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Copper contamination effects on earthworms by disposal of pig waste in pastures

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INTRODUCTION

The addition of large amounts of copper salts to pig rations to increase weight gain in the fattening pig has led to the production of excreta with high copper concentrations. Regulations governing the discharge of, among others, agricultural effluents into watercourses, the high cost of transporting pig waste slurries to waste treatment plants, and the difficulty involved in the treatment of this material have resulted in the application of pig waste on adjacent pastures.

Copper can have toxic effects on earthworm populations. It is known that in orchard soils a copper level of 85 ppm is not tolerated by worms (van Rhee, 1963, 1969), and in grassland high copper concentrations (260-360 ppm) proved sufficiently toxic to eradicate worm populations almost entirely (Nielson, 1951). Laboratory experiments provide confirmation of the view that this element checks the reproductive capacity, albeit at higher concentrations than under field conditions (van Rhee, 1969). Extermination of worms will inhibit the biodegradation of organic matter. In pastures such effects result in the formation of a thick mat of undecomposed dead plant parts generally carrying loose and poor soils.

A similar problem arises from the disposal of harbour sludge. Regular dredging of the Rotterdam harbour is necessary to maintain adequate depth especially for the large ships touching at this port. Because of technical difficulties associated with the discharge of the mud in the North Sea, an ideal disposal process was found in land-fill of areas in the vicinity of the harbour. On such deposits a favourable development of natural vegetation was observed. However, it would also be desirable to investigate the development of shortlived organisms, i.e. such decomposers as earthworms, which contribute to a rapid recycling of mineral components in plant wastes back into the plants. It

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seemed possible that earthworms would be excluded by the influence of deleterious substances occurring in the harbour mud as a result of, for instance, the high level of industrial wastes in the Rhine water. In this case complete recycling would not take place, and disturbances would gradually appear in the system.

The following is a brief report of recent studies on both problems.

DISPOSAL OF PIG WASTE IN PASTURES

For the evaluation of the effects of the application of pig waste in pastures it was of primary interest to know what level copper accumulation had reached already in such soils and to study the worm populations.

The sites chosen were mainly on poor-class sandy soils and a few on peaty soils, all located in the Veluwe (Province of Gelderland, The Netherlands). From a large number of pastures, which received pig waste over a period of 10 years, samples of surface soil (0-5 cm) were analysed for their content of copper and organic matter. The organic matter content serves as an indication for the rate of decomposition of plant residues. Worm sampling was done in three places (0.25 m^2) per pasture, the worms being dug out and removed by hand.

As for the effect of copper accumulation on worm populations it should be mentioned that the populations of the pastures under study were very similar in species composition. *Lumbricus rubellus* was most abundant numerically, followed by *Allolobophora caliginosa*. *A. rosea* was found in very small numbers. Therefore, in Table 1 worm densities are expressed only in total numbers. It is seen in this Table 1 that not all of the pasture soils were comparable, the variations being due mainly to recent ploughing. But a toxic effect is nevertheless evident, because in pastures with high copper levels worm numbers were on average lowest. More evidence is expected from a planned comparison between pastures with and without application of pig waste.

In Fig. 1 a positive correlation between the copper and organic matter content is shown. This suggests a poor development of earthworm populations in pasture soils where high copper concentrations are reached, leading to inhibition of the biodegradation of organic matter. The low value of r is in correspondence with the variations in the pasture soils such as caused by ploughing, which must have interfered with the relationship.

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DISPOSAL OF HARBOUR MUD

To investigate the chances for penetrating earthworms to survive in deposits of harbour mud, worms were introduced to such areas. The inoculated worms, predominantly *A. caliginosa*, failed to establish. After a period of two months most of them were in very bad condition and some had even died. Breeding experiments with worms in soil samples takem from three deposits showed the same effects (see Table 2) Bad physical conditions is manifested in a decrease of body weight as well as complete disappearance of the clitellum.

Further research on the extent of contamination showed that the mud soils are polluted with large amounts of various rather toxic substances. To collect more data about toxic effects on worms, laboratory experiments were made in polder soil mixed with these substances up to concentrations corresponding with those found in the mud. Soil of the Oostelijk Flevoland polder is known to be very suitable for earthworms.

The results (Table 3) showed that oil only had no effect at all. Both DDT and NaCl checked cocoon production, and mixtures of these substances had even more noxious effects, as shown by a sharp decrease of body weight and complete disappearence of clitellum. With respect of NaCl, it should be kept in mind that high concentrations in soil are usually rapidly reduced as a result of the action of rain.

Table 1. Comparison between pastures with high and low copper contents

Farm	Pastures with high copper content			Pastures with low copper content			Remarks
	org.matter (%)	copper content (%)	worms per m²	org.matter (%)	copper content (%)	worms per m²	
1	7.4	64.6	16	8.5	7.4	143	
2	12.3	36.0	10	6.3	7.1	176	
3	6.4	45.8	169	5.7	6.0	215	
4	12.2	31.4	138	9.6	11.8	182	
5	7.1	33.0	69	4.7	5.6	0	low numbers because the top 10 cm layer was yellow sand
6	12.1	34.1	153	4.3	8.2	42	as a result of recent ploughing

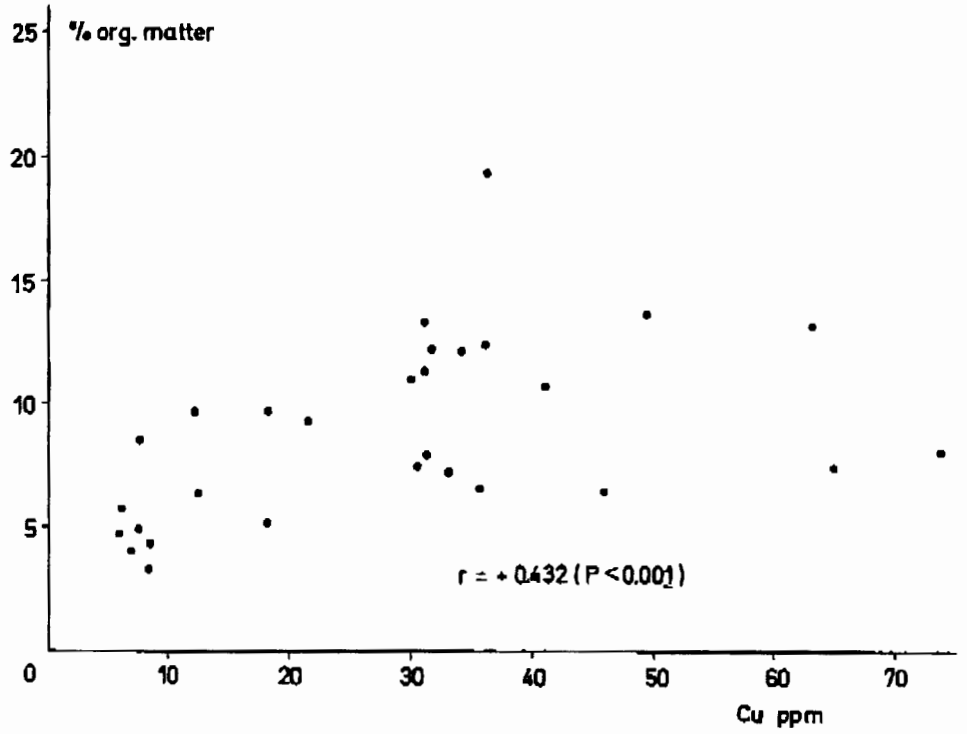

Fig.1. Organic matter content in relation to copper content.

T a b l e 2. Breeding experiments with *Allolobophora caliginosa* in deposit soils (duration of experiment 13 weeks)

Soil	Body weight (% initial weight)	Cocoons/worm week	Worm with clitellum (%)	Mortality (%)
Control (polder soil)	100	0.5	100	0
Deposit A	-	0	0	77
B	57	0	0	0
C	80	0	0	0

Table 4 shows the effect of non-ferrous metals. A significant loss of body weight was observed only in soils mixed with zinc and in those containing a mixture of metals. Some of the animals died, and the survivors lost their clitellum. The effect of other metals was manifested in a reduction of cocoon production, and copper also reduced the viability of the cocoons.

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T a b l e 3. Breeding experiments in polder soil mixed with oil, DDT, and NaCl (duration of experiment 4-7 weeks). Polder soil containing negligible quantities of soil. DDT, and NaCl

Treatment	Body weight (% initial weight)	Cocoons/worm week	Worms with clitellum (%)	Species (adult specimens)
nil	137	0.75	65	*Allolobophora longa*
Oil 500 mg/kg	140	0.4	65	
DDT 75 ppm	140	0	30	
NaCl 2.5 g/kg	100	0	20	
nil	137	1.3	100	*Allolobophora caliginosa*
DDT+oil+NaCl	53	0	0	
Oil+NaCl	66	0	0	

T a b l e 4. Breeding experiments with *Allolobophora caliginosa* in polder soil mixed with non-ferrous metals (duration of experiment 8½ weeks). Polder soil containing in ppm: 0.05-0.2 Hg, 2 Cu, and 16-60 Zn

Treatment (metals in ppm)	Body weight (% of initial weight)	Cocoons/worm week juveniles ( )	Mortality (%)	Worms with clitellum (%)
nil	154	1.95 (0.54)	0	100
10Hg + 20Co	127	0.68 (-)	0	80
110 Cu	170	1.43 (0.17)	0	90
1100 Zn	73	0	22	0
Hg+Co+Cu+Zn	52	0	22	0

CONCLUSION

The subjects discussed form only two aspects of the problem of soil pollution. Although the work is not yet complete, it is somewhat disturbing to note that in both cases the contamination of soil is largely irreversible. Little more can be done at the moment than point to the existence of a particular hazard such as ligh levels of especially zinc and copper where maintenance of worms becomes very difficult. This can have consequences for natural life in the soil, and disturbances of the system are to be expected in due time.

References

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Diskussion

C. A. Edwards: Might I ask if you investigated the influence of heavy metal contamination on pH in your first experiment?

J. A. van Rhee: I know that, on mud deposits, a pH of 7.5 was found.

K. H. Domsch: I like to point out, that data on heavy metals of waste products are generally based on total content. The amount available to organisms is certainly much lower (1-2 orders of magnitude). The concentrations used in rearing experiments - using soluble salts of heavy metals - are therefore much more toxic and not directly comparable to field observations.

J. A. van Rhee: In my experiments salts of heavy metals (chloride) were added. This means a large increase of the chloride content. First, these high concentrations of chloride have to be reduced to much lower concentrations.

J. Satchell: There seemed to be a very wide variability in the relationships you showed us between organic matter, earthworm populations and copper content. The relationship is presumably very complex involving the microflora on which the earthworms feed. Would the microbiologists present like to comment on microbial toxicity of heavy metals which have been mentioned?

J. A. Van Rhee: It is known to the author that the influence of copper - contaminated pig waste has been studied. An increase of COD was found as a result of high copper levels.

A. J. Reinecke: You showed an approximately direct relation

between organic matter content and copper content. How is this to be explained? If we can expect organic matter stratification can't we expect Cu stratification as well in a certain soil and a resulting vertical migration of earthworms as a result of this stratification.

J. A. van R h e e : No analyses were made for the copper content in different layers. The 0-5 cm top layer only was analysed. Earth worms were found in the 0-15 cm layer.