AMMONIFICATION AND NITRIFICATION. LABORATORY VERSUS FIELD

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INTRODUCTION

In the report of the 1979 Workshop on Side-effects of Pesticides on the Soil Microflora (Greaves et al., 1980) it is concluded that 'ammonification and nitrification', as part of the nitrogen-mineralization process, are useful criteria to study potential side-effects of pesticides. Therefore, laboratory tests with regard to these processes were recommended as a requirement for regulatory assessment in The Netherlands, assuming that these tests would serve as 'yardsticks' for the impact of pesticides applied in the field.

The questions at issue now are whether this assumption has been justified by experience and whether and how laboratory data can be translated to field conditions. Unfortunately, reports of laboratory measurements of ammonification and nitrification in soils treated and untreated with pesticides, accompanied by simultaneous measurements in the field with the same soil are very scarce. Mostly laboratory tests and field experiments have not been carried out with the same soil at the same time; in such cases the different results may partly be caused by differences in soil properties and/or populations. I am not aware of field experiments with crops where effects of pesticides on both processes were deduced from a complete nitrogen balance sheet, taking into account nitrogen uptake by the crop, nitrogen leaching, denitrification, nitrogen fixation, in short the complete nitrogen cycle in the soil. If such data were available, the conclusion is based on our experience with soil fumigation in autumn where the situation is indeed less complicated because no crop is present. Field conditions usually differ markedly from those in the laboratory experiments (Table 1).

Table 1 Difference between experimental conditions in the laboratory and in the field

	Laboratory	Field
Pesticide distribution	even	uneven
Temperature	constant (20°C)	varying daily seasonal
Moisture	constant (pF 2.5)	varying short-term seasonal
Aeration	sufficient	varying
Pesticide dissipation rate	rel. high rate of transform. (20°C)	lower rate of transform., but other ways of dissipation possible (volatilization, leaching)
Presence of plants	no plants	usually cropped

FIELD VS LABORATORY EXPERIMENTS

Distribution of pesticides in soil

The distribution of pesticides in the soil in field situations is always uneven, unless extremely persistent pesticides gradually accumulate after repeated applications. In laboratory tests a homogeneous distribution is ensured. Actual distribution patterns of fumigants in the field, for example, show that the concentration in the surface layer is always practically zero. Surface-applied herbicides may not reach a significant concentration below 10 or 20 cm depth. Thus, part of the biologically active soil remains 'untreated', which is of great importance for the recovery potential of natural transformation processes. In those cases the actual rate of recovery is often increased by soil mixing (tillage).

Temperature

The (differences in) temperature dependence of the rates of ammonification and nitrification are known, so extrapolation from laboratory to field conditions is, in principle, possible. The temperature dependence of the dissipation rate of the pesticide, however, is a complicating factor. A prolonged inhibition of nitrification after soil fumigation in autumn (Lebbink and Kolenbrander, 1974) may only be due to a low soil temperature or partly also due to a retarded dissipation of the fumigant at that temperature.

Moisture content and aeration

Moisture content and aeration of the soil in field situations also vary. Within the range of moisture contents that normally occur in the field, the rate of ammonification may vary by a factor of 3 to 5. Ammonification does not stop under anaerobic conditions. Little or no nitrification takes place in dry or extremely wet soils (periods of extreme drought or excessive rainfall are, however, rare and normally not long in our region). In laboratory tests the occurence of anaerobic sites leading to denitrification is avoided. Field data on nitrate contents may not be 'clean' in this respect. The moisture content usually also influences the dissipation rate of the pesticides and often their distribution pattern. The presence of anaerobic sites may seriously affect their transformation rate and, thus, the recovery rate of nitrogen transformations.

Other pathways of pesticide dissipation

Other possible pathways of pesticide dissipation in the field (leaching, volatilization) also introduce uncertainty with regard to the possibility of translating laboratory data on nitrogen transformations, not only because of differences in actual disappearance rate but also because of the consequences for distribution and, thus, recovery potential.

Presence of plants

The presence of plants and the type of plants present are modifying factors for the soil population. The presence of plants (rhizosphere) affects the metabolic processes in the soil, presumably also the transformation rate of pesticides and, thus, their possible side-effects.

DISCUSSION

The adequacy of the recommended laboratory tests was checked by Van Faassen and Lebbink (1984) by comparing the effect of soil fumigation with high rates of 1,3-dichloropropene (600 l/ha) or chloroform (1200 l/ha) in the field with that of chloroform treatment in the laboratory. The relevant results are summarized in Table 2. Size and duration of the effect (if present) of fumigation on ammonification and nitrification, as observed in incubation measurements with soils treated in the field or in the laboratory, differed considerably. A negative effect on ammonification was only observed in tests with soils fumigated with chloroform in the laboratory and amended with lucerne meal. In the field the recovery apparently was quick, probably because there,

Table 2 Effect of soil fumigation in the field and in the laboratory on ammonification and nitrification

	Field fumigation with dichloropropene/ chloroform at high rates		Fumigation with chloroform in the laboratory	
	sandy soil	sandy loam soil	sandy soil	sandy loam soil
Ammonification of soil org. nitrogen	n.a.	+	n.a.	+
Ammonification in lucerne amended soil	+	+	-	-
Nitrification of $(NH_4)_2SO_4$	-/n.a.	s	-	-

+ = activity increased
n.a. = not affected
s = limited effects and/or rapid recovery
\- = strong effects with slow recovery

soil life is never completely exterminated; the reasons are an uneven distribution of fumigant, and/or unaffected species rapidly taking over from eliminated ones, or (particularly with short-lived pesticides) ammonification rapidly being restored from less vulnerable rest-structures of the hit species. Judging from this experience, the laboratory tests on ammonification in fact still provide no information about the effect of pesticides on ammonification in the field.

Apart from that, the maximum effect of pesticides, when applied at recommended rates, on ammonification in the field (a nitrogen flush in the order of 10 kg nitrogen/ha) is agronomically rather insignificant.

Contrary to ammonification, the effect of soil fumigation (and of pesticide use in general) on nitrification in laboratory tests and in the field qualitatively is always the same and, if occurring, it may be of agronomic significance. For example, the amount of nitrogen saved from leaching in wet winters may be as high as 50 kg/ha on sandy soils after autumn fumigation with dichloropropene (Lebbink and Kolenbrander, 1974) and even more when animal manure has been applied.

Concerning duration of nitrification inhibition in the field two factors are of prime importance, viz., the actual persistence of the inhibitor and the time of the year in which it is applied.

CONCLUSIONS

The recommended ammonification tests are inadequate for assessing the effect of pesticides on this process, or on the soil microflora generally, in the field.

The nitrification test should be maintained because of its sensitivity and the agronomic significance of this process.

For the time being there are few prospects for predicting the field effect from laboratory data; there are too many uncertainties.

A point of further discussion is whether laboratory tests on nitrification should be laid down for all pesticides, irrespective of their usage pattern (dosage rate, mode and time of application), mode of inhibitory action and actual persistence in the upper soil horizon.

REFERENCES

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