ENVIRONMENTAL FATE AND HUMAN HEALTH RISKS OF LINDANE IN GHANA

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Introduction

Extensive agricultural application of Lindane (99% pure γ-HCH) in Ghana began in 1959 when Lindane was formulated as Gammalin 20EC and introduced as a restricted-use organochlorine insecticide alongside other organochlorine insecticides, mainly DDT, against cocoa capsids or mirids. The use of Lindane on cocoa continued for decades until it was officially prohibited in 2002[1]. Lindane was also formulated as Gammatox for the control of ectoparasites on livestock and was reported to be the most widely used organanochlorine insecticide applied as an acaricide on livestock in Ghana[2]. Limited monitoring data/field measurements for most chemicals, especially from developing countries, does not allow the comprehensive assessment of their spatial and temporal distributions. A multicompartment mass balance model for Ghana was set up to provide estimates of Lindane concentrations in various environmental media, for the purpose of comparing model-derived concentration estimates with concentrations measured in the field. The combined model and field results were then used to estimate the extent of current human exposure to Lindane. The most important pathways and human exposure routes for the general population of Ghana were also determined.

Materials and Methods

The Canadian Centre for Environmental Modeling and Chemistry (CEMC) Level III Model (Steady-state Fugacity-Based Multimedia Environmental Model, Version 2.80, May 2004) was adopted for the multimedia fate modeling with possible modifications to suit the local environment. The study area comprised the southern and middle regions of Ghana. Environmental and chemicals specific basic data sets were sourced from literature and local sources. The datasets include: (1) parameters characterizing dimensions and properties of the compartments and sub-compartments; (2) input and output rates and concentrations; and (3) thermodynamic and kinetic diffusive and non-diffusive transfer processes. Three mode-of-entry emission scenarios were used to simulate the distribution of Lindane concentrations in various compartments/inter-compartmental transfer fluxes. Model-derived concentration estimates of Lindane in various environmental media were compared with concentrations measured in the field. The combined model and field results were then used to (1) estimate the extent of current human exposure to Lindane, and (2) determine the most important pathways and human exposure routes for the general population of Ghana.

Results and Discussion

Preliminary model calculations were based on an estimated Lindane emission rate of 2.56E+04 kg/h (1.28E+05 kg/h for Gammalin 20EC)[1]. Three modes of entry scenarios which were considered in the simulations were as follows: (A) 10% emissions to air and 90% emissions to soil; (B) 40% emissions to air and 60% emissions to soil; (C) 10% emissions to air, 5% emissions to water, and 85% emissions to soil.

There was a good correlation between model-derived concentrations and field measurements to a large extent especially for soil and water (approximately a factor of 2). With the exception of water, the model values exceeded field measurements. The exceptionally high model-derived concentration for air could be attributed to the fact that air concentrations were measured long after intensive field applications were ceased (see Fig. 1).

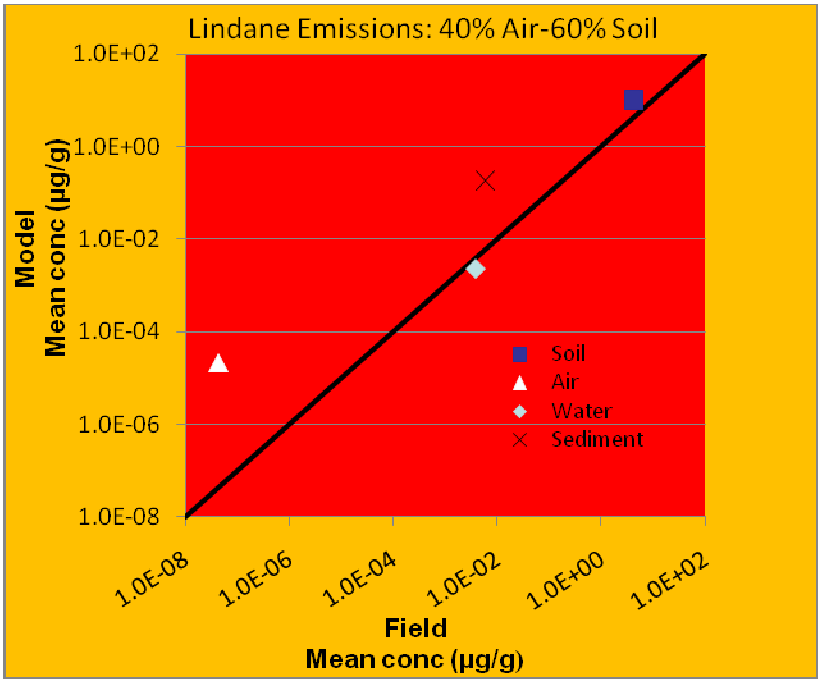

Fig. 1: Model-derived concentrations vs. field measurements

From both model derived concentrations and field measurements, it was found that: (1) The most important exposure pathways of Lindane for the general population of Ghana are: Diet/food and drinking water; and (2) Ingestion (mainly) and dermal contact (to some extent) are the most important exposure routes of Lindane for the general population of Ghana. The estimated total daily intake of Lindane for the average Ghanaian was calculated to be 1.45 µg(kg-bw)$^{-1}$ day^{-1} for a 65 kg adult. The large contribution from diet was expected since Lindane was mainly applied on cocoa (before 2002) and misapplied on non target crops (mainly vegetables). For the non-dietary pathways, water was the main contributor and was very significant to the total daily intake of Lindane. The contributions from air and soil were almost negligible (see Fig. 2).

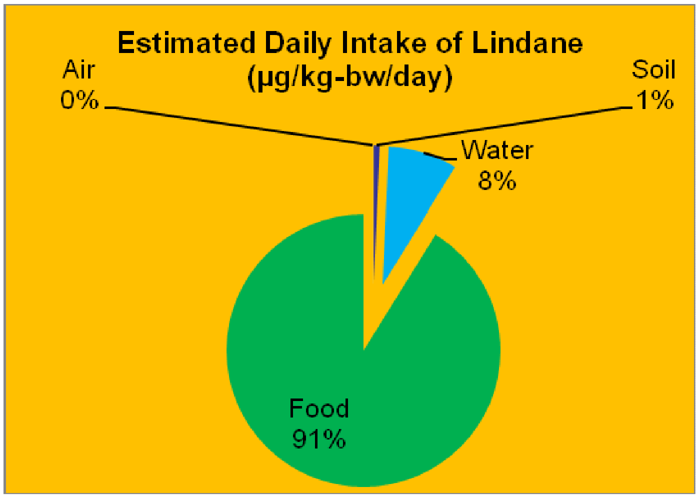

Fig. 2: Estimated daily intake from field measurements

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The Codex Alimentarius has set an Acceptable Daily Intake (ADI) of Lindane to be 0.001 mg $(kg\text{-}bw)^{-1} day^{-1}$ and a maximum daily dose/intake of 0.06 mg for a 60 kg adult[3]. The current national estimated average daily intake of Lindane does not therefore constitute significant health risks to the general population of Ghana.

The preliminary model calculations has shown that the multicompartment modelilng approach is a useful tool for the assessment of environmental fate and the description of the most important exposure pathways of Lindane for the general population of Ghana. It has also been established that human exposure to Lindane in Ghana is primarily via diet (mainly vegetables) followed by drinking water, and to a lesser extent soil and air. Additional field monitoring data and biomonitoring studies are however required for a comprehensive assessment of human exposure to Lindane in Ghana

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