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Understanding the Full Costs of Pesticides: Experience from the Field, with a Focus on Africa

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1. Introduction

Pesticide use in Africa accounts for less than 5% of global pesticide use and per hectare averages are low, estimated at around 1 kg/ha active ingredient applied (compared with 3-7kg/ha in Latin America and Asia (Repetto and Baliga, 1996; Agrow, 2006; CropLife International, 2009). However, low use volumes do not necessarily equate to low risk, particularly as some of the most toxic pesticides continue to be applied in Africa, often under extremely dangerous conditions. African studies on pesticide impacts on health frequently highlight poor pesticide practice (e.g. Sibanda et al., 2000 in vegetables; Ngowi et al., 2001, in coffee; Matthews et al., 2003 in tree crops), in the case of both farm workers on large farms and smallholders on their own farms. These studies make general recommendations for better education in handling practices and sometimes stricter controls on pesticide distribution but tend to focus on health effects on those directly spraying pesticides – usually men.

This chapter takes a broader look at the impacts of pesticide poisoning, from case studies mainly of West African smallholders. The findings are discussed in terms of exposure for farm families and the social and economic costs of ill health and environmental harm, to affected households and to society at large. Detailed information is provided on endosulfan and cotton systems, before exploring the effectiveness of regulatory controls and governmental pesticide policies to reduce harm. A final section examines efforts in food supply chains to reduce hazard, risks and use of pesticides and the chapter concludes with examples of action research with farming communities to address pesticide harm and promote safer alternatives.

2. Health impacts

In the early 1990s, the World Health Organisation (WHO) estimated that there were 3 million acute pesticide poisonings a year worldwide, almost all in developing countries: 700,000 occupational; 300,000 accidental; and 2 million by intent (WHO, 1990). Jeyaratnam (1990) estimated 25 million occupational pesticide poisonings each year among agricultural workers in developing countries alone. The International Labour Organisation estimated 2-5 million occupational poisonings per year, with 40,000 fatalities (ILO, 1994). The discrepancies between these estimates reveal how little is known about the actual incidence

and scale of poisonings. WHO 1990 figures are considered a severe underestimate mainly because many cases are not formally documented in health surveillance statistics: estimates for Thailand put likely poisonings at thirteen times higher than official records (Jungbluth, 1996). Murray et al. (2002) provide an overview of under-reporting with a focus on Central America, estimating 98% under-reporting. Kishi's review (2005) confirms the difficulties in obtaining an accurate picture of pesticide-related health impacts, the significant underestimations of occupational ill health, and includes specific country studies which indicate much higher incidence than previously thought. Clinical records often seriously over-represent suicides, thus tending to downplay occupational and accidental exposure (Murray et al. 2002; London et al. 2005). Increasing health surveillance reveals a more realistic estimate of actual poisoning levels: in South Africa, intensive monitoring found a ten-fold increase in poisoning rates, many from occupational exposure (London and Baillie, 2001).

Kishi (2005) suggests there is little sign of poisonings decreasing. After nearly ten years of efforts to implement the FAO/WHO International Code of Conduct on the Distribution & Use of Pesticides, an FAO survey found very limited improvement in health problems and 'substantially worse' environmental problems (Dinham, 2005). A further assessment for developing countries suggests up to 2.9 million cases of acute poisoning per year, with acute poisoning a major public health problem for those countries where much of the workforce is employed in farming (Kangas and Tuomainen, 1999). Poorer farmers and women workers may be particularly affected (Mancini et al., 2005).

2.1 Collecting pesticide impact data from the field in Africa

Pesticide Action Network (PAN) UK, PAN Africa Regional Centre (based in Senegal) and several of its national affiliates (most notably the Beninese Organisation for Promotion of Organic Agriculture, OBEPAB), have been collecting information on human and animal pesticide poisoning incidents for over a decade in Africa. The rationale has been to raise awareness among decision makers in Ministries of Agriculture, Health and Environment, Environmental Protection Agencies, the media, crop protection researchers, international donors and development partners, and farmers themselves, of the unacceptably high levels of pesticide-related ill health and environmental damage in African farming communities (Thiam and Touni, 2009). By providing concrete figures, along with qualitative data that illustrate the main pesticide exposure routes and risk scenarios, this work has helped to fill a critical information gap, particularly as only 2% of human poisoning incidents documented reported seeking medical attention and thereby entering official health records.

This informal data collection started in 1999, triggered by a sudden increase in serious and fatal poisonings in cotton growing areas in Benin, following the introduction of the insecticide endosulfan (see case study in section 3). Working in local languages, PAN Africa and OBEPAB staff visit villages and through a process of meeting village leaders, word of mouth and direct questioning identify farm families who have possibly been adversely affected. These families are then interviewed in their home with a standard questionnaire to identify the pesticides implicated, record symptoms and to assess likely exposure routes, as well as to warn farm families of the danger of handling hazardous pesticides without safety precautions. During 1999-2001, 703 human poisoning incidents were documented in Benin and Senegal by interviewing farm families mainly, but not exclusively, in cotton growing areas, and the data entered in a database run by PAN Africa. Where minimum factual information was unavailable for a supposed case, it was not included. Data was analysed by gender, age, compounds responsible (where known) and exposure 'scenario'. Twelve

different scenarios by which family members were poisoned were identified, of which application in the field accounted for 33% in Senegal and 24% in Benin. Contamination of food and re-use of empty containers for food and drink accounted for 57% of all cases in Benin and 86% of all fatal poisonings, showing how important this route is in putting families in danger. Other routes included unsafe storage and inhalation in rooms, children playing with pesticides, confusing pesticides for other products, inappropriate use for treating headlice or ticks, stomach ache, as well as 67 suicide attempts and 2 cases of murder. On average, 16% of the 619 incidents in Benin were fatal and 23% of the 84 cases in Senegal (Williamson, 2005; PAN UK, 2007; Williamson et al., 2008).

Data collection continued during 2002-2009, with 128 villages in Senegal and Mali visited, documenting 305 poisoning cases. In this round of data collection the questionnaire protocols were updated to bring them closer in line with the Health Incidents Reporting Form developed by the Rotterdam Prior Informed Consent (PIC) Convention for identifying 'severely hazardous pesticide formulations' in the field (<http://www.pic.int/home.php?type=t&id=38&sid=34>). The PIC monitoring methodology is not designed to use statistically representative samples but relies on self-selection, combined with experience and judgement to document individual incidents of ill health which are likely to be related to the rough pesticide exposure data recorded for each case. Qualitative data gathered in interviews on what happened and over what time periods, any information from local press and radio reports and discussion with independent experts enables PAN Africa to build up a picture of the main poisoning scenarios. The PIC methodology does not include medical verification of symptoms, indeed many of the incidents recorded took place weeks, if not months, earlier. However, symptoms reported by farmers are checked to verify if they demonstrate typical results of acute exposure to organophosphate, carbamate, pyrethoid and organochlorine insecticides- the main pesticide families implicated in the research. Table 1. summarises the data for the 1,008 cases recorded from the two survey rounds, disaggregated by age, gender and incident severity. Table 2. Summarises data on the most commonly implicated active ingredients.

Further survey work conducted in Senegal, Mali and Tanzania in 2007-09 as part of PAN's global community-based health monitoring, generated useful figures on most frequent symptoms of acute, temporary ill health experienced by smallholders, based on interviews with 420 farmers (PAN International, 2010). In Senegal, rice and cotton farmers suffered most from headaches (57% and 61%, respectively) and blurred vision (49% and 59%), while Malian cotton farmers' two most frequent symptoms were headaches (21%) and dizziness (including blackouts, 8%). Vegetable farmers in Tanzania, in contrast, reported skin rashes (66%) and excessive salivation (58%).

2.2 Issues arising from poisonings research

People often assume that poisoning risk is highest for those handling pesticides directly yet the data from Benin and Senegal shows that women and children feature significantly even though they generally are not the ones doing pesticide application. In Benin, children under 10 years old made up 20% and 30% of poisoning cases recorded in 2000 and 2001. High poisoning rates among women and children were also documented in Ethiopia, from statistics provided by the Amhara Regional Health Bureau for 2001 from hospital records. Women made up 51% of these 185 cases even though pesticides are almost exclusively sprayed by men in Ethiopia, while children 5-14 years old accounted for 20% of cases.

Country/Period	Male	Female	Adult	Children	Fatality rate
Benin / '99-'00 n=148 cases	86%	14%	72%	28%	7%
Benin / '00-'01 n=265	75%	25%	65%	35%	9%
Benin / '01-'02 n=206	61%	39%	44%	56%	32%
Senegal / '99-'01 n=84	67%	33%	68%	32%	23%
Senegal / '02-'09 n=258	86%	4% (10% gender not specified)	90%	5% (5% age not specified)	10%
Mali / '02-'09 n=47	100%	0%	100%	0%	0%

Sources: PAN UK, 2003; PAN UK, 2004; Williamson, 2005; Thiam and Touni, 2009

Table 1. Summary of poisoning cases collected in West Africa, 1999-2009

Active ingredient and/or formulated product	Benin / '99-'00	Benin / '00-'01	Benin / '01-'02	Senegal / '99-'01	Senegal + Mali / '02-'09
endosulfan	60%	83%	53%	12%	24%
methamidophos					21%
dimethoate					6%
dimethoate+cypermethrin	13%		4.5%	1%	
cypermethrin +profenofos					6%
Nurelle (cypermethrin + chlorpyrifos)	6%				
chlorpyrifos		2%	10%		
lambda-cyhalothrin +profenofos or cypermethrin (Cotalm)	4%	10%	16.5%		
Granox (carbofuran + thiram + benomyl)				6%	
diamine +propanil					6%
cypermethrin +acetamiprid +triazophos					6%
methamidophos + methomyl					4%
deltamethrin					3%
Other named products	17%	1.5%	4.5%	8%	
Undetermined pesticides		3.5%	11.5%	73%	24%

NB: % figures relate to total number of poisoning cases documented, NOT to % cases where a compound was implicated.

Sources: PAN UK, 2003; Williamson, 2005; Thiam and Touni, 2009

Table 2. Active ingredients or products implicated in poisoning cases

Similar frequency of poisonings among women and children has been documented in recent studies in Ecuador (Sherwood et al., 2005) and in India (Mancini et al., 2005), emphasising

how pesticide-related ill health can seriously affect farm families and rural communities, yet government risk assessment generally only considers scenarios for male spray operators. Widespread use of hazardous insecticides in the home, unsafe storage in kitchens and bedrooms, dangerous treatment of grains and beans and use of empty insecticide containers all contribute to these tragic figures. Washing pesticide-contaminated work clothing poses another risk. Using insecticides for home 'remedies' is especially dangerous- in Ethiopia, farmers used highly toxic insecticides to treat headlice, fleas and bedbugs, and even to try and cure open wounds, using malathion or DDT, sometimes with fatal results (PAN UK, 2003). Farmers explained that it was the poorest people who resorted to this potentially lethal 'cure'. Easy availability of such hazardous chemicals in rural areas contributes to increased suicide rates, particularly of women and teenage girls, mentioned as a growing worry by farmers in Ethiopia, and cotton farmers in Senegal and Benin.

While the Benin and Senegal poisoning data are rather small case studies, purposively sampled and therefore not statistically representative, similar findings were reflected by qualitative and quantitative data from Ghana (Williamson, 2005). Crude estimates of incidence were made from those villages studied where we had data on population levels. For incidents recorded in 77 Beninese villages, average annual frequency estimates of 21.3 serious poisonings per 100,000 population in 2000-01 (the season with highest documented cases) and 11.9 per 100,000 in 1999-00 (the lowest) were made. Fatality incidence per year ranged from 0.8 to 1.9 deaths per 100,000 people. Calculations from the official figures from Amhara Regional Bureau of Health give 1.1 poisoning cases per 100,000 population, for those attended at clinics and hospitals.

Regular ill health from pesticide exposure may not be as dramatic or as visible as serious poisonings but can be far more widespread. Cotton and cowpea farmers in Ghana estimated that 33-60% of economically active people in their villages were adversely affected each season after spraying pesticides. Although farmers were worried about the immediate effects in terms of losing days off work, they viewed the symptoms as temporary 'mild' poisoning. However, scientific studies provide growing evidence that regular exposure to neurotoxic and other pesticides can lead to chronic impairment of the nervous, immune, reproductive and hormone systems in humans. Children are particularly vulnerable as their organs are still developing (Ecobichon, 2001; Szmedra, 2001; Meredith, 2003; Colborn, 2006). More recent studies by other researchers confirm PAN assessment that poisonings are commonplace. In Benin, 105 cases, including 9 fatalities, were documented during May 2007-July 2008, due to endosulfan (Badarou and Coppieters, 2009). In market gardening in Côte d'Ivoire, only 27% of pesticides used by growers were authorized for such use and a range of poisoning symptoms reported, with 55% suffering headaches and stomach pains (Dolumbia and Kwadjo, 2009). Researchers hypothesised that 65% of illnesses suffered by these market gardeners could be linked to pesticide use.

Lack of adequate, or in most cases, any personal protective equipment (PPE) stands out as another key factor in the high levels of pesticide poisoning documented. Most farmers are aware that they should be protecting themselves but the vast majority do not, mainly for reasons of lack of availability or affordability of suitable kit (PAN International, 2010). This problem extends to those selling and distributing pesticides too, as evidenced by a survey of 35 pesticide stores in Mali. Only 63% of these held a relevant licence to sell pesticides and less than 50% had received training. Those who had been trained reported topics covered mainly precautions for mixing and storing pesticides at retail level. Less than a quarter of

stores stocked some form of PPE, demonstrating the woeful lack of consideration given to farmer protection by either regulatory agencies or pesticide distributors.

3. External costs of pesticide use

3.1 Studies on pesticide externalities

Ill health impacts are not just sad incidents for farm families - they also impose serious economic costs on farming communities, in terms of time off work and treatment costs. The work of Cole, Sherwood and colleagues in smallholder potato production in Ecuador is possibly the best and most detailed multidisciplinary study to analyse the costs of acute and chronic health impacts (Cole et al., 2000; Sherwood et al., 2005). Using a combination of questionnaire surveys, focus groups, bioassay, physical tests and household exposure sampling, their findings highlighted the 'invisible' face of chronic exposure to hazardous insecticides, from low-level but cumulative effects on the nervous system, motor coordination and behavioural function. Levels and patterns of exposure to some of the insecticides were found to adversely affect farmer decision-making capacity to a level that would justify worker disability payments in developed countries. That study revealed alarming levels of fatalities at 21 deaths per 100,000, among the highest reported in the world. In economic terms, while increased use of carbofuran insecticide improved crop production, it also lowered neurobehavioural function and thus productivity. Treatment costs imposed a significant financial burden on the public health system, with each non-fatal poisoning costing six worker days.

Factoring externalities into the equation shows that full costs of pesticide use can be enormous. Recent research shows that a very conservative estimate of these costs in Germany, UK, US and China (rice only) amounts to between US\$8-47 per hectare of arable land, or an average US\$4.28 per kg of pesticide active ingredient applied (Pretty & Waibel, 2005). In the Chinese case, these external costs exceeded the market value of the pesticides - for every US\$1.0 worth of pesticide applied, costs to society in the form of health and environmental damage averaged US\$1.86. This may be a good reflection of the situation in other developing countries, where the majority of global pesticide poisonings occur.

3.2 Data from Africa

Pesticides can and do cause serious human and environmental damage throughout Africa. Numerous studies over the last 15 years have shown that a considerable proportion of farm workers suffer regular ill health. Others have documented frequent incidence of health problems among smallholder farmers using pesticides, particularly those growing vegetables, coffee or cotton. Table 3 summarises what is known about the economic burden of these hidden health and other costs from the few studies published.

A recent study for the UN Food & Agriculture Organisation (FAO) analysed externalities caused by spraying high concentrations of organophosphate insecticides (mainly malathion and fenitrothion) for locust control operations in Senegal during the last outbreak in 2003-2005 (Leach et al., 2008). It estimated external costs of over 8 million euros: 2.75 million for environmental costs; 2.5 million on human health; 2.1 million in agricultural production losses; and 0.7 million in damage prevention costs. The researchers concluded that failure to recognize and factor in such externalities can result in inappropriate balances of net costs and benefits of pesticide use decisions, favouring 'cheap' solutions that incur higher net costs for society than safer alternatives which are perceived as 'more expensive'.

Country of study	Estimated external costs	Date of study	Reference
Zimbabwe	Cotton smallholders lost US\$3-6 per year in acute health effects, equivalent to 45-83% of annual pesticide expenditure. Time spent recuperating from illnesses attributed to pesticides averaged 2- 4 days.	1998-1999	Maumbe et al., 2003
Cote d'Ivoire	Average US\$2-5 pesticide-related health expenses incurred by cotton and rice growing households. Cotton farmers suffer at least one adverse health effect 20% of the time.	1996-1997	Ajayi, 2000
Niger	Health costs, livestock losses and costs of obsolete stocks disposal = US\$2 per hectare treated	1996	Houndekon et al., 2006
Mali	Annual national poisoning health costs= US\$0.25-1.5 million Costs to farming from ineffective pest management due to pesticide resistance and destruction of natural pest control organisms = US\$8.5 million	2000	Ajayi et al., 2002

Table 3. External cost studies from Africa

Interviews conducted by PAN UK with cotton and cowpea farmers in Northern Region, Ghana, in 2003 revealed that insecticide-related ill health was widespread and considered by most to be a “fact of farming life”. Farmers reported that exposure during spraying made them so weak and sick that they had to stay in bed for 2-7 days afterwards to recover. Table 4 details the number of days off sick after spraying insecticides per season, routine preventative costs (mainly purchase of milk drunk before or after spraying to mitigate poisoning symptoms) and costs of more severe poisoning treatment at the local clinic or hospital (usually administration of saline drips). Active ingredients in products most often associated by farmers with these health effects included endosulfan, chlorpyrifos and lambda-cyhalothrin.

Average no. days off sick after spraying cotton (n=26)	Cost in terms of average daily farm labour rate	Average no. days off sick after spraying cowpea (n=19)	Cost in terms of average daily farm labour rate	Preventative treatment costs (n=13)	Medical treatment costs (n=30)
21.7	33	15.1	17	0.9	51

Source: adapted from Williamson, 2005

Table 4. Estimated costs of days off work and treatment following insecticide spraying by Ghanaian farmers (in euros, adapted from Ghanaian cedis, 2003 rate: 1 euro equivalent to approx. 8,895 cedis)

These health costs are underestimates because they do not include chronic pesticide health effects, or suffering and other non-monetary costs. Taking preventative measures to avoid getting ill after spraying also costs money, for purchase of protective clothing (in the minority of smallholders who use it), or for purchasing milk to drink before application to try and mitigate harmful effects. Ivorian (Ajayi, 2000) and Ghanaian farm families accept temporary episodes of illness as almost an inevitable part of using pesticides and seriously underestimate the real costs to their household, as they only consider cash outlay on medicines, and ignore the costs of days off sick. PAN's 2007 Tanzanian study identified smallholder vegetable production as a high risk situation, with 73% farmers applying pesticides weekly. Over 65% reported suffering some form of poisoning in the previous season, with 22% experiencing symptoms more than three times and 58% had been admitted to hospital for poisoning (PAN International, 2010).

A further issue relates to managing pesticide poisoning in rural communities, especially in the cotton producing areas of northern Benin. In this area, there is complete lack of capacity and expertise by medical personnel in rural clinics, hospitals or medical centres to accurately recognize even the basic and simplest symptoms of pesticide poisoning. Therefore wrong diagnoses of pesticide poisoning cases are common, resulting in giving the wrong treatment to people who experience pesticide poisoning and, who continue to suffer (A Youdeowei, pers.comm, 2010). State-run poison information centres exist in only 13 countries in Sub-Saharan Africa.

4. Case study: endosulfan and cotton systems

4.1 Health and environmental harm from endosulfan use

The persistent organochlorine insecticide endosulfan was introduced in cotton production in francophone West Africa over the 1999/00 season, as part of a regional programme to combat pyrethroid insecticide resistance in the bollworm *Helicoverpa armigera*. Endosulfan already had a reputation as a highly toxic and dangerous pesticide, particularly under poor spraying conditions without any use of protective clothing, and was banned in a number of countries. In the first season of its introduction, cases of acute poisonings, including fatalities, were picked up: official sources in Benin stated that at least 37 people died over the 1999/2000 season in the northern Borgou province due to endosulfan poisoning, while another 36 people experienced serious ill health. In view of the relative share of the Borgou province in national cotton crop area, PAN UK's partner NGO in Benin, OBEPAB, estimated that at least 70 people may in fact have died in Benin over that single season from endosulfan poisoning. From that year OBEPAB started careful documentation of poisoning cases in different parts of the country. Their work has proven invaluable in alerting West African decision makers to the real problems of endosulfan and other hazardous pesticides in widespread use in smallholder production under conditions which can never be 'safe' (Thiam and Touni, 2009).

Over the last ten years, endosulfan is increasingly viewed globally as a priority for phase-out (Watts, 2008). The EU withdrew its approval in 2006 and notified it to the UN Prior Informed Consent (PIC) Rotterdam Convention as banned for agricultural use in Europe for health and environmental reasons (PAN UK, 2008a). Partly as a result of poisoning data collection by PAN partners in Benin, Senegal, Mali and Burkina Faso, in 2007 the CILSS regional Sahel Pesticides Committee decided to stop endosulfan distribution and ban its use a year later (Thiam, 2009). Apart from human health incidents, regional monitoring studies

on water and aquatic fauna indicated endosulfan is a common water pollutant, contaminating surface, groundwater and wells for drinking water. Benin, which is not part of CILSS, also decided to ban endosulfan use in 2008. Other West African studies also implicate endosulfan as a major culprit of serious, sometimes fatal poisonings, in Benin (Badarou and Coppieters, 2009) and the Toxicology Division of the Public Hospital of Lomé-Tokoin in Togo has registered over 500 annual poisoning cases linked to endosulfan (Kodjo, 2007).

The endosulfan-generated cases of deaths and poisoning in West Africa are an unforeseen consequence of the dominant narrative discourse on pesticide 'indispensability' of those responsible for regional decision-making on cotton pest management. Solutions to technical problems with crop protection were decided upon without adequate consideration of the wider contexts in which cotton pesticides are being managed and used (Ton et al., 2000). Successful use of endosulfan in Australian cotton to combat bollworm resistance to pyrethroids was taken as a blueprint for the situation in West Africa, without apparent recognition that the socioeconomic, literacy, education, cropping systems and pesticide regulatory and distribution systems are worlds apart in poor, developing countries like Benin. The case illustrates well what can happen when broad stakeholder consultation is not factored into decision making on pesticide regulation and pesticide use recommendations from research and extension. Yet some in the cotton sector continued to applaud the use of endosulfan (Martin et al., 2005) even when evidence against its appropriateness was well documented.

4.2 Health and environmental issues in conventional cotton in West Africa

West Africa also provides an illuminating case of the health and environmental impacts of current levels of reliance on pesticides commonplace in conventional cotton production. Distributing large volumes of hazardous insecticides through both public and private cotton supply chains without adequate farmer and field agent training, nor understanding of the real risks, has ended up with serious negative consequences (Ton, 2001; Silvie et al 2001). FAO's recent Regional Pollution Reduction & Sustainable Production Program is the first effort to monitor pesticides in the environment and communities of the Senegal and Niger River basins, studying 30 locations in six countries where cotton and vegetable production are the main pesticide users and polluters. Researchers found 19 pesticides regularly contaminating watercourses, including the banned organochlorine dieldrin, along with problematic active ingredients methyl parathion, monocrotophos, endosulfan and lindane (Poisot, 2007). European drinking water standards were exceeded in 90% of samples and the same percentage exceeded Maximum Tolerable Risk levels for ecological effects. The study predicted that such levels of water contamination would have acute effects on fish and aquatic invertebrates - an assessment which is supported by numerous reports of large fish kills, especially following run-off incidents from fields recently sprayed for cotton (e.g. Youdeowei, 2001; Okoumassoun et al., 2002; PAN Africa, 2009).

Insufficient consideration of hazards and risks has undermined productivity and farm family welfare by encouraging the development of pest resistance to commonly used insecticides; killing livestock, effective natural enemies and pollinators; contaminating soil, water and food; and exacerbating gender and income inequalities within rural areas (Youdeowei, 2001; Ajayi et al., 2002; Williamson et al., 2005). Cotton insecticide diversion onto food crops for domestic and local use abounds, as documented in our field work in

Ghana, Senegal and Benin (Williamson, 2003), with negative consequences for food safety and the productivity of cotton in smallholder systems. This is particularly true for the poorer farmers who often sell some of the insecticides and fertilizers they receive on credit from the cotton companies, in order to buy food during the 'lean' season.

4.3 Safer and more sustainable alternatives for cotton production

PAN UK, PAN Germany and PAN Africa have been working for 15 years to promote organic cotton in Africa, as a practical move to deliver social, environmental and economic benefits through safer alternatives in pest management (Box 1). PAN Africa also promotes Integrated Pest Management (IPM), running cotton IPM Farmer Field Schools in Senegal. PAN UK is a member of the Better Cotton Initiative, a new multi-stakeholder initiative in mainstream cotton, which recognizes serious pesticide impact challenges and aims to reduce use and hazards through IPM strategies (www.bettercotton.org).

Box 1. Promoting organic cotton systems in Africa

Details of PAN work in African organic cotton can be found elsewhere (PAN Germany, 2004; Ferrigno et al, 2005; Williamson et al., 2005; Sanfilippo, 2007) via <http://www.pan-uk.org/organic-cotton/wearorganic-homepage>. It should be noted that net income is usually higher for cotton farmers engaged in organic supply chains, as a result of cost savings on inputs and organic premiums of 10-20% on average. Yields obtained by some of the most experienced organic cotton farmers can approach those of good conventional ones. Our research in West Africa also shows that actual yields in conventional cotton are often much lower than research station averages, due to bad husbandry and poorer farmers 'selling on' their cotton agrochemical inputs (Williamson, 2003). Further benefits expressed by organic farm families are that they no longer suffer poisonings, they enjoy safer food and grow a wider range of food crops as part of the organic rotation (Truscott, 2009).

"It has been 5 years now since I decided to convert to organic cotton. I made this decision in 2001 because I had just suffered a miscarriage due to the use of pesticides. Organic cotton has given me more independence as a woman, because I receive a better income, and I am paid immediately after the harvest. I am now able to buy luxuries, clothing, crockery, something which is a real pleasure because I couldn't do it before. And more importantly, my children's health is no longer at risk."

Evelyn Ate Kokale, organic cotton farmer, Glazoué District, Benin.

Problem-solving research and development for sustainable organic cotton systems is woefully neglected by governments in cotton-producing countries and international donors. Conventional cotton systems tend to reward quantity (tons of cotton fibre at national level) rather than sustainability or social or environmental goods or services - putting the interests of ginners, exporters and foreign currency generation before those of cotton farming communities (Ferrigno et al., 2005). PAN has identified a list of R&D needs to improve organic cotton yields and systems from a farmer perspective, including: organic seed treatments; varietal improvement for resistance to pests and diseases; best practices for organic fertilization, weed management and tillage regimes in rainfed systems; and manipulating predator populations for more effective control of key pests. PAN's participatory research with farmers in Benin is adapting use of food sprays to attract key predators of cotton bollworm, first developed for large-scale cotton farms in Australia, to the resources and capacity of smallholders (Vodouhê et al., 2009).

Gaining better national or export markets for some of the numerous food crops grown by farmers as part of their organic cotton rotation is another important route for building sustainable cropping systems, livelihoods and enhancing local food security. Current work focuses on cashew and sheanut in Benin, with sesame, hibiscus and the millet-like *fonio* grain in Senegal (PAN UK, 2010).

5. Regulation into practice?

5.1 Stakeholder perceptions and policy coherence

While quantitative data is important for policymakers to make good informed decisions, qualitative and participatory methods are also essential for exploring important perceptions and experiences of farmers on pesticide use issues, which need to be considered by all those working to reduce pesticide externalities and promote IPM. One quote from a 30-year old cotton and cowpea farmer's wife from Voggu village in Ghana, obtained in 2001 fieldwork, conveys the family costs, personal tragedy and sense of disempowerment expressed by many about levels of pesticide dependency:

"I have to look after my husband and provide him with food and water on the days when he has sprayed. I don't do any spraying myself but I still get affected, I still breathe in the pesticide. Once I came back from the farm and was vomiting and I had a miscarriage from inhaling the spray and had to go to hospital. The pesticide does its job but it's the side effects we don't like. There is no option- we have to do this."

Just as important is to understand the perceptions, viewpoints and attitudes of key stakeholders, which may pose obstacles to change at policy and programme levels. Table 5 summarises ten key issues of poor policy coherence or implementation, identified from open-ended interviewing of 80 stakeholders from government, private sector, research, donor, grower associations and NGO sectors in four African countries.

As one example of poor coherence at programme and broader policy levels, research in cowpea in Ghana and on cereal/legume systems in Ethiopia revealed increasing pest control problems on higher yielding varieties. These had been introduced by government and donor programmes in an attempt to improve local food security yet these varieties were far more susceptible to attack in the field and in storage by weevil and other pests, in comparison with local landraces. However, the energetic promotion of higher yielding varieties had not been accompanied by information on their pest control needs or the associated costs, nor by training in appropriate, affordable and safe pest control methods. Farmers interviewed attempted, not always successfully, to reduce yield losses by resorting to applications of unauthorized and often dangerous insecticides. Government crop protection staff in Ethiopia complained that pest control needs had been ignored in the policy focus on potential yield increases and their department was not allocated sufficient resources to address the urgent need for better pest management (Williamson et al., 2008).

5.2 Effective implementation?

The last decade has witnessed substantial and welcome legislation enacted on pesticide controls even in the poorest countries, yet there is very little implementation or monitoring of its effectiveness (Ramirez & Mumford, 1995; Williamson, 2007; Amera & Abate, 2008; SP-IPM, 2008). For example, several studies have reported significant 'leakage' of DDT from East African malaria control programmes -its only permitted use since 2004 under the Stockholm Persistent Organic Pollutants (POPs) Convention (Gebre-Medhin, 2003; Katima & Mng'anya,

Area	Issue
<i>Pesticide policy</i>	1. Wide recognition of pesticide misuse yet subsidy & direct provision of pesticides by governments & donors continue.
	2. Hazardous pesticides are not controlled effectively at regulatory level.
	3. The informal pesticide dealing network is flourishing yet controls concentrate on formal distribution systems.
	4. Emphasis on improving regulation on paper, rather than putting it into practice.
	5. Banned & restricted pesticides remain easily accessible in informal markets.
<i>Agricultural policy</i>	6. Food security programmes promote higher yielding crop varieties which are more susceptible to pests and therefore less affordable to poorer farmers, notably women.
	7. Agricultural intensification assumes higher use of external inputs without adequately addressing health, environmental or economic costs.
	8. Lack of mainstreaming of IPM principles & projects which promote safer alternatives.
	9. Disjuncture between recognizing need to address pesticide hazards & incorporating this into institutional practice.
<i>Health policy</i>	10. Health policy fails to address pesticide-related ill health adequately or recognize it as a major public health burden.

Source: Williamson, 2006

Table 5. Poor policy coherence and implementation identified in PAN research 2000-2005 in Benin, Ethiopia, Ghana and Senegal

2009; Amara, 2009). Why are pesticide controls so poorly implemented or enforced? Our research findings suggest a combination of lack of resources, possibly of political will too, and incoherence between environmental, health, rural development, agriculture and trade policy making (Williamson, 2005). The relative 'invisibility' of pesticide external costs in policy making may contribute too- Sherwood and colleagues concluded that poisoning impacts in Ecuador may well be equivalent to the public health burden posed by some important infectious diseases in that country (Sherwood et al., 2005).

Efforts to put tougher controls in place on the ground may face fierce opposition from vested interests in commercial and public organizations. In 2000, the Health Ministries of six Central American countries identified a regional 'Dirty Dozen' active ingredients responsible for the most frequent occupational and accidental poisonings, based on evidence gathered via the Latin American World Health Organisation (WHO) expanded health surveillance programme. Their list included nine WHO Class I and three Class II compounds along with a proposal for withdrawing approvals of these top problem pesticides at regional level. Unfortunately, implementation of the phase-out was blocked by agrochemical companies, the US and national Finance/Trade Ministries under the pretext of permitting 'free trade' in the Central American Free Trade treaty (Rosenthal, 2005). More recently, inclusion of endosulfan in the Stockholm POPs Convention has been thwarted by India and its state-funded pesticides manufacturer, despite almost universal consensus from technical experts and governments worldwide that this insecticide should no longer play a role in 21st century crop protection (PAN UK, 2009a).

Nevertheless, several UN agencies recognize the continued problem of pesticide externalities and have set up initiatives and awareness raising activities to tackle them. In 2004 FAO, WHO and the UN Environment Programme (UNEP) jointly published the report '*Childhood Pesticide Poisoning: Information for Advocacy and Action*' estimating up to 5 million cases of child pesticide poisoning occur each year, resulting in thousands of fatalities. Agency experts highlighted how children face higher risks from pesticides than adults because they are exposed more to such chemicals over the course of their lifetime and because they are more susceptible in physiological terms (FAO/WHO/UNEP, 2004). Stakeholder reflection on the failure of existing pesticide controls to reduce the incidence of damage to human health and environment led FAO and WHO to launch a new initiative for a progressive ban on Highly Hazardous Pesticides (HHP) in 2006 <http://www.fao.org/agriculture/crops/core-themes/theme/pests/pm/code/hhp/en/>. The HHP initiative recognizes that WHO Class II pesticide active ingredients ('moderately hazardous' in terms of acute mammalian toxicity as determined in laboratory testing), such as endosulfan, paraquat and chlorpyrifos, can be as problematic in reality as the 'extremely' and 'highly' hazardous pesticides which make up WHO Class I. This conclusion is also drawn from PAN's poisoning cases data in West Africa (PAN UK, 2008) and locust cost externality assessment in Senegal (Leach et al., 2008).

In 2009 PAN International published its 'List of Highly Hazardous Pesticides' as a contribution to these UN discussions (PAN Germany, 2009). It provides a catalogue of the most harmful pesticides that is more comprehensive, and takes into account more potential pesticide hazards, than current listings by official bodies (for example, endocrine disrupting properties, ecotoxicity and operator inhalation toxicity are not included in the latter). PAN believes it is essential to include chronic health hazard in the definition of HHPs. WHO very conservatively estimated at least 735,000 people annually suffer specific chronic defects and a possible 37,000 cases of cancer in developing countries (WHO, 1990). The PAN International HHP list also includes five environmental hazard criteria. In its latest global report, PAN International assesses the very limited achievements of regulations, at global, regional and national levels to prevent pesticide poisonings and reduce harmful health and environmental impacts (PAN International, 2010). To redress this poor performance, report authors recommend a series of measures for governments to put in place (Box 2.), supporting the call by international agencies, including FAO and WHO, for more assertive action on pesticide hazards.

6. Pesticide use and impact reduction in supply chains

The regulatory approach, especially at international level, can be slow and tortuous. Meanwhile, some parts of the private sector have been taking action, via voluntary standards which prohibit and restrict the use of specific hazardous pesticides. Table 6 summarises WHO pesticide classes and hazard listings prohibited in six private schemes related to coffee production. Several UK supermarkets have similar prohibitions and restrictions (PAN UK, 2009b).

A concrete example of how supply chains can take positive action to phase out specific hazardous pesticides, using the PAN Highly Hazardous Pesticides list, is given in Table 7. In 2009, PAN UK was requested by British retailer Marks and Spencer to advise on prioritising top pesticides of concern from a list of 38 substances that remained in fairly common use in the retailer's non-EU supply base. Running these 38 through the HHP list

Box 2. PAN International recommendations for government action

1. Adopt and practice good governance regarding development and implementation of plant protection policies and regulations.
2. Invest in research and participatory, community-based training in agroecological systems, especially in Africa.
3. Insist on an agroecological approach in relevant policy measures and support, including incentives for rapid adoption of agroecological production (e.g. reducing taxes for land managed with agroecological approaches, ensuring access to credit and markets for agroecological producers).
4. Promote ecological, safer and non-chemical alternatives for pest management, as recommended by UNEP's Strategic Approach to International Chemicals Management (SAICM).
5. Strengthen consumer movements on food security and food safety, especially in Africa.
6. Adopt PAN International list of HHPs as the basis for a progressive ban on highly hazardous pesticides, and identify additional risky active ingredients to target for elimination, such as 'Pesticides whose handling and application require the use of personal protective equipment that is uncomfortable, expensive or not readily available' (Article 3.5, FAO/WHO Code of Conduct).
7. Base policy decisions on hazard assessment rather than risk assessment.
8. Adopt a pro-public health approach to eliminating pesticide poisonings, that takes action based on the intrinsic hazardous properties of pesticides, rather than considering pesticides on a case-by-case or incident-based approaches.
9. Adopt a precautionary approach to pesticide regulation.
10. Place liability onto pesticide manufacturers and distributors for human health and ecosystems harm. People and governments should not be left bearing the costs.
11. Legally require those who employ pesticide sprayers to provide full personal protective equipment (PPE), along with training and retraining on a regular basis.
12. Support establishment through WHO of poisoning information centres in developing countries.
13. Promote the use of community-based monitoring of pesticides worldwide. Adopt innovative strategies for measuring pesticide exposure and identifying priority areas for action.
14. Insist upon the implementation of international conventions related to chemicals.
15. Enact regulations on "right to information" and "right to know" to ensure that communities and agricultural workers are provided with full information on the pesticides that they exposed to or spray.
16. Implement legislation and regulations on pesticide management on national and regional levels, especially in Africa.

'screen' identified 28 with one or more HHP hazards. To produce a 'top 10' priority, PAN UK selected the nine pesticides which scored under three or more HHP criteria, plus endosulfan, based on PAN documentation of its major role in pesticide poisonings in many crops across the developing world. Marks and Spencer has now committed in its environmental responsibility Plan A to develop plans to phase these out in food production based on assessments of operator safety and environmental impact by 2012 (Marks and

Pesticide hazard category or list	Rainforest Alliance (SAN)	Utz Certified	FairTrade (FLO)	GlobalGAP	Common Code for Coffee (4CA)	C.A.F.É. Practices (Starbucks)
POPs list	Yes	Yes	No	No	Yes	No
PIC list	Yes	Yes	Yes	No (except 15 PIC pesticides also on EU 79/117 directive)	Yes	No (except those also WHO 1a/1b)
WHO Class 1a & 1b	No immediate prohibition but growers must phase out after 3 years of certification	No	Yes (with some specific exemption possible on certain crops but not coffee)	No	No immediate prohibition but growers must phase out within 3-5 years	Yes (with some possible specific exemption requests for nematicides)
WHO Class II	No	No	No	No	No	No
PAN "Dirty Dozen" list	Yes	No	Yes (with one exception possible for paraquat)	No	No	No
EU or US prohibited lists	Yes (some)	Yes (some)	No	Yes (some)	No	No
Methyl bromide	Yes	No	No	Yes	No	No

Yes indicates when a specific scheme DOES prohibit pesticides in the particular hazard class

Source: PAN UK, 2008c

Table 6. Pesticide prohibitions in six private coffee assurance standards

Spencer, 2010). Since most of these phase-out priorities are already banned in the EU, this type of unilateral phase-out action by a retail company makes a significant contribution to reducing hazardous exposure of farmers and farm workers in developing countries growing crops for export. Over half of these priority top 10 are either on the Rotterdam PIC list, or have been notified to PIC by the EU as qualifying as regional bans for health or environmental reasons (see PAN UK, 2008d for explanation of PIC notification in terms of which pesticides are banned in the EU). Taking action on PIC list and notified substances is a practical way in which food companies can support the aims of the Rotterdam Convention and their obligations under the FAO/WHO Pesticide Code of Conduct to address pesticide problems in developing countries (PAN Germany, 2005).

Active ingredient	No. hazard criteria under PAN HHP list	HHP hazard criteria
1. Aldicarb	3	WHO Ia; EU operator inhalation risk (R26 risk phrase); EU endocrine disrupting chemical (EDC)
2. Benomyl	4	Poss. cancer (US EPA); EU mutagen; EU reprotoxic; PIC list
3. Cadusafos	3	WHO Ib; v. persistent-sediment; highly toxic to bees
4. Lambda-cyhalothrin	3	R26; EDC; bees
5. Fentin hydroxide	3	R26; prob. cancer (EPA); poss. cancer (EU)
6. Metolachlor	3	Poss. cancer (EPA) v. persistent- water; v. persistent-sediment
7. Parathion-methyl	4	WHO Ia; R26; EDC; PIC list
8. Procymidone	4	Prob. cancer (EPA); poss.cancer (EU); EU reprotoxic; EDC
9. Trifluralin	4	Poss. cancer (US +EU); EDC; v. bioaccumulative
10. Endosulfan	2	R26; EDC

Table 7. Ten priority pesticides recommended by PAN UK for priority phase-out by Marks and Spencer retailer

Taking out specific pesticides based on intrinsic hazard is criticized by some as overcautious, economically risky or even unscientific (FERA, 2008; Farmers Weekly, 2008). Such voices advocate instead an approach based on risk management and mitigation, while some private sector initiatives blend hazard and risk-based approaches (e.g. Unilever, 2010). Reliance on probabilistic risk assessment based mainly on current known facts, often extrapolated from laboratory studies and based on overoptimistic assumptions about compliance with good agricultural practices, simply cannot tackle the scientific uncertainties around the extent of health and environmental exposure and the complex and largely unknown interactions inside non-target organisms, including humans, between pesticides and other chemicals at ecologically relevant concentrations in the field. Critics point out that pesticide regulation policy is a value-laden process and the narrative space around it dynamic and highly contested (Bro-Rasmussen, 1999; Watterson, 2001; and Irwin & Rothstein, 2003). The stance of the agrochemical industry and some governments on pesticide exposure and risk minimization stands in contrast to the industrial hygiene approach used in many other occupational health and safety fields, where the most effective option is to 'remove the hazard', recognizing that human error can never be eliminated (Sherwood et al., 2002; Gee, 2004). The authors of PAN International's latest global overview of poisonings stress how the current regulatory approach of delaying action until evidence of health or environmental impacts becomes apparent places an enormous and unfair burden on pesticide users, farm workers and rural communities, particularly in developing countries. It also causes environmental damage and incurs hidden economic costs (PAN International, 2010).

Beyond debate over the merits of reducing risk versus hazard, PAN UK's assessment is that prohibiting or phasing out a set of pesticides can trigger useful change in pest management practice- 'what do you do instead of using pesticides x, y and z'? Such actions can be powerful drivers for IPM, for example, British retailer Marks & Spencer are trialling alternatives to hazardous compounds used in large-scale viticulture, as well as safer pest management in rice cultivation by Indian smallholders (Franklin, 2009). Unilever's sustainable agriculture programme has focused on reducing pesticide reliance in general and in India has supported its smallholder gherkin growers to reduce fungicide use by 78% mainly by better agronomic practices and changing attitudes among farmers and advisers (Ramesh, 2008). Helping farmers to put IPM into practice does require the food and fibre sectors to invest in technical R&D and advice. PAN UK would like to see much more private investment, with public research institutes and farmer associations, into a more ecologically-informed Integrated Production approach, addressing not just pesticide use but also fertilizers, energy, carbon footprints, climate change, soil and water management, as for example, Unilever is doing in its supply chains (Smith, 2008).

7. Conclusion

Evidence from field documentation of poisonings and results from the few programmes of increased health surveillance show clearly that in the 21st century, hazardous pesticides are still routinely used in unsafe situations. African farmers are possibly the least equipped among the developing world to protect themselves and their community against the hazards of pesticide use, in terms of literacy, education, access to information and poverty. While pesticide use in Africa appears lower than in other parts of the world, rural populations and the environment are likely to suffer significant exposure. To date, while most African countries have ratified the major pesticide-relevant global conventions, they lack the resources to implement these properly.

Researchers, policy makers and donors need to pay more attention to external costs and implement a variety of policy and programme measures to cut back on use of hazardous pesticides and implement safer alternatives. This is also a major conclusion from the global report of the International Assessment of Agricultural Science, Knowledge and Technology for Development (IAASTD, the UN expert assessment 'equivalent' to the Millennium Ecosystem Assessment), to which 58 countries have signed up (IAASTD, 2009). The African IAASTD regional chapter highlights "*the economic, environmental and health costs associated with greater use of agrochemicals suggests that agricultural knowledge, science and technology options involve reorienting research away from high-input blanket doses towards technologies that enable technically efficient applications specific to local soil conditions and towards integrated nutrient management approaches*" (IAASTD 2009b). The need to address external costs as one of the priorities also features in a key review on food security challenges published in *Science* this year (Godfray et al., 2010) and in recent assessments conducted for better decision making on appropriate pest control choices in Mediterranean citrus production (Leach and Mumford, 2008).

Innovative ecotoxicology monitoring with government agencies and staff of PAN Africa affiliate NGOs in Ethiopia and Tanzania, under the auspices of the FAO and World Bank-funded African Stockpiles Program, illustrates the research and policy value of community-based monitoring methods, backed up with expert technical support. In Ethiopia secondary

school students were trained as data collectors for an assessment of pesticide use and IPM impact in cotton and subsequently engaged enthusiastically in hazard awareness-raising in their villages and as local 'champions' for IPM (Amera, 2009). Ecotoxicology experts provided a Rapid Risk Assessment (RRA) for the two most widely used pesticides as reported in the survey: the herbicide 2,4-D and illegal use of DDT insecticide. The RRA highlighted serious risks to certain wildlife in the Rift Valley's unique alkaline salt marshes, an important passage zone for aquatic and insectivorous Palaearctic migrant birds (Amera & Abate, 2008).

In Tanzania, PAN has pioneered new ways to reduce the distance between policymakers, implementing agencies and communities affected by pesticides (Touni, 2009). Conducting training in community-based monitoring with local NGOs, villagers and government officers led to the joint development of an Environmental Incident Reporting procedure – the first attempt in the world to establish an upward reporting chain from community level to the Secretariat of the Rotterdam PIC Convention. Village environment committees are the key link in the chain, with an 'open door' to report directly to Tanzania's Designated National Authority for the Rotterdam Convention, hosted in the Ministry of Agriculture, Food Security & Cooperatives. A pilot project is adapting a suitable health monitoring form, combining elements of the PIC health incident reporting form with community monitoring tools developed by PAN Asia Pacific, which are more suitable for rural communities with low literacy levels. Such work enables international Conventions to reflect concerns and problems identified at field level.

Research has a crucial role in making farming a safer, as well as a more sustainable and rewarding, livelihood for the millions of small-scale farmers and farm workers in developing countries (Murray et al., 2002; Pretty and Waibel, 2005; Kishi, 2005; Leach et al., 2008). This requires researchers to work closely with farmer groups and food and fibre supply chain actors, plus civil society stakeholders, in liaison with relevant government and donor programmes for poverty reduction, health and environmental improvement. Undertaking small surveys combining quantitative and qualitative methods to estimate human health, livestock and wildlife impacts from acute toxicity can serve as an invaluable first step to opening the eyes of farmers themselves and decision makers about the reality of external costs. Such research is most effective when using multidisciplinary and participatory approaches, not relying on questionnaire surveys alone, but adding social science methods that can identify important perceptions behind people's opinions and concerns. PAN's experience is that a fruitful marriage of natural and social science methods, with community participation of this kind, is true 'action research' and one which can lead to real change at policy and practical levels in reducing the burden of pesticide-related harm. Ultimately, the huge gap between aspirational standards in international pesticide policy recommendations and conventions and the reality of those living and working near pesticide use can only be bridged by promoting safe and sustainable strategies for agricultural development.

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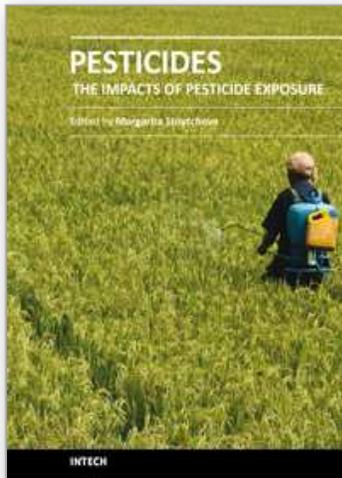
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Pesticides are supposed to complete their intended function without “any unreasonable risk to man or the environment”. Pesticides approval and registration are performed “taking into account the economic, social and environmental costs and benefits of the use of any pesticide”. The present book documents the various adverse impacts of pesticides usage: pollution, dietary intake and health effects such as birth defects, neurological disorders, cancer and hormone disruption. Risk assessment methods and the involvement of molecular modeling to the knowledge of pesticides are highlighted, too. The volume summarizes the expertise of leading specialists from all over the world.

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