Assessing and Reducing Risk Due to Chlorpyrifos Use among Rice Farmers in Vietnam: From Probabilistic Risk Assessment to Safety Strategy Development

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ABSTRACT

Vietnamese farmers are at high risk of pesticide exposure due to usage of pack-back sprays for application of pesticides with their rice crops. Chlorpyrifos has been the most common organophosphate registered for agricultural use in Vietnam, however the health risk due to the use of this compound by rice farmers has not been evaluated. The primary objective of this study was to evaluate the health risk of chlorpyrifos exposure to rice farmers, using a probabilistic approach, with a secondary objective of developing safety strategies for pesticide risk reduction, using qualitative needs assessment methods used for evaluating health promotion programs.

Farmer exposure to chlorpyrifos from pesticide application was measured by biological monitoring. Urine samples were collected from farmers (18) over pesticide spraying application time and analysed for 3,5,6-trichloropyridinol (TCP), the major urinary metabolite of chlorpyrifos, using an enzymatic pre-treatment before extraction followed by high-performance liquid chromatography tandem mass spectrometry (HPLC-MS/MS). Absorbed Daily Doses (ADD) of chlorpyrifos for farmers was then estimated from urinary TCP levels, expressed as µg/g creatinine. The exposure doses, comprising baseline exposure dose (ADD_B), post-application exposure dose (ADD_A), and lifetime average daily exposure dose (LADD_E) were calculated. The baseline exposure dose (ADD_B) ranged from 0.03 to 1.98 µg/kg/d with a mean of 0.24 µg/kg/d. The post-application exposure dose (ADD_A) ranged from 0.35 to 94 µg/kg/d with a mean of 19.4 µg/kg/d which is approximately 80 times higher than the mean values of ADD_B (0.24 µg/kg/d). The lifetime average daily dose (LADD_E) ranged from 0.01 to 1.7 µg/kg/d with a mean of 0.3 µg/kg/d. Multivariate regression analysis indicated that personal protective equipment reflected by percentage of body coverage, amount of chlorpyrifos used and length of application made major contributions to ADD_A. However, the best regression model for the relationship between ADD_A and exposure factors was observed with two independent variables comprising body coverage and amount of chlorpyrifos used.

Dose-response relationships for chlorpyrifos was evaluated from the scientific literature, comprising acute and chronic exposures associated with specific adverse health effects observed from human epidemiological studies, as well as studies on surrogate animals. The doses obtained from epidemiological studies on human populations, which showed adverse health effects, were converted to the Absorbed Daily Dose (ADD_D), acute neurological effect Absorbed Daily Dose (ADD_DN) and
Lifetime Average Daily Dose (LADD_D). The animal doses were converted to the Human Equivalent Dose (HED) for both acute (HED_A) and chronic dose (HED_C). The level of Absorbed Daily Dose corresponding to neurological effects (ADD_DN) observed from epidemiological studies with human populations ranged from 5 to 181 µg/kg/d, and a low level of ADD_D was seen to be associated with developmental and reproductive effects (0.5-1.6 µg/kg/d). The Lifetime Average Daily Doses corresponding to adverse health effects (LADD_D) ranged from 0.3 to 6.2 µg. The acute Human Equivalent Dose (HED_A) observed with rats for neurological effects varied widely from 4,900 to 162,000 µg/kg while HED_A observed with mutagenicity were from 730 to 3,400 µg/kg.

Health risk of chlorpyrifos for participant farmers was characterized using probabilistic techniques by several methods: (i) the Hazard Quotients (HQ_{95/guideline}) estimated using guidelines of chlorpyrifos exposure recommended by national and international agencies; (ii) the Hazard Quotients (HQ_{95/5}) estimated using the high exposure dose (the 95th percentile) and low dose (the 5th percentile) corresponding to the sensitive group exhibiting adverse health effects; (iii) the Risk Quotient distribution that is the ratio between exposure doses and doses corresponding to biological adverse effects using Monte Carlo Simulation (MCS); and (iv) the Overall Risk Probability (ORP) method. The limitations and differences in interpreting the risk derived from each method are discussed in this study.

The evaluation of chronic exposure was carried out with the Hazard Quotients (HQ_{95/guideline} and HQ_{95/5}), quantified as the ratios between baseline exposure (ADD_B), lifetime exposure (LADD_E) and chronic guidelines, which were exceeded unity when using the chronic guideline recommended by US EPA but were below unity when using chronic guidelines recommended from other national and international agencies. Whereas, the evaluation of acute exposure with HQ_{95/guideline} and HQ_{95/5}, quantified as the ratio between the ADD_A and acute guidelines, were all over unity. Similar results were found with the HQ_{95/5} method. The risk estimated using MCS for ADD_A was at the 33%, but the risk estimated using MCS for ADD_B and LADD_E were effectively zero. The ORP method evaluated the level of risk at 0.6% for ADD_B, 1.5% for LADD_E, and 29% for ADD_A.

Several qualitative methods were involved in the needs assessment for risk reduction. A comparative analysis of pesticide regulation in USA and Vietnam was conducted to identify comparative needs for improving pesticide regulations in Vietnam. In-depth interviews with authorities and experts in authorized agencies were
used to identify normative needs for improving pesticide regulations and safety practices. Observations on pesticide practices of farmers were used to identify expressed needs for pesticide occupational safety, and focus group discussions with three groups of farmers were conducted to identify felt needs for pesticide safety measures from farmers. All identified needs were finally evaluated by the hierarchy of control measures applied for occupational safety and health.

The needs for improving pesticide safety management legislation obtained from the comparative and normative needs assessment include: enhancement of pesticide legislation; multi-sectoral involvement in, and improvement of capacity for, pesticide regulations; risk-benefit guidance for pesticide registration; reforms of pesticide regulations on restriction, cancellation, suspension, transport, storage and disposal of pesticides; development of occupational hygiene and safety policy and programs for agricultural activities. The expressed needs based on actual observations of the pesticide practices of farmers comprise: improvement of knowledge and behaviour of farmers on pesticide safety, focusing on some specific safety activities such as mixing and loading, and spraying pesticides, etc.; and support for better safety facilities and supply of personal protective equipment. The farmers also expressed felt needs on technical training for occupational safety and hygiene of pesticide application, and supporting safety facilities and protective equipment.

This study shows that dose-response data derived from epidemiological studies are more appropriate for conducting risk assessment and establishing occupational exposure guidelines, since the data is derived from actual human populations. Vietnamese farmers have a relatively small risk of adverse health effects resulting from baseline or lifetime daily dose of chlorpyrifos. However they are at high risk of acute adverse health effects after a single event of chlorpyrifos application by spraying. The probability of having acute neurological effects among farmers is from 29% to 33%. Health risk assessment of chlorpyrifos using the Monte Carlo Simulation (MCS) and the ORP method have significant advantages over other methods in dealing with variability and uncertainty of risk characterization, since MCS and ORP methods used whole sets of data from both exposure and dose-response in quantifying risk. The ORP method, using epidemiological dose-response data, is likely to be more sensitive than the MCS method for risk estimation with low doses of pesticide exposure.

Overall, the health risk assessment in this study strongly indicates that many Vietnamese rice farmers are likely to be exposed and have adverse health effects, predominately neurological effects, from chlorpyrifos application events. For risk
management, the results of comprehensive needs assessment found a wide range of needs to improve occupational health and safety in pesticide use. These were dominated by legislative improvement, health risk assessment practices, workplace protection and personal hygiene, safety information and training, and first aid training for pesticide risk reduction among Vietnamese farmers. Recommendations to significantly or greatly reduce pesticide risks are presented.
STATEMENT OF ORIGINALITY

This work has not previously been submitted for a degree or diploma in any university. To the best of my knowledge and belief, the thesis contains no material previously published or written by other person except where due reference is made in the thesis itself.

Dung Tri Phung

2012
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<td>ADI</td>
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<td>Federal Insecticide, Fungicide, and Rodenticide Act</td>
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