Persistence of Selected Pesticides used in Sugarcane Production in Soil and Water in the Northern Lake Victoria Catchment

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ABSTRACT

Pesticide use in the Lake Victoria catchment area of Uganda has continuously been increasing in the last ten years due to increase in the production of horticultural export crops and sugarcane. The farms have to use pesticides for increased crop productivity in order to meet market demands. This study was conducted to monitor pesticide levels in soils and runoff water following treatment of a sugarcane field in the Northern Lake Victoria watershed. Soil and water samples were collected over a period of 304 days after planting of the sugarcane and analysed for pesticide residues. In soils, glyphosate levels ranged from 0.8-135.5 μg/kg. Ametryn ranged from 44.9-1705.4 μg/kg, and Dichlorophenoxy acetic acid (2.4-D) 15.6 – 835.2 μg/kg. In water, glyphosate levels ranged from 1.3 to 42.2 upstream and 0.4 to 9.3 downstream, ametryn ranged from < 15 to 31.5 μg/l upstream and from <15- 18.6 g/l downstream and, 2.4-D<10 to 15.7 μg/l upstream and <10 to 13.4 μg/l downstream. The quality of water obtained was compared with the Canadian Environmental Quality thresholds for fresh water, irrigation and livestock water for selected pesticides. At the applied rates the use of herbicides Touch down (48% glyphosate trimesium) and Gesapax-H (21% ametryn and 29%, 2,4-D) for the control of weeds in sugarcane farming system at Kakira was found to be within acceptable levels.

Keywords: Pesticides, soil, water, pollution, concentration.

INTRODUCTION

Pesticides are used to control pests and thus increase crop productivity. Soils play a major role in the fate and efficacy of applied agricultural pesticides. The chemicals may be introduced in the soil either directly or indirectly as a result of their use in controlling crop pests such as insects and mites, weeds, fungi and nematodes. Ideally, the chemicals should serve their intended function and then dissipate in such a way and to the extent that their residues cause no immediate or long-term problems on the environment. The potential for a pesticide to become an environmental hazard depends to a large extent on what happens to its molecules in the soil (Felsot and Dahm, 1979, Monke and Mayo, 1990; Arienzo *et al.,* 1994). Persitence is a function of many factors including the degradation rate of the chemical in the soil (Racke *et al.,* 1996). Pesticide degradation depends on a number of factors, which include the properties of the chemical itself, the soil in which the chemical has been introduced and also environmental factors such as precipitation and atmospheric temperature (Cheng, 1990).

Pesticides in soils may dissipate as a result of volatilisation of parent material or products of its transformation (Eisenreich *et al.,* 1981; Whang et al., 1993), degradation by micro-organisms or, physical or chemical mechanisms within the soil (Konrad *et al.,* 1967, 1969; Kearney and Konston, 1976; Saltzman *et al.,* 1994; Johnson *et al.,* 1995; Racke *et al.,* 1996), photo-degradation (Takahashi *et al.,* 1985) and surface runoff and leaching (Johnson *et al.,* 1995). The combined effect of all these forms of dissipation is difficult to assess but can be estimated using data from field and laboratory studies. Plant influence is also very important for monitoring the mobility and persistence of pesticides under more realistic conditions (Kookana *et al.,* 1995) and providing data with which to assess simulation models (Nicholls *et al.,* 1982; Pennel *et al.,* 1990).

The Lake Victoria basin is densely populated (Bugenyi and Magunda, 1996) and agricultural activities in the area are intense. To be able to sustain agricultural productivity in the catchment the use of pesticides has become progressively increasing. Among the most widely used pesticides are herbicides, organophosphate insecticides and synthetic pyrethriods (Wejuli and Magunda, 1998). At Kakira Sugar Works in Jinja, the herbicide Touch down (Glyphosate trimesium) is used to control weeds in the gleysols, which occur in valley bottoms and Gesapax H (2,4-Dichlorophenoxy acetic acid; 2,4-D, and Ametryne) is used to control weeds in the nitisols, which occur on hilltops. The objective of this study was to monitor the concentration of applied herbicides in two soils and surrounding surface waters with time following field treatment. In addition comparison of the results with the global guidelines as a way of monitoring freshwater pollution from agricultural activities in the Lake Victoria basin was done.

MATERIALS AND METHODS

Description of study site

The terrain of Kakira Sugar Estates comprises of an undulating topography, with two major soil types, nitisols and gleysols. Nitisols are deep, dark reddish brown well-drained clayey soils. The soils are very porous and also have a high moisture storage capacity. Their permeability is rapid to moderate, even in the deeper subsoils (Drissen and Dudal, 1991). Gleysols are dark soils with permanent or temporary wetness near the surface. The surface soil consists of a very dark grey to black heavy clay. The soils have higher organic matter levels, higher cation exchange capacities and base saturation, and usually also higher levels of phosphorus and potassium contributing to generally finer texture and slower organic matter decomposition, but also caused by influx of ions from adjacent (higher) lands in this case nitisols (Drissen and Dudal, 1991).

Sugarcane was planted on 14th April 1999. Fertilisers, N and P, were applied at planting at the rate of 200 kg N/ha as Urea and 150 kg P/ha as TSP. Touch Down (48% Glyphosate Trimesium) was applied one week after planting and three weeks after in the gleysol area at the rate of 6 l/ha. Gesapax H (21% ametryn and 29% 2,4-D) was applied one day after planting at the rate of 7 l/ha and again at the rate of 3.5 l/ha one-week after planting in the nitisol area. The estates department of Kakira Sugar Works applied these herbicides as part of their routine sugarcane plantation management.

Both soil and water samples were initially collected 2 days prior to planting sugarcane and analysed for major physical chemicals. Background levels in soil and water samples of glyphosate, 2,4-D and ametryn were determined. Soil and water samples were then collected at different periods after planting and herbicides treatment and analysed for herbicide levels. The water samples were collected at the point of discharge in the field and 100 m down stream. Soil samples were collected at a depth of 0-10 cm from the soil surface. The samples were collected from different sampling points and bulked-up (composite) to give 10 soil samples from the nitisols while all the samples from the gleysols were analysed for accumulation of the pesticides due to run-off from nitisols. Water samples were collected twice, in the morning and afternoon the day soils were sampled and then bulked up. Only one water sample was collected after a rain shower.

Soils of the experimental site were sampled on grid of 25-m interval, at a depth 0-30 cm. These samples were analysed for key properties including pH, organic matter and clay. This information was then interpolated on the study site surface area to allow the demarcation in a GIS environment the different soil units.

Extraction and analysis

The pesticides were extracted from the soil using a 1:1 acetone:hexane mixture in a soxhlet extraction apparatus for 5 hours. The extracts were cleaned up using a column packed with florisil and eluted with 200 ml of 6% diethyl ether and then 200 ml of 15% diethyl ether. Glyphosate was analysed using an HPLC with UV Detector. The mobile phase consisted of 0.848g of KH_2PO_4/ 960 ml of water, 40 ml of methanol (HPLC Grade) brought to pH 1.9 by 85% H_2PO_3. The detection limit of the HPLC/UV using the detector response method was 0.08 μg/L for glyphosate. Ametryn and 2,4-D were determined using Gas Chromatography with FID. The column type used was Ov-1 and the carrier gas was nitrogen. The detection limit, using the detector response method was 10 μg/L and 15 μg/L for 2,4-D and ametryn respectively.

RESULTS AND DISCUSSION

The distribution of the selected soil properties is presented in Figure 1, 2, 3 and 4. On the experimental site, nitisols are found on the upper portion of the slopes and gleysols in the bottomlands and river valleys. Nitisols comprised approximately 4.06 hectares and gleysols 1.16 hectares.

The value of pH ranged from 3.8 to 6.1 grouped into three broad classes. Nitisols had pH values ranging from 3.8 to 5.4, while gleysols had pH values ranging from 4.6 to 6.1. Organic matter ranged from 1 to 9% on nitisols while it ranged from 4 to 9% on gleysols. The clay content on nitisols ranged from 42 to 69% and from 51 to 69% on gleysols.

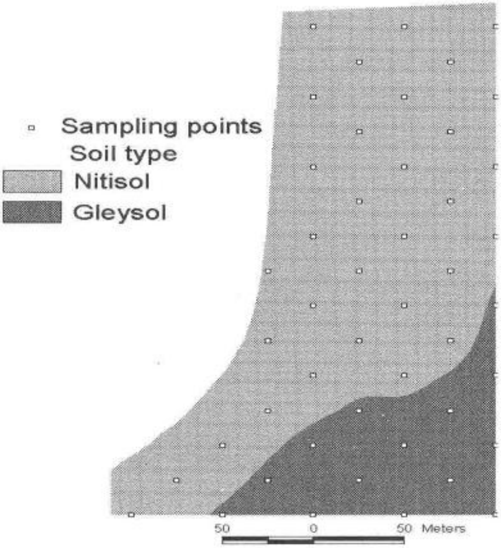

Figure 1: Soil map of study field at Kakira, Northern Lake Victoria catchment

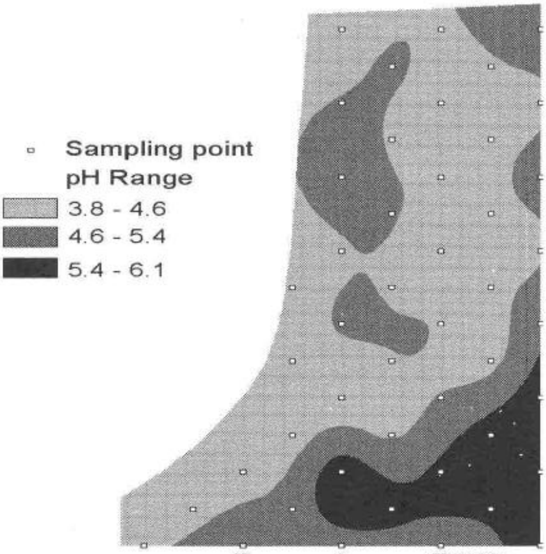

Figure 2: Distribution of pH in the surface soil (0-30 cm) of the study field at Kakira, Northern Lake Victoria catchment

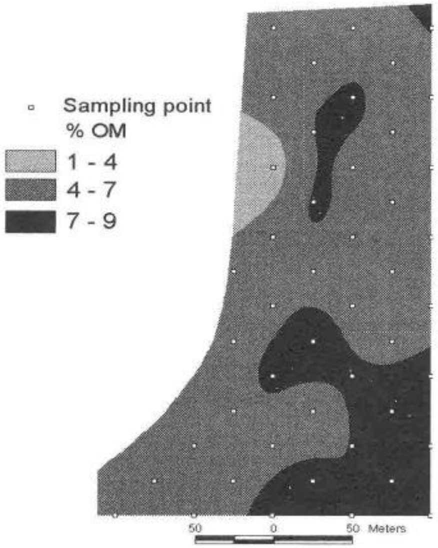

Figure 3: Organic matter distribution in the surface soil (0-30 cm) of the study field at Kakira, Northern Lake Victoria catchment

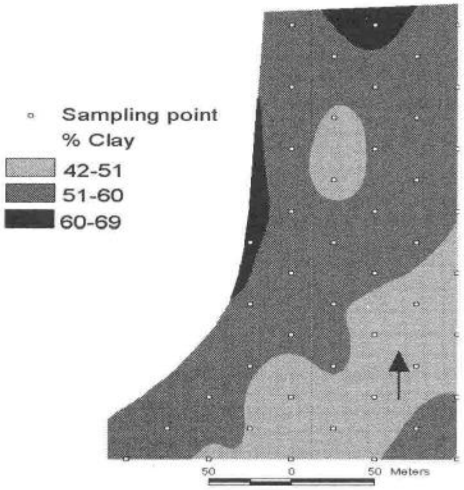

Fig. 4: Clay distribution in the surface soil (0-30 cm) of the study field at Kakira, Northern Lake Victoria catchment.

The level of pesticides in soils and water samples collected over a period of 304 days after planting are shown in Table I. Glyphosate levels in soils increased for the first 50 days, before decreasing overtime, while the level of ametryn and 2,4-D in soils decreased monotonously overtime. The level of glyphosate, ametryn and 2,4-D had a similar pattern as in the soil though with a relatively low magnitude, both up-stream and down-stream. It is important to notice that the levels of ametryn and 2,4-D were very low three months after pesticides application.

Table 1: Pesticide levels in soil and water following treatment of sugarcane field (Detectable limit: glyphosate = 0.08 µg/L; Ametryn = 15 µg/L; 2,4-D = 10 µg/L)

Days after planting	Soil µg/kg dry soil			Water (up-stream)			Water(down-stream) µg/litre		
	Glyph	Amet	2,4-D	Glyph	Amet	2,4-D	Glyph	Amet	2,4-D
*-2	0.14	bd		0.2	bd	bd	bd	bd	bd
7	135.5	1705.4	835.2	0.4	bd	bd	0.3	bd	bd
20	59.8	991.4	583.3	22.4	31.5	15.7	9.3	18.6	13.4
54	171.7	569.2	265.5	42.2	17.5	13.8	25	15.1	12.2
90	69.3	225.4	176.6	13.6	15.4	12.9	9.2	bd	11.3
125	25.6	122.0	112.6	12.2	bd	bd	4.5	bd	bd
161	20.2	88.5	79.6	8.7	bd	bd	3.6	bd	bd
179	13.4	61.4	57.6	6.5	bd	bd	3.2	bd	bd
215	11.6	55.5	49.3	5.4	bd	bd	1.8	bd	bd
248	8.3	51.6	38.4	5.7	bd	bd	2.2	bd	bd
273	2.2	49.2	27.5	2.1	bd	bd	0.6	bd	bd
304	0.8	44.9	15.6	1.3	bd	bd	0.4	bd	bd
**Q Gd									
FhW				65	-	2.600	65	-	2.600
IrrW				-	-	0.025	-	-	0.025
LsW				280	-	25.000	280	-	25.000

*Negative sign indicates days before planting. **Canadian Environmental Quality Guidelines (1999); Q Gd = Quality Guidelines; FhW = Fresh Water; IrrW = Irrigation Water; LsW = Livestock Water; Glyph = Glyphosate; Amet = Ametryn; bd = below detectable limit.

The relatively high levels of ametryn and 2,4-D in soil a few days after planting were most likely due to the fact that samples were taken on the same day after the second application of the herbicide, Gexapax-H. Whereas the relatively low levels of glyphosate were likely due to the time of sampling and also the longer interval between the two applications compared to Gesapax-H application. The general trend in dissipation for the three herbicides was similar and was very much associated to sugarcane growth. A full canopy of sugarcane is normally attained 3-4 months after planting (depending on the variety and growth conditions such as rainfall and soil fertility). Dissipation of the pesticides was higher before the full canopy formation. This is observed in 120 days after planting (Fig. 5). The highest levels of pesticides lost through surface run-off were also observed in this period (Fig. 6 and Fig. 7). The high rate of dissipation in the first 120 days was most likely due to volatilisation and surface run-off. As soil quality guidelines for more persistent chlorinated pesticides in Canada range from 100 μg/kg for tetra and tri-chloroethylene to 900 μg/kg DDT (total), we could expect higher values for less persistent pesticides. Furthermore, higher values would be expected for same chemicals in the tropics as compared to temperate conditions. Taking a tentative guideline value of 1000 μg/kg, it is provisionally taken that levels of pesticides in soil three weeks after application were below this guideline level.

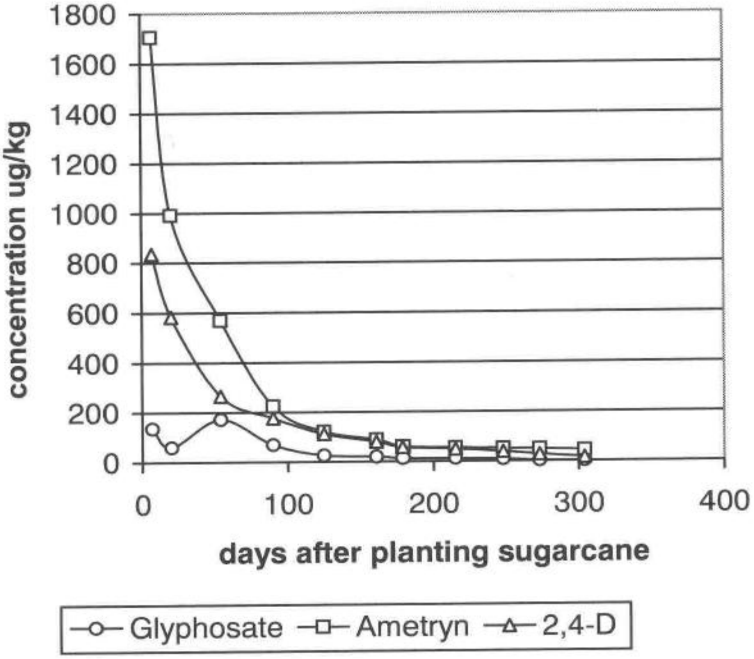

Figure 5: Herbicide levels in soils after planting sugarcane (Glyphosate applied as touch down in gleysols; Ametryn and 2,4-D applied as Gesapax H in nitisols)

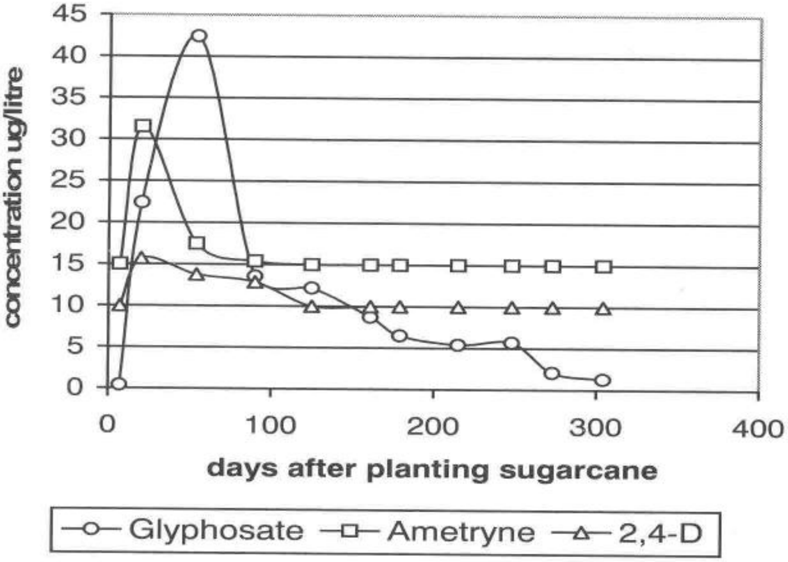

Figure 6.Herbicide levels in up-stream water after planting sugarcane (Detectable limit: Glyphosate = 0.08 μg/l; Ametryn = 15 μg/l; 2,4-D = 10μg/l. Value on detectable limit implies value was below detectable limit)

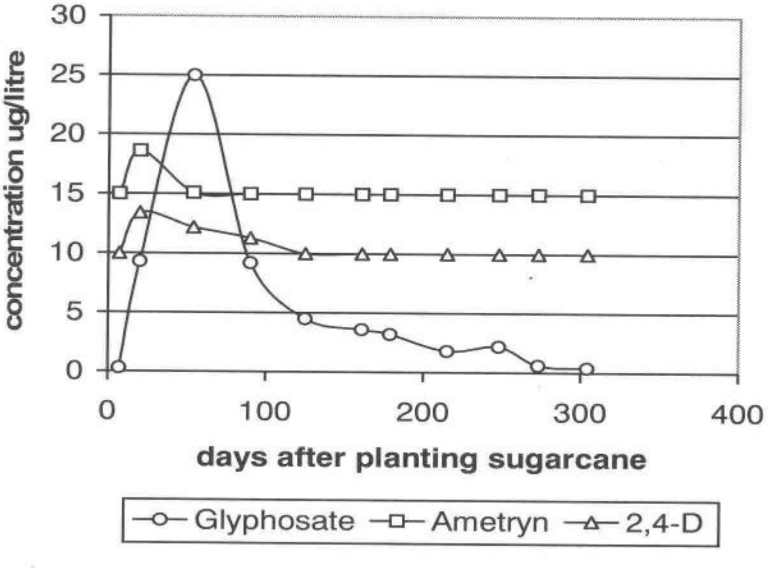

Figure 7. Herbicide levels in down-stream water after planting sugarcane (Detectable limit: for Glyphosate = 0.08 μg/l; Ametryn = 15 μg/l; 2,4-D = 10μg/l. Value on detectable limit implies value was below detectable limit)

The levels of glyphosate and 2,4-D (for livestock purposes) in water did not exceed the guideline concentration as seen in Table I. However, the guideines used are derived in Canada (temperate region) where it is much cooler and hence degradation much slower. Guidelines under tropical environments would be much higher due to higher degradation rates. There was also limitation in the analysis of ametryn and 2,4-D due to high detectable limits. More sensitive equipment and procedure would have given better results and picture.

CONCLUSION

The levels of Touch down (glyphosate trimesium) and Gesapax-H for the control of weeds in sugarcane farming system at Kakira were below the tolerable levels in runoff water and soil. However due to the relatively higher temperatures in the tropics loss by volatilisation may be a major pathway for pesticide dissipation. There is need to monitor loss by volatilisation in the field following application.

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REFERENCES

Arienzo, M., T. Cristanto, M. J. Sanchez-Martin, and Sanchez-Camazano, M. (1994). Effect of soil characterisatics on adsorption and mobility of (^{14}C) diazinon.

Becker R. L., D. Herzfeld, K. R. Ostlie, and Stamm-Katovich, E. J. (1989). Surface Runoff, Leaching and Exposure Concerns. Minnesota Extension Service, University of Minnesota.

Bugenyi, F. W. B. and Magumba, K. M. (1996). The present physiochemical ecology of Lake Victoria, Uganda. In: T.C. Johnson and E.O. Odada (eds). The Limnology, Climatology and Paleoclimatology of the East African Lakes. Gordon and Breach Publishers. Pp. 141-154.

Canadian Environmental Quality Guidelines, (1999). Canadian Council of Ministers of the Environment. http://www.ec.gc.ca/water/index.htm

Cheng, H. H. (1990). Pesticides in the soil environment: Processes, Impacts, and Modelling. Soil Science Society of America, Madison, Wisconsin.

Driessen, P. M. and Dudal, R. (1991). The major soils of the world. Lecture notes on their geography, formation, properties and use. Agricultural University Wageningen and Katholieke Universitiet Leuven.

Eisenreich, S. J., Looney, B. B. and Thornton, J. D., (1981). Air-borne organic contaminants in the Great Lakes ecosystem. Environ. Sci. Technol. 15:30-38.

Felsot, A.S., and Dahm, P. A., (1979). Sorption of organophosphorus and carbamate insecticides by soil. J. Agric. Food Chem. 27:557-563.

Johnson, W. G., Lavy, T. L. and Gbur, E. E., (1995). Sorption, mobility and degradation of triclopyr and 2,4-D on four soils. Weed Science 43:678-684.

Kearney, P.C. and A. Kontson. (1976). A simple system to simultenously measure volatilisation and metabolism of pesticides from soils. J. Agric. Food Chem. 24(2):424-426.

Konrad, J. G., Armstrong, D. E. and Chesters, G., (1967). Soil degradation of diazinon, a phosphorothioate insecticide. Agronomy Journal 59:591-594.

Konrad, J. G., Chesters, G. and Armstrong, D.E., (1969). Soil degradation of malation, a phosphorothioate insecticide. Soil Sci. Soc. Amer. Proc. 33:259-262.

Kookana, R. S., Di, H. J. and Aylmore, L. A. G., (1995). A field study of leaching and degradation of nine pesticides in a sandy soil. Aust. J. Soil Res. 33:1019-1030.

Monke, B. J., and Mayo, Z. B., (1990). Influence of edaphological factors on residual activity of selected insecticides in laboratory studies with emphasis on soil moisture and temperature. J. Econ. Entomol. 83:226-233.

Nicholls, P. H., Walker, A. and Baker, R. J., (1982). Measurement and simulation of the movement and degradation of atrazine and metribuzin in a fallow soil. Pesticide Science 12:484-494.

Pennel, K. D., Kornsby, A. G., Jessup, R. E. and Rao, P. S. S., (1990). Evaluation of five simulation models for predicting aldicarb and bromide behaviour under field conditions. Water Resources Research, 26:2679-2693

Racke, K. D., Steele, K. P., Yoder, R. N., Dick, W. A. and Avidov, E., (1996). Factors affecting hydrolytic degradation of chlorpyrifos in soil. J. Agric. Food Chem. 44:1582-1592.

Saltzmann, S., Yaron, B. and Mingelgrin, U., (1974). The surface catalysed hydrolysis of parathion on kaolinite. Soil Sci. Soc. Amer. Proc. 38:231-234.

Takahashi N., Mikami, N., Yamada, H. and Miyamoto, J., (1985). Photodegradation of the pyrethriod insecticide fenpropathrin in water, on soil and on plant foliage. Pesctic. Sci. 16:119-131.

Wejuli, M. S. and Magunda, M. K., (1998). Land Use Management Project Annual Report. KARI-NARO, LVEMP.

Whang, J. M., Schomburg, C. J., Glotfelty, D. E. and Taylor, A. W. (1993). Volatilisation of fonofos, chlorpyrifos, and atrazine from conventional and no-till surface soils in the field. J. Environ. Qual. 22:173-180.