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MITIGATION OF PESTICIDE LEACHING IN BIOBEDS

1. PURPOSE OF THE PROJECT

The purpose of the work was tostudy the fate of pesticides in lined and unlined biobeds to establish possible occurrence and mitigation of pesticide leaching.

2. HYPOTHESIS

1. Biobeds may leak pesticides if conditions for preferential flow arise.
2. Preferential flow conditions in a biobed may arise when: a) the clay layer is not wet and forms cracks, b) the biomix has low sorption capacity and low microbial activity, c) there is a poor grass establishment on the biobed.

The present study focused on points 1 and 2a.

3. INTRODUCTION

3.1 Definition of Biobed

An important point source of contamination by pesticides is the filling or cleaning of the spraying equipments. However, the use of simple units as the biobeds has minimized the risks of pollution from this point source.

A biobed is a simple and cheap construction on farms intended to collect and degrade spills of pesticides (Torstensson & Castillo 1997, Torstensson 2000). Biobeds are defined as facilities composed of: a) a biomixture or biomix (mixture of straw, mineral topsoil and peat); b) a grass layer that covers the biobed, and c) a clay layer at the bottom of the biobed. A biobed is also equipped with a ramp making it possible to drive the sprayer over the bed.

The purpose of the clay layer is to limit the flow of water downwards. The clay should be wet to swell and form a homogenous and compact structure. A dry clay layer can form cracks giving risk for preferential flow. The biomixture should have the ability to retain and degrade pesticides. It should have a good adsorption capacity and a high microbial activity. Both capacities are affected by the composition, homogeneity, age, moisture and temperature of the mixture. The grass layer is to promote an upwards water transport and to serve as a tool that reveals pesticide spills, especially herbicides. Absence of the grass layer gives poor evapotranspiration and can generate a hydrophobic crust at the top of the biobed, with decreased microbial activity. Moreover, a crust also promotes the drainage of water to the bottom of the biobed by preferential flow (Fogg 2004, Henriksen 2003) increasing the risk of pesticide leaching. For a good biobed performance its three components should be working properly.

3.2 Types of biobeds

Depending on whether or not the bottom of the biobed is isolated from the environment, there are two types of biobeds, lined and unlined.

The unlined biobed has no impermeable synthetic layer that isolates it from the ground. The original Swedish-designed biobed belongs to this group. In many cases a natural clay layer is present at the bottom of the biobed pit. If this is not the case, a clay layer is added. There is no collection of drainage water in this system (Fig. 1.1).

The lined biobed resembles the original Swedish biobed but is lined by a synthetic impermeable layer (plastic, concrete, tarpaulin, etc) that isolates it from the ground. This design allows the collection of drainage water in special wells that are built at the side of the biobed (Fig. 1.2). Drainage layers (gravel, macadam or sand) are usually placed below the clay. This design is in use in the United Kingdom.

3.3 Water content – An important factor affecting biobed performance

Ideally, the moisture in the biobed should be high enough to promote microbial processes and solubilisation of pesticides, but still leave enough pore space for oxygen to support aerobic processes. Moreover, moisture levels near saturation increase the risk of transport of chemicals from the biobed and promote anaerobic processes {Fomsgaard, 1995 #2447}.

Oversaturation with water can occur in the biobed, for example when the sprayer is washed on the biobed {Basford, 2004 #2453; Spliid, 2003 #2452}. To avoid this situation, Swedish biobeds should not be used for washing of the sprayer. Instead, an extra water container for the washing the equipment at the field is recommended. Rainwater is allowed into the biobed. However, persistent rainfall can also cause oversaturation of biobeds and in such cases covering of the biobeds is recommended {Henriksen, 2003 #2368}. In Sweden it is also recommended that biobeds in areas with high precipitation should be covered from late autumn and during the winter period.

1) Unlined biobed

2) Lined biobed

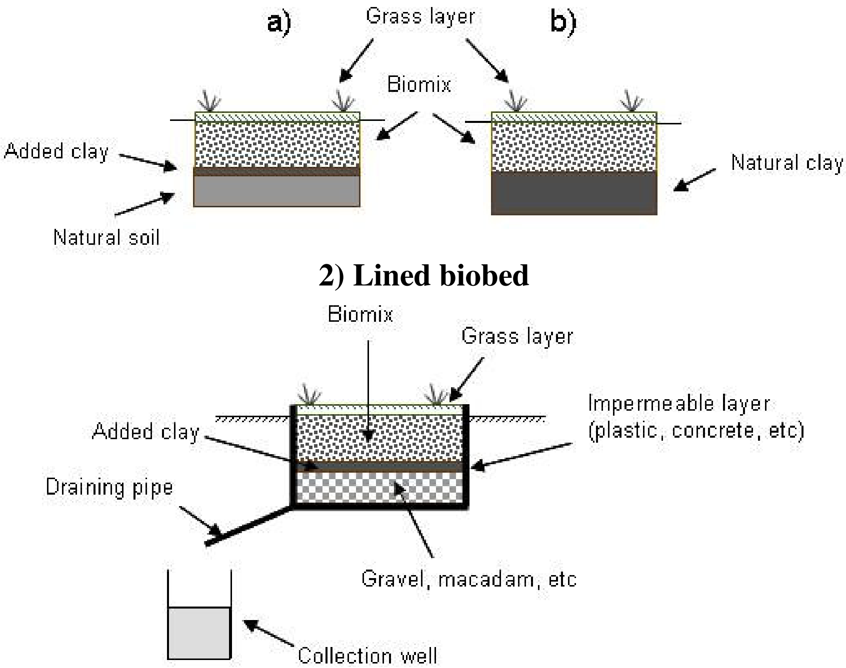

Fig. 1. Types of biobeds. 1) Unlined biobed with a) an added or b) a natural clay layer. 2) The lined biobed is isolated with an impermeable layer that allows collection of drainage water in a well.

According to Swedish studies of unlined biobeds, most of the pesticides are retained in the upper 20 cm of the biobed, with concentrations below the limit of detection in the clay layer at the bottom, suggesting limited downward transport {Torstensson, 2000 #2162} . However, studies in Denmark and the UK reported leaching of pesticides from lined biobeds. Later, a study in Sweden performed at a lined biobed at Göran Ohlsson´s farm, Odling i balans, Sjötorps, Norregård, Dalby showed also pesticide leaching. Table 1 shows a summary of these four experiences.

Therefore, the questions that arise are:

1. Are biobeds, including the unlined ones, leaking pesticides?
2. Or is the leakage of pesticides in lined biobeds an artefact of the profile used?

In order to answer these questions the mobility of pesticides in biobeds and therefore their potential leakage was studied by evaluating the fate of pesticides in lined and unlined biobeds. Pesticide occurrence and concentration in the top biomixture and clay layer at different locations of the biobed were determined. Pesticide concentration was also measured in the leakage water of lined biobeds.

Table 1 Leaching of pesticides in lined biobeds – Studies performed in Denmark, UK and Sweden

	Model Biobed, Denmark	**Field biobed, Denmark**	**Lysimeter biobed, UK**	**Field biobed, Sjötorps, Dalby, Sweden**
Size	2 m^2	15 m^2 concrete pit	PVC-piping (19 cm int. diam. x 75 cm L)	24 m^2
Surface layer - grass	Grass turf (poorly established)	Grass turf	No grass layer	Grass turf (poorly established)
Middle layer - Biomixture	Chopped straw (50%), peat (25%), soil (25%) - 50 cm	Chopped straw (50%), peat (25%), soil (25%) - 50 cm	Unchopped barley straw (50%), peat-free compost (25%), soil (25%) – 50 cm	Unchopped straw (50%), peat (25%), soil (25%) - 50 cm
Bottom layer	– Clay -10 cm – Gravel - 10 cm with drainpipes leading to reservoir – Bentonite - 10 cm	– Rammed clay – 10 cm – Gravel – 10 cm with drainage tube leading to reservoir	– Washed sand - 15 cm – Gravel - 2-3 cm – Pipe sealed using a socket fitted with a drain outlet	– Clay -10 cm – Macadam - 10 cm with drainpipes leading to reservoir – Plastic membrane

	– Plastic membrane	– Concrete bottom		
Pesticides leaching	Under worst-case scenario leaching of isoproturon - 0.22 mg L^{-1} (1.4 % of applied) and MCPP - 2.09 mg L^{-1} (13 % of applied)	10 of 21 pesticides were found in the percolate. Bentazone showed highest concentration (0.17 mg L^{-1}).	Peak concentrations of isoproturon (0.13 mg L^{-1}) and dimethoate (0.05 mg L^{-1})	Glyphosate (max 2.3 μg L^{-1}), bentazon (max 20 μg L^{-1}), AMPA (max 1.2 μg L^{-1}) and other pesticides in lower concentrations
Reference	{Henriksen, 2003 #2368}	{Spliid, 2006 #2795}	{Fogg, 2004 #2629}.	This study

4. MATERIALS AND METHODS

4.1 Biobeds and sampling

Four biobeds were evaluated in this study, two unlined (Table 2) and two lined (Table 3). Pesticide occurrence and levels were determined in biomixture, clay layer and leakage water samples.

Table 2. Unlined biobeds – Description and sampling procedure

Biobed	Description	Samples/sampling date
Gessie, Vellinge	Unlined biobed with a natural clay layer at the bottom (as in Fig. 1a). Biomixture prepared with unchopped straw, peat and soil. The biobed was built in the year 1998 and rebuilt into a lined biobed in April 12, 2006. The samples were taken before it was rebuilt. The biomixture was removed completely from the biobed	Biomixture (0-20 cm) and clay (0-5 cm) at several locations of the biobed. Also a composite sample from the removed biomixture. /12-Apr-2006.
Stamgård, Tygelsjö	Unlined biobed with natural clay at a depth of 88 cm, a thin straw layer above it, added clay layer at 60 cm depth and covered with single layers of straw, peat and soil, not as a mixture (Fig. 2). Built in the spring of 2004.	Biomixture (0-20 cm) and clay (0-5 cm) at several locations. Natural clay at 88 cm depth. /11-Jul-2006.

Table 3. Lined biobeds – Description and sampling procedure

Biobed	Description	Samples/Sampling dates
Gessie, Vellinge	Lined biobed with a profile shown in Fig. 3. Outlet tubing and a well for accumulation of the leakage water were included. A water seal was placed at the outlet tubing for regulation of the water height in the bed (Fig. 3) and consequently the moisture of the clay layer. The biobed was built in April 12, 2006 as part of this project.	Biomixture (0-20 cm), clay (0-5 cm). /11-Jul-2006; 29-Aug-2007. Leakage water (from the outlet tubing or from the storage well) /11-Jul-2006; 2-Sep-2006; 22-Nov-2006; 20-Dec-2006; 29-Aug-2007
Sjöstorp, Dalby	Lined biobed with a profile consisting of: a plastic layer at the bottom followed by 10-15 cm of macadam, 10 cm clay and 50 cm biomixture. Outlet tubing and a well for accumulation of the leakage water were included (as in Fig. 1.2). No water seal was present. The biobed was built in May, 2005.	Biomixture, clay. /29-Aug-2007. Leakage water (from the outlet tubing or from the storage well) /3-Oct-2005; 5-Nov-2005; 3-Dec-2005; 23-Dec-2005; 29-Aug-2007

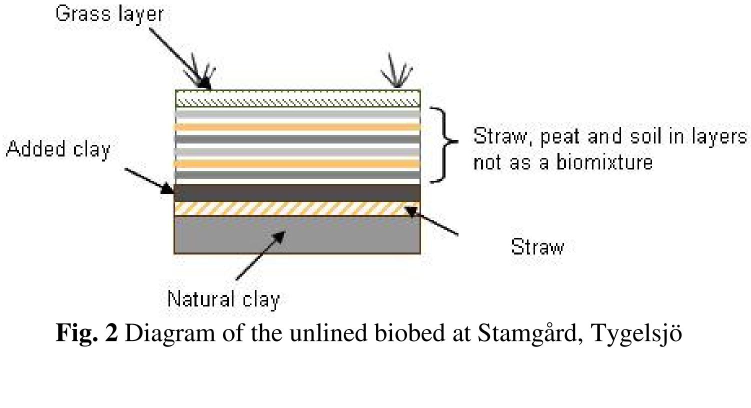

Fig. 2 Diagram of the unlined biobed at Stamgård, Tygelsjö

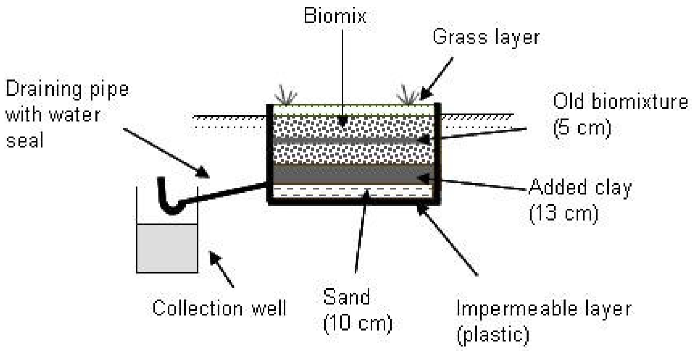

Fig. 3 Diagram of the lined biobed built (2006-04-12) at Gessie, Vellinge.

4.2 Pesticides used at the studied farms

Table 4 shows the pesticides normally used at the three farms studied in this work.

4.3 Analytical methods

The analyses of the biomixture, clay and leakage water samples were performed at the Department of Environmental Assessment at the Swedish University of Agricultural Sciences (accredited by SWEDAC). The analytical techniques used were: OMK 49, 50, 51, 53, 54 and the INO 18 (http://www.ma.slu.se/ShowPage.cfm?OrgenhetSida_ID=7805).

5. Results

5.1 Unlined biobeds

5.1.1 Unlined biobed - Gessie, Vellinge

The profile of this biobed corresponds to a normal unlined biobed with a natural clay layer at the bottom. The biomixture consisted of unchopped straw, peat and soil. It was built in the year 1998 and rebuilt into a lined biobed in 2006. Samples were taken before the biobed was rebuilt and at different locations (under the boom edges, the area of handling of the concentrates and the ramp). Also, after the biomixture was removed samples were taken from different parts of the heap and mixed together into a composite sample. As shown in Table 5 the samples of the upper layers of the biomixture showed residues of the pesticides used at the beginning of the spraying season. Higher levels where found under the ramp compared to the boom edge and the concentrates handling area. This finding corroborates other studies showing that pesticides are retained on the wheels and washed out (ADAS, undated, River Cherwell Catchment Monitoring Study 1998-2000). This also corroborates our observations that very often there is no grass layer under the driving ramp probably due to pesticide spill.

All the samples taken in the upper 5 cm of the clay layer showed small amounts of clopyralid (10 – 20 $\mu g\ kg^{-1}$).

A surprising result was the one related to benazolin. This chemical was found in the composite sample (200 $\mu g\ kg^{-1}$) and in the clay layer (20 – 40 $\mu g\ kg^{-1}$) but not in the biomixture samples taken at the surface.

The presence of clopyralid and benazolin in the upper part of the clay layer suggests that these pesticides were not effectively retained in the biomixture. Two reasons may explain the poor retention and degradation of these pesticides: a) the use of unchopped straw gives smaller specific area for sorption and activity and a smaller volumetric weight which in turn gives smaller amounts of straw in the biomixture, and b) young biomixtures are suspected to give poor microbial activity and structure. Benazolin (Benasalox) was used not later than year 2000 probably when the biomixture was still young. Clopyralid was used more often and it is unclear when it was transported to the bottom.

5.1.2 Unlined biobed - Stamgård, Tygelsjö

The profile of this biobed consisted of a natural clay layer at the bottom followed by a thin straw layer, another clay layer at a height of 65 cm and then straw, peat and soil added in layers and not as a mixture. This biobed was built in the spring of 2004.

As shown in Table 6 the samples of the upper layers of the biomix showed residues of the pesticides used at the beginning of the spraying season and azoxystrobin and pirimicarb athigher concentrations (200 and 100 $\mu g\ kg^{-1}$, respectively). Amounts of pirimicarb (7 $\mu g\ kg^{-1}$) near the limit of detection were detected in the added clay layer. Esfenvalerat in low amounts was found in the added clay layer (0.4 $\mu g\ kg^{-1}$) and in the natural clay layer att 88 cm depth (0.1 µg kg^{-1}). However, it is unclear how this chemical could appear in this biobed because it was not used at all at this farm.

Even though the biobed was built wrongly, i.e. the materials were placed in layers and not as a biomixture, and the added clay layer was placed above a thin straw layer, limited transport of the pesticides to the bottom was observed. Also, the clay layer at 88 cm depth was perfectly wet and swelled with no apparent risk for preferential flow transport.

5.2 Lined biobeds

5.2.1 Lined biobed at Gessie, Vellinge

The biomixture in this biobed was carefully prepared by using chopped straw (a straw chopper was used) and by mixing carefully. Also, a layer of old biomixture was placed in between as an inoculum. The biobed was used shortly after it was rebuilt, i.e. the biomixture was still young. Also, the grass layer was not fully developed.

In an attempt to control the moisture in the clay layer and therefore avoiding formation of cracks and preferential flow, a water seal was placed at the draining pipe outlet. The position upwards or downwards of the water seal was intended to give higher or lower moisture in the clay, respectively.

The first sample from the storage well was taken three months (April to July 2006) after the biobed was rebuilt and when the water seal was placed downwards (lower moisture in the clay layer). Pesticide residues as clopyralid (15 µg/l), benazolin (3.5 µg/l) and glyphosate (1 µg/l) were found (Table 7) giving an accumulation rate of 5, 1.2 and 0.3 µg/l/month, respectively. Other pesticides found at lower concentrations were MCPA, quinmerac and metamitron.

The following sampling at the storage well was done after 7 months of accumulation (December 2006 to August 2007) and with the water seal in the upwards position for an intended higher clay moisture. At this sampling occasion clopyralid (17 µg/l) and benazolin (5 µg/l), were again found. In addition bentazon and quinmerac appeared at a concentration of 0.5 and 0.078 µg/l, respectively. No glyphosate was found at this occasion. Compared to the first sampling the accumulation rate for clopyralid, and benazolin was lower (clopyralid 2.4 and benazolin 0.71 µg/l/month).

Point samplings were also made directly at the outlet tubing and before the release to the storage well. Clopyralid, bentazon, glyphosate, and quinmerac were found in this water. MCPA and fluroxypyr were also observed but at levels near the limit of detection. Even though benazolin was not used at the farm during the study period, it appeared at levels between 7-10 µg/l, probably from residues coming from the old biomixture placed as middle layer and as inoculum.

Table 4 Pesticides used at the studied farms

Gessie, Vellinge 2005-2006	**Sjöstorp, Dalby May-September 2005**	**Stamgård, Tygelsjö 2004 - 2006**
aclonifen	amidosulfuron	aclonifen
asulam	azoxystrobin	azoxystrobin
azoxystrobin	bentazon	deltamethrin
bentazon	clethodim	diquat dibromide
carfentrazoneethyl	clopyralid	dimethoate
chloridazon	diflufenican	ethofumesate
clomazone	diquat dibromide	phenmedipham
clopyralid	esfenvalerate	glyphosate
cyprodinil	fenitrothion	chloridazon
deltamethrin	fenpropimorph	quinmerac
diflufenican	flupyrsulfuron-methyl-Na	metamitron
dimetomorph	fluroxypyr	metazachlor
esfenvalerate	flurtamone	pirimicarb
ethofumesate	glyphosate	
florasulam	iodosulfuron-methyl-Na	
fluazinam	MCPA	
fluroxipyr-1-metylheptylester	metazachlor	
fluroxypyr	metsulfuron-methyl	
glyphosate	propiconazole	
isoproturon	prosulfocarb	
mancozeb	prothioconazole	
MCPA	pyraclostrobin	

metamitron
metazachlor
metribuzin
phenmedipham
pirimicarb
propiconazol
prothioconazole
pyraclostrobin
quinmerac
triazamate
triflusulfuronmethyl
quimerac
sulfosulfuron
tau-fluvalinate
tribenuron-methyl

Lined biobed at Sjöstorp, Dalby

The profile of this biobed is shown in Fig. 1.2 and has macadam below the clay layer. As reported earlier, bentazon, glyphosate and AMPA were found at significant levels (see Table 8) in the outlet tubing and in the well during 2005. A new sampling done at the well in August 2007 showed that bentazon, glyphosate, AMPA were still found at concentrations above the limit of detection. Other pesticides were also observed in the leakage water (fenpropimorph, pirimicarb, propiconazole, metsulfuron-methyl, amidosulfuron, tribenuron-methyl and carfentrazone-acid).

The leakage of pesticides in 2005 could have been due to the immaturity of the biomixture and/or the poor establishment of the grass layer since the biobed was recently rebuilt at that time. However, the leakage still remained after 2 years.. A reasonable explanation is the potential formation of cracks in the clay layer due to limited moisture because of the presence a draining layer as the macadam.

<u>Other observations</u>

The purpose of this project has been mainly to study the risk for leakage of pesticides from biobeds however we have been able to make other observations that are important for a good management of the biobeds:

- The materials of the biomix have been added in layers and not as a mixture with the consequent risk for reduction in sorption capacity and microbial activity.
- The area of the biobed is too small and the management of the concentrates is done outside the biobed. This case we found at the Stamgård´s farm where a table with the concentrates was placed outside the biobed. Samples taken from the soil under the table showed pesticide residues at the same level as those found in the biobed under the sprayer.
- Other materials than straw are used in the biobed as *Salix* residues that may affect the homogeneity of the mixture if added as long pieces.
- The area underneath the driving ramp has pesticide residues of the same order of magnitude as the area under the sprayer because of the wash out of the chemicals from the wheels. It has been observed that the grass layer in this area is not repaired as often as other areas of the biobed. This could increase the risk for impairing the water balance control and thereby the transport of the pesticides downwards.

6. DISCUSSION

The hypothesis of this work was that biobeds can leak pesticides if conditions for preferential flow arise. Preferential flow conditions in a biobed arise when: a) the clay layer is not wet and forms cracks, b) the biomix has low sorption capacity and low microbial activity, c) there is a poor grass establishment on the biobed. Also a combination of these factors is possible.

Preferential flow can occur in the biomixture when it is young and when the particle size of the straw is too long and thereby reducing sorption capacity and microbial activity. The unlined biobed at Gessie showed this scenario. Benazolin and clopyralid, both very mobile, appeared at the bottom of the biomixture because they were applied when the biomixture was young. In the bottom of the biobed, the pesticides are slowly degraded, however sorption and aging processes in a wet and homogenous clay layer will prevent further transport.

Another important issue is that if pesticides accumulate at the bottom of the biomixture it is not recommended to reuse the exhausted biomixture as inoculum or as a enhancer of the structure in new biomixtures. It may be possible that the aged pesticides can become mobile again. This was observed when the biobed at Gessie was rebuilt from unlined to lined and part of the old biomixture was reused in the new one.

The unlined biobed at Stamgård was very efficient and very limited transport was observed to the bottom of the biobed. Besides that, one of the only two pesticides observed at the upper part of the clay layer was not used at the farm. We cannot explain if this was due to old residues, a contamination of the sample or limitation of the analytical method (some of the pesticides analyzed were not included in the Accreditation). This is also valid for the biobed at Sjöstorp where mecoprop was not used at the farm but residues were found in the leakage water.

Preferential flow in the clay layer may occur when the clay is not wet and forms cracks. Natural clays are normally wetted by capillary forces in underlying soil. If a draining layer is located below the clay, such water transport is broken and the clay will dry. This effect is more evident in lined biobeds where a draining (as macadam or gravel) and an impermeable layer prevent the wetting of the clay. Our results show that this is a reasonable explanation for the appearance of pesticides residues in lined biobeds even though that the biomixtures were not young and the grass layer was established as in at the Sjöstorp biobed sampled 2 years after its construction. In the lined biobed at Gessie we intended to control the moisture transport to the clay layer with a water seal. However, we are not sure that we succeeded because of low precipitation and limited amounts of water release from this biobed. This means that this biobed may have functioned as a normal lined biobed with high risk of crack formation at the clay layer. Hence, it appears that leaking through the clay layer in lined biobeds is due to its profile.

It can be concluded that the major risks for leakage comes from biobeds with non-functioning biomixture, grass and clay layers. Biomixture sorption and microbial activity can be enhanced but this is not sufficient to ensure that pesticides will not be leaking. A well functioning clay layer is important. Lined biobeds show a higher potential for non-functioning clay layers because of their profile. However, lined biobeds can be an interesting alternative if higher amounts of water are intended to be treated in the biobed and also at places with no natural clay at the bottom.

Further studies are needed to:

1. Study different alternatives to reduce the risk of leakage in young biomixtures by testing precomposting of the biomix.
2. Study and optimize lined biobeds with recirculation in the cases where no clay is available or safe to use.
3. Make a survey of biobeds to evaluate if they are constructed and managed according to recommendations. Special attention should then be given to the materials used, the size of the straw and the size of the biobed.

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Table 5 Pesticides found in the biobed at Gessie, Vellinge
Unlined biobed with a natural clay layer at the bottom - Sampling 12 April 2006

Active substance	Biomix composite sample ($\mu g\ kg^{-1}$)	Biomix 0-20 cm under concen. handling area ($\mu g\ kg^{-1}$)	Biomix 0-20 cm under ramp ($\mu g\ kg^{-1}$)	Biomix 0-20 cm under boom edge ($\mu g\ kg^{-1}$)	Clay 0-5 cm under sprayer ($\mu g\ kg^{-1}$)	Clay 0-5 cm under concen. handling area ($\mu g\ kg^{-1}$)	Clay 0-5 cm under ramp ($\mu g\ kg^{-1}$)	Detection limit ($\mu g\ kg^{-1}$)
Aclonifen	nd	nd	nd	nd	nd	nd	nd	20
Azoxystrobin	10	8	30	6	nd	nd	nd	2
Chloridazon	6	10	8	10	nd	nd	nd	3
Deltamethrin	0.7	2	1	2	nd	nd	nd	0.5
Esfenvalerate	1	1	3	0.6	nd	nd	nd	0.05
Ethofumesate	4	nd	20	nd	nd	nd	nd	3
Phenmedipham	10	nd	40	nd	nd	nd	nd	10
Isoproturon	2	10	30	1	nd	nd	nd	1
Metamitron	nd	nd	nd	nd	nd	nd	nd	10
Metazachlor	nd	nd	nd	nd	nd	nd	nd	6
Pirimicarb	20	nd	30	20	nd	nd	nd	3
Diflufenican	12	39	160	7	nd	nd	nd	0.5
Bentazon	nd	nd	nd	nd	nd	nd	nd	1
Clopyralid	traces	10	traces	nd	10	20	10	2
Fluroxipyr	traces	nd	traces	nd	nd	0	nd	1
MCPA	traces	nd	nd	nd	nd	nd	nd	1
Benazolin	200	traces	nd	nd	40	nd	20	1
Dicamba	nd	nd	nd	nd	nd	nd	nd	1
Dichlorprop	nd	nd	nd	nd	nd	nd	nd	1
2,4-D	nd	nd	nd	nd	nd	nd	nd	1
Mecoprop	nd	nd	nd	nd	nd	nd	nd	1
Quinmerac	traces	traces	7	nd	nd	nd	nd	2
Flamprop	nd	nd	nd	nd	nd	nd	nd	1

nd: not detected

Table 6. Pesticides found in the biobed at Stamgård, Tygelsjö – Unlined biobed with an added clay layer. Sampling 11-Jul-06

Active substance	Biomix 0-20 cm under sprayer (μg kg^{-1})	Biomix 20-40 cm under sprayer (μg kg^{-1})	Biomix 0-20 cm under ramp (μg kg^{-1})	Clay 0-5 cm under sprayer (μg kg^{-1})	Natural clay under sprayer 88 cm (μg kg^{-1})	Detection limit (μg kg^{-1})
aclonifen	20	nd	100	nd	nd	10
azoxystrobin	200	nd	30	nd	nd	10
chloridazon	nd	nd	100	nd	nd	10
cyprodinil	nd	nd	nd	nd	nd	1
deltamethrin	20	10	10	nd	nd	1
difuflenican	nd	nd	nd	nd	nd	1
esfenvalerat	0.3	20	0.1	0.4	0.1	0.05
ethofumesate	nd	nd	nd	nd	nd	5
phenmedipham	nd	nd	nd	nd	nd	20
isoproturon	nd	nd	nd	nd	nd	3
pirimicarb	100	50	9	7	nd	5
propiconazole	nd	nd	nd	nd	nd	5
benazolin	nd	nd	nd	nd	nd	0.3
bentazon	nd	nd	nd	nd	nd	0.3
clopyralid	nd	nd	nd	nd	nd	4
fluroxipyr	nd	0.9	nd	nd	nd	0.5
MCPA	nd	nd	nd	nd	nd	0.5
quinmerac	nd	nd	nd	nd	nd	10

nd: not detected

Table 7 Pesticides (μg l^{-1}) found in the drainage water of a lined biobed - Gessie, Vellinge

Substance	Well 11-Jul-06 Accum. 3 months Water seal down	Outlet tubing 02-Sep-06 Water seal down	Outlet tubing 22-Nov-06 Water seal up	Outlet tubing 20-Dec-06 Water seal up	Well 29-Aug-07 Accum. 7 months Water seal up	Detection limit (μg l^{-1})
clopyralid	15	5.2	1.8	0.62	17	0.03
mecoprop	na	traces	traces	nd	nd	0.01
dicamba	na	nd	nd	nd	nd	0.01
MCPA	0.11	0.02	0.04	nd	traces	0.02
dichlorprop	na	traces	traces	nd	nd	0.01
2,4-D	na	nd	nd	nd	nd	0.01
bentazon	0.038	0.2	0.18	0.054	0.5	0.01
fluroxypyr	traces	0.034	0.034	nd	nd	0.02
benazolin*	3.5	8	10	7	5	0.01
quinmerac	0.068	0.15	0.12	nd	0.078	0.02
flamprop	na	nd	nd	nd	nd	0.02
aclonifen	nd	nd	nd	nd	nd	0.04
azoxystrobin	nd	nd	nd	nd	nd	0.01
deltamethrin	nd	nd	nd	nd	nd	0.003
diflufenican	na	nd	nd	nd	nd	0.006
esfenvalerate*	nd	nd	nd	nd	nd	0.001
ethofumesate	traces	traces	nd	nd	nd	0.01
phenmedipham	nd	nd	nd	nd	nd	0.1
fenpropimorph	na	nd	nd	nd	nd	0.01
isoproturon	traces	traces	traces	nd	nd	0.01
chloridazon	traces	nd	nd	nd	traces	0.04
metamitron*	0.07	nd	nd	nd	nd	0.05
metazachlor	nd	nd	nd	nd	nd	0.02
pirimicarb	nd	nd	nd	nd	nd	0.02
propiconazole	nd	nd	nd	nd	nd	0.02
glyphosate	1	0.19	nd	nd	nd	0.04
AMPA*	nd	traces	nd	nd	nd	0.2
thifensulfuron-methyl	na	nd	nd	nd	nd	0.05
metsulfuron-methyl	na	nd	nd	nd	nd	0.05
florasulam*	nd	nd	nd	nd	nd	0.2
rimsulfuron*	na	nd	nd	nd	nd	0.05
amidosulfuron*	na	nd	nd	nd	nd	0.05
sulfosulfuron	na	nd	nd	nd	nd	0.1
tribenuron-methyl	traces	nd	nd	nd	nd	0.05

flupyrsulfuron-methyl-Na*	na	nd	nd	nd	nd	0.1
iodosulfuron-methyl-Na*	na	nd	nd	nd	nd	0.05
triflusulfuron-methyl	nd	nd	nd	nd	nd	0.05
pyraclostrobin*	nd	nd	nd	nd	nd	0.05
carfentrazone-acid*	na	nd	nd	nd	nd	0.2
fluazinam*	traces	nd	nd	nd	nd	0.003
cyprodinil	nd	na	na	na	na	0.006
dimethoate	nd	na	na	na	na	0.03
metribuzin	nd	na	na	na	na	0.01

nd: not detected na: not analyzed *not included in Accreditation

Table 8 Pesticides ($\mu g\ l^{-1}$) found in the drainage water of a lined biobed - Sjöstorps, Dalby

Substance	**Outlet tub. 03-Oct-05**	**Outlet tub. 05-Nov-05**	**Outlet tub. 03-Dec-05**	**Well 23-Dec-05**	**Well 29 Aug 2007**
clopyralid	1.5	0.2	Nd	traces	nd
mecoprop	0.1	nd	Nd	na	nd
dicamba	na	na	Na	na	nd
MCPA	nd	nd	Nd	nd	nd
dichlorprop	na	na	Na	na	nd
2,4-D	na	na	Na	na	nd
bentazon	20	1	0.5	0.8	7.6
fluroxypyr	0.8	nd	Nd	nd	traces
benazolin*	na	na	Na	na	35
quinmerac	nd	nd	Nd	nd	nd
flamprop	na	na	Na	na	nd
aclonifen	na	na	Na	na	nd
azoxystrobin	nd	nd	Nd	nd	nd
deltamethrin	na	na	Na	na	nd
diflufenican	traces	nd	Nd	traces	traces
esfenvalerate*	nd	nd	Nd	nd	nd
ethofumesate	na	na	Na	na	nd
phenmndipham	na	na	Na	na	nd
fenpropimorph	nd	nd	Nd	nd	0.09
isoproturon	na	na	Na	na	nd
chloridazon	na	na	Na	na	nd
metamitron*	na	na	Na	na	nd
metazachlor	traces	nd	Nd	nd	nd
pirimicarb*	na	na	Na	na	0.04
propiconazole	traces	nd	Nd	nd	0.9
glyphosate	2.3	0.12	0.11	1.3	1.7
AMPA*	1.2	0.72	0.5	2	2
thifensulfuron-methyl	na	na	Na	na	nd
metsulfuron-methyl	0.2	nd	Nd	nd	0.62
florasulam*	na	na	Na	na	nd
rimsulfuron*	na	na	Na	na	nd
amidosulfuron*	0.8	0.1	Traces	traces	1
sulfosulfuron	nd	nd	Nd	nd	nd
tribenuron-methyl	nd	nd	Nd	nd	0.15
flupyrsulfuron-methyl-Na*	nd	nd	Nd	nd	nd
iodosulfuron-methyl-Na*	nd	nd	Nd	nd	nd
triflusulfuron-methyl	na	na	Na	na	nd
pyraclostrobin*	nd	nd	Nd	nd	nd
carfentrazone-acid*	na	na	Na	na	0.6
fluazinam*	na	na	Na	na	nd
cyprodinil	na	na	Na	na	na
dimethoate	na	na	Na	na	na
metribuzin	na	na	Na	na	na
Fenitrothion	nd	nd	Nd	nd	na
Flurtamone	nd	nd	Nd	nd	na
Prosulfocarb	nd	nd	Nd	nd	na