Fate of Chlordecone in volcanic tropical soils and water in the French West Indies


1 INRA, UMR LISAH, Montpellier, France
2 CIRAD, UPR Systemes Bananes et Ananas, Capesterre-Belle-Eau, Guadeloupe, France
3 IRD, UMR LISAH, Montpellier, France
4 Forschungszentrum Juelich GmbH, IBG 3, Juelich, Germany
5 Supagro, UMR LISAH, Montpellier, France
6 INRA, UR ASTRO, Domaine Duclos, Petit-Bourg, Guadeloupe, France

*voltz@supagro.inra.fr

Introduction

In the French West Indies, chlordecone (CLD), an organochlorine pesticide, which is highly persistent in the environment, was applied in banana plantations from 1972 to 1993 against the banana weevil Cosmopolites sordidus (Lesueur et al., 2012). Pollution surveys conducted in 2001 by the French Department of Health revealed the presence of chlordecone in soils, rivers, springs over large areas in Guadeloupe and Martinique islands. Contamination of drinking water, food crops, aquatic species by CLD has been observed as well as its presence in blood of men, pregnant women and newborns. There is therefore a large social concern about the extent and evolution of CLD pollution in the French West Indies and its impact on human health and ecosystems. From 2008 to 2012 the multidisciplinary project CHLORDEXCO took place to study the CLD fate in water, soils and the contamination characteristics of aquatic species and food crops. Here, we summarize results obtained on the processes controlling the spatial and temporal patterns of soil and water contamination at the scale of the banana cropping area in Guadeloupe and of the Perou catchment.

Main results

The main soils in the contaminated areas are andosols and nitisols according to the FAO soil classification. They formed from the weathering of volcanic ashes. They have a high organic carbon content and high content of secondary minerals, allophane for andosols and halloysite for nitisols. An analysis of the levels of CLD in soil over 1045 field plots showed that the soil type had a strong impact on its distribution (Levillain et al., 2012). Andosols, had the highest CLD concentrations and stocks compared to itisols. These results are explained by the higher sorption capacity of andosols (Koc = 1218 to 2547 L/kg) compared to that of nitisols (Koc = 66 to 167 L/kg), as observed in laboratory batch sorption experiments (Fernandez-Bayo et al., in press). A significant « farm effect » in CLD stock, due to between-farm variations in application times and amounts, was also noticed. The observed stocks of CLD clearly correspond to an accumulation in soil after successive treatments due to the high persistence of CLD in soil.

The mineralisation, sorption of chlordecone and the formation of possible metabolites were evaluated using 14C-CLD in microcosms with andosol material during 215 days (Fernandez-Bayo et al., 2013). At the end of the experiment, more than 80% of CLD was shown to remain extractable with organic solvents. For the first time a significant mineralisation of chlordecone was measured in a soil microcosm under aerobic conditions. Nevertheless, the mineralisation rate decreased by one order of magnitude throughout the incubation period. It
therefore confirms the persistence of CLD over the long term but also indicates the existence of chlordecone degrading microorganisms in a tropical andosol. The reasons why their activity is restricted need to be elucidated. Possible reasons are a heterogeneous distribution a chlordecone between sub-compartments with different microbial activity or a degradation of chlordecone by co-metabolic processes controlled by a limited supply of nutrients.

Soil column studies of the transport of aged CLD showed that CLD concentration in percolation water varied little, from 5 to 10 μg/L. They were of same magnitude for both soils although their initial contamination levels, sorption properties and hydrodynamic behaviours differed. Equilibrium and non equilibrium transport modelling is currently being performed to analyze the reasons for these observations.

At the scale of the Perou catchment, 15 km², contamination of surface waters was permanent with CLD concentrations one order of magnitude less than in soil percolation water, which can be explained by dilution effects caused by water from uncontaminated uphill areas. CLD concentrations were highest in base flow indicating that the main pathway of applied CLD to surface waters is by percolation and groundwater flow. During storm flow CLD concentrations in surface waters decreased since the flow contribution of uncontaminated areas increased.

Conclusion

Contamination of soil and water in the banana cropped areas of the French West Indies is general and permanent. Despite large variations in contamination levels and hydraulic properties between the two main soils in areas, contamination of soil percolation water is currently similar. This suggests that a long-term equilibrium in CLD release from soil stocks has been reached. If no soil remediation strategies are applied, this severe environmental contamination will last over centuries as estimated by Cabidoche et al. (2009). Since CLD propagates mainly by subsurface flow, buffer strips, usually recommended in many regions to limit the pollution of water by pesticides, will not be useful. This study, however, suggests that CLD mineralization in soils is possible, which opens the way to the development of bioremediation approaches.

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References


