AIWERASIA VERA NGOWI

Health Impact of Exposure to Pesticides in Agriculture in Tanzania

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ACADEMIC DISSERTATION
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To my parents

Eunike Masilayo and Festo Mashalla

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List of original publications

This dissertation is based on the following original publications, which are referred to by Roman numerals in the text.

I. Mbakaya CFL, Ohayo-Mitoko GJA, *Ngowi AVF,* Mbabazi R, Simwa JM, Maeda DN, Stephens J and Hakuza H. The status of pesticide usage in East Africa. Afr J Health Sci 1994;1:37-41.

II. *Ngowi AVF*, Maeda DN, Wesseling C, Partanen TJ, Sanga MP, Mbise G. Pesticide Handling Practices in Agriculture in Tanzania: Observational Data on 27 Coffee and Cotton Farms. Int J Occup Environ Health 2001;7:326-332.

III. *Ngowi AVF*, Maeda DN, Partanen TJ, Sanga MP, Mbise G. Acute Health Effects of Organophosphorus Pesticides on Tanzanian Small-Scale Coffee Growers. J Expo Anal Environ Epidemiol 2001;11:335-9.

IV. *Ngowi AVF,* Maeda DN, Partanen TJ. Knowledge, attitudes and practices among extensionists on prevention of health effects of pesticides in coffee and cotton growing areas in Tanzania. Med Lav: In press.

V. *Ngowi AVF*, Maeda DN, Partanen TJ. Assessment of the ability of health care providers to treat and prevent adverse health effects of pesticides in agricultural areas of Tanzania. Int J Occup Med Environ Health 2001;4:347-354.

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Summary

The present study assessed health hazards posed by pesticide handling, storage and use on agricultural estates and small farms in Tanzania where coffee, cotton, and other important crops are grown, with a view to developing strategies for the control of pesticide exposure and prevention of pesticide poisoning.

The Tanzanian component of an extensive field study entitled *East Africa Pesticide Network* used a standard protocol developed jointly between research partners in Kenya, Tanzania, Uganda, Canada, and Finland. The target population was made up of farmers and other agricultural workers applying pesticides in coffee and cotton farms, as well as of non-agricultural control subjects, health care providers and extensionists in the same areas. Background data were collected, focused observations of target farms carried out, erythrocyte acetylcholinesterase and organochlorine residue levels in blood samples determined, and extensive interviews of agricultural workers, control subjects, health care providers, and extension service workers conducted.

A total of 104 pesticide chemical names and 179 trade names were compiled in Tanzania. Most of the pesticides were organophosphates, but carbamates, organochlorines, and pyrethroids were also represented. The pesticides included aldrin, endosulfan, DDT, dieldrin, camphechlor and lindane, some of which are confirmed endocrine disruptors or persistent organic pollutants, which were banned or restricted in their countries of origin, and some were classified as World Health Organization Hazard Class Ia and Ib. For the period 1989/90, a total of 736 pesticide-poisoning cases were reported in the Tanzanian in-patient district hospital medical records with more women than men poisoned, however, the medical records were inadequate as they failed to show the cause or type of poisoning. More pesticide formulations were used on coffee compared with cotton, and in individually owned compared with cooperative farms. Coffee farms more often displayed unlabeled pesticide containers and missing instructions, while cotton pesticides were stored in bedrooms, near food, and near open fires, and pesticide leftovers were often present. Hazardous practices were more pronounced at the individually owned than the cooperative farms, with significant differences for pesticide storage areas, unlabeled and non-original containers. Assessment of the extent and intensity of organophosphate exposure showed that erythrocyte acetylcholinesterase activities during spraying and non-spraying period were comparable (mean 32.0 vs. 33.0 U/g Haemoglobin, $p = 0.26$). Similarly, the prevalence of cough, headache, abdominal pain, excessive sweating, nausea, diarrhoea, and vomiting did not differ significantly between spraying and non-spraying periods. There was no suggestion of decreased acetylcholinesterase activity in exposed subjects who complained of organophosphate–related symptoms compared to symptomless exposed subjects. Use of boots, head cover, face cover, and coverall was not significantly associated with acetylcholinesterase activity. Eighty per cent of 104 health care providers interviewed reported to have seen pesticide poisoning, nine having seen two to four cases in the preceding three months. Pesticide poisoning was considered a major problem in the community by 63% of the health care providers, and a third thought that a number of poisoning cases remained unrecognised. Only one percent of the respondents could identify the group of pesticides predominantly used in the study areas. Only every fourth of the agricultural extension workers perceived pesticides as a major health problem in the

community they served. Although high proportion claimed knowledge of first aid procedures in case of pesticide poisoning, many procedures described were not appropriate for the treatment of pesticide poisoning.

The availability of obsolete, endocrine disruptor, persistent organic pollutant, and World Health Organization hazard Class Ia and Ib pesticides on the open market indicated that the existing regulatory system in Tanzania is inadequate and requires improvement in order to safeguard pesticide users, the general public, and the environment. Pesticide handling-practices on farms increased the risks of exposure of farm workers and their families to pesticides, thus undermining pesticide safety in many small farms in Tanzania. There was no strong indication for adverse effects of organophosphorus pesticides during the study period, either based on erythrocyte acetylcholinesterase or on symptoms. However, a great concern over potential long-term effects arising from the use of pesticides in these areas is eminent because pesticides suspected of long-term adverse effects are being used in hazardous work and living conditions. The extensionists were not aware of the health effects of pesticides and did not know what measures should be taken in case of poisoning. The failure of health care providers to distinguish the pesticide class, e.g. organophosphates and organochlorines, reflects a lack of understanding of the fundamental principles of diagnosis and treatment of pesticide poisoning, and may have a great impact on the prognosis. It also undermines the medical recording system especially for pesticide poisoning incidences.

Muhtasari

Utafiti huu ulikisia hatari zitokanazo na matumizi na hifadhi ya viuatilifu (pesticides) katika mashamba makubwa na madogo nchini Tanzania ambapo kahawa, pamba, na mazao mengine muhimu hulimwa, kwa nia ya kujenga mbinu za kuzuia mgusano (exposure) na viuatilifu na kukinga matukio ya kudhurika na sumu ya viuatilifu (poisoning).

Uchunguzi huu nchini Tanzania ni sehemu ya utafiti mkubwa ulioitwa *East Africa Pesticide Network.* Ulitumia taratibu halisi zilizotengenezwa kwa pamoja kati ya watafiti washirika kutoka Kenya, Tanzania, Uganda, Canada, na Finland. Watu waliohusika katika kuchunguzwa walikuwa wakulima na wafanyakazi katika mashamba wakiwa wamejihusisha na viuatilifu ndani ya mashamba ya kahawa na pamba, pamoja na watu wasio wakulima na wasiojihusisha na viuatilifu, wahudumu wa afya, na mabwana na mabibi shamba kutoka sehemu hizo hizo. Takwimu za awali zilikusanywa, maangalizi ya mashamba kadhaa yalifanyika, wepesi wa kutenda kazi wa enzaimu (*erythrocyte acetylcholinesterase activity)* na masalia ya oganoklorin (*organochlorines)* katika sampuli za damu vilichunguzwa, na mahojiano makubwa ya wakulima na wafanyakazi mashambani, watu wasiojihusisha na viuatilifu, wahudumu wa afya, na mabwana na mabibi shamba yalifanyika.

Jumla ya majina ya kemikali za viuatilifu 104 na majina ya kibiashara ya viuatilifu 179 yalikusanywa nchini Tanzania. Vuatilifu aghalabu vilikuwa vya aina ya oganofosfati (*organophosphates*), lakini kabameti (*carbamates*), oganoklorini, na pairethroid (*pyrethroids*) ziliwakilishwa kwa kiwango kikubwa. Ndani ya orodha kulikuwa na vuatilifu kama vile aldrin, endosalfan, DDT, dieldrin, kamfiklor na linden, ambavyo kati yake vinajulikana kukatisha kazi za endokrain (*endocrine disruptors)* au vichafuzi sugu vya oganik (*persistent organic pollutants*) vilivyopigwa marufuku au vyenye masharti katika nchi vitokako na vingine vilikuwa vimeainishwa katika daraja la hatari Ia na Ib na Shirika la Afya duniani. Katika kipindi cha 1989/90 matukio ya kudhurika na sumu ya viuatilifu 736 yalionyeshwa katika taarifa za wagonjwa wa ndani wa hospitali za wilaya nchini Tanzania, wanawake waliodhurika wakiwa wengi kuliko wanaume, isipokuwa rekodi za hospitali hazikutosheleza kwa kushindwa kuonyesha kilichosababisha madhara na ni madhara ya aina gani. Michanganyiko zaidi ya viuatilifu ilitumika kwenye kahawa kuliko kwenye pamba na wakulima binafsi kuliko mashamba ya ushirika. Mashamba ya kahawa aghalabu yalikuwa na vifaa vya viuatilifu visivyokuwa na vibandiko (*unlabeled*) na ukosekanaji wa maelekezo, wakati viuatilifu vya pamba vilihifadhiwa ndani ya vyumba vya kulala, karibu na chakula, na karibu na moto, na masalia ya viuatilifu yalikuwepo aghalabu. Desturi za hatari zilikuwa wazi zaidi katika mashamba ya watu binafsi kuliko ya ushirika, kukiwa na tofauti za uhakika katika maeneo ya kuhifadhi viuatilifu, ukosefu wa vibandiko na vifaa vya viuatilifu visivyokuwa vya awali. Kadirio la kiasi na kiwango cha mgusano na viuatilifu aina ya oganofosfati vilionyesha kwamba wepesi wa kutenda kazi wa enzaimu (*erythrocyte acetylcholinesterase*) msimu wa upuliziaji viuatilifu na msimu wa kutokupulizia ulikuwa unawiana (wastani 32.0 vs 33.0 U/g *haemoglobin*, $p = 0.26$). Vile vile, kuenea kwa kikohozi, kuumwa kichwa, maumivu ya tumbo, jasho kupita kiasi, kichefuchefu, kuharisha, na kutapika wakati wa msimu wa upuliziaji hakukutofautiana kwa hakika na wakati wa msimu wa kutokupulizia viuatilifu. Hapakuwa na dokezo la kupungua kwa wepesi wa kutenda kazi wa enzaimu kwa waathirika waliokuwa wakilalamika kuwa na dalili za madhara yanayofanana na yale yatokanayo na oganofosfati na wale wasiokuwa na

dalili zozote. Matumizi ya buti, kifuniko cha kichwa, kifuniko cha uso, na ovaroli hayakuunganika kwa uhakika na wepesi wa kutenda kazi wa enzaimu. Asilimia themanini ya wahudumu wa afya 104 waliohojiwa waliarifu kuona matukio ya kudhurika na sumu ya viuatilifu, tisa kati yao wakiwa wameona kati ya watu wawili na wanne miezi mitatu ya nyuma. Matukio ya kudhurika na sumu ya viuatilifu yalidhaniwa kuwa tatizo kubwa katika jamii na 63% ya wahudumu wa afya, na theluthi moja walihisi kuna idadi ya wadhurika ambao hawatambuliki. Ni asilimia moja tu ya wahojiwa walioweza kutambua kundi la viuatilifu vinavyotumika zaidi katika eneo lao la kazi. Ni robo tu ya mabwana na mabibi shamba walihisi kuwa viuatilifu ni tatizo kubwa kiafya katika jamii wanazohudumia. Wengi wao waliashiria kujua taratibu za huduma ya kwanza kama kukiwa na tukio la mtu kudhurika na sumu ya viuatilifu, ila taratibu nyingi zilizoelezwa hazikuwa za kufaa madhara yatokanayo na sumu ya viuatilifu.

Upatikanaji wa viuatilifu visivyofaa, vinavyokatiza kazi za endokrain, vichafuzi sugu vya oganik, na vya daraja la hatari Ia na Ib la Shirika la afya duniani katika soko huria kunaonyesha kuwa taratibu za kuthibiti viuatilifu nchini Tanzania zina upungufu na zinahitaji kupitiwa upya ili kuhakikisha usalama wa watumiaji wa viuatilifu, wananchi kwa ujumla na mazingira. Desturi za utumiaji wa viuatilifu katika mashamba zinaongeza hatari za mgusano na viuatilifu kwa wakulima, wafanyakazi wa mashambani na familia zao, hivyo kuleta mashaka ya usalama wa viuatilifu katika mashamba madogo nchini Tanzania. Kudhurika kukali (*acute*) na sumu ya viuatilifu katika mashamba ya kahawa hakukuelekea kuwa tatizo kubwa, lakini kuna kufikiria kwa makini madhara ya muda mrefu yatokanayo na matumizi ya viuatilifu katika maeneo haya. Mabwana na mabibi shamba hawakuelewa madhara ya kiafya yatokanayo na viuatilifu na hawakujua watafanya nini iwapo mtu atadhurika na sumu. Kushindwa kwa wahudumu wa afya kutofautisha makundi ya viuatilifu, mfano, oganofosfati na oganoklorini, kunaelekeza kutokuwa na ujuzi wa chimbuko la msingi wa uchunguzi wa ugonjwa na dalili zake na tiba ya kudhurika na sumu ya viuatilifu, na hii ina athari kubwa katika uaguzi. Vili vile kunahujumu utaratibu mzima wa takwimu haswa zile za walioathirika na sumu za viuatilifu.

1 Introduction

Pesticides[1] pose significant occupational health and environmental risks throughout the world (WHO 1990, Forget 1991). It is widely recognized that agricultural workers are the largest occupational group at risk of adverse health effects, although public health workers and workers in manufacturing/formulating factories may also be exposed. Although most agricultural workers may be facing pesticide hazards, spraymen are usually the most highly exposed group because of inadequate clothing, drift of spray droplets, leaks and other defects in the spray equipment, or other reasons. The general population, on the other hand, is at risk of pesticide poisoning through non-agricultural pesticides e.g. household pesticide use, contaminated food, water, soil, and through air, dust, or accidental pesticide ingestion (WHO 1990, Wesseling et al. 1997).

Pesticide hazards are frequent and severe in developing countries, where pesticide use is widespread, pesticides banned elsewhere on account of their toxic, carcinogenic or other properties may be used, and agricultural workers together with health professionals may not be adequately informed or trained in the recognition and prevention of pesticide poisoning. Methods of reducing personal exposure, such as use of protective equipment, may not be available, accessible, affordable or even feasible (Jeyaratnam et al. 1987, Forget 1991). Coupled with lack of adequate legislation, non-enforcement of existing pesticide laws and regulations, lack of coordination between authorities of health and agriculture, the hazard to agricultural workers and their families is substantially greater than in developed countries.

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[1] Pesticide as defined by FAO (1986) comprises any substance or mixture of substances intended for preventing, destroying, or controlling any pest, including vectors of human or animal disease, unwanted species of plants or animals causing harm during, or otherwise interfering with, the production, processing, storage, transport, or marketing of food, agricultural commodities, (including commodities such as raw cereals, sugar beet, and cottonseed) wood, wood products, or animal feedstuff, or which may be administered to animals for the control of insects, arachnids, or other pests in or on their bodies. The term includes substances intended for use as plant-growth regulator, defoliant, desiccant, fruit-thinning agent or an agent for preventing premature fall of fruit, and substances applied to crops either before or after harvest to prevent deterioration during storage or transport.

Pesticides are defined by TPRI Act.No.18 of 1979 as "any matter of any description (including acaricides, arboricides, herbicides, insecticides, fungicides, molluscides, nematicides, hormonal sprays and defoliants) used or intended to be used, either alone or together with other material substances - a) for the control of weeds, pest and disease in plants; or b) for the control of external vector of veterinary or medical disease and external parasites of man or domestic animals or c) for the protection of any food intended for human or animal consumption."

Organophosphates, carbamates, organochlorines and pyrethroids are potentially hazardous pesticides that are widely used in various parts of East Africa (Mbakaya et al. 1994, Ohayo-Mitoko et al. 2000). In addition to causing acute signs[2] and symptoms[3] of pesticide poisoning, there is growing concern because these pesticides are suspected of being mutagenic, carcinogenic, or teratogenic (Maroni and Fait 1993).

The type, frequency, and severity of pesticide poisoning in developing countries has not been adequately assessed. While extensive use of pesticides is known to lead to serious public health and environmental problems (Blair and Zahm 1993, Dinham 1993), the number of people exposed and/or affected has been difficult to estimate. A survey of self-reported pesticide poisonings in four Asian countries revealed that 3% of agricultural workers in developing countries are poisoned by pesticide each year (Jeyaratnam 1990). Applying this rate to the estimated number of workers exposed to pesticides (3.3 million) in coffee and cotton growing areas of Tanzania, 99,000 cases would be expected annually. These estimates do not include the long-term effects of pesticides (Maroni and Fait 1993). Thus, for example cancers, birth defects, sterility, and neuropsychological disturbances are not included in the estimated figures.

Advances in acute pesticide poisoning surveillance and treatment in developed countries have lead to some achievements in the control of pesticide poisoning (Ballard and Calvert 2001). However, pesticide poisoning is still definitely a public health problem globally, particularly in developing countries (Wesseling et al. 1997, He et al. 1998, Wesseling et al. 2001). Tackling pesticide poisoning along with other public health problems, including infectious and parasitic diseases as well as malnutrition requires knowledge of pesticide toxicology, specific signs and symptoms of poisoning, and hazardous patterns peculiar to each community, together with development and application of appropriate strategies for poisoning prevention and control.

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[2] Signs are objective findings that can be observed and described by a health care professional. These findings do not rely on subjective reporting of sensations by the affected individual.
[3] Symptoms are any subjective evidence of a disease or condition as perceived and reported by the affected individual. These include reported changes from normal function, sensation, or appearance.

This thesis represents the Tanzanian component of an extensive field study entitled *East Africa Pesticide Network* (Partanen et al. 1999), conducted in Kenya, Tanzania, and Uganda with the objective of characterizing and documenting the pesticide exposures and poisonings in the region, and describing the health significance as well as intellectual and policy implications. The present study addresses the availability of pesticides in Tanzania, hazardous practices in specific areas, extent and intensity of organophosphate exposure, associations between external exposure, exposure biomarkers, and symptoms, and use of protective equipment. The knowledge of health care providers in the prevention and treatment of adverse health effects of pesticides is assessed, and the knowledge, attitudes and practices of agricultural extension workers concerning health effects of pesticides are evaluated. Strategies for the reduction and control of exposure to pesticides and prevention of pesticide poisonings in Tanzania are discussed.

2 Background

2.1 Pesticide exposures

Exposure to pesticides and other agrochemicals constitutes a major occupational hazard (Pearce and Reif 1990, Popendorf and Donham 1991, Sullivan et al. 1992, Zejda et al. 1993, Meridian Research Inc. 1994, Connally et al. 1996, Hanrahan et al. 1996), accounting in some countries for as much as 14% of all occupational injuries in the agricultural sector and 10% of all fatal injuries. Hazardous occupations include pesticide mixers, loaders, flaggers for aerial applications, applicators (spraymen), fumigators, pilots, emergency response personnel, manufacturers and supervisors (Namba 1971, Warnick and Carter 1972, Ellenhorn and Barceloux 1988, Maddy et al. 1990, Lessenger and Riley 1991).

Agricultural production, vector control in public health and animal husbandry are increasingly dependent on pesticide usage. Agriculture is the largest user, followed by vector control. Two million tons of pesticides, derived from 759 active ingredients, are considered being in current use (Forget 1991, Akhabuhaya et al. 2000). While pesticide use in Europe and North America moves towards saturation or decline, increasing trends are expected for Africa (WHO 1990) and Central America (Wesseling et al. 2001). Pesticides forbidden or severely restricted in industrialized countries are exported to developing countries despite the internationally agreed conventions governing pesticide trade (Smith 2001). They include potential carcinogens, endocrine disruptors and persistent organic pollutants.

The substantial use of insecticides, fungicides and herbicides and other agrochemicals in East Africa highlights worker exposure as an important health hazard (Mbakaya et al. 1994, Kimani and Mwanthi 1995, Mbakaya et al. 1996).

2.2 Pesticide poisonings

Developing effective preventive policies and allocating resources requires accurate and valid information on occurrence of poisoning, which in turn depends on an efficient reporting system (Wesseling et al. 1997, Ballard and Calvert 2001).

Acute health effects of a number of pesticides, like organophosphates, are well characterized (Alderman et al. 1978, Jeyaratnam et al. 1987, Hayes and Laws 1991, Wesseling et al. 1993, Clarke et al. 1997, Ohayo-Mitoko et al. 1997) but the long-term health effects of routine, small exposures are uncertain. Based on hospital registries, World Health Organization estimated that three million cases of acute pesticide poisoning (two million suicides, one million accidental poisonings) resulting in 220,000 deaths, occur worldwide each year (WHO 1990). The burden of pesticide related illness and injury is difficult to determine since many cases of pesticide poisoning remain undiagnosed and/or unreported (Reigart and Roberts 1999, Ballard and Calvert 2001). Diagnostic problems are particularly prominent in developing countries (He et al. 1989, Mbakaya et al. 1994, London and Myers 1995, Keifer et al. 1996), due to insufficient medical training and a high level of background ill health.

Suicidal, homicidal and accidental pesticide poisonings although underreported, constitute a burden to governments and people in East Africa. In a case study of the coffee growing regions of Tanzania (Ngowi et al. 1992) for the period 1980–1990 an average of 62 poisoning cases were recorded in hospitals per year, most of which were suicide cases. The preference for pharmaceuticals, mostly chloroquin, rather than pesticides as means of committing suicide is noticeable in Tanzanian news. The situation might be slightly different in the other East African countries, as shown by the higher incidence of pesticide induced suicides in adults and accidental poisoning in children in Kenya compared to Tanzania (Mbakaya et al. 1994). Unintentional pesticide poisoning, mainly among farmers and farm workers, is mostly occupational. Annual incidence rates of between 0.3 and 18 per 100,000 have been reported based on studies in populations from 17 countries (Levine 1986). In Sri Lanka and Malaysia, pesticide poisoning was reported in 7% of agricultural workers (Jeyartanam et al. 1987). A study on pesticide poisoning in Costa Rica between

1980 and 1986 indicated that 4.5% of agricultural workers were poisoned per year (Wesseling et al. 1993). Cholinesterase inhibition and other adverse health effects of organophosphate pesticides in agricultural workers have been revealed in several studies (Ngatia and Mgeni 1980, Rama and Jaga 1992, Ciesielski et al. 1994, Ohayo-Mitoko et al. 1997) although limited by inadequate comparison groups and small sample sizes.

Acute poisoning resulting from pesticide contaminants or their degradation products as exemplified by the epidemic of malathion poisoning in Pakistan in 1976 resulted from exposure to iso-malathion, affecting 40% of workers during a malaria control programme. Five men died and approximately 2800 experienced at least one episode of acute poisoning (Alderman et al. 1978).

Pesticides by design interfere with a variety of biological systems, such as the nervous and enzyme systems. The toxicity of pesticides differs greatly, and diverse health effects, including systemic poisonings and topical lesions, are produced by the many chemical compositions in each pesticide. Pesticides may cause respiratory, immunological, neurological, and developmental effect as well as reproductive dysfunction and cancer (Hayes and Laws 1991). The magnitude of effect may be mild or severe and the onset may be immediate or delayed. The resulting condition may be short or long-term, reversible or irreversible.

Organophosphorus insecticides that inhibit the normal function of cholinesterase enzymes mainly cause acute pesticide poisonings which account for 79% of the total poisonings in China, 69% in Sri Lanka and 54% in Malaysia (He et al. 1998) and are a major public health concern in most African countries where approximately 80% of the workforce is in agriculture. Organophosphates cause neurotoxic effects with signs and symptoms ranging from dizziness, headache, nausea, vomiting, miosis, excessive sweating, lachrimation, muscular fasciculations, shortness of breath, coma, pulmonary oedema and respiratory depression. Organophosphate-induced delayed polyneuropathy, which occurs following a latent period of 2–4 weeks after a cholinergic crisis, appears as weakness, ataxia and paralysis of the extremities, and sensory disturbances (Hayes and Laws 1991). Fatality rate and lifelong disability resulting from organophosphorus pesticide poisoning in developing countries are usually high due to poor diagnosis and delayed treatment, and causes suffering and loss of income.

Firm conclusions on the adverse effects of chronic exposure to pesticides on human health are difficult to draw at present but the endocrine disruption and carcinogenic potential of a number of pesticides has been demonstrated in animal bioassays and a number of experimental studies (Maroni and Fait 1993, Wesseling 1997). Although there are calls to phase out such pesticides in the developed world, it takes longer for the developing countries to cut off supplies and rid themselves off old stocks. Meanwhile, people continue to suffer from unexplained illnesses that might have been induced by pesticides.

2.3 Interventions to reduce exposure and poisoning

2.3.1 Medical care

Surveillance systems have contributed towards recognition and prevention of pesticide exposure and subsequent illness in many developed countries (Ballard and Calvert 2001) but they are rare in developing countries.

Health care providers normally attend acute poisoning cases, with the outcome depending on the immediacy and correctness of diagnosis, and the appropriateness of the treatment. However, when there is no antidote, such as in paraquat poisoning, health care workers lack the means to improve the outcome (Reigart and Roberts 1999). The need for constant re-training of physicians in agricultural areas due to new chemicals frequently introduced on the market has also been reported in countries worldwide (WHO 1990, Lessenger 1996).

Effective diagnosis and treatment requires knowledge of health aspects of pesticides and sometimes costly equipment, which are usually not available in developing countries. Due to poor access to health care in rural areas, diagnosis and treatment of chronic illness from exposure to pesticides are frequently inadequate increasing fatality of acute poisonings as well. Because of the general lack of adequate health services, it is especially important to minimise risks by judicious choice of less toxic pesticides or use of non-chemical pest control methods.

2.3.2 Agricultural extension service

Agricultural extension is a major channel of communication between farmers and experts to improve crop production. It provides a link between the farmer and the research where agricultural technologies, including pesticides, are developed, tested and modified. Agricultural extension workers in Tanzania collaborate with research institutions and co-ordinate technological support services for the agricultural sector.

In the developed countries, to avoid exposures to pesticides, education and training are provided on the pesticides likely to be handled by agricultural workers e.g. how the substances enter the body, the nature of the toxic effects, and the proper methods of use and disposal. Such education is usually part of the agricultural extension workers' curricula. However, in developing countries such training is rarely available, instead, there is a great reliance on farm workers' experience or advice from neighbours.

2.3.3 Information and training

Governments and farmers need information on the health and environmental effects of pesticides to be able to make informed choices on their use. There is considerable effort to institute training and education at various levels in many countries (Anonymons 1997) and much effort is directed at producing training materials on the health and safety aspects of pesticides (ILO 1991). However, materials developed without taking local conditions into consideration are difficult to use and less effective in producing the required output.

The use of pesticides may have implications for the community either through direct exposures during application or through contamination of food and water supplies. Education and information must therefore also be available to the local community.

2.3.4 Pesticide regulation

Several national labour laws and occupational safety and health regulations exclude agriculture from their provisions (Das et al. 2001). Even in developed countries, where legislation is relatively comprehensive, agricultural workers are a neglected occupational group (Iorio 1985). The toxic property of pesticides however, has dictated that their production and use be regulated. Many developed countries are promoting the least hazardous alternatives by using regulations to ensure that high-risk chemicals, those which are toxic, persistent and bio-accumulating and the use of which cannot be adequately controlled, are phased out or banned. Regulations vary from country to country, but there are internationally agreed principles to avoid the overuse and misuse of pesticides (FAO 1990, ILO 1991). The government of Tanzania has enacted laws (TPRI Act. 1979, Plant Protection Act. 1997) to regulate the production, import, export, registration, and use of chemical formulations used in agriculture. However, more than 20 years since the first pesticide registration and control law was passed, pesticides are still used haphazardly and the scale of pesticide poisonings in the country is unknown.

2.4 Agriculture and pesticides in Tanzania

Agriculture is the core of economy and the largest employer in Tanzania. The country has a population of 32 million, with its 3% annual growth rate being among the highest in the world (WHO 1999). More than 80% of the population lives and works in rural areas, with approximately 90% of the adult population being farmers who make their living exclusively cultivating the soil, and only 5% being part-time farmers. Small-scale farms (<40 hectares) produce more than half of the marketed agricultural produce. Agriculture covers not only primary production, i.e. farming, poultry, fish-farming, livestock breeding, but many other associated operations such as irrigation, pest management, crop processing, storage and packaging, and associated services including domestic tasks. Agricultural work involves to a great extent whole families (children, women, and the elderly), who perform a wide variety of tasks, and are exposed to several risk factors including biological, physical and chemical agents. Pesticides are recognized as an important occupational hazard for agricultural workers. Over the years, the use of pesticides in agriculture has spread rapidly in Tanzania (Ministry of Agriculture 1997). While the important contribution of pesticides in increasing agricultural yields and reducing vector-borne diseases has generally been appreciated, concern over their harmful effects on man and environment has only recently gained attention.

2.4.1 Major crops

A variety of crops are grown in Tanzania, including food crops (maize, beans, rice, potatoes and others) and commercial crops (cotton, coffee, tea, cashew, wheat, sugar cane, horticultural crops, and others). The major cotton growing areas in Tanzania are the north-western part of the country, including Mwanza and Shinyanga, and small areas in the west (Kigoma and Kagera) and south-west (Mbeya and Morogoro). Coffee cultivation is concentrated in the north-eastern part of the country (Arusha and Kilimanjaro), in the west (Kagera), and in the southern highlands (Mbozi and Mbinga).

Coffee and cotton are the main crops of interest in the present study due to high pesticide use. Coffee as a permanent crop covers the highest acreage in the major regions (Fig.1) and is grown by both large- and small-scale farmers. The total area under coffee cultivation has been on the increase for the past 30 years, but the yield during the same period has dropped (Fig. 2) in most regions (Ministry of Agriculture 1997). Cotton is a temporary crop in many small-scale farms, and is frequently, like coffee, treated with pesticides. It is estimated that the number of agricultural workers engaged in cultivation of these crops in Tanzania is 3.3 million. Since over three million people are involved in the cultivation of coffee and cotton, the public health impact of pesticide intoxication can be seen to be potentially very important.

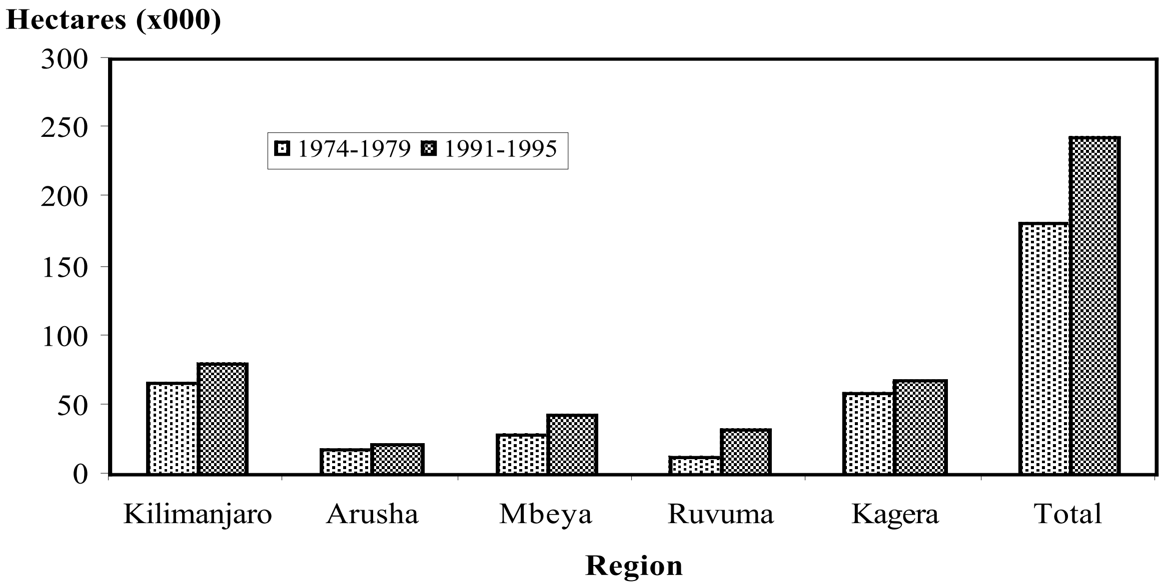


Fig. 1: Coffee acreage in major regions in Tanzania

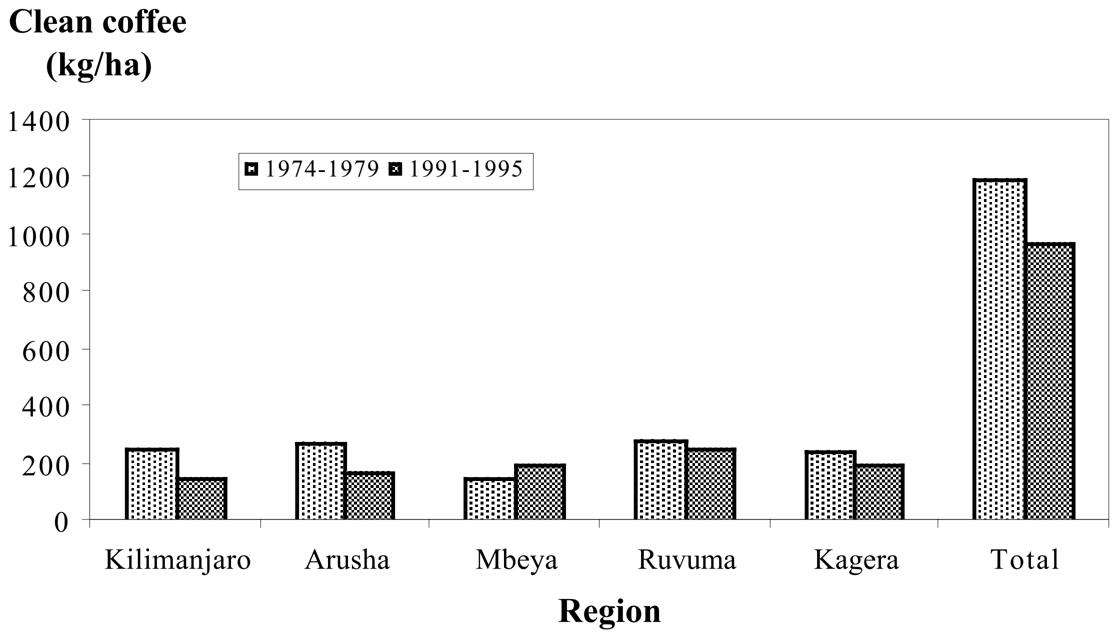


Fig.2: Average of coffee yield in major coffee regions

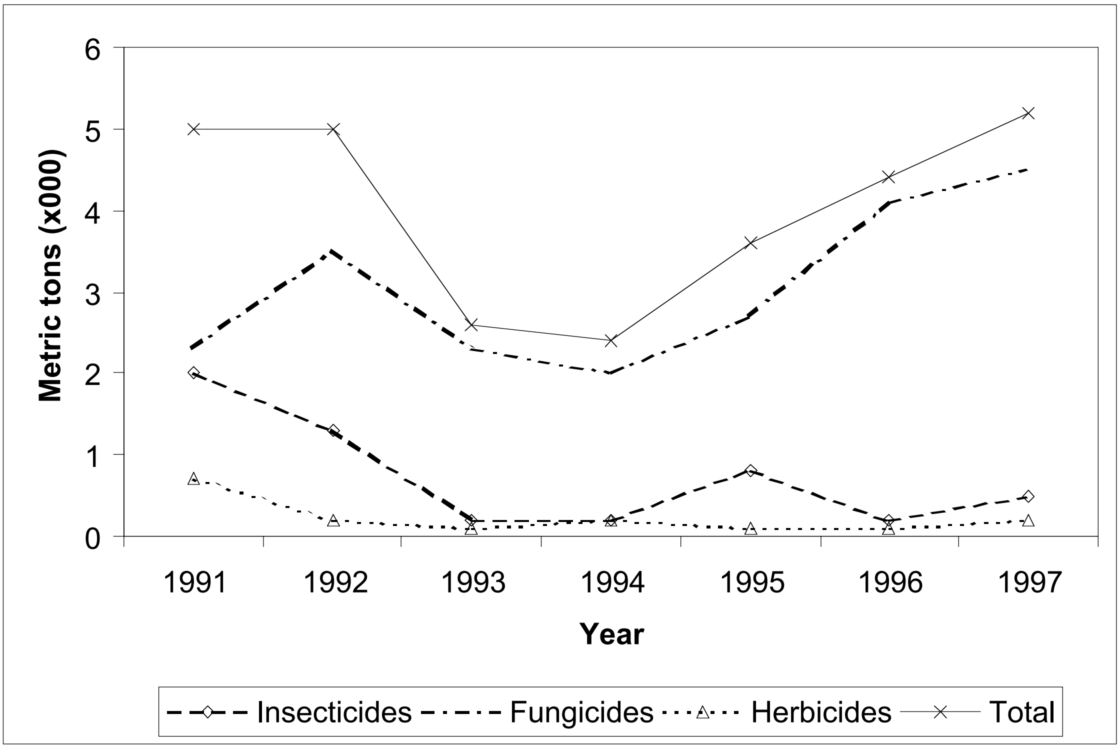
2.4.2 Pesticide use

Tanzania does not manufacture synthetic pesticides but produces crude pyrethrum from flowers of *Chrysanthemum*, which grow well in the high altitude zones of the country. Pyrethrum is extracted from the flowers by the Tanganyika Extract Company at its factory in Mafinga, and exported in its crude form to Europe and Japan. A small portion of the produce is used locally for the production of household insecticides. Originally the pyrethrum waste product was sold to China and Europe, but most of it is now used locally for the control of maize stem borer and production of mosquito coils. Pyrethrum production in Tanzania has been on the decline over the past two decades due to poor agricultural policy as well as unrealistic competition from synthetic pyrethroids. Synthetic pyrethroids are more potent but comparatively more damaging to the environment through production and use. Unlike its neighbouring Kenya, pyrethrum production, research and development in Tanzania is minimal.

Tanzania is annually increasing its importation of pesticides from European and North American countries (Kaoneka and Ak'habuhaya 2000). Formulation factories within the country are subsidiaries of multinational companies, such as Syngenta and Hoechst. Since 1992 the importation and distribution of pesticides was completely liberalized. Agricultural development in Tanzania has accelerated for a number of years in parallel with farm inputs to boost both the quality and quantity of harvests. Pesticides take up 90% of the agricultural inputs in coffee (Ministry of Agriculture 1997). In general, pesticides are widely used in Tanzania, not only for agricultural and veterinary purposes but also in public health activities, particularly vector control programmes.

Although it is not possible to obtain the figure for quantity of pesticides used in or sold to the agricultural sector, however, the available information indicates that the recorded purchase of pesticides rose five fold between 1984 and 1986, and continues to rise (Fig 3). This is likely to reflect an increase also in the true purchases despite the perception of public and government interest groups that the use of pesticide in Tanzania is limited, particularly by poor farmers who have difficulty affording pesticides. There is also rapid expansion and demand for pesticides in floriculture and horticulture. The dip in metric tons of imported pesticides between 1993–1994 is a reflection of policy changes that occurred in

1992 to remove government subsidy for pesticides. Pesticide control regulations in Tanzania came into effect in 1984, which might explain the recorded five-fold increase in pesticide purchase. Unlike for developed countries, figures for Tanzania on pesticides quantity per land area are not available.



Source: (Ministry of Agriculture 1997, Lekei and Mndeme 1999)

Fig. 3: Pesticide imports into Tanzania 1991–1997.

2.4.3 Pesticide regulation

The registration and control of pesticides in Tanzania was regarded part of a comprehensive law, the Tropical Pesticides Research Institute Act (TPRI 1979), until 1997 when a new law, the Plant Protection Act, was passed by the parliament to deal with the so called “plant protection substances”. Therefore, pesticides used in agriculture, animal husbandry and public health are regulated under two laws within the Ministry of Agriculture. There are numerous pesticide importers and traders whose activities are regulated, but there are no official regulations governing the distribution of pesticides in Tanzania. Pesticides reach end users through various channels, which include crop marketing boards; retail shops (private and associations); Ministry of agriculture (for sale to farmers in large scale operations against for example, armyworm, bird pests and special operations).

The country still uses persistent organic pollutants, endocrine disruptors and outdated organochlorines such as DDT, dieldrin and highly toxic organophosphorus pesticides, which have been banned or severely restricted in many developed countries. Although mechanisms to control manufacture and importation of pesticides exist, the poor mechanism of distribution of pesticides in Tanzania reflects on the inefficiency of the existing regulatory systems. Legally authorized pesticides find their use in dangerous areas elsewhere, for example, DDT imported for the control of plague, transmitted by fleas, was found in use against pests that attack cabbage. Surprisingly, DDT was also found in use for the control of stored maize pests in one of the prisons in Tanzania. Lack of expertise and adequate experience by pesticide regulatory authority staff makes it hard to exert influence on policy makers and importers of pesticides.

Pesticide exposure and poisoning is a highly neglected public health problem in Tanzania and most other developing countries (Partanen et al. 1991, Ngowi et al. 1992). Citizens and policy makers are not generally aware of this problem due to a lack of valid information on the subject. In view of the extensive exposures, adverse health effects and over-stretched health care resources in many developing countries, prevention of pesticide poisoning emerges as the most viable option to reduce the harmful impact on the population. Every time a person gets ill or dies of pesticide poisoning a number of people, especially dependants, suffer. Children become particularly vulnerable to hosts of physical, emotional and societal dangers. Moreover, communities and the nation suffer a shortage of labour force necessary for development. The present study provides a local scientific basis for the development of strategies to reduce and control poisonings in farming communities by prevention of pesticide exposures.

3 Aims of the study

The general objective of the present study was to assess acute health hazards posed by pesticide handling, storage, and use on agricultural estates and small farms in Tanzania where coffee, cotton, and possibly other important crops are grown, with a view to developing strategies for the reduction and control of exposure to pesticides and prevention of pesticide poisoning. Specifically, we set out to

1. Compile lists of pesticides available, in use, suppliers, crops treated, poisoning cases, pesticide legislation, and pesticide training policy in Tanzania;

2. Evaluate pesticide handling practices during the spraying season;

3. Determine the frequency and intensity of exposure to organophosphates and associations between external exposure, exposure biomarker, symptoms, and use of protective equipment;

4. Assess the knowledge, attitudes, and practices of agricultural extension workers with respect to health effects of pesticides in Tanzania;

5. Identify relevant experiences and practices, and assess the knowledge of health care providers in the prevention and treatment of adverse health effects of pesticides.

4 Materials and methods

4.1 Design

A detailed standard protocol was developed jointly between Kenya, Tanzania, Uganda, Finland, and Canada to follow the best epidemiologic principles of a field study. The study followed a sequence of three phases: (i) preparatory (pilot) phase; (ii) implementation stage I (data collection); and (iii) implementation stage II (further data collection, analysis, and reporting). The preparatory phase was devoted primarily to collection of background data; recruiting, hiring, and training of staff; acquisition of supplies and obtaining and installation of equipment; developing and refining of procedures and study instruments, and finally, selection of study sites and recruitment of study subjects. The implementation phases were devoted to actual data collection and accomplished in two stages. Implementation stage I, supposed to take one year, focused on exposures to organophosphates and carbamates in coffee growing areas of north-eastern and southern Tanzania. Implementation stage II also took one year and focused on exposures to organochlorines and pyrethroid insecticides in cotton growing areas of eastern and western part of the country. The study was a multiple programme including a systematic observation of farms and farm practices, interviews of administrators, health care providers and agricultural extension workers.

4.2 Study areas and population

Information on pesticide importation was collected (PAPER I) at the national level through questionnaires sent to the Ministries of Health, Agriculture and Livestock Development, Industry and Trade, Cooperatives, Crop authorities, and Pesticides Registration and Control Division at the Tropical Pesticides Research Institute. Twenty-five questionnaires were sent out by post and by hand, and the information received on importation was compared with the permits issued by the Registrar of Pesticides at the Tropical Pesticides Research Institute. Using a questionnaire designed for the district level, information on pesticide usage was collected in 37 farming districts in the regions of Arusha, Kilimanjaro, Tanga, Morogoro, Iringa, Mbeya, Mwanza, Shinyanga, Mara, and Bukoba, where pesticides were mostly used. All the major pesticide suppliers in the ten regions were visited, and a list of pesticides in their stock collected. Fourteen wards and 86 farms were visited at random for background information using questionnaires designed for these levels (Table 1).

The field study was conducted in 1991–1994 in rural areas in northern and southern Tanzania, where all districts (Arumeru, Arusha, Hai, Moshi rural, Rombo, Mbinga, Mbozi, Sengerema, Magu, Kwimba, Kahama, Bariadi, Meatu, Shinyanga rural, Morogoro rural and Kilosa) conducting intensive farming of coffee or cotton as major crops, and with pesticides being sprayed, were selected as the study areas. Pesticide handling practices by farm workers were observed in 27 small- and large-scale farms selected at random from those who expected to spray at the site during our visit (Paper II). The coffee farms had diverse locations and practices, whereas cotton farms were highly similar.

Table 1. Participants in different (I–V) sub-studies.

Sub Study	**Participants**	**No. of participants receiving forms (No. of respondents)**
I-Background Information Collection	– Ministry of Health, Agriculture and livestock development, Industry and trade, Cooperatives, Crop authorities, Pesticide registration and control division – District authorities – Ward authorities – Village authorities	25 (24) 37(37) 14(14) 86(86)
II-Farm observations	Small- and large-scale farms with spraying in process	27(27)
III- Acute effects*	Small-scale farmers -spraying period n=458 -non-spraying period n=578 →users of OP who participated at both periods	133(133)
IV-Agricultural extension service	Agricultural extension workers	61(61)
V- Health care	Health care workers	104(104)

*participants also had blood assays

The study population for acute effect evaluation (Paper III) was restricted to small-scale coffee farmers who sprayed pesticides, their relatives who did the spraying, and hired spraymen. A total of 350 subjects were recruited into the study, and of these 182 subjects who were in contact with organophosphorus pesticides were considered exposed. Based on the subset of 133 exposed subjects (73%) who were available for blood sampling and interviewing during both spraying and non-spraying periods, acute effects were evaluated.

The service provider population included all agricultural extensionists (Paper IV) and all health care workers (Paper V), both government and private, within 15 km of each farm estate or village under study. The study groups were selected on the grounds that they were either responsible for the agricultural inputs, including pesticides, in their service areas or they were in charge of diagnosis and treatment of poisonings occurring in their service areas. One hundred and four health care workers and 61 extensionists were interviewed.

4.3 Data collection

4.3.1 Questionnaires and interviews

Nine standard forms were developed, translated into Swahili language and back translated into English to ensure validity, pre-tested for understandability and acceptability in the country, furnished with detailed interview instructions, and finally administered during 1989–1994. Accordingly, nine data sets were established:

(1) *National Questionnaire* (12 questions) targeted at ministries, crop marketing boards, cooperatives, farmers' associations, chemical companies and large farms with questions pertaining to pesticides imported, produced, and formulated, and on crops, legislation, and training policies;

(2) *District-level Form* (13 questions) administered to district agricultural development officers, district development directors, and district medical officers aimed at obtaining information on pesticide use, farms, estates, crops, wholesalers, retailers, and other outlets, and on health care facilities and pesticide poisonings;

(3) *Ward-level Form* (11 questions) administered to ward leaders on geographic locations and other basic data on the farms and extensionists;

(4) *Village-level Form* (17 questions) administered to village leaders on farm sizes, numbers of employees, applicators, procurement, equipment, and maintenance;

(5) *Farm Observation Form* (44 items) on spraying, mixing, maintenance, and storing practices;

(6) *Worker Interview Form/Spraying Season* (95 questions) on knowledge, attitudes, practices, and 42 pesticide-related symptoms;

(7) *Worker Interview Form/Non-spraying Season* (62 questions) on 42 pesticide-related symptoms;

(8) *Health Care Provider Interview Form* (35 questions) on knowledge, attitudes, practices, and facilities;

(9) *Extensionists Interview Form* (27 questions) on knowledge, attitudes, and practices.

The principal investigator visited the districts to establish contact with the relevant authorities (agricultural, co-operative union, and health officers) to ensure collaboration. During these meetings, the interview and blood sampling dates were set and the study subjects identified and recruited with the help of village leaders, co-operative union, and agricultural officers. The standardized questionnaires (farm worker, health care worker, agricultural worker) consisting of structured and unstructured items were administered during the pesticide spraying and non-spraying periods, face to face by two trained interviewers, technicians with diplomas from technical colleges, and three researchers with at least first degree diplomas in science subjects.

4.3.2 Observation

Pesticides handling practices were observed and recorded during site visits using an observation form in farms chosen at random from those due to spray. The average duration of observation was six hours per farm (range 4–8 hours). On one occasion the observation took two days. The principal investigator or a co-investigator did the observation and recording.

4.3.3 Cholinesterase Assay

Erythrocyte acetylcholinesterase levels, indicative of exposure to cholinesterase-inhibiting organophosphate and carbamate insecticides, were determined for all recruited subjects. Blood acetylcholinesterase activity and blood haemoglobin levels were determined using the Testmate^{TM} Organophosphate field kit during spraying and nonspraying periods. The kit was pre-tested, and approved for field use by the World Health Organization. Approximately 18 ml of blood was drawn by veni-puncture. Ten µl was assayed (Anonymous 1991). The acetylcholinesterase activity, measured in international units (IU), was automatically corrected for ambient temperature and haemoglobin. Field staff tested themselves to make sure the assay function properly. A technician blinded in regard to exposure status of subjects performed the field kit measurements.

4.4 Statistical methods

Data analyses consisted of significance testing for cross-tabulations. Outcome measures are presented as absolute numbers, prevalences, prevalence ratios, arithmetic means, and p-values. Statements made on observations and open-ended questions that were not coded were also used for illustration and concretisation of numerical data (PAPERS I–V). P-values were based on the chi square distribution, uncorrected for continuity, and two-sided Fisher's exact test, when the smallest expected frequency was <5. The mean acetylcholinesterase levels during the spraying period, for users and nonusers of personal protective equipment, were compared and tested for significance with t-distribution. Paired t-tests were used to test for difference between spraying and non-spraying periods of the mean acetylcholinesterase and of the number of symptoms. The differences in symptom prevalences between spraying and non-spraying periods were tested with McNemar test (Paper III).

4.5 Ethical considerations

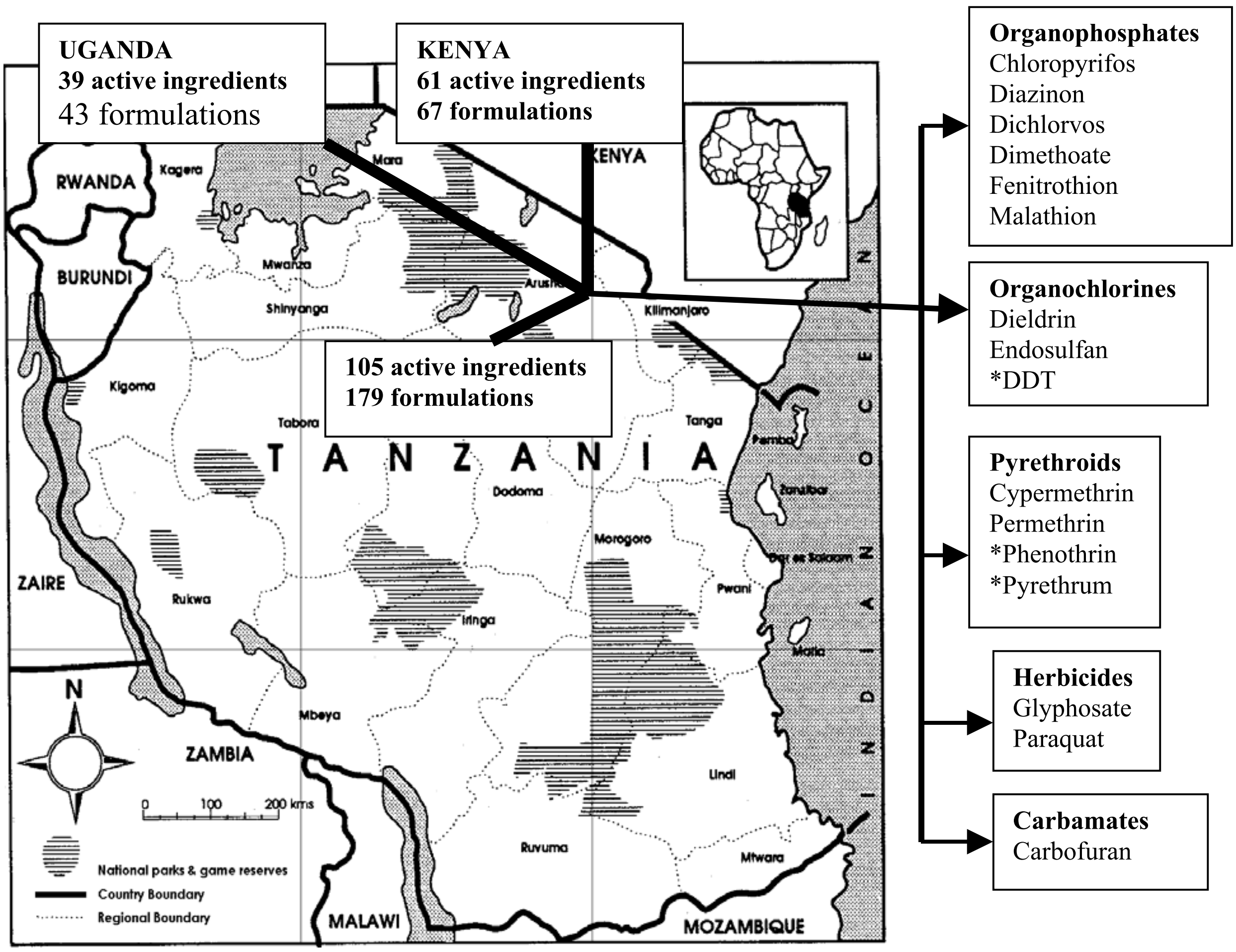
The ethics committee of the Ministry of Health of Tanzania approved of the study and the study participants provided an informed consent. A guiding principle was “Do not harm”. The study was explained to all study subjects, detailing procedures and potential benefits of the study to them and their communities. Subjects were not obliged to participate and they were free to drop out at any time. Those with adverse health effects possibly due to pesticide exposure were informed of them and referred to the nearest health care facility.

5 Results

5.1 Pesticide usage and acute effects

5.1.1. Usage

Most of the pesticides used in East Africa (Fig. 4) were imported from Europe, North America, and Japan. However, some were formulated locally by multinational subsidiary companies, such as ZENECA (now Syngenta) and Hoechst (TZ) Ltd (Table 2).



* Used only in Kenya and Tanzania

Fig. 4 Types of pesticides commonly used in East Africa

Table 2 Major Pesticide Formulation companies in Tanzania.

Company	No. of formulation	No. of Active Ingredient.
ZENECA (now Syngenta)	26	17
Sapa Chemicals	29	18
Tanzania Links Ltd.	14	7
Hoechst (TZ) Ltd	2	2
Mansoor Daya	1	1
Jenus Ltd	2	2
Rentokil	2	2
Express Africa Ltd	2	2
CPL Dar-es-Salaam	2	2
Tanzania Pesticides & Pharmaceuticals Ltd	1	1

There were about 81 formulations produced from 54 active ingredients, which consisted of organophosphorus and carbamates (29%), organochlorines (17%), pyrethroids & pyrethrins (14%), and others, which include fungicides, herbicides, rodenticides and fumigants (40%).

Twenty-four out of 25 questionnaires sent out to the Tanzanian national bodies known to import pesticides into the country were completed and returned. Ninety eight percent of the information given in the questionnaire matched with the records available in the registrar's office on permits issued, there being no dominant importer of pesticides for the period 1987 to 1991 (Fig 5). Only 2% of the pesticide imports in the total period of 1987 to 1991 entered the country through unknown channels. Although the main formal international trade in pesticides concentrated on pyrethrum products through a Preferential Trade Area agreement, illegal trade existed for the imported products (PAPER I).

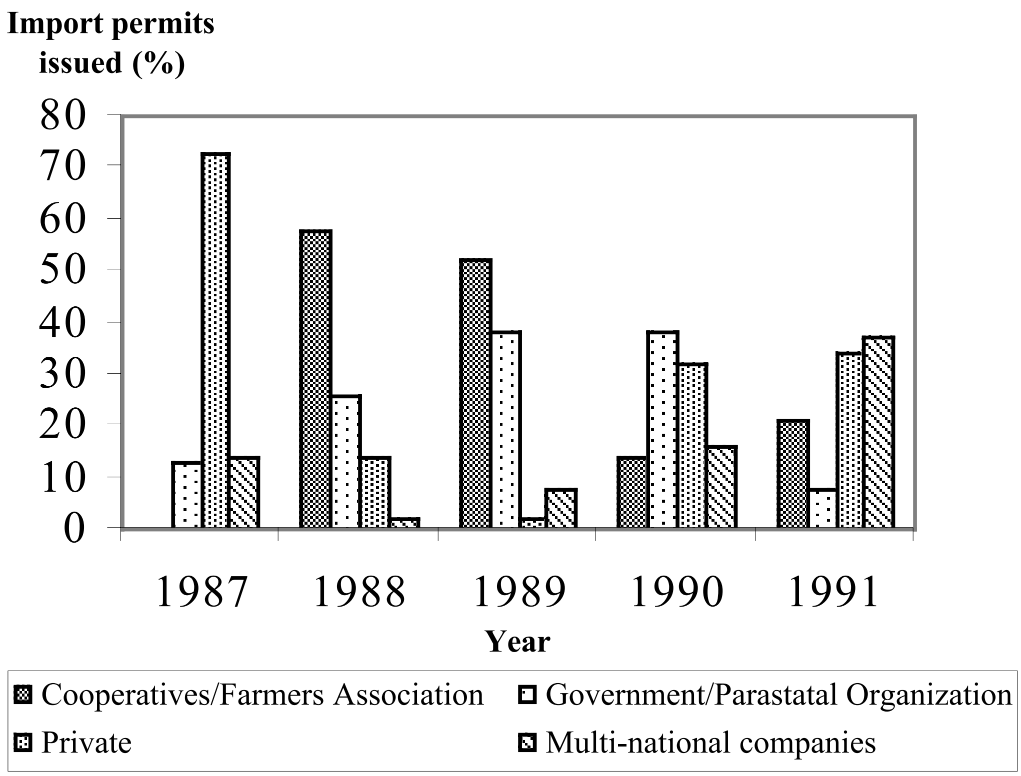


Fig 5 Distribution of pesticide import permits by applicants in Tanzania.

Tanzania recorded more active ingredients (105) and formulations (179) and used more pesticide mixtures than the other countries in the region (Fig. 4). Most of the pesticides used in coffee and cotton growing areas of Tanzania (PAPER II) belonged to the World Health Organization Hazard Class[4] II, but there were more pesticides available in the country, including some in World Health Organization Hazard Class Ia such as aldicarb, phosphamidon, ethoprophos and Ib chlorfenvinfos, dichlorvos, carbofuran, and methomyl (APPENDIX 1). Persistent organic pollutants such as aldrin, DDT, dieldrin and toxaphene; endocrine disruptors including atrazine, DDT, lindane and toxaphene; and carcinogens such as captafol were also recorded. The pesticide mixtures also contained World Health Organization Hazard Class Ia and Ib compounds, which were used mostly as household pesticides (non-agricultural) and herbicides. The active ingredient and common names of about 12 different formulations used mostly on non-agricultural pests could not be identified, as they were not among the 206 formulations registered for use in the country in 1998 (Lekei and Mndeme 1999).

[4] World Health Organization Hazard Classification (WHO 1998): Class Ia=extremely hazardous; Ib=highly hazardous; II=moderately hazardous; III=slightly hazardous; O=obsolete as pesticide; U=unlikely to present acute hazard in normal use.

Table 3 Pesticides Distribution in Tanzania

Distributors	% Distribution
Crop Marketing Boards through Cooperative Societies.	69.9
Retail Shops, TFA*, etc.	22.6
Non Officials (most black marketeering)	6.5
Ministries	0.5
Donors	0.5

* TFA - Tanganyika Farmers Association

The distribution of pesticides was well organized in Tanzania, although there were no regulations to govern the process. Crop marketing boards through their cooperative societies (Table 3) were found to be the largest distributor of pesticides to farmers. These cooperatives loaned pesticides to farmers and recovered the costs later from their produce sales. In this respect, the arrangement was more favourable to farmers than buying pesticides with cash from retail shops and other sources.

5.1.2 Health effects

For the period 1989/90, a total of 736 pesticide-poisoning cases were reported in the Tanzanian in-patient district hospital medical records. Adults accounted for 93% of the poisoning cases, the number of poisoned women was 6% higher than men, but the situations (occupational or non-occupational) leading to poisoning could not be ascertained from the records. The recording system did not include data on cause or type of poisoning.

Erythrocyte acetylcholinesterase activities in exposed subjects (PAPER III) during spraying and non-spraying period were comparable (mean 32.0, SD 7.8 vs. 33.0, SD 8.7 units per g HgB, $p = 0.26$). The prevalence of cough, headache, abdominal pain, excessive sweating, nausea, excessive salivation, diarrhoea, and vomiting did not differ significantly between spraying and non-spraying periods (Table 4).

Table 4. Prevalences of organophosphate related symptoms among exposed subjects during spraying and non-spraying.

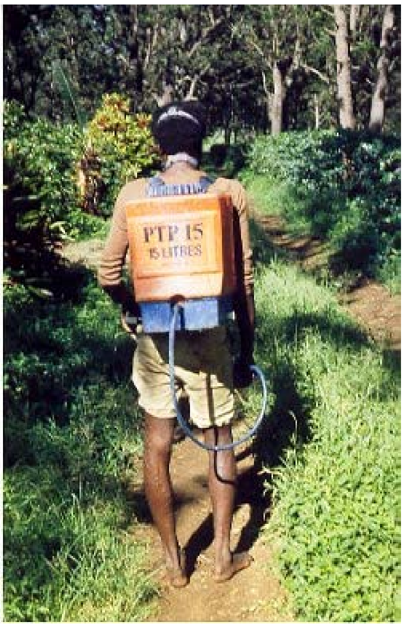
Symptom	Prevalence (%)		
	Nonspraying period (N=133)	Spraying period (N=133)	p[1]
Cough	30.8	33.8	0.69
Headache	27.1	30.1	0.64
Feeling weak	25.6	22.6	0.64
Difficulty in seeing	27.1	22.6	0.38
Dizziness	19.5	15.0	0.38
Abdominal pain	6.0	12.8	0.06
Excessive sweating	7.5	12.8	0.23
Nausea	10.5	11.3	1.00
Excessive salivation	8.3	10.5	0.66
Diarrhoea	5.3	8.3	0.45
Vomiting	4.5	6.8	0.58

[1]McNemar test

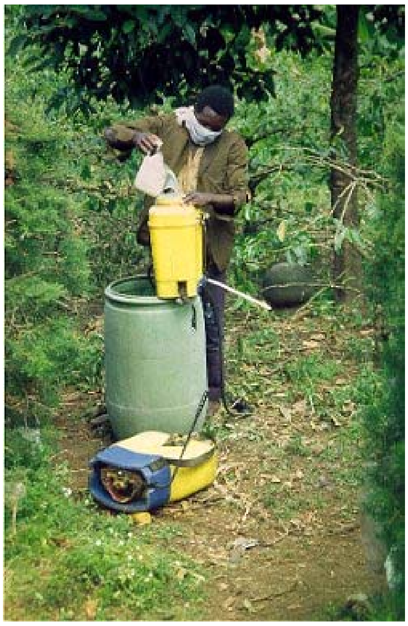
There was no suggestion of decreased erythrocyte acetylcholinesterase in exposed subjects who complained of organophosphate related symptoms compared to symptom-less exposed subjects. However, the mean change in erythrocyte acetylcholinesterase level from nonspraying to spraying periods in farmworkers who developed symptoms during spraying and in those who did not showed significant differences for excessive salivation (change –8.90, p = 0.001) and diarrhea (change –7.30, p = 0.005). All subjects who experienced the listed symptoms (PAPER III, Table 3) only during spraying had on the average increased acetylcholinesterase levels during spraying for all the symptoms while the levels decreased during spraying on the average in all those without symptoms. The use of gloves, long boots, head cover, face cover, and coverall was not significantly associated with acetylcholinesterase activity.

5.2 Hazardous practices

Pesticides banned or restricted in the country of origin (PAPER I), due to unfavourable effects and classified into World Health Organization Hazard Class Ia and Ib were available on the Tanzanian market (Appendix 1). The pesticide formulations were available as mixtures, at times further mixed with other formulations during application.



Spraying herbicide barefoot, without gloves, but with respirator on to protect from inhalation exposure.



Refilling sprayer without gloves, but with kerchief to protect from inhalation exposure

Ultra Low Volume spraying on cotton was less hazardous compared to use of knapsack in coffee spraying.

Pesticide handling expose individuals as well as the environment.

Distribution on market day involved transport of pesticides with food items.

Inappropriate containers may be damaged in store leading to leakage, contaminating warehouse environment and items stored together with the pesticides.

Disposal of empty pesticide containers may lead to environmental contamination.

Dumped obsolete pesticides may lead to environmental contamination through leakage

The present study (PAPER II) revealed that the number of pesticide formulations applied in coffee farms were three times more than in cotton farms and twice more in individually owned compared to cooperative farms. In the coffee farms, unlabelled pesticide containers and missing mixing instructions were encountered in one out of ten farms, while pesticides stored in bedroom, near food, or open fire, were found in two out of ten cotton farms. Hazardous practices were more frequent in individually owned than cooperative farms, and likewise the differences in pesticide storage areas, unlabelled, and non-original containers were noticeable.

Bulk supplies constituted a hazard at distribution points.

Smaller containers are more appropriate and preferred.

An elevated platform serving as a pesticide storage within reach of unauthorized persons particularly children.

Pesticides hidden inside a shack contaminate other items including grains for food and animal feed.

5.3 Agricultural and health care service

A large proportion of the Tanzanian agricultural extensionists claimed knowledge of first aid procedures in case of pesticide poisoning (PAPER IV). However, many procedures described were not appropriate for pesticide poisoning. Most extensionists knew that pesticides could enter human body, but only a quarter perceived pesticides as a major problem in the community they served. The extensionists identified many pesticides and operations as potentially responsible for pesticide poisoning. The pesticides identified ranged from captafol, which was banned in Tanzania in 1986, to chlorothalonil, which under the World Health Organization Hazard Classification is considered unlikely to cause any harm. Spraying was the main operation recognized as causing poisoning. Moreover, the majority declared awareness of the potential health hazards of the different pesticides used in their service areas. The extensionists also proposed a range of perceived effective ways for preventing work related pesticide poisoning in their communities.

A survey of the Tanzanian health care providers found that 80% of them reported having attended to a pesticide poisoning case, with a substantial proportion reporting seeing more than 20 pesticide poisoning cases. Personnel in coffee areas reported more cases than in cotton areas, and hospital staff more than other staff. Pesticide poisoning was considered a major problem in the community by two thirds of the health care providers, especially hospital personnel. A third of the health care providers believed that a proportion of pesticide poisonings remains unrecognised, more so in cotton than in coffee growing areas. The respiratory route was the most frequently recognized route of pesticide entry into the human body, followed by gastrointestinal, skin, and eyes, in that order. Non-hospital personnel recognized more routes of exposure than hospital staff. The health care providers were not able to classify pesticides as organophosphates, organochlorines or pyrethroids.

6 Discussion

6.1 Main findings

The general objective of the present study was to assess the health hazards posed by pesticide handling, storage, and use in agricultural estates and small farms in Tanzania where coffee, cotton, and other important crops are grown, with a purpose to develop strategies for the control of pesticide exposure and prevention of pesticide poisoning. The general motivation for an assessment of pesticide use and practice in Tanzania was a growing concern about the risk of pesticides to human health. The particular motivation for the study was an almost complete lack of relevant information in the country. The findings of the present studies could lay foundation for the development of strategies to prevent and control pesticide poisoning not only in Tanzania but also in the other East African countries.

The results demonstrated an indiscriminate availability and use of pesticides banned or restricted in the country of origin including aldrin, endosulfan, DDT, dieldrin, camphechlor, and lindane. Some of these pesticides are known to be endocrine disruptors, which can produce adverse effects by interfering in some unknown way with body hormones or chemical messengers. As yet, there are still many aspects of these substances that are not understood even by their manufacturers. Others are persistent organic pollutants that have created global alert and concern leading to an international convention aimed at stopping their production and use worldwide. A similar scenario was found to exist in East Africa and other countries in Africa, including Malawi (Hillocks et al. 1999). In Tanzania, the existing regulatory system appeared ineffective and, consequently requires improvement in order to safeguard pesticide users, the general public, and the environment. There is general concern about high potential of occupational and non-occupational exposures, which could produce unintentional or intended poisoning, due to extensive and inappropriate use of pesticides.

The current survey indicates that only 2% of all pesticide imports came in through unknown channels, a fact which was not recognized before. However, former experience suggests that the pesticide regulatory authorities in Tanzania are not well equipped to regulate the pesticides registered for use in the country (Kaoneka and Ak'habuhaya 2000). It is generally known that the competence necessary to review and integrate critical hygienic, toxicologic, epidemiologic, risk assessment, and risk management data, supplied to them by pesticide registrants is lacking. Local resources available at institutions, including universities and other research institutions, within or outside the ministries are under-utilised in the registration process.

The present study also revealed that pesticide handling practices in individually owned farms were more hazardous than in cooperative farms, frequently increasing health hazards of workers and their families. Several studies conducted in a number of developing countries have reported similar practices (Cox 1985, Haynes 1985, London 1994, Kimani and Mwanthi 1995, Clarke et al. 1997); however, most of the reported practices were based on spraying only, while the present study had a wider scope. Under normal working conditions around the farms in Tanzania, we traced hazardous practices at pesticide packaging, storage, mixing and disposal of excess pesticides, as well as of empty containers. Pesticide safety in small farms in Tanzania thus turned out questionable. The farming community was found to be dangerously unaware of the existing pesticide hazard, for example they stored pesticides in a rather careless manner. Packaging, labelling and disposal of pesticides was predominantly inadequate and poorly controlled.

Organophosphate compounds were the most widely used pesticides in Tanzania, in terms of number of active ingredients and formulations as well as potential health hazards. There was also a policy shift towards substituting organochlorines with organophosphates and carbamates, which are considered less persistent and cumulative. However, such measures have not been effective in pest control and have led to introduction of more highly toxic products. Organophosphates and carbamates have considerable health implications, and increasing their importance will require parallel measures to deal with their impact. Limiting the use of the World Health Organization Hazard Class Ia and Ib pesticides, emphasis on integrated pest management; appropriate training and education are among the measures that could be taken to minimize adverse health impacts of pesticides.

Inappropriate handling of pesticides remained common in farming communities in Tanzania. Acute poisoning was not very common and was not as conspicuous in coffee growing areas of Tanzania as in many other countries in the third world. In a sister East Africa Pesticide Network study in Kenya, workers in horticultural farms who used organophosphates, as would be expected in similar farms in Tanzania, were found to have an acetylcholinesterase inhibition that was also associated with symptoms. However, the present study found no strong indication for adverse effects of organophosphorus pesticides under investigation during the study period, either on erythrocyte acetylcholinesterase or symptoms. The results obtained for the mean change in erythrocyte acetylcholinesterase level from nonspraying to spraying period in farmworkers who developed symptoms during spraying and those who were symptomless did not support the hypothesis of harmful effects. The inconsistency may be due to bias e.g healthy worker effect. It was possible that among those similarly exposed on long term (similar levels in nonspraying season) those healthy opted to spray. It would however be better if confirmed by further research by adjusting for the health status. The study population had small farms and sprayed mostly World Health Organization Hazard Class II pesticides due to restricted access to more toxic pesticides for the coffee crop, hence, exposures might have been too low to detect any acute effects. However, there is a great concern over long-term effects arising from the use of pesticides in these areas, due to increases in immuno-deficiency, cancer, reproductive health (infertility) problems, and neuropsychological sequelae (Mwaluko et al. 1991, Wesseling et al. 2001), possibly associated with exposure to pesticides. The present study did not address these endpoints directly.

Several efforts have been made to control the risk of exposure to pesticides in developing countries, in Tanzania they have been implemented through the agricultural extension service. However, there had been no attempt so far to assess the knowledge, attitudes and practices of agricultural extension workers with respect to health effects of pesticides in the country. The present study revealed that the majority of extensionists claimed knowledge of first aid procedures in case of pesticide poisoning, but many procedures described were not appropriate for pesticide poisoning. In other countries, agricultural extension is audited regularly and action taken to rectify shortcomings, but there is no such evaluation in Tanzania. Nevertheless, the appropriate role of extensionists in reducing the adverse health impact of pesticides would be advocating pesticides of low toxicity or non-chemical pest control.

There has been a tendency to give blanket coverage to pesticide users in campaigns to prevent unintentional pesticide poisoning. An association of pesticide industry, *Groupement International des Associations Nationales de Fabricants de Produits Agrochimiques* (now CropLife International), sponsored safe use projects in Guatemala, Kenya and Thailand in 1991. Although the industry claimed a success of their campaign to reduce pesticide related illness and environmental problems, the claim was however, challenged by Murray and Tailor (2000) for the unscientific conclusions drawn from the programme, particularly in Guatemala. Putting a greater effort in populations with the highest hazards is likely to be more effective. This conclusion is consistent with the results of the present study.

Pesticide poisoning implies a need for health care services. The health care providers contacted in the present study were not able to identify pesticides as organophosphates, organochlorines, or pyrethroids. The failure to distinguish organophosphorus and organochlorine compounds reflects a lack of knowledge of the fundamental principles of diagnosis and treatment of pesticide poisoning, and their impact on the prognosis. As an example of the risks involved He et al. (1989) reported deaths resulting from incorrect diagnosis and inappropriate treatment of patients in China.

Assessment of the extent of the problem is difficult, as the national health management information system in Tanzania (Ministry of Health 2000) does not distinguish between pesticide poisoning and other poisonings in the medical records and statistics. The higher percentage of hospital personnel considering pesticide poisoning a major problem when compared with non-hospital staff reflects the fact that poisonings are treated more frequently in hospitals than in other health care facilities (Albertson and Cross 1993, Eddleston et al. 1998). Poisoning victims are frequently referred to hospitals in many countries, but delays in correct diagnosis, evaluation and treatment of poisonings, particularly those due to organophosphate pesticides, frequently occur in developing countries resulting in an increased risk of casualties. The present study indicates a need for improvement of training, equipment and supplies in the health care facilities diagnosing and treating pesticide poisoning.

6.2 Validity

A pilot study was conducted to standardize practices of the survey. All study subjects were fluent in Swahili, the official language of Tanzania, despite the fact that the study subjects spoke many tribal languages. The field design (PAPER II and III) allowed pre-post exposure comparisons, and included interviews and biological assays conducted during the spraying and non-spraying periods. Study size in the farmer/farm worker component study (PAPER II and III) was sufficient to detect moderate and strong effects. The extension workers and village leaders who selected the farmers and farm workers might have selected those more likely to represent the practices, thus rendering a possible selection bias. The direction of the bias, if any, is hard to conjecture, since the selection may have favoured either heavily exposed and affected subjects or those with less exposure and better health. As far as was understood in discussions with the agricultural extension workers, village leaders and farmers, however, the selection was representative of the target populations.

Although measures were taken to ensure that the questions in all interview forms were clear and understandable, the possibility for questions not being fully understood, particularly among farmers and farm workers, cannot be ruled out. There is also a possibility of bias in the reporting of symptoms in case of farm workers who might have felt uneasy about job stability, if they would be referred to a hospital for medical checks or treatment on account of symptoms. Moreover, there were conditions which could have caused similar symptoms, leading to misclassification which if non-differential tend to attenuate or diminish results. There was no data on amount of pesticides sprayed that could have explained the acetylcholinesterase activities.

Systematic observation of farms and farm practices and interviews of administrators, health care providers and agricultural extension workers strengthen the study considerably. Comprehensive evaluation of factors contributing to pesticide exposures is in this sense rather unique worldwide. The present study was the first study looking at the multiple aspects of pesticides exposures in Tanzania in a scientific way.

6.3 Implication

The present study demonstrates a need to monitor pesticide safety, particularly on coffee farms and on individual farms. The findings reported in PAPER III on acute effects of organophosphates in coffee growing areas in Tanzania will be useful in formulating *intervention studies* for the relevant areas, but may not be directly applicable to other locations and crops where organophosphates are used. The survey indicated a need for training of hospital staff in toxicity of pesticide exposure, and for agricultural extensionists in first aid. In order to reduce the adverse health impact of pesticide exposure in agriculture in Tanzania, there is a need for further research, law enforcement, surveillance, education and training.

6.3.1 Further research

The use of epidemiological methods in the assessment of pesticide poisoning in Tanzania is rare due to a shortage of expertise and other resources. However, by consolidating the north-south and south-south collaboration initiated by the current research, other studies should be possible. Scientific research involving researchers and farmers to identify the types of pesticide risk in farmers' operations as well as structural constraints inhibiting safe use practices is necessary, together with prospective studies to quantify the extent and public health impact of health hazards of pesticides for proper interventions.

Further, there is a need to introduce integrated pest management due to potential adverse health effects from the hazardous pesticide practices and poor support services in the agricultural areas of Tanzania. Assessment of the linkage between farmers' implementation of integrated pest management procedures and reduced health risk, along with an increase in net economic returns, will ensure that pest management programmes yield concrete improvements in pesticide problems.

The hazardous storage and disposal practices revealed in the present study justify the need for evaluation and regulation of pesticide storage and disposal facilities, particularly in the coffee farms.

6.3.2 Regulation

Elimination and reduction of pesticide supplies offers a good exposure control strategy. The authorities should introduce measures to eliminate highly toxic pesticides from the market, and to ensure competency of the applicant before issuing a license for pesticide trading. Quantities and types of pesticides in actual use should be surveyed regularly to establish use patterns. The regulatory authority in Tanzania should regulate the distribution of pesticides in the country. A pesticides inventory (trade and common names), indicating the appropriate chemical class for each pesticide could be kept available at each store at supply points, as well as farms, to be used by specialists as needed. Pesticide inventories could be used together with databases, such as International Chemical Safety Cards and material data sheets, to provide relevant information for health and safety interventions. The shortcomings in pesticide packaging and labelling legislation should be corrected.

6.3.3 Surveillance

The current study was hampered by unavailability of reliable pesticide poisoning data. Measures should be taken by relevant authorities to establish a pesticide poisoning surveillance registry, which tracks pesticide exposures and illnesses throughout the country. Health care professionals should be required to report pesticide-induced illnesses to this registry, and individuals who are concerned that they may have a pesticide-induced illness may also submit a report. The reported information should be used to analyse the validity of poisoning data as well as to characterize disease patterns.

6.3.4 Education and training

To reduce the incidence of pesticide exposures and pesticide-related illnesses, the public should be educated about potential situations that may lead to exposure and subsequent adverse health effects. Research needs to be carried out to determine the kind of training that might be most effective to achieve a sustained behavioural change in the adoption of safe practices in agriculture.

There should also be an initiative to raise awareness regarding pesticide poisoning prevention, recognition, management, and reporting by health care professionals. Agricultural extension workers should be educated on pesticide hazards and safety measures, and on alternative pest control methods available, to improve their capacity to fulfil their duties.

6.3.5 Local Collaboration

The primary health care system should be closely linked to the agricultural extension services and include occupational health care in the system. Prevention, recognition and treatment of pesticide poisoning should be regarded as a priority in agricultural areas and any future project will need to be tailored to local conditions. In this study, the health care services with respect to adverse effects of pesticides were regarded as inadequate.

7 Conclusions

The aim of the present study was to gather information with a view to developing strategies for the reduction and control of exposure to pesticides and prevention of pesticide poisoning. The conclusion presented in Table 5 is based on the present study material.

The proposed strategies and the evaluation of feasibility of the strategies provide a framework that could be used for future initiatives to address the problem of harmful pesticide exposures in Tanzania. The strategies proposed are those that are feasible under the present situation should there be adequate funding and linkages for collaboration. Local training materials and qualified experts are in short supply, however, the capacity of local institutions, such as TPRI and the universities could be enhanced to enable them develop relevant materials and offer training in relevant pesticide fields. Higher training programmes could also be arranged with other universities outside the country as a short-term measure while the possibility of incorporating the subject in the local curricula is sought.

Table 5 The summary of study results and proposed strategies, feasibility of carrying out strategies and local limitations in the different study areas.

Study area	**Findings**	**Proposed strategies**	**Feasibility of carrying out strategies**
1. Pesticide legislation	- Existing regulatory system ineffective - Regulatory authorities poorly equipped	- Study appropriate ways of regulating pesticides - Strengthen regulatory authorities in terms of qualified manpower and equipment - Increase collaboration with other institutions	The existence of a well established pesticide registration and control scheme in Tanzania, with basic facilities such as laboratories at TPRI makes it feasible to carry out the strategies
2. Availability and use of pesticides	- Pesticides obsolete, - Extremely and highly hazardous, - Endocrine disruptors, and - Persistent organic pollutants	- Pesticide distribution and use regulated effectively, - Obsolete pesticides disposed, - Limiting WHO Class Ia & Ib pesticides, - Government to ratify and comply with international conventions dealing with pesticides, - Shifting to alternative pest control strategies	- Regulatory authorities exist - Government designated authorities dealing with different conventions have been appointed
3. Pesticide poisoning cases	Unreliable figures	- Surveillance to determine the extent of poisoning countrywide, - Training and equipping medical personnel to recognition and diagnosis pesticide poisoning case, - Establishing record network for poisoning cases	- Research institutions are available to conduct surveillance studies - TPRI offers regular Pest Management training which include pesticide toxicology and is capable to tailor make courses for health care personnel - There is a health information system in Tanzania which can be improved by incorporating pesticide poisoning records

Study area	Findings	Proposed strategies	Feasibility of carrying out strategies
4. Pesticide handling practices	- More hazardous in small scale farms - Workers and families exposed	- Intervention studies could be initiated - Training communities on health hazards and possible solutions - Introducing safer alternative pest control methods	Research institutions and training facilities exist e.g TPRI Research into alternative pest control methods conducted at research institutions in the country
5. Acute effects of pesticides	Blood assays, signs and symptoms did not indicate cause of harmful effects	Further research	Research institutions exist with limited number of qualified staff
6. KAP* extension workers	Had no knowledge of first aid procedures in case of pesticide poisoning	-Education and training -Collaboration with health care workers	Training facilities and staff are available
7. Health care workers experiences & practices	Lack pesticide knowledge and aspects related to pesticide poisoning	-Education and training -Collaboration with agricultural extension workers	Training facilities and staff are available
8. Pesticide training policy	No national training policy	Review of current pesticide policy to incorporate training at all levels	Pesticide laws under review, TPRI coordinating changes

*KAP Knowledge, Attitude, and Practice

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Appendices

Appendix 1. List of pesticides used in Tanzania

(compiled from various sources in 1990)

A: ORGANOPHOSPHATES

COMMON NAME	WHO Class*	TRADE NAME	USAGE
Ethoprophos	Ia	Mocap	As nematicide on horticultural crops
Phosphamidon	Ia	Demecron 50 SCW	Insecticide on rice, cereals and vegetables
Chlorfenvinphos	Ib	Stelladone	Veterinary tick control
Dichlorvos	Ib	Nuvan 50EC Nogos 50EC Vapona	Public,health and storage pests Insecticide for tobacco, rice and vegetable As household insecticide, public health fumigant and on stored products Insecticide for pineapples
Dicrotophos	Ib	Carbicron 40% EC Neocidal 60EC	Insecticide for rice, cotton, coffee, and other crops
Propetamphos	Ib	Blotic	Livestock tick and flea control
Diazinon	II	Basudin 600EC, Diazinon 60EC, Luxan Diazinon Neocidal 60EC	In public health and livestock against fleas and ticks
Dimethoate	II	Rogor L 40, Rogor 30 AS	Insecticide on cotton, tomatoes and various crops
Etrimfos	II	Satisfar	As insecticide

COMMON NAME	WHO Class*	TRADE NAME	USAGE
Fenitrothion	II	Sumithion 50 EC	Insecticide on various crops against storage pests & public health
		Novathion 50EC	Insecticide for coffee
Fenthion	II	Lebaycid 50% EC	Insecticide on various crops,
Methacrifos	II	Damfin 560 EC	Crop storage against insect pests
Profenofos	II	Selecron 720 EC	Insecticide on coffee and vegetables
Quinalphos	II	Ekalux 25 EC, Ekalux ULV Malathion 4% D	Against caterpillars and scale on vegetables, groundnuts and cotton fruit trees
Azamethiphos	III	Snip-Fly Killer, Alfacron	Household Insecticide
Pirimiphos-Methyl	III	Actellic	Against storage insect pests.
Trichlorphon	III	Dipterex 95 SP dipterex 2.5 G, Dipterex 25 EC	Insecticide for various crops On maize, millet and sorghum against stalk borer
Quintiophos	NC	Bac Dip	Control of livestock ticks
Dioxathion	O	Delnav DDF	On livestock against ticks

B: CARBAMATES

COMMON NAME	WHO Class*	TRADE NAME	USAGE
Aldicarb	Ia	Temik	Insecticide, nematicide, miticide
Carbofuran	Ib	Furadan 5 G	On bananas against nematodes/weevil and in public health
Methomyl	Ib	Lannate	Foliar insecticide on cotton, fruits and vegetables
		Sevin 85 WP	On various crops; livestock and insecticide, ectoparasites and domestic insect pests
		Vermin powder	Vermin control
		Stopvermin Powder	Vermin control
Carbaryl	II	Boom Powder	For poultry and pets against fleas
		Sevin 85 WP	On various crops; livestock and insecticide, ectoparasites and domestic insect pests
Propoxur	II	Baygon	Insecticide against ants, aphids, cockroaches, mosquitoes, etc.
		Finito	Household insecticide
1 Naphtyl-y-N Methicarbamate	NC	Vermin powder	Vermin control
Methyl carbamate	NC	Stopvermin Powder	Vermin control
Dioxycarb	O	Famid 80% W.P	As insecticide

C: ORGANOCHLORINE

COMMON NAME	WHO Class*	TRADE NAME	USAGE
BHC	II	Luxan Lindane 20 % EC	Not specified
Chlordane	II	Luxan Chlordane 96% EC	Anti-termite
DDT	II	DDT 75% DDT 5% Didimac 10%, Victory Didimac 5%, DDT 10%	Insecticide on vegetables and maize
Endosulfan	II	Thiodan 35% ULV, Thiodan 5%, Thiodan 4% Dust, Luxan Endosulfan, Thiodan 35 EC, Thiodan 25%	Insecticide on various crops
Gamma BHC	II	Gammalin 20 EC	Insecticide for cocoa, cashew and crop storage. Termite control
		BHC 26 WP	Insecticide for termites, storage pests and skin protection
Lindane	II	Agrocide 3 % Dust	On vegetables and gardens against termites, grab, storage pests and skin protection
Triforine	U	Saprol 19% EC	As fungicide on coffee and horticulture
Aldrin	O	Aldrin 40 WP	Against soil insects, ants and termites
Camphechlor	O	Toxaphene, Lirophene, Sapatox 75%	On livestock against ticks
Dieldrin	O	Dieldrex 18 EC, Kynadrine	On coffee against stem borer and construction against termites

D: PYRETHROIDS

COMMON NAME	WHO Class*	TRADE NAME	USAGE
Flucythrinate	Ib	Cybolt 13.3 g/l ULV, Cybolt 17 g/I ULV, Cybolt 100 EC	Insecticide for cotton, cereals, vegetables and fruit
African Pyrethrum	II	Py-grease	Cattle dressing
Cyfluthrin	II	Solfac 10% W.P	As household Insecticide
Cyhalothrin - Lamda	II	Karate 5 EC	Insecticide on cotton
Cypermethrin	II	Cypermethrin 5% Ripcord 1.8 ULV, Cymbuch 2.5 g/l Cymbush 6 EC, Cypermethrin 80% ULV Cypermethrin 10 % EC, Ripcord 100 g/I	Insecticide for cotton
		Action 51	Insecticide on cereal crops against armyworm
Deltamethrin	II	Decis 5% EC, Decis 2.5% EC	Insecticide on cotton
Fenvalerate	II	Fenvalerate 3% ULV, Fenvalerate 20%EC Sumicidin	Insecticide on cotton against american bollworms, and spinybollworms
Natural Pyrethrin	II	Luxan Pyrethrum Spray	Multipurpose insecticide for domestic use
Permethrin	II	Denka Cooper	Anti-termite liquid Grain storage
Pyrethrum	II	Mos-kill, Fate, Red Cans	Household insecticide
Phenothrin	U	Flyex, Luxan, Aerosol, Sokit, X-pel	Household insecticide
Cypermethrin high cis	NC	Ectopor	Veterinary use
Flumethrin	NC	Bayticol Pour-on	As acaricide against ticks on livestock

E: FUNGICIDES

COMMON NAME	WHO Class*	TRADE NAME	USAGE
Phenylmecury Acetate	Ia	Agrosan D	On cereals as seed dressing
Bromopol	II	Bronocot 10 P	Cotton seed dressing
Copper sulphate	II	Blue Copper	On coffee and tomatoes
Cuprous Oxide	II	Perenox	On coffee, tomatoes against leaf-rust, coffee berry disease and blight
Propiconazole	II	Tilt 250 EC	On wheat, barley, sugarcane, coffee, grapevin
Copper Oxychloride	III	Micro Crop, Cobox 50, Recop	On coffee and vegetables
		Vitigran	On vegetables against blight
Copper-Hydroxide	III	Kocide 101	On coffee, tomatoes, beans and peanuts
Cupric Hydroxide	III	Champion 50 WP	On coffee, tomatoes,cucumbers & groundnuts
		Nordox	On coffee
Dithianon	III	Delan 75% WP	On coffee
Metalaxyl	III	Ridomil (Apron)	Fruits, seed treatment, etc.
Triadimefon	III	Bayleton 25% WP	Coffee, cereals, fruits, flowers and vegetables
Triadimenol	III	Bayfidan	As fungicide on coffee
Thiophanate methyl	U	Topsin-M-ULV	As fungicide
Chlorothalonil	U	Bravo 500 FW, Diconil	On coffee and vegetables
Ethoxy-ethyl - Mercury Hydroxide	NC	Tillex C	On sugarcane setts treatment
Mancozeb	U	Dithane M-45 Luxan Mancozeb 80% WP	Against a wide range of foliage diseases on potatoes and tomatoes On various crops against various foliage fungal diseases
Prochloraz-Manganese Complex	NC	Octave 50% WP	Either as a seed treatment or as a foliar spray for fruits and vegetables
Anilazine	O	Dyrene 480 WP, Dyrene 75	On coffee against coffee berry disease
Benedanil	O	Calirum 50% WP	On coffee, ornamentals against leaf-rust

F: HERBICIDES

COMMON NAME	WHO Class*	TRADE NAME	USAGE
Alachlor	Ia	Lasso	On maize, coffee, cotton and beans.
2-4-D	II	Fenesta 60, Agroxone 20, Luxan 2-4-D Isobutylester 60%	Control of broad leaved weeds in wheat, sugarcane and grassland
2-4-D Amine	II	2-4-D Amine	Against broad leaved weeds in wheat, barley, oats, maize, & sugarcane
Bromoxynil	II	Buctril	As herbicide on horticultural crops
Difenzoquat- Methyl sulfate	II	Avenge 250	As herbicicide in sugarcane
Haloxyfop-ethoxy ethyl	II	Gallant	As herbicide
Paraquat	II	Gramoxone 20%	On plantation crops, coffee, sisal, cotton, tea, bananas against common broad leaves
Methyl sulfate 40% Acid equivalent of MCPA	III	Agroxone 40	Weed killer in wheat barley, maize, sugarcane and grassland
Ametryne	III	Gesapax	On sugarcane
Diclofop methyl	III	Illoxan 36 EC	As herbicide on barley and wheat
Dimethametryn	III	Avirosan 500 EC	On rice against broad leaved weeds
Fluazifop-p-butyl	III	Fusilade	On various crops against annual and perennial weeds
Fomesafen	III	Flex W 25 As	Against broad leaved weeds including chinese lantern in beans
Glufosinate ammonium	III	Basta	As herbicide in horticultural crops
Isoproturon	III	Arelon 500 disp	As herbicide

COMMON NAME	WHO Class*	TRADE NAME	USAGE
Mepiquat Chloride	III	Pix	As herbicide
Pendimethalin	III	Stomp 500 EC	Herbicide on sugarcane, cotton, rice and cereals
Propanil	III	Riselect	On potatoes, wheat, rice against post emergence weeds.
Sethoxydim	III	Nabu 20%EC	As herbicide
Atrazine	U	Atred 80 WP, Gesaprim 500 FW	On maize, sorghum, sugarcane against pre- and post-emergence weeds
Bromacil	U	Hyvar-x	On sisal
Chlorsulfuron	U	Glean 75% DF	As herbicide
Fluometuron	U	Cotoran	On cotton
Glyphosate	U	Round-up	On coffee, citrus, bananas against all types of weeds, particularly couch grass
Metoxuron	U	Dosanex Instant 81%	As herbicide
Metsulfuron-Methyl	U	Granstar 75 DF	As herbicide
Oxadiazon	U	Ronstar 25 EC	On rice, sunflower against all types of weeds particularly couch grass
Trifluralin	U	Treflan	As an herbicide for cotton, soyabeans etc.
Fenoxaprop-p-ethyl	O	Puma Super	As herbicide in sugarcane

G: OTHERS AND COMPOUND MIXTURES

COMMON NAME	WHO Class*	TRADE NAME	USAGE
Aluminium Phosphide	Ib	Phostoxin Pellets	Fumigant
Brodifacoum	Ia	Klerat Pellets, Klerat Wax Block	Rodent control
Bromadiolone	Ia	Lanirat 0.005% Rodine C	Rodent control
Alachlor/Atrazine	Ia+U	Lasso-Atrazine	On maize and sorghum
Coumatetralyl	Ib	Racumin Tracking Powder	As rodenticide
Warfarin	Ib	Cumarax	Rodent control
Zinc Phosphide	Ib	Panyatox 1	Rodent control
1 % Propoxur + DDVP 0.5%	II+Ib	Raid - Cockroach Killer	Aerosol household pests
Monocrotophos 100g + 400 gm DDT /Lt	Ib+II	Nuvacron ULV Air	Insecticides. On cotton and bean seeds
Pyrethrum + DDVP, Dichlorvos	II+Ib	It	Household insecticide
Pyrethrum + Permethrin+ Dichlorvos	II+II+Ib	Doom	Home use insecticide kills flies, Mosquitoes, cockroaches, etc.
Dichlorvos + Tetramethrin	Ib+U	Tiktak	Household insecticide
Methidathion + DDT	Ib+II	U-Combl	Insecticide, for cotton
c Bioallethrin +	II	Doom	Household insecticide
Metaldehyde	II	Ariotox, Aruitix	Slug-balt

COMMON NAME	WHO Class*	TRADE NAME	USAGE
Mixture of 2-4- D max 12% as Amine Salt	II	Tordon 101	Herbicide for clearing bush
Profenofos + cypermethrin	II+II	Fenon P 425 EC	On coffee against chewing and sucking insect
Pyrethrin + Pyrethrin 2	II+II	Kiboko Yao	Control of household insects, cockroaches, bed bugs, etc.
Dimethoate + Phenthoate	II+II	Rogodial	Insecticide for cotton
Paraquat + Diuron Dichloride	II+U	Gramuron	On plantation crops, coffee, sisal, cotton, tea, banana, etc
Fenitrothion + Tetramethrin	II+U	Topkill	Household insecticide
Terbuthylazine+ Paraquat	U+II	Gardopat 600 FW	As herbibicide
Tetramethrin + Phenitrothion	U+II	Flying insect killer, Hatari, Crawling insect Killer	Household insecticide
Piperophos+ Dimethametryne	II+III	Avirosan	As herbicide
Pirimiphos Methyl + Permethrin	III+II	Actellic Super	Against storage pests in maize
Propanil+ Thiobencarb	III+II	Satunil 60 EC	As herbicide on rice
Pyrethrins + Malathion	II+III	Flyrex solution	Household against domestic insect pests
Thiram + Lindane	III+II	Fernasan D	Fungicide for sorghum and millet, maize and groundnuts
Dazomet	III	Basamid	As fungicide, insecticide,

COMMON NAME	WHO Class*	TRADE NAME	USAGE
Atrazine & Ametryne	U+III	Herbicombi	As herbicide on sugarcane, rice, coffee, sisal & beans.
Atrazine + Bentazone	U+III	Laddock	Insecticide on cotton
Bromofenoxin + Terbutryn	III+U	Faneron Super	As herbicide
Carboxyn + Thiram	U+III	Vitavax 200 WP	As fungicide
D-Allethrin+ D- Phenothrin	III+U	Pesguard PS 201	Insecticide in public Health against mosquitoes
Metalaxyl + Mancozeb	III+U	Ridomil	Fungicide for potatoes and tomatoes
Metobromuron + Metolachlor	U+III	Galex	Herbicide for beans, sunflower, maize & tobacco
Metolachlor + Atrazine	III+U	Primagram 500 FW	Herbicides for maize and sugarcane
Oxadixyl + Mancozeb	III+U	Sandofan M	Insecticides- Used in vegetables, tobacco, potatoes, pineapples, & oranges
Oxadiazinon+ Propanil	U+III	Ronstar PL	As herbicide
Bentazone + Mecoprop	III+III	Basagran PL2	As herbicide on rice, beans & maize
Copper chromium arsenic	NC	Celcure	As insectcide
Coumarine	NC	Dora-Rat Killer	Rodent control
Dichlofenthion + Thiram	O+III	Aatifon	As fungicide & insecticide

COMMON NAME	WHO Class*	TRADE NAME	USAGE
Propanil + Phenopal	III+NC	Stam T 8 EC	for post-emergence weeds
Tetramethrin+	U+?	Safari	Household insecticide
Triadimenol + Imazil+ Fuberidazole	III+II+III	Baytan Universal	Fungicide
Ethylene Dibromide	F	Ethylene Dibromide	As fumigant & Insecticide
Not specified	NK	Toxadrin	Unknown
Not specified	NK	Nematox	Unknown
Not specified	NK	Luxan Rat Bait	Rodent control
Not specified	NK	Arluymaton	insect killer
Not specified	NK	Finishto	Unknown
Not specified	NK	Canguro	Insect killer
Not specified	NK	Chirton	Fly and wasp killer
Not specified	NK	Tangatox	Unknown
Not specified	NK	D-Zone	Against cockroaches and bed bugs
Not specified	NK	Mosquito Doom Coil	Mosquito repellent
Not specified	NK	Out Door Rat Killer	Rodent control
Not specified	NK	Flyspray	As household insecticide

**WHO hazard classification: Class Ia=extremely hazardous; Ib=highly hazardous; II=moderately hazardous; III=slightly hazardous; O=obsolete as pesticide; U=unlikely to present acute hazard in normal use; NC=not classified; NK=not known.

Original publications