Pesticides in Water – Research Meets Politics

Pesticides have been consistently detected in high concentrations in Swiss surface waters over a number of decades. The direct payments scheme introduced in 1993 for ecological measures in agriculture was designed to improve the situation. The goal was to halve the pesticide pollution by the year 2005. A pesticide pollution analysis carried out by EAWAG in the Greifensee region reveals that the target has not been fully achieved. Although there has been a reduction in the total quantity of pesticides used, the measures designed to reduce the pesticide loss from the treated farmland have largely failed to take effect.

With its innovative changeover from a product-subsidized agricultural policy to one that is environmentally and market-oriented, Switzerland acts as a pacesetter in broader Europe. Intangibles corresponding to environmental services claimed by society, which could not be traded on a free market system, could only be funded by a subsidy system involving direct payments by the state to farmers (also see article by C. Widmer, p. 6). This direct payments scheme consumes 5% of the total federal budget, i.e. around 2.4 billion Swiss francs per year. Agricultural enterprises receive these funds on the condition that they provide a proof for ecological performance (PEP). Along with measures such as regulated fertilizer balance and crop rotation, the PEP also includes requirements for targeted selection and application of pesticides. About 0.4 of the 2.4 billion Swiss francs are allocated for special environmental services, beyond those specified in the PEP. These cover subsidies for water protection and environmental quality as well as contributions for ecological compensation areas used for extensive grain and rape production (Extenso Production), for organic agriculture and for animal-friendly husbandry. With the introduction of the direct payments scheme, the number of farms participant in the PEP has increased rapidly. Whereas in 1993 only about 17% of agricultural land was managed in compliance with ecological guidelines, today this proportion has increased to 97%. Considering the enormous costs involved in converting Swiss agriculture to more ecological practices, it begs the question as to how effective the measures are in reality.

Photographs: EAWAG

Filling the tank of a sprayer with a pesticide mixture.

Goal: Halving the Pesticide Pollution of Water Bodies

With the start of the ecological compensation policy in 1993, concrete targets were defined for ecological relevant parameters such as biodiversity, nitrogen, phosphorous, and pesticide loads, which should have been achieved by the end of 2005. The target for pesticides was to reduce the pollution by half. Two actions should be taken: a 30% reduction in the total quantity of pesticide applied and the remaining 20% being achieved through loss limitation measures (see box: Measures).

This article attempts to answer the question of whether the pesticide load since the introduction of the ecological measures in 1993 has in fact been reduced. One logical starting point in judging the success of the measures is the analysis of pesticide sales figures. More direct information, though, is available from long-term pesticide pollution analyses of water bodies, for which pesticide concentrations are measured. With interruptions, EAWAG has carried out such investigations since 1991 in the Greifensee (see Box: Pollution Analyses). Since 1997, they have been financed by the Federal Department of Agriculture as part of the project "Evaluation of ecological measures".

Declining Pesticide Sales

Figure 1 shows that pesticide sales by volume [1] decreased between 1993 and 2003 by about 25%. It is not possible, however,

Measures Involved in the Proof of Ecological Performance

Minimization of pesticides used:

- **Application of the threshold principle: pesticides are only used if the expected damage by pests exceeds the cost of application.**
- **Take advantage of natural regulation mechanisms: indirect plant protection, e.g. adapted variety selection and crop rotation.**
- **Encourage the insecticide and fungicide-free extensive production (Extenso Production) of grain and rape.**
- **Encourage the pesticide-free organic agriculture.**

Minimization of pesticide losses:

- **3-meter wide buffer strips alongside streams and lakes (see article by C. Widmer, p. 6).**
- **Erosion prevention measures (e.g. winter plant cover).**

to conclude from this figure that there has also been a 25 % reduction in pesticide use. One reason for this is that pesticides imported from abroad, and pesticides stored on farms, are not included in this figure. Another reason is that the amount of land under cultivation has reduced significantly over the past 10 years. Adjusting the figures accordingly lowers the effective pesticide reduction to only 20 %, i.e., from 6.5 kg per hectare to 5.4 kg. Furthermore, the market has been supplying an increasing number of new pesticides which require much lower quantities in application to gain the same effects. The increased potency of the new pesticides has consequences not only for agricultural use, but also for the aquatic ecosystems. A more meaningful indicator for pesticide use should be based on an adequate consumption survey and take into account both the treatment intensity and the potency of the pesticide.

Application of pesticides onto farmland.

Prominent Cereal and Maize Herbicides

The collective term pesticide in Switzerland covers around 400 approved individual substances. Sufficiently accurate and sensitive analytical methods are available only for a portion of the pesticides. A comprehensive determination of pesticide pollution is therefore not possible.

For the pollution analysis at Greifensee, around 50 of the 100 pesticides used in this area were investigated. Herbicides from the widespread maize and cereal cultivation are regularly detected. One of these, the maize herbicide atrazine, has been banned in other countries, such as Germany, but remains one of the most used pesticides in Switzerland. Since the only data available for the first half of the 1990s is for atrazine, having been collected as part of other EAWAG research projects before the start of the national evaluation programme, this herbicide was selected for a detailed analysis.

Decreasing Atrazine Pollution

The data available since 1990 for the Greifensee region show that the quantities of atrazine used during the 1990s fell from

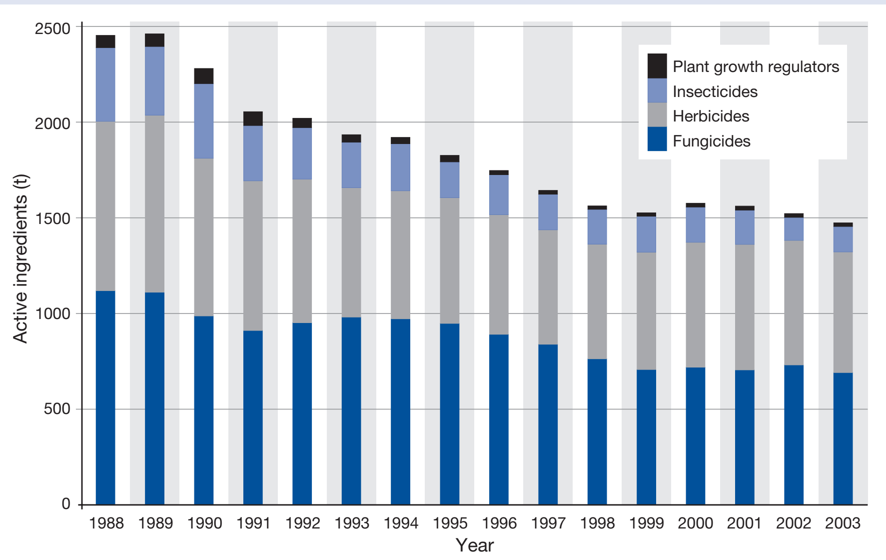


Fig. 1: Pesticide sales data for the period 1988 to 2003 [1].

Pollution Analysis of the Greifensee

Lakes make ideal observation systems for a pollution analysis. With water residence times of usually several hundred days, all of the activities in the catchment area are integrated, and, to the contrary of highly dynamic running waters, the loads (pesticide quantities entering the lake) can be measured at relatively low cost and over extended time periods [2]. On behalf of the Swiss Federal Office for Agriculture, EAWAG has been conducting a pollution analysis of the Greifensee since 1997. The 160 km^2 catchment area of the Greifensee provides a good overall picture of the various agricultural practices and the related pesticide sources and transport pathways. In addition, EAWAG already collected pesticide data from the Greifensee in the periods 1990–1991 and 1993–1994. The most comprehensive data record exists for the maize herbicide atrazine.

over 1100 kg to about 400 kg (Fig. 2A). The reasons for this reduction are the implementation of various application restrictions for atrazine (quantitative and temporal limitations and a general ban of atrazine use on railway tracks) between 1988 and 1994, and the subsequent adoption of substitute products. The reduction of the quantities applied has had positive consequences for the Greifensee atrazine load: whereas the total atrazine load in the lake at the beginning of the 1990s laid between 30 and 45 kg, this value has dwindled to today's 5–10 kg (Fig. 2B). This is a significant reduction, although surprisingly the level of atrazine (atrazine load in Fig. 2A) detected in the Greifensee varies greatly from year to year during or shortly after the application period (May till June). Thus, in 1999, when already more than 90 % of agricultural enterprises were participating in the PEP and the applied atrazine volume had fallen by more than 60 %, there was more atrazine entering the Greifensee than in 1994 shortly after the implementation of the ecological measures. In order to evaluate the success of the ecological measures, not only the quantities applied, but also those influencing factors which have an effect on the pesticide transport from the field to the water, need to be known.

No Detectable Reduction of Pesticide Losses

The quantity of pesticide entering the water body is chiefly dependant on the point in time and the quantity and intensity of precipitation events following the application of the pesticide. The corollary being that up to half of an annual load can be washed by the rain into a water body in a matter of days or weeks following a pesticide application. Altogether, the proportion of pesticide which is transported from the land to the water body amounts to only a few per cent of the total applied.

Figure 3 shows no variation in the atrazine losses to the Greifensee after introduction of the PEP. Instead, a strong correlation between rain intensity and atrazine runoff is evident. The largest rainfall was registered in 1999: in this year 3.4 % of the applied atrazine was transported into the Greifensee. On the other hand, in low rain years, the transported atrazine quantities range between 0.5 and 1.9 %.

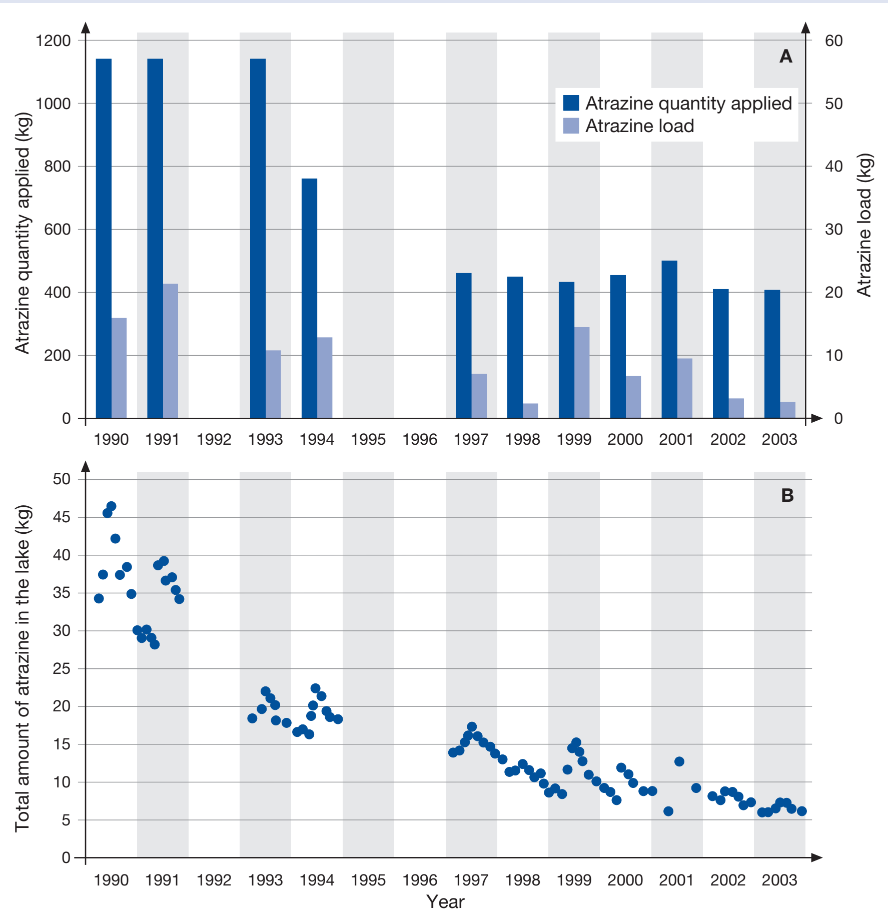


Fig. 2: More than a decade of Greifensee pollution by atrazine – (A) applied quantities in the catchment area and the quantities entering the lake (load), and (B) total quantity in the lake. Through combination of the monthly depth-profile measurements of pesticide concentrations with a lake simulation software, the atrazine load could be determined to sufficient precision [2].

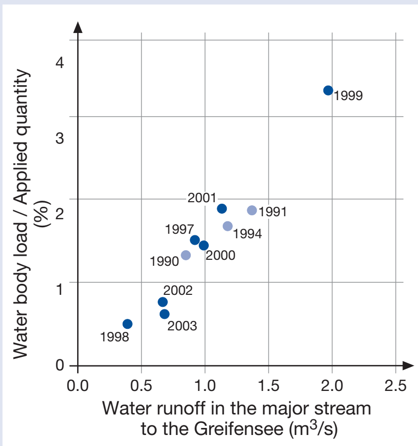
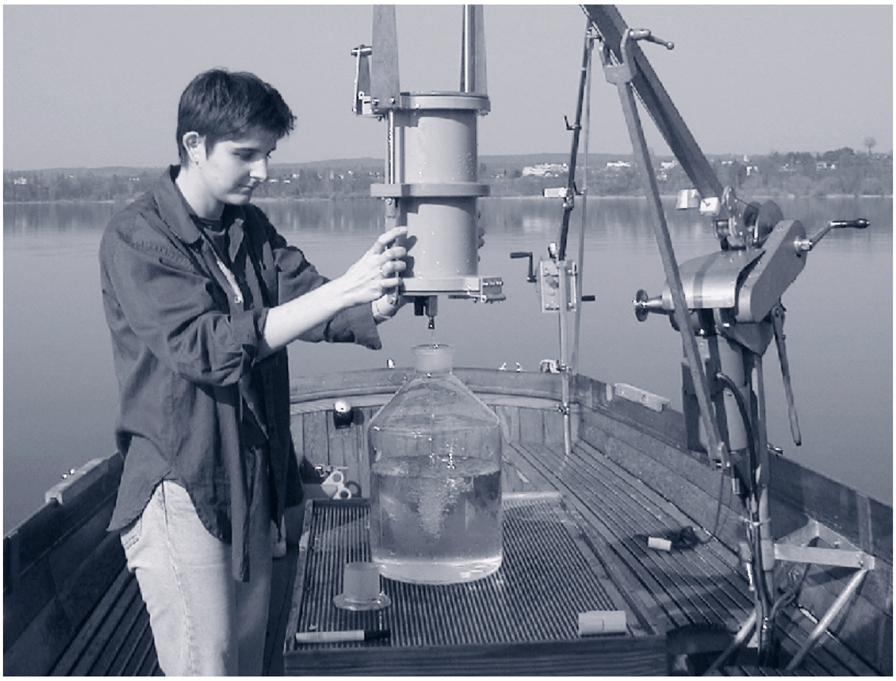


Fig. 3: The percentage of the atrazine transported from the field to the water body during or shortly after the application period increases with increased water runoff during rain events. Data and correlation uncertainties are not shown.



Pollution analysis – taking water samples in Greifensee.

A similar picture appears for other maize herbicides. Results from a field study which investigated the maize herbicides atrazine, dimethenamid, metolachlor, and sulcotrione, in smaller sections of the Greifensee catchment area, show that these substances have a similar transport behavior [3]. Rain washes them away very quickly so that the herbicides dissolved in the rain water could not attach the soil matrix. The rapid transport of pesticides during a heavy rain event is due mainly to surface runoff and rapid flow into subsurface drainage systems.

Further Measures for Success

Further studies in the catchment area of the Greifensee show that waterlogged sites with direct connection to a water body have a great potential for pesticide loss [4]. Also from an agronomical point of view, these sites are not ideal as farmland [5]. On such sites of high risk for pesticide losses, pesticide usage should be avoided. This should be possible in practice since high pesticide losses often appear as local "hot spots", and Swiss agriculture is structured in relatively small-scale units. Pesticide-free areas could be allocated in part as ecological compensation areas required to obtain subsidies through direct payment. A clear identification of high-risk sites is a great challenge for future pesticide research.

During disposal of pesticide residues, and during cleaning of the field sprayers, pesticides can be transported directly via the sewerage system or indirectly through the sewage plant into the water bodies. In the Greifensee, these point sources for substances which are used exclusively in agriculture make up between 15 and 20% of the total pesticide load [6]. A solution lies in appropriate training in order to learn the correct handling of pesticides, which can be regulated with licenses. Any person who uses pesticides professionally must be in possession of the appropriate license. In addition, the spraying machines must be regularly inspected. Since most spraying machines are quite old, financial assistance in acquiring modern sprayers brings additional improvement potential. Freshwater tanks on modern sprayers make it possible, for instance, to clean the machines directly in the field.

Conclusion

A causal relationship between the implemented policy measures for improving the environmental impact situation in agriculture and for reducing the pesticide load in water bodies is difficult to establish, and necessitates many simplifications and restrictions. On the one hand, the complexity and temporal behavior of environmental systems per se appear not to be compatible with the timeframes of political decision-making. Politics demand simple, clear and rapid answers, whereas research attempts to bring about an understanding of complex and chaotic systems, which normally requires resource-consuming and expensive investigations extending over a long time period. For this reason, it would have been important to have already started the corresponding assessment programme prior to the introduction of the ecological measures in 1993.

Nevertheless, despite data uncertainty and knowledge gaps, certain concrete trends are identifiable: The measures for limiting pesticide usage have led to a visible if only partial success. On the contrary, the transport limiting measures have been less successful and must be reconsidered for the future.

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