Pesticide Monitoring in the Central Rift Valley 2009-2010

Ecosystems for Water in Ethiopia

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Abstract

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The availability and quality of surface water resources in the Central Rift Valley are increasingly threatened through the intensified use of land and water resources. Irrigated agriculture by smallholders (mostly horticulture) has largely expanded, while also large-scale, export-oriented enterprises developed around Lake Ziway. One of the main concerns is the increased use of pesticides and the impacts of pesticide residues on the aquatic environment and on human health.

This report describes the results of the pesticide monitoring in 2009 and 2010, including a preliminary assessment of risks and possible mitigation strategies.

Keywords: Pesticides, Ethiopia, Water quality.

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Summary

The availability and quality of surface water resources in the Central Rift Valley are increasingly threatened through the intensified use of land and water resources. Irrigated agriculture by smallholders has largely expanded, while also large-scale enterprises developed around Lake Ziway. One of the main concerns is the increased use of pesticides and the impacts of pesticide residues on the aquatic environment and on human health. This report describes the first results of the monitoring of pesticide residues in surface waters in and around Lake Ziway.

In 2009 and 2010 ten (10) surface water samples were collected from eight (8) different locations in the agricultural areas north of Lake Ziway (Meki and Ketar rivers), along Lake Ziway between the towns Meki and Ziway, along floriculture enterprises at Ziway, and at the intake of the Batu (Ziway) Water Supply Service Enterprise (Batu WSSE). The samples were analyzed on more than 300 pesticides, by an EN/ISO/IEC 17025 accredited laboratory for residue analysis in water.

The monitoring in 2009 and 2010 shows that most surface water samples taken from the agricultural areas north of Lake Ziway and between Meki and Ziway town contain residues of pesticides. The concentrations of these pesticides occasionally exceed 0.1 μg/l, which is the European and Dutch standard for drinking water. The presence of DDT and its breakdown products in surface waters in the areas north of Lake Ziway and between Meki and Ziway town shows that DDT, being an obsolete and high risk pesticide, is still being used. The environmental risks of pesticide residues from these areas cannot be assessed on the basis of the limited monitoring so far, as concentrations will vary in time and hazardous peak concentrations may occur at the time that the pesticides are applied in the field.

The effluent water from the floriculture enterprises contains a range of (residues of) pesticides with concentrations exceeding 0.1 μg/l, including some high risk pesticides. In the water from the floriculture enterprises no DDT or breakdown products of DDT were found, neither unregistered pesticides. This effluent water is collected in a drain and periodically discharged onto Lake Ziway. The concentrations of the (residues of) pesticides in the effluent water are occasionally above the thresholds where ecotoxicological effects on water organisms can be expected.

In the two (2) samples from the raw water intake of the Batu WSSE a total of seven (7) (residues of) pesticides have been detected. The concentrations of the herbicide metsulfuron-methyl and the fungicide sulphur exceed the European and Dutch standards for drinking water (0.1 μg/l). Considering the chemical (toxic) characteristics and observed concentrations these seven (7) pesticides do not pose an immediate risk to human health, however the occurrence of pesticides in drinking water should always be prevented. With the limited 2009-2010 monitoring it is not possible to identify with certainty the sources of the contaminations at the water intake of the Batu WSSE. Regular sampling, incorporating more risk locations, is required to obtain more decisive results on contaminations, concentrations, sources and risks, and to gain insight in the degree that concentrations of pesticide residues vary in time.

Measures that cope with impacts of (residues of) pesticides should consider the local context and nature of the sources. The agricultural areas north of Lake Ziway and between Meki and Ziway town are diffuse sources of contaminations of surface waters, whereas the effluent outlet of the large floriculture enterprises at Ziway represents a distinct point source. Environmental and health impacts of the use of pesticides can be reduced

through preventive measures, aimed at reduced or better pesticide application, and mitigating measures, aimed at reducing the impacts of emissions.

Both in the smallholder areas and at the large floriculture enterprises emissions can be reduced through good agricultural practices, which also includes the safe use of more effective and less hazardous pesticides. Various projects have already been initiated, aimed at the prevention and reduction of emissions of hazardous (residues of) pesticides through improved legislation and on-farm management.

In areas with intensive agriculture emissions of agrochemicals, including pesticides, are to a certain extent unavoidable. The monitoring showed that most of the pesticides identified are biodegradable, which offers good opportunities for the mitigation of present and future residual contaminations. The biodegradation of (residual) pesticides can be enhanced through (integrated) measures that increase the water retention (increase residence times of residual pesticides), introduce oxygen and stimulate biological activity in the water system. Innovative solutions are required. In the area with floriculture enterprises various measures in the domain of improved on-site water management have been implemented recently, which probably have enhanced the biodegradation of residual pesticides through increased water retention.

As Lake Ziway is subject to more threats than (residues of) pesticides an integrated approach is required, which addresses all water quality issues and which combines the mitigation of impacts of (residues of) pesticides, increased fertiliser use and (urban) waste waters. As salinization and eutrophication are also strongly linked with quantitative water management, a strategy for operational water management of Lake Ziway, including the operation of the Bulbula regulating gate, needs to be developed, which both serves water quantity and water quality issues. Further monitoring is required to verify and assess the effectiveness of on-going and future measures that are aimed at the reduction of emissions of (residues of) pesticides and other agrochemicals. Networks and systems for (routine) water quality monitoring, including pesticide monitoring, should be developed.

1 Introduction

1.1 Land use planning programme

The project 'Land use planning program for the Ethiopian Central Rift Valley (CRV)' is based on the outcomes of various participatory stakeholder workshops that have taken place during the period December 2008-June 2009. These workshops contributed to the on-going policy dialogue and the participatory identification of four priority activities contributing to the sustainable future of the area:

1. Pilot commercial smallholder horticulture;
2. Water quality monitoring;
3. Buffer zone development;
4. Tourism promotion.

The objective of the land use planning program and its four components is to strengthen the capacity of key stakeholders in the field of natural resource management and governance through on-the-ground activities aimed at learning-by-doing and building new alliances and partnerships. This note presents results of the project component 'Water quality monitoring'. The project is financed by the LNV-OS programme 2009-2011. The project area is presented in Figure 1.

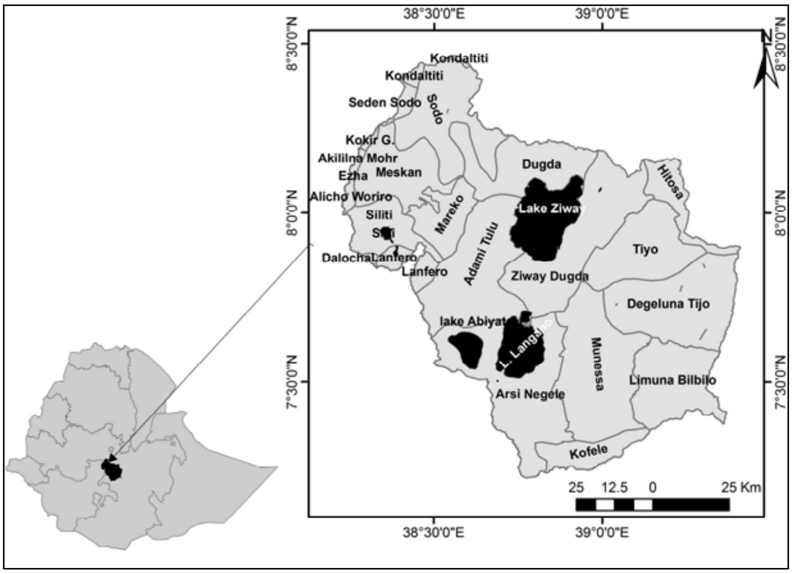

Figure 1
Location of Central Rift Valley

1.2 Water quality monitoring

The availability and quality of surface water resources in the CRV is increasingly threatened through the intensified use of land and water resources. The national Agricultural Development Led Industrialization (ADLI) strategy promotes the commercialization of smallholder agriculture and the development of large-scale export-oriented agriculture. In the CRV the area of irrigated agriculture by smallholders (mostly horticulture) has largely expanded, while also new enterprises developed around Lake Ziway.

The main concerns with respect to the increased use of water are:
1. Water shortages affecting downstream water use(r)s and ecosystems, e.g. Lake Abyata;
2. Increase of salinity of Lake Ziway due to insufficient outflow through the Bulbula River.

The main concerns with respect to the increased use agrochemicals (fertilisers and pesticides) are:
1. Eutrophication of surface water resources, particularly Lake Ziway;
2. Contamination of surface water resources with pesticides.

Like the shrinkage and degradation of Lake Abyata the risk of salinization of Lake Ziway is principally a quantitative water management problem. The salinity of Lake Ziway will increase if the required 'environmental flow' in the downstream Bulbula River cannot be maintained, e.g. as a result of excessive water use in the Meki, Ketar and Ziway areas.

Eutrophication is both a qualitative and quantitative water management problem. The increased use of fertilisers by smallholders and enterprises, the increased volumes of (untreated) urban waste waters and the reduced outflow from Lake Ziway to the Bulbula River can cause eutrophication, which can result in turbid water, algae blooms, fish mortality, and poor quality of drinking water. The contamination by pesticides is principally a qualitative water management problem.

There are currently great concerns about the impacts of the increased use of agrochemicals in the CRV, both by smallholders and enterprises, on Lake Ziway. Securing the water quality of Lake Ziway is utmost important as this lake represents the main fresh water resource in the area. The water in Lake Ziway is also critical for the public water supply of Ziway. Because of the high fluoride content in the groundwater the Batu (Ziway) Water Supply Service Enterprise (Batu WSSE) had to abandon their groundwater exploration wells approximately 10 years ago, and shifted to using the water from Lake Ziway as source. Therefore special attention is required to the quality of the raw water intake of the Batu WSSE. In addition the water in Lake Ziway is critical for the fishery industry and agriculture, both around the lake and in downstream areas.

1.3 Existing initiatives and projects

The Government of Ethiopia is aware of the risks of the intensifying agriculture with respect to human health and the environment. Various projects have been initiated with the endorsement of a wide range of stakeholders, such as horticultural growers, the Ministry of Agriculture and Rural Development, the Ethiopian Institute for Agricultural Research, the Ministry of Trade and Industry, the Ethiopian Horticulture Producers and Exporters Organization and the Ethiopian Horticulture Development Agency. These activities are also supported by the LNV-OS programme and by international organizations.

A variety of projects is aimed at increased sustainability of the agricultural sector in Ethiopia. These projects incorporate a broad scope of activities, which also contribute to the prevention and reduction of emissions of agrochemicals and, therefore, have synergy with the activities described in this report. Examples are:
- Reducing risks of pesticides in Ethiopia. Joint collaborative project on pesticide registration and post registration by the Ethiopian Government, in collaboration with the Food and Agriculture Organization of the UN and the Government of the Netherlands (Peeters and Alemayehu Woldemanual, 2010);
- Within the current project capacity building of local horticulture extension staff and training on Good Agricultural Practices including pesticide use is one of the priority activities (Section 1.1; De Putter and Van Koesveld, 2010);

- The development of buffer zones is also one of the priority activities within the current project (Section 1.1), aimed at erosion and dust reduction, better economic use of the lake margins, development of tourism, land use rights and water quality improvement;
- Establishment of a crop science facility by Crop Life International;
- Introduction of Integrated Pest Management in Ethiopia to reduce pesticide use in floriculture enterprises (Ethiopian-Netherlands Partnership Program; Den Belder, 2009);
- Measures to reduce risks of residual pesticide treatment. Cooperation between Wageningen UR and the African Stockpile Project of FAO (Harmsen et al, 2009);
- Dialogues and discussions have been initiated by the floriculture enterprises at Ziway to develop treatment options for the point solutions.

1.4 Objectives

The objective of the project component 'Water Quality Monitoring' within the Land use planning program for the CRV is to promote sustainable water quality in Lake Ziway for the Batu (Ziway) Water Supply Service Enterprise, livestock watering, aquatic ecosystems and irrigated agriculture. The scope of this project component includes salinity, nutrients and pesticides.

This report presents the results of the monitoring of (residues of) pesticides in 2009 and 2010.

Chapter 2 presents the set-up of the pesticide monitoring. Results and the preliminary risk assessment are given in Chapter 3. Conclusions and recommendations follow in Chapter 4.

2 Pesticide monitoring

2.1 Introduction

Pesticides are a group of biocides intended for preventing, destroying, repelling or mitigating any pest. Pesticides include fungicides, herbicides, insecticides, algicides, molluscicides, miticides and rodenticides.

The monitoring of pesticides is aimed at:
- identify chemical compounds that are already impacting on the water quality;
- detect possible pollution sources;
- analyze risks, particularly for the public drinking water supply of Ziway Town;
- recommend on preventive and mitigation measures;
- support the local authorities to establish an operational water quality monitoring system, embedded in the appropriate organization(s).

The monitoring of pesticides in 2009 and 2010 consisted of the ad-hoc (annual) collection and analysis of water samples at a limited number of locations in agricultural areas of predominantly smallholders, at floriculture enterprises and at the intake of the Batu (Ziway) Water Supply Service Enterprise (Batu WSSE).

2.2 Sampling locations and procedure

2009
In July 2009 seven (7) water samples were taken from six (6) locations. The locations are presented in Appendix 1, Figure 2 and Figure 3.

At each location a non acidified and an acidified sample (1 ml acid was added) were collected and stored in a brown glass sampling bottle. Unfortunately some of the bottles broke during storage. The remaining eight (8) bottles (from four locations) were transported to The Netherlands and analyzed by AgriQ (a joint venture of the TNO and Blgg), which is an EN/ISO/IEC 17025 accredited laboratory for residue analysis in waters. The analyses also included the suspended sediments in one of the water samples.

The monitoring in 2009 resulted in data for:
- Two locations in the agricultural area north of Lake Ziway (Meki and Ketar areas): W09-00327 and W09-00328;
- Discharge drain at a floriculture enterprise (2 samples): W09-00324 and W09-00325;
- Raw water intake at the Batu WSSE: W09-00326.

2010
Based on the results of 2009 a second water sampling round was organized in July 2010 for five (5) locations (Figures 2 and 3 and Appendix 1). The sampling included two (2) locations that were also sampled in 2009, being the discharge drain at a floriculture enterprise and the raw water intake of the Batu WSSE. The same sampling and storing procedure as in 2009 was applied in 2010. In 2010 no suspended sediments were analyzed.

The monitoring in 2010 resulted in data for:

- One additional location in the agricultural area north of Lake Ziway (Meki area): W10-00418;
- Two locations along Lake Ziway in the agricultural area between the towns Meki and Ziway: W10-00417 and W10-00419;
- Discharge drain at a floriculture enterprise (1 sample; same location as in 2009): W10-00421;
- Raw water intake at the Batu WSSE (same location as in 2009): W10-00420.

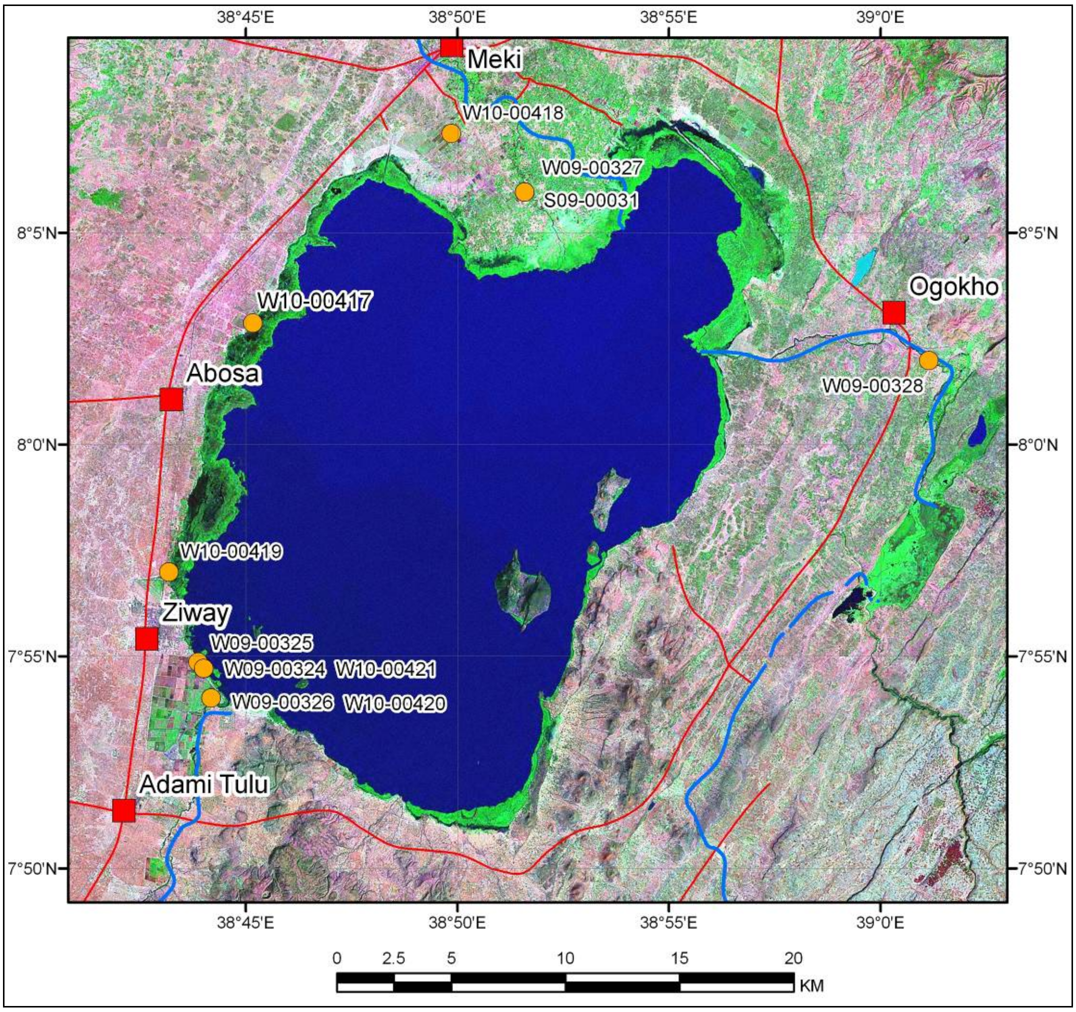

Figure 2

Sample locations (details on the sample locations near Ziway in Figure 3)

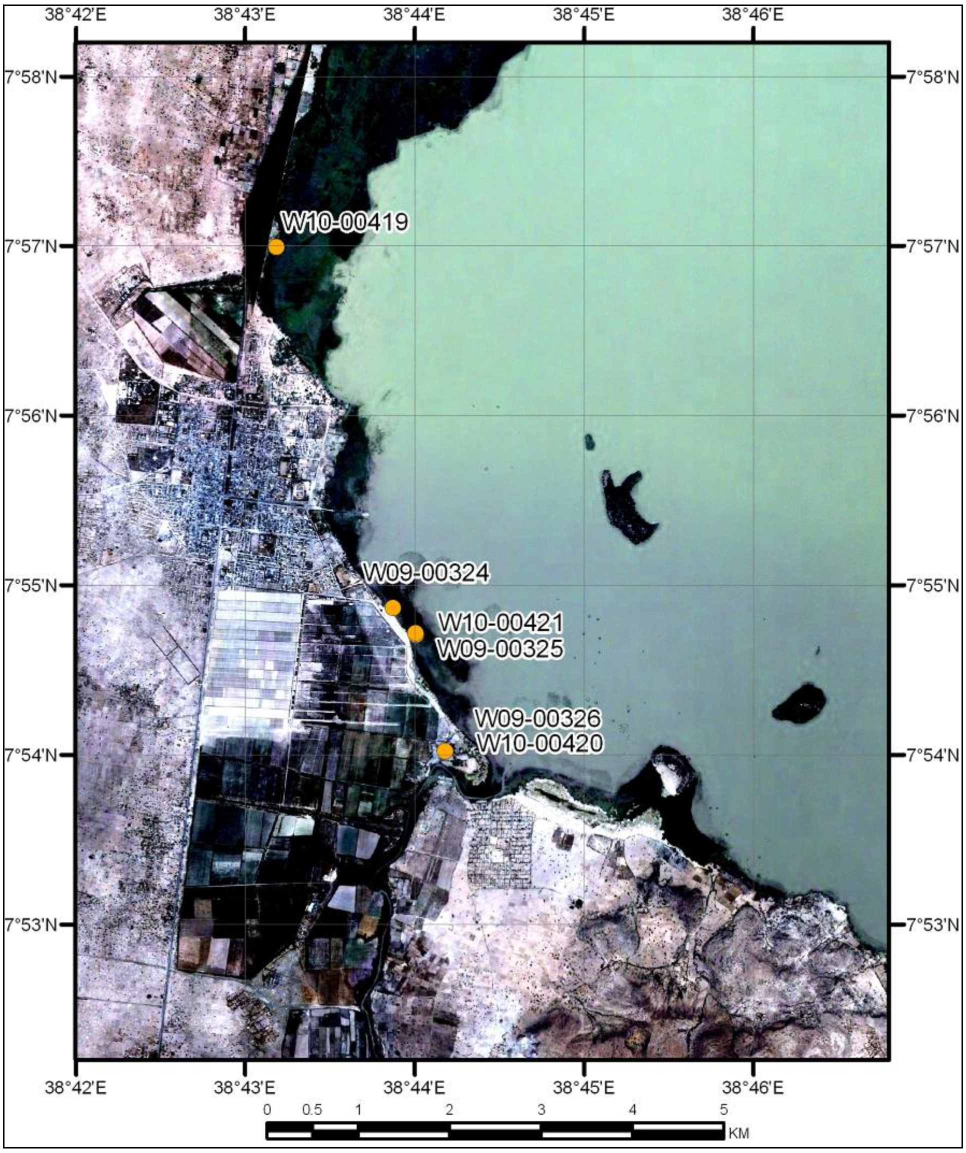

Figure 3
Sample locations near Ziway

2.3 Selected pesticides

As there was no complete and reliable information on the pesticides that are used in the CRV the water samples were screened on the presence of a wide range of pesticides. In 2009 the samples were screened for more than 200 pesticides, in 2010 the presence of more than 300 pesticides was investigated. Appendix 2 presents the list of the pesticides that were analyzed in 2010. Both quantitative and semi-quantitative methods were used. More than half of the analyses were executed according to the ISO 17025 accreditation.

3 Monitoring results

3.1 Analysis results 2009-2010

A total of ten (10) water samples were analyzed, originating from eight (8) locations:
- Three (3) locations in the agricultural area north of Lake Ziway (Meki and Ketar areas);
- Two (2) locations along Lake Ziway in the agricultural area between Meki and Ziway;
- Two (2) locations along the discharge drain at a floriculture enterprise;
- The raw water intake at the Batu WSSE.

Appendix 3 presents a listing of all pesticides that were detected in any of the samples. Details on the methods, the detection limits and quality of these analyses are also added. A complete overview of all analysis results is presented in Appendix 4. Pesticides that are not presented in the tables were not detected (i.e. their concentration was below the detection limit).

It was also investigated whether the detected pesticides are registered with the Animal and Plant Health Regulatory Authority Directorate of the Ministry of Agriculture and Rural Development (APHRD, 2010).

Meki and Ketar areas
In the water sample from the downstream section of the Meki River (W09-00327) no residues of pesticides above the detection limit were found. Also in the suspended material no pesticides were detected (Appendix 4).

Traces of DDT were found in the water sample from the Ketar River (W09-00328). In Ethiopia the use of DDT is allowed for the control of malaria but banned for use in agriculture. However, the pesticide is still used by farmers in the CRV (Amera and Abate, 2008). No residues of other pesticides above the detection limit were found. The turbidity was low and the amount of suspended material was insufficient to be analyzed.

In 2010 an irrigation canal in the agricultural area east of Meki was sampled (W10-00418). At the time of sampling no irrigation took place. A total of 13 different pesticides were detected in the water, which included DDT. Except for sulphur (7 μg/l) and metalaxyl (0.11 μg/l) all concentrations were less than 0.1 μg/l (Appendix 4).

Area between Meki and Ziway
In the area between Meki and Ziway two (2) water samples were taken from irrigation canals that are directly connected to Lake Ziway (W10-00417 and W10-00419). At the time of sampling no irrigation took place. A total of 17 different pesticides were detected in the water, which included DDT and several breakdown products of DDT. Except for sulphur (3 μg/l) all concentrations were less than 0.1 μg/l (Appendix 4).

In the agricultural areas north of Ziway DDT, metalaxyl, metsulfuron-methyl, sulphur, triadimefol, triadimefon, caffeine and tris(2-chloroethyl) phosphate were detected in more than one water sample.

Floriculture enterprises
In 2009 two (2) samples were taken from the drain with effluent water from the floriculture enterprises at Ziway (W09-00324 and W09-00325). In 2009 the water in the drain was stagnant, without outflow to Lake Ziway. In 2010 the effluent water was being discharged to Lake Ziway and one sample was collected from the

outlet of the drain (W10-00421). Appendix 4 presents the pesticides that were identified in the effluent water. In the stagnant water (in 2009) concentrations were in the range of 0.01- 9 μg/l. In the water discharging to Lake Ziway (in 2010) concentrations up to 2.2 μg/l were found. In 2010 the effluent water discharging to Lake Ziway contained 20 pesticides with a concentration of 0.1 μg/l or higher, being bitertanol, boscalid, bupirimate, carbendazim, clofentezine, dodemorf, ethirimol, fenarimol, fenitrothion, imidacloprid, iprovalicarb, metalaxyl, methoxyfenozide, propamocarb, pyraclostrobin, tetradifon, triadimefol, triadimefon, trifloxystrobin and triforine.

Batu WSSE
At the water intake of the Batu (Ziway) Water Supply Service Enterprise in 2009 low concentrations of methomyl (0.02 μg/l), a metabolite of pyridate (0.01 μg/l) and biphenyl were detected (Appendix 4). In 2010 the water contained isoproturon (0.03 μg/l), metsulfuron-methyl (0.3 μg/l), sulphur (10 μg/l) and tolyltriazole.

3.2 Impacts and risks

Meki and Ketar areas, area between Meki and Ziway
The pesticide monitoring programme showed that most surface water samples from the agricultural areas around the Meki and Ketar rivers and between Meki and Ziway towns contain a range of residues of pesticides. The sample from the Ketar River and from the irrigation canals in agricultural areas north of Ziway shows that DDT is still being used in the area. DDT is an obsolete and high risk pesticide.

The apparent absence of pesticides in the Meki and Ketar River is probably due to dilution in those (main) rivers, and the decay of pesticides in the relatively oxygen-rich water. In addition, the once-only (ad-hoc) monitoring is not adequate to follow the impact of a number of discrete pesticide spraying events by farmers. With exception of DDT the pesticide concentrations measured in the surface waters do not pose an immediate risk to human health or the environment.

Floriculture enterprises
In the three samples from the effluent waters of the floriculture enterprises at Ziway a total of 30 different pesticides were detected in concentrations of 0.1 μg/l or higher. Five of these pesticides are classified as high risk pesticides, being fenitrothion (0.16 μg/l), iprovalicarb (0.01-0.38 μg/l), methomyl (0.26-2.7 μg/l), triadimefon (0.16 μg/l) and triforine (0.1-0.4 μg/l). In addition imidacloprid (0.04-0.3 μg/l), metalaxyl (0.18-0.51 μg/l), spiroxamine (1.1-4 μg/l) and triadimefol (0.1 μg/l) are moderate toxic compounds that were detected in the effluent water[1].

The concentrations of pesticides in the effluent waters from the floriculture enterprises at Ziway are occasionally above the thresholds where ecotoxicological effects on water organisms can be expected (PPDB website; EU, 2001). Discharge of untreated effluent water to Lake Ziway may, therefore, have adverse impacts on the local aquatic ecosystem. The observed water pollutions are comparable with the situation of intensive agricultural production systems elsewhere in the world such as Europe, USA and South-east Asia (Stoate et al., 2001; Hallberg, 2003; Wang Tieyu et al., 2005).

[1] In the water discharging into Lake Ziway 20 pesticides with concentrations of 0.1 ug/l or higher were detected. Methomyl was not detected in this water (situation in 2010).

Batu WSSE

During the two sampling rounds a total of seven (7) pesticides have been found in the raw water intake of the Batu WSSE, namely the insecticide methomyl (0.02 µg/l), a metabolite of the herbicide pyridate (0.01 µg/l), biphenyl and tolyltriazole (detected, no quantitative determination), the herbicides isoproturon (0.03 µg/l) and metsulfuron-methyl (0.3 µg/l) and the fungicide sulphur (10 µg/l). These pesticides will most probably not be removed by the current water treatment system. According to European and Dutch regulations drinking water should contain less than 0.1 µg/l of a single pesticide, while the total concentration of detected pesticides should not exceed 0.5 µg/l (Waterleidingbesluit, 2010). For the raw water of the Batu WSSE this standard is exceeded for metsulfuron-methyl (0.3 µg/l) and sulphur (10 µg/l). The observed concentrations of metsulfuron-methyl and of sulphur do, however, not pose an immediate risk to human health. At the observed concentrations metsulfuron-methyl is also not a concern to birds, mammals, bees and other arthropods or aquatic organisms like fish and invertebrates. Being a herbicide it may impact on vascular water plants. In an aquatic environment metsulfuron-methyl is moderately persistent to persistent. For the observed concentrations the dissipation of metsulfuron-methyl will be in the order of four weeks (Scheepmaker, 2008).

The WHO guidelines for drinking water quality do not present standards for metsulfuron-methyl and sulphur. For most pesticides the WHO accepts higher guideline values than the European and Dutch regulations (WHO, 2010).

The detected concentration of methomyl (0.02 µg/l) is below the threshold of 0.1 µg/l, but it should be noted that this pesticide is highly toxic to humans (via the oral route). Methomyl is also highly toxic to birds, moderately to highly toxic to fish, and highly toxic to aquatic invertebrates and bees. Methomyl is a degradable pesticide with a half-life time of 14 days in soil. It is, however, very well soluble in water and not much subject to adsorption to soil particles, which implies a high risk of surface water and groundwater contamination (EXTONET website). If exposed to sunlight methomyl decomposes more rapidly than in groundwater (its half-life in surface water is six days versus over 25 weeks in groundwater). Following soil treatment, plants take up methomyl through their root system and move it throughout the plant by a process called 'translocation'. When methomyl is applied to plants, its residues are short-lived (half-life time of three to five days).

Pyridate is more easily degradable, its half-life time is less than one day. However, the degradation of the metabolite 6-chloro-3-phenyl-pyridazin-4-ol can take some weeks (EU, 2001). The concentration of the pyridate metabolite in the Batu WSSE water inlet is at the detection limit.

Isoproturon is characterized by low acute toxicity and low to moderate toxicity after short- and long-term exposures. The WHO guideline for drinking water is 9 µg/litre, hence the observed concentration is well below this limit. Isoproturon is slightly more persistent and can be detected in water for periods ranging from days to weeks after application. It can decay through photodegradation, hydrolysis and biodegradation.

The current concentrations of pesticides in the drinking water, therefore, do not pose an immediate risk to human health. They also do not pose an immediate risk to the environment. The strictest ecotoxicological thresholds for methomyl and metsulfuron-methyl are 1.6 µg/l and 1.8 µg/l, respectively, for aquatic invertebrates (*daphnia magna*) (PPDB website; EU, 2001). These values are much higher than the concentrations found in the inlet of the Batu WSSE.
For aquatic plants the strictest ecological thresholds for isoproturon is 13 µg/l for algae, which is well above the observed concentration. For metsulfuron-methyl the strictest threshold is for Lemna gibba: 0.62 µg/l, which is also above the observed concentration. For sulphur the strictest ecotoxicological threshold is 63 µg/l.

3.3 Sources of contaminations at Batu WSSE

It is important to identify possible sources of contamination of the water intake of the Batu WSSE. However, with the limited monitoring in 2009 and 2010 it is not possible to identify with certainty these sources of contaminations. There is no one-to-one relation between the pesticides detected in the effluent water samples and the pesticides detected in the raw water intake of the Batu WSSE. While acknowledging this uncertainty, some remarks are made.

The seven (7) pesticides that were detected in the raw water intake of the Batu WSSE were not all present in the effluent waters around Lake Ziway: Isoproturon, being fairly persistent, and the pyridate metabolite were not found in any of the water samples, except at the raw water intake of the Batu WSSE. This can be explained by the fact that it takes time before applied pesticides reach the water intake of the Batu WSSE. Detected pesticides may have been applied weeks ago. Moreover, the possible sources are not continuous: the application of pesticides occurs during a number of discrete spraying events. Finally, the number of sampling locations was limited and did not incorporate all (potential) risk areas. Pesticides may therefore originate from areas that were not monitored.

The observed contamination by methomyl in 2009 may originate from the floriculture enterprises at Ziway, as methomyl was also found in both effluent samples from these enterprises, while the water intake of the Batu WSSE is relatively close (1350 metres) to the effluent outlet. Considering the degradability (half-life times) residue concentrations of methomyl can be expected at some distance of the source.

It is also likely that the observed contamination by sulphur and metsulfuron-methyl originates from other agricultural areas, as these compounds were detected in most water samples taken around Lake Ziway, but not in the effluent water from the floriculture enterprises. Due to their relatively high persistence in surface waters these pesticides may spread over a large area and can thus impact on the quality of the water intake by the Batu WSSE.

The traces of tolyltriazole, being a corrosion inhibitor, is probably a contamination caused by the Batu WSSE themselves, possibly at the pumping station or treatment plant.

4 Conclusions

The monitoring of (residues of) pesticides in July 2009 and July 2010 consisted of two sampling campaigns, comprising ten (10) water samples from eight (8) different locations in the Central Rift Valley. The monitoring results provide a first indication of the risks of pesticide use associated with agricultural intensification. It can be concluded that the use of pesticides in the Central Rift Valley has impact on the water quality in Lake Ziway and the intake of drinking water from the lake by the Batu WSSE.

The pesticide monitoring programme showed that most surface water samples from agricultural areas contain a range of (residues of) pesticides. In three samples from agricultural areas north of Ziway town the obsolete and banned pesticide DDT was detected. Further, the effluent water from the floriculture enterprises at Ziway is a source of pollution, which has (potential) adverse impacts on the local aquatic ecosystem (situation of July 2010).

Small quantities of pesticides were detected at the raw water intake of the Batu WSSE. Although the measured concentrations are low and do not pose an immediate risk for human health the occurrence of pesticides in the raw water, certainly high toxic pesticides such as methomyl, are a concern as the occurrence of pesticides in drinking water should always be prevented. Because of the limited size of the monitoring, which also did not incorporate all (potential) risk areas, no decisive conclusions can be drawn with respect to the sources of contamination at the Batu WSSE.

In agricultural areas peak concentrations are expected to occur at the time that the pesticides are applied. It is not known how concentrations of pesticides vary in time and whether peak concentrations are above the water quality standards.

5 Recommendations

A more comprehensive monitoring programme, incorporating more locations and following the growing periods of crops, is required to draw decisive conclusions with respect to (sources of) contaminations, concentrations and risks. If more data become available it will be possible to identify and assess strategies to maintain environmental and health impacts of the use of pesticides within safe levels. Such strategies should address the need to reduce the concentrations of (residues of) pesticides in the surface waters through prevention and/or mitigation of emissions.

Preventive measures refer to actions that reduce pesticide use, such as practices to improve crop health, early scouting of pests and diseases and the proper application and treatment of pesticides. Emissions of (hazardous) pesticides can also be prevented or reduced by strengthening the legal framework, e.g. through a pesticide (post) registration system, and by law enforcement to ban the use of illegal pesticides. In Section 1.3 various relevant initiatives are listed.

Despite of preventive measures, emissions of agrochemicals (fertilisers and pesticides) are, to a certain extent, unavoidable in areas with intensive agriculture. The monitoring showed that most of the pesticides identified are biodegradable. This property offers good opportunities for the mitigation of present and future contaminations of the water system, from both the floriculture enterprises and the other agricultural areas. The biodegradation of (residual) pesticides can be enhanced through (integrated) measures that increase the water retention (increase residence times of residual pesticides), introduce oxygen and stimulate biological activity in the water system. Appendix 5 presents some options of mitigation measures. Measures to remove the residual concentrations have to consider the local conditions, be cost-effective and fit in the local context. Diffuse contaminations may require other measures than point contaminations. Innovative solutions are required.

In the area with floriculture enterprises various mitigation measures in the domain of improved on-site water management have been implemented recently. These measures enhance the biodegradation of residual pesticides through increased water retention and may, therefore, reduce the emissions onto Lake Ziway.

Lake Ziway is subject to more threats than (residues of) pesticides. Eutrophication is becoming more manifest (Section 1.2). Fish mortality has been experienced, for example in the area where untreated urban waste waters from Ziway discharge into Lake Ziway. Nutrients are responsible for algae blooms, which release toxic substances to the water of the lake. Also the Batu WSSE experiences problems with toxins originating from algae blooms (Ayana et al, 2010). In addition there is a risk of salinization of Lake Ziway if the outflow through the Bulbula River is being reduced (Section 1.2; Jansen, 2009).

Any solution to mitigate the water pollution by (residues of) pesticides must consider measures to minimize the emission of nutrients and vice versa, as proper measures can reduce both (residual) pesticide and nutrient emissions. More knowledge is required to understand the transport and accumulation dynamics (with regard to first flush effects) in order to design effective measures. The introduction of any (natural) mitigation system, therefore, requires an integrated approach, that considers all water quality issues.

An integrated approach includes the link between managing water quality and quantitative water management. Integrated solutions should also address the operation of the regulating gate at the outlet of Lake Ziway. It is, therefore, recommended to liaise with the operators of the Bulbula regulating gate, being the Water Works Design & Supervision Enterprise, the Federal Ministry of Water Resources and the Oromia Water Resources Bureau, to develop a strategy for operational water management that both serves water quantity and water quality issues.

Horticulture and other intensive agricultural enterprises are encouraged to monitor residual pesticides in their system and effluents to enable the design of effective, tailored mitigation measures, and to verify and assess their effectiveness. At the moment there is no institutional setting for routine monitoring of water quality and Ethiopia has limited laboratory facilities for pesticide analyses. Given the increased importance of water quality issues networks and systems for (routine) water quality monitoring, including pesticide monitoring, should be developed.

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Appendix 1 Sampling locations

Sample nr	Date	X	Y	EC (µS/cm)	pH	Turbidity 0 = clear water 1 = slightly turbid 2 = turbid	Colour 0 = no colour 1 = slightly coloured 2 = coloured brown	Description
Water samples								
(sample was lost)	11-07-2009	38°48.890’	08°08.056’	134.9	7.71	2	2	Meki River (Meki Town gauge)
W09-00328	11-07-2009	39°01.145’	08°01.974’	192.5	7.16	1	0	Ketar River (bridge)
W09-00327	11-07-2009	38°51.597’	08°05.951’	130.3	7.67	2	2	Meki River (downstream)
W09-00324	12-07-2009	38°43.875’	07°54.862’	n/a	n/a	0	0	Drain floriculture complex
W09-00325	12-07-2009	38°44.010’	07°54.705’	246.9	10.1	0	0	Drain floriculture (outlet-stagnant-)
(sample was lost)	11-07-2009	38°44.022’	07°53.599’	462.2	8.35	1	1	Bulbula River (near gate)
W09-00326	11-07-2009	38°44.182’	07°54.017’	451	8.55	1-2*	1-2	Batu WSSE raw water inlet
W10-00417	10-07-2010	38°45.166’	08°02.866’	848.7	7.86	1	1	Lake Ziway (north-western agricultural area)
W10-00418	10-07-2010	38°49.859’	08°07.337’	154.2	7.76	2	2	Meki agricultural area
W10-00419	10-07-2010	38°43.188’	07°56.991’	545.5	7.44	1	1	Lake Ziway (between Meki and Ziway
W10-00420	11-07-2010	38°44.182’	07°54.017’	430.6	8.48	1	1	Batu WSSE raw water inlet
W10-00421	11-07-2010	38°44.008’	07°54.713’	173.5	7.89	0	0	Drain floriculture (outlet-flowing-)
Sediment samples (suspended material in water)								
S09-00031	11-07-2009	38°51.597’	08°05.951’	n/a	n/a	n/a	n/a	Meki River (downstream)

* The amount of suspended material was insufficient for a separate analysis.

Appendix 2 Details of screened pesticides 2010

Pesticide	Function	Pesticide	Function	Pesticide	Function
3,4-dichloroaniline	Metabolite	butoxycarboxim	Insecticide	cyprodinil	Fungicide
Abamectin	Insecticide/Acaricide	captan	Fungicide	cyromazine	Insecticide
acephate	Insecticide	carbaryl	Insecticide	daminozide	Herbicide
acequinocyl	Insecticide	carbendazim	Fungicide	deltamethrin	Insecticide
acetamiprid	Insecticide	carbetamide	Herbicide	demeton	Acaricide/Insecticide
aclonifen	Herbicide	carbofuran	Insecticide	demeton-S-methyl	Insecticide
alachlor	Herbicide	carbofuran,3-hydroxy-	Metabolite	demeton-S-methylsulfone	Insecticide
aldicarb	Insecticide/Acaricide	carboxin	Fungicide	desethylatrazin	Metabolite
aldicarb-sulfone	Metabolite	carfentrazone-ethyl	Herbicide	desisopropylatrazin	Metabolite
aldicarb-sulfoxide	Metabolite	chloorfenvinfos	Acaricide/Insecticide	desmedipham	Herbicide
ametryn	Herbicide	chloorprofam	Herbicide	desmetryn	Herbicide
amidosulfuron	Herbicide	chlorbromuron	Herbicide	diazinon	Insecticide
asulam	Herbicide	chlorbufam	Herbicide	dichlobenil	Herbicide
atrazin	Herbicide	chlorfluazuron	Insecticide/growth regulator	dichlofluanid	Fungicide
azaconazole	Fungicides	chloridazon	Herbicide	dichlofluanide	Fungicide
azamethiphos	Insecticide	chlorothalonil	Fungicide	dichloorbenzamide	Metabolite
azinphos-ethyl	Insecticide/Acaricide	chlorotoluron	Herbicide	dichloorfenthion	Insecticide, Nematicide
azinphos-methyl	Insecticide/Acaricide	chloroxuron	Herbicide	dichloorvos	Acaricide/Insecticide
azoxystrobin	Fungicide	chlorpyrifos	Insecticide	dichloran	Fungicide
bendiocarb	Insecticide	chlorpyrifos-methyl	Insecticide	dicofol	Insecticide
benzyladenine,6-	Growth regulator	chlorthal-dimethyl	Herbicide/Metabolite	dicrotophos	Insecticide
bifenazate	Acaricide	clodinafop-propargyl	Herbicide	diethofencarb	Fungicide
bifenthrin	Insecticide	clofentezine	Acaricide	diethyltoluamide	Insecticide
bioallethrin	Insecticide	clomazone	Herbicide	difenoconazole	Fungicide
bitertanol	Fungicide	clothianidin	Insecticide	difenoxuron	Herbicide
boscalid	Fungicide	cumafos	Insecticide	diflubenzuron	Insecticide
bromacil	Herbicide	cyanazin	Herbicide	diflufenican	Herbicide
bromophos	Insecticide	cycloxydim	Herbicide	dimethenamid	Herbicide
bromophos-ethyl	Insecticide	cyfluthrin (som)	Insecticide	dimethirimol	Fungicide
bromopropylate	Insecticide	cyhalothrin,lambda-	Insecticide	dimethoaat	Acaricide/Insecticide
bupirimaat	Fungicide	cymoxanil	Fungicide	dimethomorf	Fungicide
buprofezin	Insecticide	cypermethrin (som)	Insecticide	diniconazole	Fungicide
butocarboxim	Insecticide	cyproconazole	Fungicide	disulfoton	Acaricide/Insecticide

Appendix 2 Details of screened pesticides 2010 (continued)

Pesticide	Function	Pesticide	Function	Pesticide	Function
disulfoton-sulfone	Metabolite	fenpropimorf	Fungicide	imidacloprid	Insecticide
disulfoton-sulfoxide	Metabolite	fenpyroximate	Acaricide	indoxacarb	Insecticide
diuron	Herbicide	fensulfothion	Insecticide/Nematicide	iprodione	Fungicide
DMSA	Metabolite	fensulfothion-sulfone	Metabolite	iprovalicarb	Fungicide
DMST	Metabolite	fenthion	Insecticide	isoproturon	Herbicide
dodemorf	Fungicide	fenthion-sulfone	Metabolite	isoxaflutole	Herbicide
dodine	Fungicide	fenthion-sulfoxide	Metabolite	kresoxim-methyl	Fungicide
emamectine	Insecticide	fenvalerate_esfenvalerate(sum RR&SS)	Insecticide	lenacil	Herbicide
endosulfan-alfa	Insecticide	fenvalerate_esfenvalerate(sum RS&SR)	Insecticide	lindane	Insecticide, Rodenticide
endosulfan-beta	Insecticide	fipronil	Insecticide	linuron	Herbicide
endosulfan-sulfate	Metabolite	flonicamid	Insecticide	lufenuron	Insecticide
epoxiconazool	Fungicide	florasulam	Herbicide	malathion	Acaricide/Insecticide
eptam	Herbicide	fluazifop-butyl	Herbicide	mesotrione	Herbicide
esfenvalerate	Insecticide	flucycloxuron	Acaricide/Insecticide	metabenzthiazuron	Herbicide
ethiofencarb	Insecticide	flufenoxuron	Acaricide/Insecticide	metalaxyl	Fungicide
ethiofencarb sulfon	Metabolite	flumioxazin	Herbicide	metamitron	Herbicide
ethiofencarb sulfoxide	Metabolite	fluopicolide	Fungicide	metazachloor	Herbicide
ethion	Acaricide	fluoroglycofen-ethyl	Herbicide	methamidophos	Acaricide/Insecticide
ethirimol	Fungicide	fluoxastrobin	Fungicide	methidathion	Insecticide
ethofumesaat	Herbicide	fluroxypyr meptyl	Herbicide	methiocarb	Acaricide/Insecticide
ethoprofos	Insecticide/Nematicide	flutolanil	Fungicide	methiocarb sulfon	Metabolite
etridiazool	Fungicide	folpet	Fungicide	methiocarb sulfoxide	Metabolite
etrimfos	Insecticide	fonofos	Insecticide	methomyl	Insecticide
famoxadone	Fungicide	fosalon	Acaricide/Insecticide	methoxychlor	Insecticide
fenamidone	Fungicide	fosfamidon	Acaricide/Insecticide	methoxyfenozide	Insecticide
fenamiphos	Nematicide	fosmet	Acaricide/Insecticide	metobromuron	Herbicide
fenamiphos-sulfone	Metabolite	fosthiazate	Nematicide	metolachloor	Herbicide
fenamiphos-sulfoxide	Metabolite	fuberidiazole	Fungicide	metoxuron	Herbicide
fenarimol	Fungicide	furalaxyl	Fungicide	metribuzin	Herbicide
fenchloorfos	Insecticide	furathiocarb	Insecticide	metsulfuron-methyl	Herbicide
fenhexamid	Fungicide	heptenofos	Insecticide	mevinfos	Acaricide/Insecticide
fenitrothion	Insecticide	hexaflumuron	Insecticide	monocrotophos	Acaricide
fenoxycarb	Insecticide	hexythiazox	Acaricide	monolinuron	Herbicide
fenpiclonil	Fungicide	imazalil	Fungicide	monuron	Herbicide
fenpropathrin	Insecticide	imazamethabenzmethyl	Herbicide	myclobutanil	Fungicide

Appendix 2 Details of screened pesticides 2010 (continued)

Pesticide	Function	Pesticide	Function	Pesticide	Function
nicosulfuron	Herbicide	propachlor	Herbicide	terbutylazin	Algaecide, Herbicide,
nitrothal-isopropyl	Fungicide	propamocarb	Herbicide	tetrachloorvinfos	Insecticide
omethoate	Acaricide/Insecticide	propazin	Herbicide	tetradifon	Insecticide
oxadixyl	Fungicide	propham	Herbicide, Growth Regulator		
oxamyl	Insecticide/Nematicide	propiconazool	Fungicide	tetramethrin	Insecticide
oxycarboxin	Fungicide	propoxur	Insecticide	thiabendazole	Fungicide
oxydemeton-methyl	Metabolite	propyzamide	Herbicide	thiacloprid	Insecticide
paclobutrazol	Growth regulator	prosulfocarb	Herbicide	thiametoxam	Fungicide, Insecticide
parathion	Acaricide/Insecticide	pymetrozine	Insecticide	thiocyclam	Insecticide
parathion-methyl	Insecticide	pyraclostrobin	Fungicide	thiodicarb	Insecticide, Molluscicide
penconazole	Fungicide	pyrazofos	Fungicide	thiofanox	Insecticide
pencycuron	Fungicide	pyridate metabolite (CHPP)	Herbicide	thiofanox-sulfone	Metabolite
pendimethalin	Herbicide	pyrifenox	Fungicide	thiofanox-sulfoxide	Metabolite
permethrin(sum)	Insecticide	pyrimethanil	Fungicide	thiometon	Insecticide
phenmedipham	Herbicide	quinoclamine	Algaecide, Herbicide	thiophanate-methyl	Fungicide
phenmedipham metabolite (MHPC)	Herbicide	quizalofop-ethyl	Herbicide	THPI	Metabolite
phenylphenol,2-	Fungicide	rotenone	Insecticide	tolclofos-methyl	Fungicide
phorate	Insecticide	sethoxydim	Herbicide	tolylfluanid	Fungicide
phorate-sulfone	Metabolite	simazin	Herbicide	topramezone	Herbicide
phorate-sulfoxide	Metabolite	spinosad	Insecticide	triadimefon	Fungicide
phosphamidon	Insecticide/Nematicide	spirodiclofen	Acaricide	triadimenol	Fungicide
picolinafen	Herbicide	sulcotrione	Herbicide	tri-allate	Herbicide
picoxystrobin	Fungicide	sulfotep	Insecticide	triazofos	Acaricide/Nematicide
pinoxaden	Herbicide	sulphur	Fungicide, Insecticide	triazoxide	Fungicide
piperonyl-butoxide	Antiparasiticide/Synergist	tebuconazool	Fungicide	trichlorfon	Insecticide
pirimicarb	Insecticide	tebufenozide	Insecticide	tricyclazole	Fungicide
pirimicarb,desmethyl-	Insecticide	tebufenpyrad	Acaricide/Insecticide	trifloxystrobin	Fungicide
pirimifos-methyl	Insecticide	temephos	Insecticide	triflumuron	Insecticide
pirimiphos-ethyl	Insecticide	tepraloxydim	Herbicide	trifluralin	Herbicide
pirimiphos-methyl	Insecticide	terbufos	Insecticide	triforine	Fungicide, Insecticide
prochloraz	Fungicide	terbufos-sulfone	Metabolite	vamidothion	Acaricide/Insecticide
procymidon	Fungicide	terbufos-sulfoxide	Metabolite	vinclozolin	Fungicide
profoxydim	Herbicide	terbuthylazine	Algaecide, Herbicide, Microbiocide		
prometryn	Herbicide	terbutryn	Herbicide	zoxamide	Fungicide

Appendix 3 Details on analyses of detected pesticides

Pesticide	2010			2009		
	Accreditation	Detection limit (ug/l):	Method	Accreditation	Detection limit (ug/l)	Method
acetamiprid	ISO 17025	0.02	LC-MS		0.05	LC-MS
azoxystrobin	ISO 17025	0.25	GC-MS	ISO 17025	0.25	GC-MS
biphenyl			Not analyzed			Screening GC-MS
bisphenol A			Not analyzed			Screening GC-MS
bitertanol		0.01	LC-MS		0.01	LC-MS
bitertanol					0.05	GC-MS
boscalid		0.01	GC-MS			Screening GC-MS
bupirimaat	ISO 17025	0.05	GC-MS	ISO 17025	0.05	GC-MS
carbaryl			LC-MS	ISO 17025	0.02	LC-MS
caffeine			Screening GC-MS			Not analyzed
carbaryl	ISO 17025	0.05	GC-MS	ISO 17025	0.05	GC-MS
carbendazim	ISO 17025	0.01	LC-MS	ISO 17025	0.01	LC-MS
clofentezine	ISO 17025	0.02	LC-MS			Not analyzed
cyprodinil		0.05	GC-MS		0.05	GC-MS
o,p'-DDD			Screening GC-MS			Not analyzed
o,p'-DDE			Screening GC-MS			Not analyzed
p,p'-DDM [bis(4-chlorophenyl]			Screening GC-MS			Not analyzed
DDT/ P,p'-DDT			Screening GC-MS			Screening GC-MS
diazinon	ISO 17025	0.01	GC-MS	ISO 17025	0.01	GC-MS
3,5-dichloroaniline			Screening GC-MS			Not analyzed
diethyltoluamide	ISO 17025	0.02	GC-MS	ISO 17025	0.02	GC-MS
dimethoate	ISO 17025	0.01	LC-MS		0.01	LC-MS
dimethoate		0.02	GC-MS		0.02	GC-MS
dimethomorf	ISO 17025	0.05	GC-MS	ISO 17025	0.05	GC-MS

Appendix 3 Details on analyses of detected pesticides (continued)

Pesticide	2010			2009		
	Accreditation	Detection limit (ug/l):	Method	Accreditation	Detection limit (ug/l)	Method
diuron-metabolite			Not analyzed			Screening GC-MS
dodemorf	ISO 17025	0.02	GC-MS	ISO 17025	0.02	GC-MS
endosulfan-sulfate			GC-MS			Not analyzed
ethirimol	ISO 17025	0.01	LC-MS		0.01	LC-MS
etoxazol			Not analyzed			Screening GC-MS
fenamiphos	ISO 17025	0.01	LC-MS	ISO 17025	0.06	GC-MS
fenamiphos-sulfone	ISO 17025	0.01	LC-MS		0.01	LC-MS
fenamiphos-sulfoxide	ISO 17025	0.01	LC-MS		0.01	LC-MS
fenarimol	ISO 17025	0.05	GC-MS			Screening GC-MS
fenhexamid	ISO 17025	0.01	LC-MS		0.01	LC-MS
fenitrothion		0.03	GC-MS		0.03	GC-MS
fludioxonil			Screening GC			GC-MS semi-quantitative
flusilazole			Screening GC			Not analyzed
hexaflumuron			LC-MS			Not analyzed
hexythiazox		0.05	LC-MS			Not analyzed
imidacloprid	ISO 17025	0.01	LC-MS	ISO 17025	0.01	LC-MS
iprodione		0.2	GC-MS		0.2	GC-MS
iprovalicarb	ISO 17025	0.01	LC-MS		0.01	LC-MS
isoproturon	ISO 17025	0.01	LC-MS	ISO 17025	0.01	LC-MS
linuron	ISO 17025	0.01	LC-MS	ISO 17025	0.01	LC-MS
lufenuron			GC-MS	ISO 17025	0.02	GC-MS
metalaxyl	ISO 17025	0.05	GC-MS	ISO 17025	0.05	GC-MS
methiocarb	ISO 17025	0.01	LC-MS	ISO 17025	0.01	LC-MS
methomyl	ISO 17025	0.01	LC-MS	ISO 17025	0.01	LC-MS

Appendix 3 Details on analyses of detected pesticides (continued)

Pesticide	2010			2009		
	Accreditation	Detection limit (ug/l):	Method	Accreditation	Detection limit (ug/l)	Method
methoxyfenozide		0.02	LC-MS		0.01	LC-MS
metsulfuron-methyl		0.02	LC-MS			Not analyzed
naphthalic anhydride			Screening GC			Not analyzed
oxamyl	ISO 17025	0.01	LC-MS			Not analyzed
piperonyl-butoxide		0.01	GC-MS			Not analyzed
profenofos			Screening GC			Not analyzed
profenofos metabolite			Screening GC-MS			Screening GC-MS
pyraclostrobin	ISO 17025	0.01	LC-MS	ISO 17025	0.01	LC-MS
pyridate metabolite (CHPP)	ISO 17025	0.01	LC-MS	ISO 17025	0.01	LC-MS
spiroxamine I			Screening GC-MS			Not analyzed
sulphur*			GC-MS			Not analyzed
tebufenpyrad		0.05	GC-MS			GC-MS semi-quantitative
tetraconazole			Screening GC-MS			Screening GC-MS
tetradifon		0.05	GC-MS			GC-MS semi-quantitative
thiametoxam	ISO 17025	0.01	LC-MS		0.01	LC-MS
thiophanate-methyl		0.02	LC-MS	ISO 17025	0.01	GC-MS
tolyltriazole			Screening GC-MS			Not analyzed
tributyl phosphate			Screening GC-MS			Not analyzed
triadimefol	ISO 17025	0.01	LC-MS		0.01	LC-MS
triadimefon	ISO 17025	0.01	LC-MS		0.01	LC-MS
trifloxystrobin		0.05	GC-MS			Not analyzed
triforine		0.05	LC-MS		0.05	LC-MS
tris (2-chloroethyl) phosphate			Screening GC-MS			Not analyzed

Appendix 4 Results of pesticide analyses

Meki and Ketar areas

Sample number:	W09-00327	W09-00328	W10-00418	Remarks **):	Method / accreditation
Compound:	**Concentration (µg/l)**				
biphenyl		detected		Slightly hazardous	Screening GC-MS
caffeine			detected	Moderate toxicity	Screening GC-MS
DDT		0.04	detected	***Obsolete pesticide; High risk pesticide***	Screening GC-MS Poor finding
dimethoate			0.03	Registered pesticide (insecticide); High risk pesticide	LC-MS / ISO 17025
endosulfan-sulfate			0.06	Registered pesticide (fungicide)	GC-MS (low accuracy)
fenitrothion			0.08	Registered pesticide (insecticide); High risk pesticide	GC-MS
metalaxyl			0.11	Registered pesticide (insecticide and fungicide) Moderately hazardous	GC-MS / ISO 17025
metsulfuron-methyl			0.04	Slight toxicity	LC-MS
piperonyl-butoxide			0.02	Moderate toxicity	GC-MS
sulphur			7	Registered pesticide (fungicide); Slightly hazardous	GC-MS (low accuracy)
triadimefol			0.05	Moderately hazardous	LC-MS / ISO 17025
triadimefon			0.04	Registered pesticide (fungicide); High risk pesticide	LC-MS / ISO 17025
tributyl phosphate			detected	Slightly hazardous	Screening GC-MS
tris (2-chloroethyl) phosphate			detected	High risk pesticide	Screening GC-MS

***) Based on WHO, 2009,* www.pesticideinfo.org/ and APHRD, 2010

Area between Meki and Ziway

Sample number:	**W10-00417**	**W10-00419**	**Remarks **):**	**Method / accreditation**
Compound:	**Concentration (µg/l)**			
caffeine	detected	detected	Moderate toxicity	Screening GC-MS
carbaryl	0.05		Registered pesticide (insecticide); High risk pesticide	GC-MS / ISO 17025
diazinon		0.09	Registered pesticide (insecticide); High risk pesticide	GC-MS / ISO 17025
p,p'-DDM		detected		Screening GC
o,p'-DDE		detected	Breakdown product of DDT	Screening GC
o,p'-DDD		detected	Breakdown product of DDT	Screening GC
p,p'-DDT		detected	***Obsolete pesticide; High risk pesticide***	Screening GC
hexaflumuron		0.01	Slight toxicity	LC-MS (low accuracy)
linuron		0.02	High risk pesticide	LC-MS / ISO 17025
metalaxyl		0.09	Registered pesticide (insecticide and fungicide) Moderately hazardous	GC-MS / ISO 17025
metsulfuron-methyl	0.06	0.08	Slight toxicity	LC-MS
sulphur	1	3	Registered pesticide (fungicide); Slightly hazardous	GC-MS (low accuracy)
thiametoxam		0.01	Registered pesticide (insecticide)	LC-MS / ISO 17025
tolyltriazole	detected			Screening GC-MS
triadimefol		0.02	Moderately hazardous	LC-MS / ISO 17025
triadimefon		0.02	Registered pesticide (fungicide); High risk pesticide	LC-MS / ISO 17025
tris (2-chloroethyl) phosphate	detected	detected	High risk pesticide	Screening GC-MS

***) Based on WHO, 2009,* www.pesticideinfo.org/ and APHRD, 2010

Floriculture enterprises at Ziway

Sample number:	W09-00324	W09-00325	W10-00421	Remarks **):	Method / accreditation
Compound:	**Concentration (µg/l)**				
acetamiprid	7.6			Registered pesticide (insecticide)	LC-MS
azoxystrobin		2.2		Registered pesticide (fungicide)	GC-MS / ISO 17025
bisphenol A		detected			Screening GC-MS
bitertanol	0.07				GC-MS
bitertanol	0.11		0.8		LC-MS
boscalid	detected*	detected*	2.6	Registered pesticide (fungicide)	GC-MS (* = screening)
bupirimate			0.19	Registered pesticide (fungicide)	GC-MS / ISO 17025
caffeine			detected	Moderate toxicity	Screening GC-MS
carbendazim	9.1	0.14	0.5	Slight toxicity	LC-MS / ISO 17025
clofentezine			0.1	Registered pesticide; Slightly hazardous	LC-MS / ISO 17025
cyprodinil	0.19	0.16	0.05	Slight toxicity	GC-MS
3,5-dichloroaniline			detected		Screening GC-MS
diethyltoluamide		0.14	0.06	Slightly hazardous	GC-MS / ISO 17025
dimethomorf		0.77	0.09	Registered pesticide (fungicide); Slight toxicity	GC-MS / ISO 17025
diuron-metabolite	detected	detected		High risk pesticide	Screening GC-MS
dodemorf	0.45	0.5	0.13		GC-MS / ISO 17025
endosulfan-sulfate			0.06	Registered pesticide (insecticide)	GC-MS (low accuracy)
ethirimol		0.01	0.32		LC-MS / ISO 17025
etoxazol	detected				Screening GC-MS
fenamiphos			0.08	Highly hazardous	LC-MS / ISO 17025
fenamiphos-sulfone			0.01	High risk pesticide	LC-MS / ISO 17025
fenamiphos-sulfoxide		0.02	0.07	High risk pesticide	LC-MS / ISO 17025
fenarimol	detected*		0.4	Slightly hazardous	GC-MS / ISO 17025 (* = screening)
fenhexamid			0.08	Registered pesticide (fungicide); Slight toxicity	LC-MS / ISO 17025
fenitrothion			0.16	Registered pesticide (insecticide); High risk pesticide	GC-MS

***) Based on WHO, 2009,* www.pesticideinfo.org/ and APHRD, 2010

Floriculture enterprises at Ziway (continued)

Sample number:	W09-00324	W09-00325	W10-00421	Remarks **):	Method / accreditation
Compound:	**Concentration (µg/l)**				
fludioxonil	0.26	0.12	detected	Slight toxicity	GC-MS semi-quantitative
flusilazole			detected	Slight toxicity	Screening GC-MS
hexythiazox			0.09	Slight toxicity	LC-MS
imidacloprid	0.04	0.15	0.3	Registered pesticide (insecticide) Moderately hazardous	LC-MS / ISO 17025
iprodione	0.25	0.81		Registered pesticide (fungicide); Slightly hazardous	GC-MS
iprovalicarb	0.01	0.04	0.38	High risk pesticide	LC-MS/ISO 17025 (2010)
linuron		0.02		High risk pesticide	LC-MS / ISO 17025
lufenuron			0.02		GC-MS (low accuracy)
metalaxyl	0.34	0.51	0.18	Registered pesticide (insecticide and fungicide) Moderately hazardous	GC-MS / ISO 17025
methiocarb			0.04	Highly hazardous; High risk pesticide	LC-MS / ISO 17025
methomyl	2.7	0.26		Highly hazardous; High toxicity to humans	LC-MS / ISO 17025
methoxyfenozide		0.01	0.5		LC-MS
naphthalic anhydride			detected		Screening GC-MS
oxamyl			0.01	Highly hazardous; High risk pesticide	LC-MS / ISO 17025
piperonyl-butoxide			0.02	Moderate toxicity	GC-MS
profenofos			detected	High risk pesticide	Screening GC-MS
profenofos metabolite		detected	detected	Registered pesticide (insecticide); High risk pesticide	Screening GC-MS
propamocarb	1	0.32	0.38	Registered pesticide (fungicide)	LC-MS/ISO 17025 (2010)
pyraclostrobin		0.03	0.15		LC-MS / ISO 17025
spiroxamine	4	1.1	detected*	Registered pesticide (fungicide); Moderately hazardous	GC-MS semi-quantitative (* screening GC-MS)
tebufenpyrad	0.09	0.09		Registered pesticide (insecticide); Moderately hazardous	GC-MS screening
tebufenpyrad	0.11	0.097		Registered pesticide (insecticide); Moderately hazardous	GC-MS semi-quantitative
tetraconazole	detected		detected	High risk pesticide	Screening GC-MS

***) Based on WHO, 2009,* www.pesticideinfo.org/ and APHRD, 2010

Floriculture enterprises at Ziway (continued)

Sample number:	W09-00324	W09-00325	W10-00421	Remarks **):	Method / accreditation
Compound:	**Concentration (µg/l)**				
tetradifon		1*	0.4	Slight toxicity	GC-MS (* = screening)
tetradifon		1.15		Slight toxicity	GC-MS semi-quantitative
thiophanate-methyl			0.05	High risk pesticide	LC-MS
tributyl phosphate			detected	Slight toxicity	Screening GC-MS
triadimefol			0.1	Moderately hazardous	LC-MS / ISO 17025
triadimefon			0.16	Registered pesticide (fungicide); High risk pesticide	LC-MS / ISO 17025
trifloxystrobin			0.34	Slight toxicity	GC-MS
triforine		0.4*	0.1	High risk pesticide	LC-MS (* = screening)
tris(2-chloroethyl) phosphate			detected		Screening GC-MS

***) Based on WHO, 2009,* www.pesticideinfo.org/ and APHRD, 2010

Intake Batu WSSE

Sample number:	**W09-00326**	**W10-00420**	**Remarks **):**	**Method / accreditation**
Compound:	**Concentration (µg/l)**			
biphenyl	detected		Slightly hazardous	Screening GC-MS
isoproturon		0.03	Moderately hazardous	LC-MS / ISO 17025
methomyl	0.02		Highly hazardous; High toxicity to humans	LC-MS / ISO 17025
metsulfuron-methyl		0.3	Slight toxicity	LC-MS
pyridate metabolite (CHPP)	0.01		Slightly hazardous	LC-MS / ISO 17025
sulphur*		10	Registered pesticide (fungicide); Slightly hazardous	GC-MS (low accuracy)
tolyltriazole		detected		Screening GC-MS

***) Based on WHO, 2009,* www.pesticideinfo.org/ and APHRD, 2010

Appendix 5 Mitigation methods to reduce the concentrations of residual pesticides

Below some options are given to reduce the amount of pesticides in water, thereby improving the water quality. These examples are not ready for implementation. A detailed study is necessary in order to design systems that are applicable under the conditions in Ethiopia.

Mitigation of emissions at floriculture enterprises
As the floriculture enterprises at Ziway currently represent a distinct point source of pesticide contamination it is recommended to liaise with these enterprises and design tangible solutions. Below some options of mitigation measures are given.

For more concentrated effluents, such as spray water and water used for cleaning tanks, a possible technological option is to install a water processing facility, for example by using granular activated coal filters. Other, less contaminated, flows can be treated by using helophyte filter technology in which biodegradation is stimulated. It could be an option to construct a centralized wetland at the premises of the floriculture enterprises at Ziway. A major advantage is that a wetland does not generate potentially hazardous waste. A disadvantage is that a constructed wetland requires relatively much space, while also strict hydrological conditions must be maintained. The space requirements (capacity) will reduce if also a separate storm water drainage system is constructed and if other, local solutions for the stimulation of biodegradation of (residual) pesticides are put in place (see also below).

Heavy rainfall can significantly reduce the residence time in a wetland, thereby reducing its efficiency. To minimize the size of a constructed wetland and to maximize its efficiency the on-site water management should be improved by creating storage capacity and separate drainage systems for storm water[2]. At times of rainfall only the initial peak runoff may be stored and/or treated and the remaining rainwater can be directly discharged. Monitoring has to show which water needs treatment and which water is clean enough to be directly discharged to the lake using a by-pass.

For a successful implementation of mitigation measures an on-site integrated approach is required, assessing the various options and conducting a design study. Such a study should be based on the on-site water balance, considering the variability and extremes of rainfall, water requirements by the enterprises, the water quality (monitored concentrations of pesticides) of the different water flows in and outside the green houses, and the pesticides used.

Mitigation of emissions in other agricultural areas
The contamination of surface waters by smallholders is diffuse in nature and requires other solutions. In the Ethiopia context, solutions that require complex and/or centralized technologies, strict operational conditions or large O&M costs are not feasible in these areas. Technically and financially feasible mitigation measures should fit in the local context and principally be aimed at increasing the retention (residence times) of (residues

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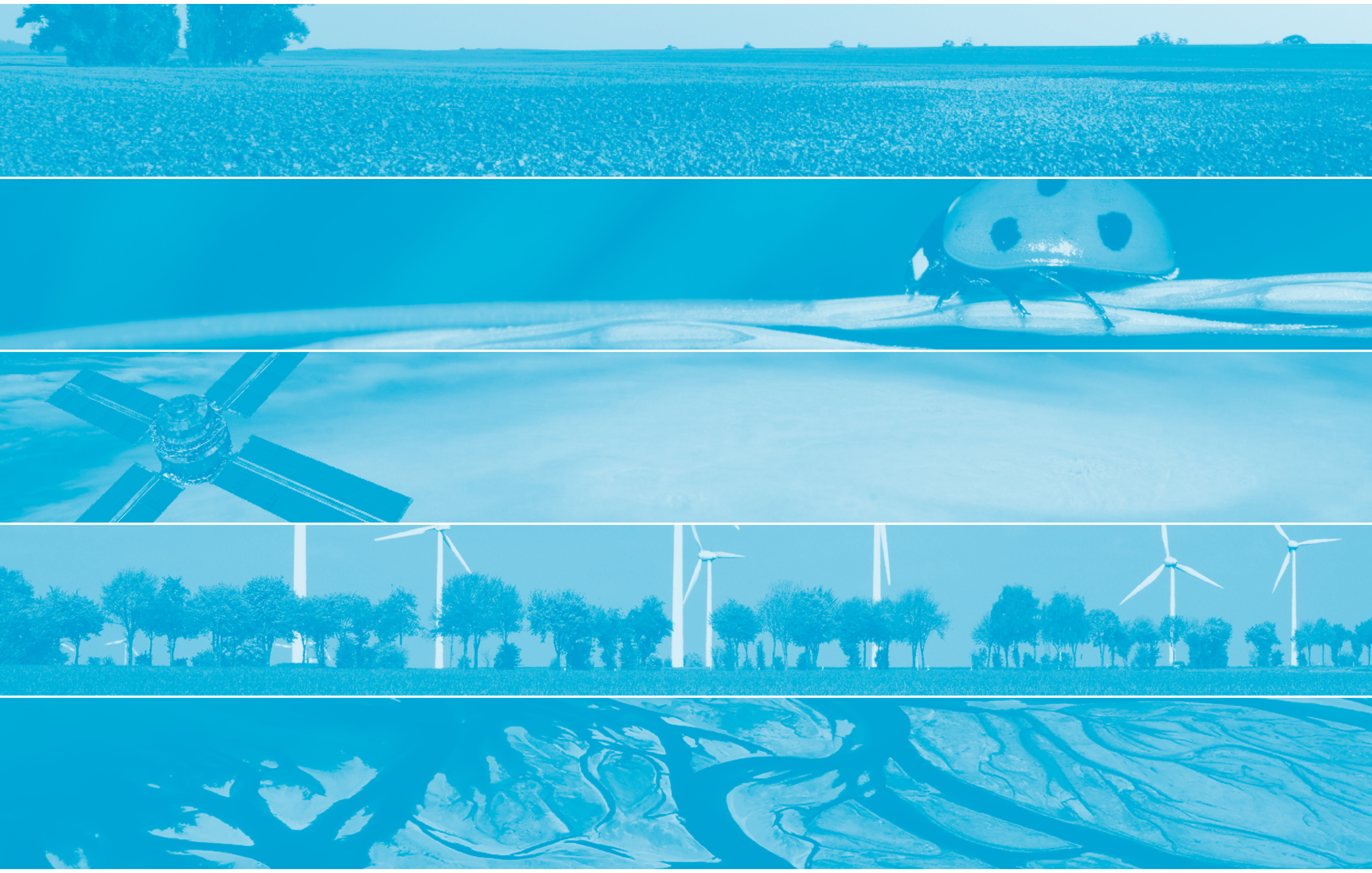
[2] At the time of issue of this report the floriculture enterprises had already created additional storage capacity at their premises and a system to capture the flash floods.

of) pesticides, the introduction of oxygen in the system and the stimulation of biodegradation of (residual) pesticides in active biological systems.

Considering the biophysical and organizational conditions in the smallholder areas innovative and integrated solutions are required. Biodegradation of the emitted pesticides has to be stimulated on strategic places in the area. Hydrological measures (e.g. construction of small weirs) and use of proper vegetation in the water system will increase water retention and stimulate biological activity. These measures are simple, make use of local conditions and are inexpensive. Such an approach, making use of the local conditions has successfully been introduced in reducing risks of African sites contaminated with pesticides (Harmsen et al., 2009). For a proper design of mitigation measures again an integrated approach is required, also taking into account all spatial and temporal variations.



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