Neth. J. agric. Sci. 17 (1969) : 128—132

Leaching of arsenic from soil

P. M. Tammes and M. M. de Lint [1]

Laboratory for Research on Insecticides, Wageningen, the Netherlands
Institute of Agricultural Engineering and Rationalization, Wageningen, the Netherlands

Received: 6 January 1969

Summary

A description was given of two field trials carried out over successive years in the Netherlands, concerned with phytotoxicity of the soil and its arsenic content. Even after extremely high levels (up to 25 times the used dose of arsenite for killing haulms of potatoes) phytotoxicity gradually disappeared during subsequent years. The arsenic was leached from the top soil. A half-life of 6.5 ± 0.4 years was calculated from 6 dosage steps in two experiments.

Introduction

Sodium arsenite is used for killing haulms of potatoes in the Netherlands. It is used on potatoes grown for seed at the beginning of the summer after a flight of aphids in order to prevent virus infection of the tubers. It is used on potatoes grown for ware at the end of the growing season if Phytophthora infestation on the leaves is severe. Killing both the leaves and the fungus reduces the rotting of tubers by Phytophthora. Sodium arsenite is effective and cheap.

On sandy soil residues sometimes damage the next crop, e.g. oats. Therefore the use of sodium arsenite is not recommended on light sandy soils.

When a toxic aftereffect was observed the question arose as to whether arsenic would accumulate in the soil in the long run and make it unfit for cultivation (Reestman and Riepma, 1955). Field trials were started in 1954 by the Advisory Service and later by the Plant Protection Service and the Institute for Biological and Chemical Research on Field Crops. Samples were analysed for arsenic by the Laboratory for Soil and Crop Testing. After digestion with a mixture of concentrated nitric and sulphuric acids, arsenic was estimated as arsenic-molybdene-blue. Some early results were reviewed by de Bruin (1957).

A further question was whether tubers whose haulms had been killed or those grown on land on which previous crops had been sprayed had a tolerable level of arsenic. This problem has been dealt with by the Institute for Public Health and falls outside the scope of this paper. The total amount of arsenic that will leach into the soil water is not discussed here either. Further it was recently found that the silt of the Rhine can contain very large amounts of arsenic up to 300 ppm As (de Groot, 1968). An investigation of water meadows along its course is under discussion.

[1] Formerly Plant Protection Service, Wageningen, the Netherlands.

Evaluation of trials

Many field trials were carried out with the normal dose of 16–20 litre per ha with a content of 675 g arsenite per litre calculated as As_2O_3. Variation between soil samples was so great that no conclusions were possible for normal doses. Duplicate samples ranged between 0 and 2.5 ppm with an average of 1 ppm; the variation in the untreated plots over successive years varied from 0–5 ppm. So only those experiments with extremely high doses could be used, and then only those which were continued for a sufficiently long period.

The evaluation was unconventional for field trials, as it was not so much the difference between the plots that had to be measured as the gradual decrease in concentration of the arsenic in the soil during successive years. A model was used based on the following general results:

a. After a single heavy application the amount of arsenic in the soil decreases gradually during the following years.

b. The more in the soil the higher also the rate of leaching from the topsoil and the larger the amount found in the subsoil.

c. Aftereffects, even after a heavy application, disappear during the following years.

If leaching from the soil is assumed to be directly related to the amount of arsenic in the soil (b), plotting the arsenic on a log scale against time on a direct scale will give straight lines. The significance of such lines and the half-life of arsenic in the topsoil can be calculated.

Field trials

A. Trials at Hornhuizen

The Advisory Service supervised these trials on light loam (plots 50 m²) with 13 % fraction < 16 μm and little calcium. Single applications of 500, 200, 100 and 40 litre sodium arsenite per ha were sprayed in March 1954. The 40-litre treatment was repeated after 5 years and therefore omitted from the table.

In April 1954, a month after treatment, maize was planted, followed in the next year by potatoes, oats and peas, and in 1956 by wheat and beans. In those years the

Table 1 Hornhuizen trials: As_2O_3 on dry soil

Litre sodium arsenite per ha	*As_2O_3 after subtraction of the average in untreated plots (ppm)*										
	1954	*1955*	*1956*	*1957*	*1958*	*1959*	*1960*	*1961*	*1962*	*1963*	*1964*
topsoil (0–20 cm) [1]											
500	99	64	57	49	46		39		24		16
200	36	16	25	26	21		17		12		9
100	14	7	7	8	8		5		6		4
subsoil (20–40 cm) [2]											
500			7	18	13		21		23		11
200			1	8	14		8		11		8
100			8	3	4		2		3		3

[1] Average content As_2O_3 in untreated plots was 8 ppm.
[2] Average content As_2O_3 in untreated plots was 6 ppm.

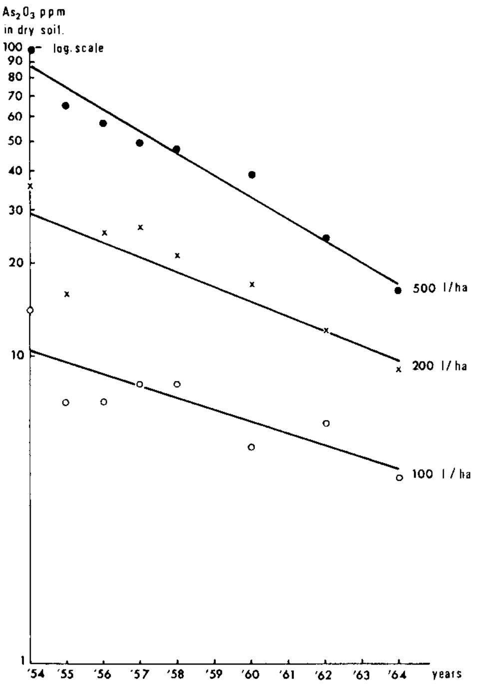

Fig. 1 Trial at Hornhuizen. Loam (Lines of least squares)

● *500 l/ha; half-life 4.33 year (3.6 – 5.4)*
x *200 l/ha; half-life 6.30 year (3.95–15.61)*
o *100 l/ha; half-life 7.78 year (4.69–21.14)*

Differences in slope insignificant.
Differences in level highly significant.

plots treated with 200 and 500 litres yielded less than normal. In 1957 in sugar-beet and in 1958 in oats no symptoms were observed, but in 1959, a drought year, aftereffects of 200 and 500 litres were noticed in potatoes. After that no more effects were observed.

Values for arsenic are given in Table 1 and Fig. 1.

B. Trials at Veenhuizen

The Plant Protection Service started these trials in October 1957 with 0, 20, 40, 80 and 160 litre sodium arsenite per ha on the soil in four replicates. In 1958 oats, peas and beets were cultivated and in 1959 rye, oats and barley. The soil is sandy, with 6% organic matter, 6.5% inorganic fraction $< 16\,\mu$m and pH 5.47.

In 1958 only 80 and 160 litres caused aftereffects; after 160 litres loss of yield of oats was significant. In 1959, an extremely dry year, aftereffects were seen in the 160, 80 and also in the 40 litre plots. In the next year no crop damage was observed. For arsenic in the soil, see Fig. 2 and Table 2.

C. Half-life

In the trials both at Hornhuizen and Veenhuizen half-life of various dosage steps was found to be consistent with one another. An average of 6.5 $\pm$ 0.4 years can be calculated.

D. Limits of accumulation

With a certain half-life and regular treatment, e.g. once every three years, arsenic

Table 2 Veenhuizen trials: As_2O_3 on dry soil

Litre sodium arsenite per ha	*As_2O_3 after subtraction of the average in untreated plots (ppm)*						
	1957	*1958*	*1959*	*1960*	*1961*	*1962*	*1963*
topsoil (0–20 cm) [1]							
160	22	22	14	11	15	15	11
80	10	11	8	9	9	9	4
40	5	5	2	3	5	3	2
20	3	2	2	3	3	4	1
subsoil (20–40 cm) [2]							
160	8			9			3
80	3			6			1
40	0			3			0
20	1			3			1

[1] Average content As_2O_3 in untreated plots was 7 ppm.
[2] Average content As_2O_3 in untreated plots was 3 ppm.

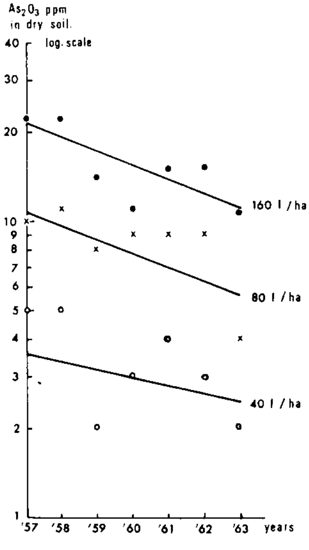

Fig. 2 Trial at Veenhuizen. Sandy soil with humus (Lines of least squares)

- ● *160 l/ha; half-life 6.49 year (> 3.59)*
- x *80 l/ha; half-life 6.32 year (> 3.56)*
- o *40 l/ha; half-life 6.80 year (> 2.78)*

Differences in slope insignificant.
Differences in level highly significant.

will accumulate to a limit where leaching equals addition.
Half-life may be prolonged if the soil is rich in adsorption complexes or if only traces of arsenic are present, in which case the adsorption equilibrium will be high.

Discussion

The use of phytotoxic compounds in agriculture has a built-in warning signal. Symptoms, such as retarded growth or even yield losses, appear in the crop or in a subsequent crop. Sodium arsenite, used for killing haulms of potatoes, has injured the next crop. Various cases are known, all on sandy soil with little humus, usually in oats, though peas and beans seem sensitive too. When ridges of haulms were left on the field, symptoms were sometimes observed the following year in some of the rows in the oat field. Arsenite is therefore not recommended on light soil. On heavier soils or soils with more organic matter no phytotoxicity was encountered on farms after the normal application of 16–20 litre per ha at intervals of three or more years on a potato crop.

Arsenite is adsorbed onto adsorption complexes in the soil in equilibrium with the water phase (Dratchew, 1933). Once adsorbed it may leach out again (Arnott, 1967). In sandy soils with few adsorption complexes the full amount of added poison will be in solution in the water phase. When this is inadequately leached out, e.g. after a dry winter, there will be damage in the next spring, especially to a sensitive crop and during dry spells. In heavier soils or with more organic matter the poison will be stored in the adsorption complexes which will act as a buffer. Leaching will then be more gradual. Clay soils especially need quite large amounts of arsenite before phytotoxic symptoms are observed (Crafts and Rosenfels, 1939). It may be assumed that in undisturbed soils the arsenic would travel in the same way as in a chromatogram. But as topsoil is mixed every year, leaching could be more gradual.

Danger of accumulation will exist in a dry climate where little or no leaching occurs. In the wet climate of the Netherlands even extreme doses of up to 25 times the prescribed dose lose their potency within a few years. A decrease of the arsenic concentration in the topsoil is also observed, with a half-life of 6.5 ± 0.4 years as an average of all rates in the two trials. Total amounts found in topsoil 0–20 cm and subsoil 20–40 cm in successive years indicate that a considerable amount of arsenic had disappeared from these areas.

Acknowledgment

The authors are indebted to the Advisory Service and to the Plant Protection Service for carrying out the field trials, to the Laboratory for Soil and Crop Testing for the arsenic analysis of the soil samples, to Dr W. van der Zweep (Institute for Biological and Chemical Research on Field Crops) for support and suggestions and to Mrs M. Wiersma Roche for correction of the English text.

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