polluted.

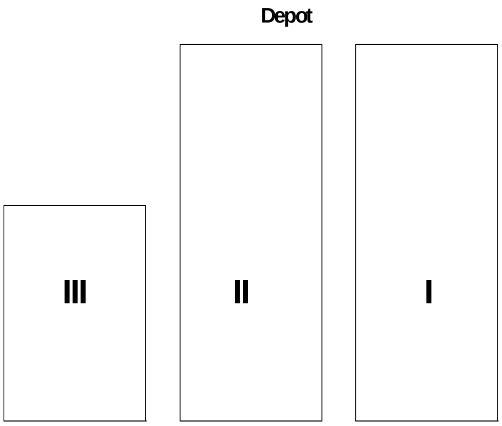

Figure 5 The depot

In general the treatment is according the following steps:

- Transport of heavily contaminated soil to depot I
- Refilling of the excavated site with active soil
- Making of a landfarm to remove the biodegradable pesticides
- Activation of the landfarm with organic matter
- Planting of vegetation around the landfarm
- First charge to the landfarm
- Make an adsorption layer with active carbon in depot 2
- First charge to depot 2
- Landfarming of second charge
- After last charge, make an adsorption layer with active carbon in depot 1
- Take all soil from the landfarm to depot 2
- Replace the landfarmed soil by clean soil
- Cover depot 1 and 2 with clean soil
- Planting of vegetation on the depot and the old landfarm

6.1.2 Specific activities

In more detail, the following actions were and still are necessary (Table 18). The first day, after arrival in Molodo in the afternoon of July 14, was used for the choice for the place of the landfarm and to discuss logistics for next day. Action 2 -10 were done on July 15 and action 11-19 on July 16.The vegetation was planted in the night between 16 and 17 and the action were stopped on July 17.Action 17-34 are future actions. Actions are presented in order of execution. The place of the action, hotspot, landfarm or depot, is given in column 2-4 with a dark color.

Table 18 Action table for Molodo

No.	hotspot	landfarm	depot	Activity	
1				Choice of the place of the landfarm	
2				Excavation of hot spot with polluted soil and transport to depot 1. Go as deep as possible, but stop if the soil becomes saturated with water. Take care about the building.	
3				Leave 5-10% of each load of the shovel on plastic near the site. This should be an average, 100 l for every transported m^3	
4				Use organic matter to be mixed with soil in depot 1. Add maximum of 5% of organic	
5				Refill of the excavated area with active soil	
6				Make the contour of the landfarm	See figure 6
7				Make a plan for the vegetation to be used	See figure 6
8				Choice of organic matter for landfarm, Charcoal for depot 2	
9				Replace the contaminated soil from depot 2 to depot 1	
10				Add clean soil to depot 2 to have a layer of 10-20 cm	
11				Make elevation at the contour of the landfarm.	

12				Mix organic matter in the upper layer of the landfarm	
13				Mix organic matter in the upper layer of the hotspot	
14				Take 2 mixed samples of polluted soil from the plastic screen	
15				Transport the contaminated soil to the landfarm on 12 equally distributed heaps. Mix the contaminated soil on the landfarm with the first 10-15 cm	
16				Mix the soil (first 10- 20 cm) in depot 2 with 100 kg of grinded charcoal. Soil has to contain 1 - 2 % of charcoal	
17				Define sampling location. It is important to return on the same places.	
18				Register locations and call them 1-5	

19				Take 5 samples and have them analysed. Use place and date as identification for the samples.	
20				Have someone watching the landfarm and make notes on situation (smell, vegetation etc)	
21				Plant vegetation in hotspot, around landfarm and around the depot.	 
22				Prevent that water from the roof will be drained to hotspot.	
23				Take 5 samples after 4 weeks and analyse	
24				Take 5 samples after 8 weeks and analyse	
25				Decide how long 1 charge has to be remediated. Results x weeks	
26				Take 6 m^{r} from depot 1 to the landfarm and mix, Reconstruct the organic matter layer on top.	
27				Take 5 samples after application of contaminated soil, see above	
28				Take 5 samples after x weeks	
29				Start with new charge after x weeks	
30				Continue until depot 1 is empty	
31				Make a plan for vegetation on landfarm and on top of the depot. Use experience with the vegetation used in the first period	
32				Add clean soil to depot 1 to have a layer of 10-20 cm Mix this soil with 100 kg of grinded charcoal	
33				Take first 25 cm of soil from landfarm and fill depot 1 with this soil	
34				Refill landfarm with clean soil	
35				Cover depot with clean soil	
36				Plant the vegetation on the landfarm and depot. This is the final situation.	

Remarks on activities

1. It was chosen to make the landfarm left of the hotspot. On this place the surface is biological active due to run-off in the past
2. Use of a shovel and truck was found to be necessary. Doing this by manpower should have taken several days. Success should be questionable, because the deeper soil was very structured and looked more like concrete.
3. This was found to be practical. An average sample was obtained by doing this, which is important for the first charge., which should be representative for this situation. Looking back, one wheelbarrow was taken from every charge of the shovel. This gave approximately 2 m^3. Two barrows could have been taken
4. Adding of organic matter in depot 1 was no problem, mixing was not found to be easy. At the end of the day the shovel was used to equalize and consequently mixing the soil. The rest of the organic matter was used to cover the depot, which also reduces the smell.
5. Also for refilling presence of shovel and truck was found to be necessary. This soil originated left from the landfarm and wsa also biological active.
6. Making of the contour was no problem. The landfarm should be about 10 * 10 to 12 meters. Because the landfarm was just beside the hotspot, part of the spils of the excavation were already on the landfarm. Spils besides this area were brought to the landfarm
7. It was decided to use Vetiver on the landfarm and Jatropha at the depot. Use of both plants will be evaluated after finishing the landfarm. Results on growing has to be registered. It was explained that the main function of the vegetation has to be evaporation of rainfall and not a maximum production. Addition of water is only allowed after planting to give the vegetation a proper chance to survive.
8. Local available compost has been used.
9. In the original plan we wanted to use manpower. Because the shovel was available this was used. We were very lucky with this change because a black cobra was present under leaves. This should be a point of attention, when replacing soil also containing other material.
10. Also due to presence and killing of the cobra it was difficult to differentiate between the contaminated layer and non contaminated layer. Most of the soil has been transferred to depot 1 and it was found to be necessary to add clean soil.
11. The size of the landarm was 11.5 * 9 m (103.5m^2). The size of the landfarm was limited, because a smaller area can be better controlled. On a smaller area it is easier to prevent unwanted spreading of the pesticides. Moreover the soil of the landfarm has to be transported to depot 1 at the end of the remediation.
12. 4 m^3 was used
13. 1 m^3 was used. There was an intensive discussion on the use of an extra m^3. Because this organic matter has to support the growth of vegetation and not biodegradation, the advise of local farmers knowing the soil and type of organic matter was decisive.

14. The contaminated soil has been sampled using a small auger. This large sample was intensively mixed. Reduced in size by quatering, sieved over 5 mm and sampled after last quatering.
15. Using the heaps distribution was well visible. Doing this all contaminated soil was equally distributed.
16. This is a very dusty activity. It should be avoided to do this with wind. We did this in the afternoon. The wind still early morning was better suitable.
17. Marks were made. And placed on the sampling places. They have to stay on these places to assure that next samples are taken from the same place. GPS coordinates were also registered. These coordinates cannot assure this sufficiently, because they have an inaccuracy of several meters.
18.
19. Using the auger, samples were taken around every sampling point.(depth 10 cm) The composite sample was sieved, mixed and a laboratory sample was taken
20.
21. Both jatropha and vetiver were planted on the inside of the elevation. This should be on both sites of the elevation. This will be corrected.
22. The water of the roof of the magazine may infiltrate in the old hotspot and may cause leaching. This has to be prevented by making a construction like a gutter

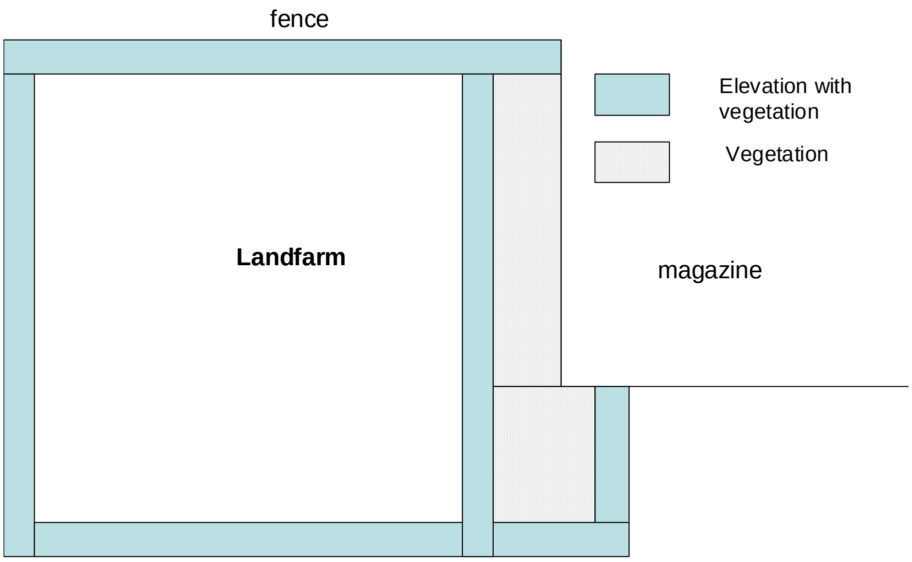

Figure 6 Contour of landfarm

6.1.3 First results Molodo

The results of this first charge on the landfarm are given in table 19.

Table 19 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.

6.2 Other implementations

After the implementation in Molodo, the Mali-team has continued on the location in Sévaré (Sylla, 2008-3). On this location biodegradable pesticides were identified and landfarming will be used to remove these. The landfarm is shown in photo 11.

Photo 11 Planting vegetation around the landfarm in Sévaré.

At the implementation in Ledfatar, isolation was the most important measure, because non-degradable dieldrin was present. Te Mauretania team (Sid'Ahmed Ould Mohamed et al.., 2009) has used a windscreen of Palme trees leaves, steel wire and Calotropus procera woods to stabilize the dunes that has to cover the pesticides. Plastic has also applied to cover the pesticides. Vegetation will be stimulated near the wind screens. The situation after implementation is shown in photo 12.

Photo 12 Situation in Ledfatar after construction of the wind screens

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Appendix 1 Suitability of charcoal to immobilize pesticides.

Introduction.

In the meeting on May 12-13, 2008, it was discussed if local charcoal could be used to immobilize non degradable pesticides. It was found to be important that the charcoal did not have effect on the pH value of the soil, because this could inhibit biological activity.

Method and results

On May 13, charcoal was bought near Bamako. This charcoal has been grinded and passed through a 2 mm sieve. pH has been measured in a suspension (ratio 2g solid material to 5 ml of water). The pH was 9.3, which value could be to high.
In the following step mixtures with soil has been made. The soil used originated from Molodo and a second soil originated from Letfatar in Mauretania. The mixtures contained charcoal up to 3%. It was intended to use a charcoal percentage of 1 - 2%. Result are given in following table. Slight increases of pH were observed.

Table. pH-values of charcoal and mixtures of soil and charcoal(results (Hans Zweers, Alterra)

	Charcoal (%)	***pH***
	100	9.30
Molodo	0.00	6.51
	0.98	6.58
	1.97	6.85
	2.90	7.07
Letfatar	0.00	7.25
	1.01	7.50
	1.95	7.89
	2.90	8.04

Conclusions.

The pH of pure charcoal is higher than pH measured in soil. After adding of charcoal tosoil, charcoal elevates the measured pH value in soil. This elevation, however, is low and will not have effect on the possibility of degradation of pesticides along as the percentage of charcoal is low (maximum 1-2%). Charcoal is therefore usable for immobilization of pesticides.