# A.4.
# Special sessions:
# Norway
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# «JOVÅ» - The agricultural environmental pesticides monitoring programme in Norway

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## Abstract

Pesticides have been monitored in 12 Norwegian streams and rivers during a three to five year's period. In six of the drainage basins data on the use of pesticides have been collected. 859 samples have been collected during the period 1995 - 1999. In 540 samples one or more pesticides have been measured above the detection limit, giving the result that 63% of samples contained pesticides residues. 34 pesticides out of the 53 substances analysed have been detected in surface water. Of these, 21 were herbicides, 8 fungicides and 5 insecticides. 13 different pesticides were detected in concentrations, supposed to have environmental impact on algae, daphnia, fish or water plants. The different pesticides showed a very different pattern according to the frequency and concentrations that are measured.

## Background

### *Objectives*

The Ministry of Agriculture, in co-operation with the Ministry of Environment, started in 1992 a national program to monitor erosion and nutrient losses from agricultural soils: "The Agricultural and Environmental Monitoring Programme («JOVÅ»)". In 1995 the program was extended with pesticides.

The primary objectives for the pesticides monitoring program were:

(a) To gain information on the occurrence of pesticides in water and potential risks for water contamination.

(b) To clarify the connection between the use of pesticides on farmland and their occurrence in water as a tool to evaluate if the authorisations of the pesticides give the wanted effects.

(c) Demonstrate possible changes in the use of pesticides within the agricultural industry.

## Activities

The monitoring programme registers and reports the extent of pesticide losses from different agricultural farming practices, natural resource basis, and various agro-climatological conditions. The development will be followed over a period of time in order to extract annual variations and trends. Figure 1 shows the streams and rivers that have been monitored.

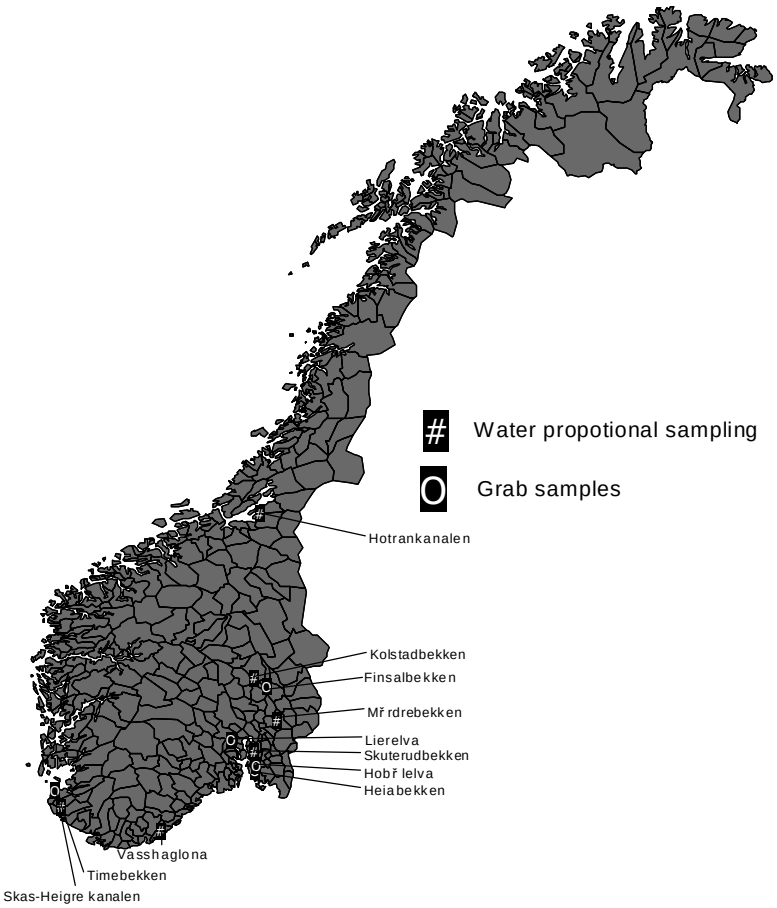


**Figure 1. Map of Norway showing the sampled streams and rivers**

There have been also investigations of pesticides in drainage water, groundwater, sediments and precipitation. This paper will focus on the results from surface water with a special focus on the detection of lindane in the stream "Time", including the investigations of lindane in precipitation collected in Rogaland county. Table 1 presents the most important information on the characteristics of the monitored drainage basins.

**Table 1. Characteristics of the drainage basins in the monitored streams and rivers.**

| Location | Drainage area ($km^2$) | Main crop | Soil type | Mean precipit. ($mm.yr^{-1}$) |
|---|---|---|---|---|
| Vasshaglona | 0.7 | vegetables, potatoes and grain | sand and loam | 1,230 |
| Time | 1.1 | grass | soils of morenic origin with loamy sand | 1,189 |
| Kolstad | 3.1 | grain | soils of morenic origin with loam soil | 585 |
| Skuterud | 4.5 | grain | silty clay, shore deposit and morenic depositions | 785 |
| Heia | 4.7 | vegetables, potatoes and grain | sand, silt and clay of morenic origin | 829 |
| Mordre | 6.8 | grain | clay and silt fractions of marine and lacustrine origin | 665 |
| Hotran | 20 | grain and 30% grass | silt loam and silt clay loam of marine origin | 892 |
| Finsal | 22 | grain and potatoes | soils of morenic origin | 585 |
| Skas - Heigre | 29 | grass | clay, sand and gravel | 1,180 |
| Auli | 147 | grain | clay of marine and morenic origin | 1,035 |
| Lier | 303 | vegetables, grain | clay and silt fractions of marine and fluvial origin | 940 |
| Hobol | 331 | grain | clay and silt fractions of marine origin | 829 |

## Methods

### *Runoff measurement*

The basis for the monitoring programme was six rather small drainage basins that have continuous discharge measurements and water proportional sampling that have been monitored from 1995 till 1999. The drainage basins vary in size from 50 to 680 hectares and the total number of farms varies from 5 to 30 farms. The farmers keep records of all their farming operations including pesticides use and run their farms without any particular consultation or restrictions on farming practices. A detailed soil and land use mapping has been carried out in the drainage basins and important soil physical parameters have been measured. In addition, climatological data were collected for carrying out water balance studies.

Pesticides have been monitored for three years or more at additional six small and medium size rivers. Drainage basins are from 20 till 230 $km^2$. Samples have been collected as grab samples.

### *Precipitation*

At the location Time in Rogaland County on the Southwest coast of Norway, precipitations were collected during the year 1998 and 1999. This was initiated by the detection of lindane in the small stream Time without having any use of lindane by the farmers in the drainage basin. Collection of water was done by very simple equipment using a steel tract and a container without cooling system. The locations of Obrestad and Bjerkreim were investigated during 1999. A steel tract with a refrigerator was used for collecting water. Lindane was analysed at the detection limit of 0.005 μg/l.

### *Chemical analyses*

Determination of pesticides residues in water is mainly performed by gas chromatography with selective detectors after extraction with organic solvents - GC multimethod. In addition, some of the more polar herbicides like the phenoxy-acids require a derivatisation step before the chromatographic analysis - GC/MS multimethod. The number of substances analysed and the detection limits have been improved during the monitoring period. In the first year only 25 substances where analysed with detection limits ranging between 0.05 and 0.1 μg/l. Every year the number of substances analysed was increased and the detection limits have been lowered. Table 2-4 illustrate the number of different analyses that have been carried out for different substances and the detection limits of the year 1999. Additional analyses have been done on important substances that require special analysing methods such as glyphosate, tribuneron-metyl, ETU (decomposition product of mancozeb) and isoproturon.

### *Water sampling equipment and strategy*

All measurement stations in the monitoring programme in Norway are provided with a data measurement and control module (data-logger). Water levels were measured continuously and discharges were calculated on the basis of the known head-discharge relation for the monitoring station. A composite water sampling system was installed in each station. A small sample was taken, each time a preset volume of water has passed the monitoring station. The sub-samples were stored in a container situated in a refrigerator for subsequent analysis. The sample container will contain a composite sample with a total volume ($V_{tot}$), representing the average water concentration ($C_{comp}$) over the sampling period. On the average every fortnight composite water sample was collected for laboratory analysis.

Pesticides samples have normally been taken from early spring (April) until frost appeared in November or December. At some locations samples have also been taken during the winter month.

Studies are now being done on the decomposition of the pesticides during the 14 days of storage before collection. The report is not finished, but preliminary results are available. The pesticides dicamba, MCPA, flamprop-isopropyl, fluroxypyr, dimethoate, fluazinam, permithrin, vinchlozolin were decomposed within 14 days at a rate of >15 % up till 100 %. The other substances showed no or little decomposition. This indicates that the method of water proportional samples underestimates the amount of these pesticides. Some pesticides will not be detected at all using the water proportional sampling method. For the other pesticides the method gave approved results.

## Results

### *Streams and rivers*

The results from the monitoring program have been published in the annual reports (Lode and Ludvigsen, 1996 to 1999). To evaluate the findings of pesticides in surface water, environmental maximum residue limits (MRL) have been set. They are based on the $EC_{50}$ or $LD_{50}$ values for daphnia, algae, water plants and fishes. A safety factor of 100 has been used for all organisms. If concentrations rise above the MRL level, there might be a potential risk for the aquatic environment. Table 2-4 show the MRL-limits and the number of cases exceeding these limits.

**Table 2. Herbicides analysed and detected in streams and rivers during 1995 to 1999.**

| Pesticides or decomposition product | Number Analysed | Positives | | Max conc. (µ/l) | Average conc.(µ/l) | Number above MRL | MR Limits(µ/l) | Detection limits 1999(µ/l) |
|---|---|---|---|---|---|---|---|---|
| | | Numbers | % | | | | | |
| glyphosate | 49 | 42 | 86 | 0.93 | 0.13 | | 12 | 0.01 |
| AMPA | 49 | 43 | 87 | 0.2 | 0.06 | | | 0.01 |
| bentazone | 859 | 352 | 41 | 6.9 | 0.19 | | 53.5 | 0.02 |
| MCPA | 859 | 186 | 22 | 9,7 | 0.55 | | 50 | 0.02 |
| metribuzin | 859 | 185 | 22 | 12 | 0.26 | 38 | 0.22 | 0.02 |
| dichlorprop | 859 | 142 | 17 | 8.9 | 0.22 | | 41 | 0.02 |
| isoproturon | 52 | 8 | 15 | 0.45 | 0.03 | 2 | 0.3 | 0.01 |
| mecoprop | 859 | 105 | 12 | 0,79 | 0.12 | | 51.5 | 0.02 |
| simazine | 859 | 70 | 8 | 0.57 | 0.07 | 1 | 0.42 | 0.02 |
| linuron | 859 | 61 | 7 | 2.4 | 0.28 | 43 | 0.07 | 0.05 |
| BAM (2,6-dichlobenzamid) | 239 | 15 | 6 | 0.24 | 0.07 | | 12 | 0.05 |
| 2,4-D | 859 | 48 | 6 | 1.1 | 0.12 | | 14 | 0.02 |
| propachlor | 859 | 36 | 4 | 19 | 0.78 | 10 | 0.29 | 0.02 |
| metamitron | 859 | 31 | 4 | 19 | 1.20 | 4 | 1.1 | 0.05 |
| chlorpropham | 138 | 4 | 3 | 0.2 | 0.14 | | 10 | 0.05 |
| chlopyralid | 138 | 2 | 1 | 1.1 | 0.65 | | 69 | 0.1 |
| dicamba | 308 | 3 | 1 | 0.12 | 0.06 | | 1,110 | 0.02 |
| flamprop | 138 | 1 | 1 | 0.16 | 0.16 | | | 0.1 |
| fluroxypyr | 582 | 4 | 1 | 0.33 | 0.18 | | 143 | 0.1 |
| aclonifen | 739 | 4 | 1 | 0.1 | 0.05 | 1 | 0.07 | 0.02 |
| terbuthylazine | 859 | 1 | <1 | 0.09 | 0.09 | | 0.16 | 0.02 |
| DDD- p,p', DDE- p,p' DDT- o,p', DDT- p,p' | 859 | 0 | | | | | | 0.02 |
| Atrazine, atrazine-desetyl, atrazine-desisopropyl | 859 | 0 | | | | | | 0.02 |
| ioksynil | 582 | 0 | | | | | | 0.1 |
| tribuneronmetyl | 11 | 0 | | | | | | 0,03 |

859 samples have been collected during the years 1995 to 1999. In 540 samples, one or more pesticide has been detected above the detection limit. Giving the result that 63% of the samples contained pesticides residues. The frequency of detection dropped with increasing the size of the basins, but the difference between the farm practise (amount of pesticide used) was the most important factor. Most pesticides were detected at locations with intensive farming. Peak concentrations occurred during spraying season and following runoff events. Some pesticides appeared also during late autumn, winter and next spring indicating persistence.

**Table 3. Fungicides analysed and detected in streams and rivers during 1995 to 1999.**

| Pesticides or decomposition product | Number Analysed | Positives | | Max conc. (µ/l) | Average conc.(µ/l) | Number above MRL | MR Limits(µ/l) | Detection limits 1999(µ/l) |
|---|---|---|---|---|---|---|---|---|
| | | Numbers | % | | | | | |
| metalaxyl | 859 | 104 | 12 | 1,62 | 0,17 | | 280 | 0,05 |
| ETU [1)] | 30 | 8 | 27 | 3 | 0,10 | 1 | 0,26 | 0,01 |
| propiconazole | 859 | 28 | 4 | 7,7 | 0,38 | 28 | 0,02 | 0,05 |
| fenpropimorph | 582 | 6 | 1 | 12 | 2,21 | 2 | 0,46 | 0,02 |
| fluazinam | 239 | 4 | 2 | 0,15 | 0,09 | | 0,55 | 0,02 |
| tiabendazole | 739 | 3 | <1 | 0,22 | 0,13 | | 2,8 | 0,05 |
| prochloraz | 739 | 2 | <1 | 0,22 | 0,21 | | 0,46 | 0,05 |
| iprodione | 582 | 2 | <1 | 0,14 | 0,10 | | 2,5 | 0,02 |
| penconazole | 308 | 0 | | | | | | 0,02 |
| pyrimetanil | 138 | 0 | | | | | | 0,02 |
| tebuconazole | 582 | 0 | | | | | | 0,05 |
| vinclozolin | 859 | 0 | | | | | | 0,02 |

[1)] ETU is decomposition product of mancozeb

34 pesticides of the 53 substances analysed have been detected in the surface water. Of these, 21 were herbicides, 8 fungicides and 5 insecticides. 13 different pesticides were detected in concentrations, supposed to have environmental impact on algae, daphnia, fish or water plants. The different pesticides showed very different pattern according to the frequency and concentrations that were measured.

**Table 4. Insecticides analysed and detected in streams and rivers during 1995 to 1999.**

| Pesticides or decomposition product | Number Analysed | Positives | | Max conc. (µ/l) | Average conc.(µ/l) | Number above MRL | MR Limits(µ/l) | Detection limits 1999(µ/l) |
|---|---|---|---|---|---|---|---|---|
| | | Numbers | % | | | | | |
| lindane | 859 | 33 | 4 | 0,16 | 0,06 | | 1,6 | 0,02 |
| chlorfenvinphos | 859 | 21 | 2 | 0,37 | 0,08 | 21 | 0,003 | 0,02 |
| dimethoate | 859 | 6 | 1 | 0,75 | 0,21 | 2 | 0,2 | 0,02 |
| azinphosmetyl | 859 | 4 | 0 | 0,64 | 0,30 | 3 | 0,01 | 0,05 |
| pirimicarb | 859 | 3 | 0 | 0,05 | 0,04 | | 0,14 | 0,02 |
| diazinon | 859 | 0 | | | | | | 0,02 |
| endosulfan -alfa, -beta, -sulfat | 859 | 0 | | | | | | 0,02 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| esfenvalerate | 308 | 0 | | | | | | 0,05 |
| phentrotion | 859 | 0 | | | | | | 0,02 |
| phenvalerate | 859 | 0 | | | | | | 0,05 |
| lambdachyhlotrin | 138 | 0 | | | | | | 0,05 |
| alfacypermethrin | 582 | 0 | | | | | | 0,05 |
| permethrin | 859 | 0 | | | | | | 0,05 |

***Precipitation***

Lindane was frequently detected in the stream Time during the years 1997 to 1999. The farmers reported no use of the insecticide on the crops in the drainage basin. Overall lindane was detected in 33 of 62 samples (53 %). In the Time stream the highest detected level of lindane was 0.16 µg/l with an average of 0.06 µg/l (Table 5 and Figure 2).

**Table 5. Lindane in the precipitation of Time drainage basin during 1998.**

| Sampling period | Time (µg/l) |
|---|---|
| 08.09 - 18.9. | 0.100 |
| 18.9 - 6.10. | 0.350 |
| 6.10 - 20.10. | 0.090 |
| 20.10 - 3.11. | 0.020 |
| Average concentration | 0.140 |

Lindane has been banned in Norway since 1993 and it is not likely that the occurrence of lindane in the Time stream was caused by contaminated soil or a point source in the area. In 1998 precipitation was also collected nearby the stream Time, to evaluate whether rainfall (including dry deposition) might be the source. In 1998 rather high concentrations of lindane were detected in precipitation with a maximum concentration of 0.35 µg/l and an average concentration of 0.14 µg/l.

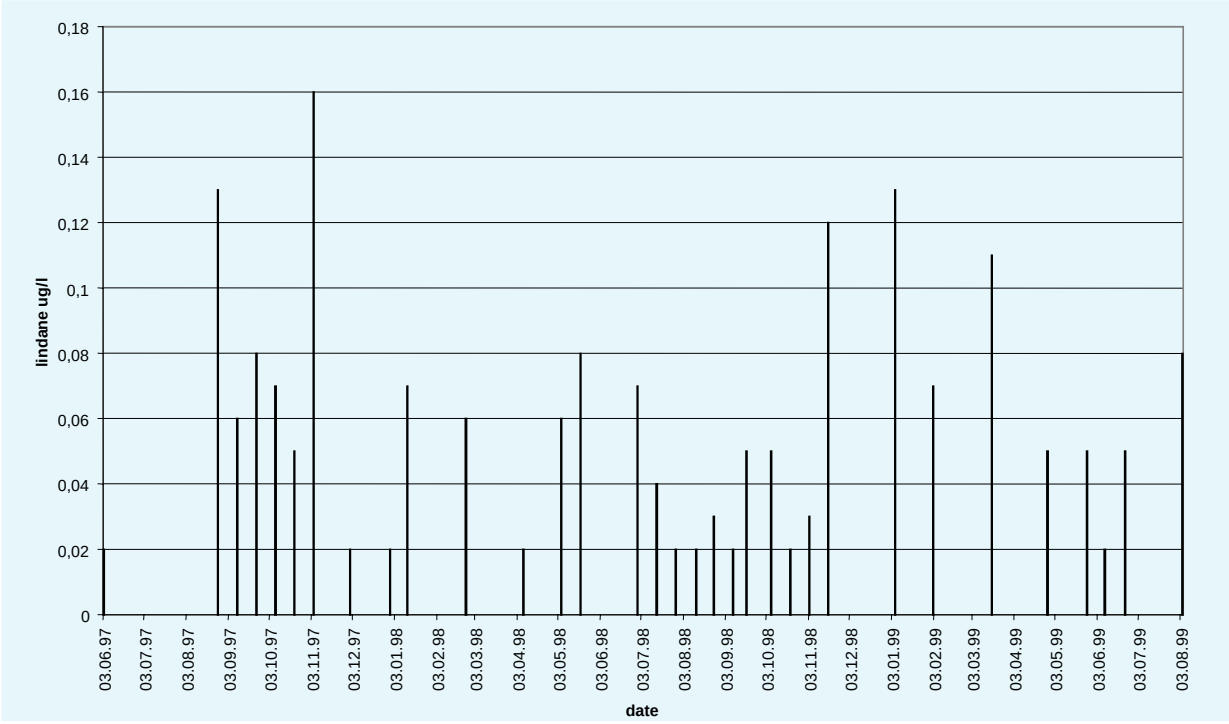


**Figure 2: Levels of lindane (µg/l) detected in the Time stream from 1997 - 1999.**

Therefore two additional locations in the district were chosen: Obrestad lighthouse 10 meters above the sea level and Bjerkreim mountain about 550 meter above the sea level, both in the same county. Precipitation was collected at these spots during 1999 and the maximum detected concentration of lindane was 0.037 µg/l (Table 6).

**Table 6. Lindane in precipitation in Time, Obrestad and Bjerkreim county during 1999.**

| Sampling period | Time (mg/l) | Obrestad (µg/l) | Bjerkreim (µg/l) |
|---|---|---|---|
| 5.1 - 19.1. | 0.040 | - | - |
| 26.5 - 23.6. | - | 0.013 | - |
| 23.6 - 4.8. | - | 0.037 | 0.024 |
| 4.8 - 14.9. | - | 0.005 | 0.015 |
| 15.9 - 1.12. | 0.034 | 0.018 | 0.006 |
| Average concentration | 0.037 | 0.018 | 0.015 |

The results indicated that the source of lindane in the Time stream might be precipitation. The concentrations that have been detected in the precipitation are rather high compared to previously reported in the Scandinavian countries (Lode *et. al* 1995 and Kreuger J. 1999).

## Discussion

### *Streams and rivers*

The results of 5 years of monitoring pesticides in streams and rivers in Norway demonstrated that pesticides are frequently detected during the growth period of the year. Most pesticides were traced at very low concentrations below the maximum residue limit (MRL) that has been set, but some pesticides exceeded the limits of MRL more frequently. Due to the methods of water proportional sampling in some of the locations, the results will underestimate the retrieval of some pesticides.

### *Precipitation*

The detection of pesticides in the stream Time and in precipitation in the Rogaland County indicated that rainfall is the major source. Further evaluation on the source being the ocean or more recent use of lindane in Europe has not been done.

## Acknowledgement

The programme is a co-operation between the institutes: (a) The Centre for Soil and Environmental Research (Jordforsk) as the programme supervisor, (b) The Norwegian Crop Research Institute (Planteforsk); Plant Protection and the Pesticide Laboratory, (c) Norwegian Institute for Water Research (NIVA). (d) Rogaland Research Institute (RF), (e) The Environmental Protection Agencies (EPA) of the Counties of Østfold, Buskerud, Nord-Trøndelag and Hedmark.

The work involved many people and the authors thank all of them for the good work and co-operation. A special thanks to: (Jordforsk): Marianne Bechmann, Anne Grete Buseth Blankenborg, Ketil Haarstad, Johannes Deelstra, Hans Olav Eggestad, Stine Marie Vandsemb, Per Ivar Våje. (Planteforsk): Børge Holen, Ole Martin Eklo, Svein Selnes, Erling Stubhaug, Per Olav Westbye. (NIVA): Torsten Källqvist. (RF): Åge Molversmyr. (EPA): Marit Grimsrud, Ola Gillund, Bjørg Leret Grøstad, Arve Røren.

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